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Demonstration Project 93

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July 1993

Innovation Through Partnerships

NOTICE

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16. Abstract

This Participants Notebook was developed as a training and reference aid for the **Traffic Signal Equipment and Software** workshop. The notebook is organized to reflect the material presented in each of the two-day sessions. The workshop is designed to provide participants (traffic signal systems engineers and technicians) with information and an opportunity to discuss and operate examples of the State-of-the-Art traffic signal technology and equipment on the market today. At the completion of this workshop, the participant should have an understanding of:

- The role and impact of traffic control systems.
- The resources and maintenance requirements for implementing and upkeeping traffic control systems.
- The concept of NEMA and Model 170 controller units.
- Controller input and output devices, i.e. detectors, time switches, time base coordinators, conflict monitors, flashers, isolators, load switches; test equipment, UPS, suppression devices, communications techniques, closed loop systems, centralized signal systems, and signal timing software.
- Become aware of new emerging traffic control technologies.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

FOREWORD

This notebook was developed as a reference aid for the Traffic Signal Equipment and Software workshop. The notebook is organized to reflect the material presented in each of the two-day sessions.

The Traffic Signal Equipment and Software workshop is designed to provide participants (traffic signal systems engineers and technicians) with information and an opportunity to discuss and operate examples of the state-of-the-art traffic signal technology and equipment on the market today, such as traffic signal controllers, vehicle detectors, communication techniques, high-resolution computer graphics, computerized signal systems, distributed intelligence systems, etc. At the completion of this two-day workshop, the participant should:

- Understand the role and impact of traffic control systems and become aware of the benefits of implementing advanced traffic control technologies in terms of measures of effectiveness in reducing urban traffic congestion.
- Understand the resources and maintenance requirement for implementing and upkeeping traffic control systems.
- Know about the concept of NEMA and Model 170 controller units.
- Know about the latest available NEMA and Model 170 traffic controller technology.
- Know about the latest available controller input and output devices, i.e detectors, time switches, time base coordinators, conflict monitors, flashers, isolators, and load switches.
- Know about traffic control equipment testers for diagnostic and maintenance applications.
- Know about uninterrupted power supply and suppression/transient devices.
- Understand the theory and concept of various traffic control system communication techniques, such as twisted-pair cable, coaxial cable, fiberoptic cable, radio, etc.
- Become familiar with the concept and application of closed loop and hybrid traffic control systems information management and the unique capabilities about various systems.
- Become aware of off-line signal timing software.
- Become aware of the emerging new traffic control technologies, such as controllers, communications, signal timing management, and traffic signal systems information management.

TABLE OF CONTENTS

	Page
I. **INTRODUCTION**	I-1
BACKGROUND	I-1
OBJECTIVES	I-4
ORGANIZATION OF NOTEBOOK	I-4
II. **CURRENT TECHONOLOGY**	II-1
HISTORY OF CONTROLLER UNIT TECHNOLOGY	II-1
CONTROLLER UNIT FUNCTIONS	II-3
CONTROLLER UNIT CONCEPTS: NEMA AND MODEL 170	II-7
OVERVIEW OF THE NEMA CONTROLLER UNIT AND COMPONENTS	II-15
MANUFACTURERS OF NEMA CONTROLLER UNITS	II-22
AUTOMATIC SIGNAL/EAGLE SIGNAL CONTROLLER UNITS	II-22
ECONOLITE CONTROL PRODUCTS, INC.	II-28
TRACONEX INC.	II-34
TRAFFIC CONTROL TECHNOLOGIES	II-37
TRANSYT CORPORATION	II-44
OVERVIEW OF THE MODEL 170 CONTROLLER UNIT	II-48
MANUFACTURERS OF MODEL 170 CONTROLLER UNITS	II-57
SAFETRAN MODEL 170SV CONTROLLER UNIT	II-57
SAFETRAN MODEL 179 CONTROLLER UNIT	II-59
SIGNAL CONTROL 170A CONTROLLER UNIT	II-61
CONTROLLER UNIT CABINETS	II-65
AUXILIARY INPUT DEVICES	II-70
INDUCTIVE LOOP DETECTORS	II-70
MICROWAVE DETECTORS	II-81
ULTRASONIC DETECTORS	II-84
INFRARED DETECTORS	II-85
3M CANOGA MICROLOOP VEHICLE DETECTOR	II-89
ECONOLITE VIDEO VEHICLE DETECTION SYSTEM	II-91
PREEMPTION SYSTEMS	II-92
TIME SWITCHES	II-97
TIME BASE COORDINATORS	II-100
ISOLATORS	II-104
AUXILIARY OUTPUT DEVICES	II-106
LOAD SWITCHES	II-106
FLASHERS	II-109
CONFLICT MONITORS	II-109
TRAFFIC CONTROL EQUIPMENT TESTERS	II-118
UNINTERRUPTED POWER SUPPLY DEVICES/TRANSIENT SUPPRESSION DEVICES	II-127

TABLE OF CONTENTS (cont.)

		Page
III.	**TRAFFIC CONTROL SYSTEM COMMUNICATION TECHNIQUES**	III-1
	DEFINITION OF TERMS	III-1
	ALTERNATIVE COMMUNICATION SYSTEM CONFIGURATIONS	III-4
	NETWORK CONFIGURATIONS	III-4
	TYPES OF COMMUNICATIONS INFORMATION	III-6
	COMMUNICATIONS MEDIA	III-6
IV.	**TRAFFIC CONTROL MANAGEMENT SYSTEMS**	IV-1
	CLOSED LOOP CONCEPT	IV-1
	MODES OF OPERATION	IV-3
	CLOSED LOOP SYSTEMS	IV-4
	AUTOMATIC SIGNAL/EAGLE SIGNAL INC.	IV-7
	BI TRAN SYSTEMS, INC.	IV-9
	ECONOLITE CONTROL PRODUCTS, INC.	IV-11
	SONEX CORPORATION	IV-13
	TRAFFIC CONTROL TECHNOLOGIES	IV-14
	TRACONEX, INC.	IV-16
	TRANSYT CORPORATION	IV-18
	WAPITI MICRO SYSTEMS	IV-20
	HYBRID TRAFFIC CONTROL SYSTEMS	IV-23
	FREDERIC R. HARRIS, INC.	IV-24
	JHK & ASSOCIATES	IV-27
	SONEX CORPORATION	IV-30
	AUTOMATIC SIGNAL/EAGLE SIGNAL	IV-33
	FARRADYNE SYSTEMS, INC.	IV-36
	COMPUTERIZED SIGNAL TIMING TECHNIQUES	IV-39
V.	**HANDS-ON TRAFFIC SIGNAL SYSTEMS SOFTWARE**	V-1
VI.	**EMERGING TRAFFIC CONTROL TECHNOLOGIES**	VI-1
	COMMUNICATIONS	VI-1
	CONTROLLER UNITS	VI-2
	ON-LINE SIGNAL TIMING	VI-2
	CURRENT IVHS PROJECTS	VI-2
	GLOSSARY	G-1
	APPENDICES	
	APPENDIX A: FHWA AND NHI COURSES AND REFERENCES	A-1
	APPENDIX B: ABBREVIATIONS	B-1
	APPENDIX C: LIST OF MANUFACTURERS AND TELEPHONE NUMBERS	C-1
	APPENDIX D: NOTE SHEETS	D-1

LIST OF FIGURES

Figure		Page
I-1	Relationships among speed, density, and rate of flow on uninterrupted flow facilities	1-2
II-1	Single Ring Controller Unit & Typical Phase Assignments	II-5
II-2	Dual Ring Controller Unit & Typical Phase Assignments	II-6 & II-8
II-3	Type 12 Programming Board Front View	II-20
II-4	Automatic Signal/Eagle Signal Models: EPIC 140 and EPAC 300	II-24
II-5	MARC 360 On-street Master Controller Unit	II-27
II-6	Econolite Models ASC-8000 & KMC-10,000 Controller Units	II-29
II-7	Traconex Model TMP-390CJ Controller Unit	II-34
II-7A	Traconex Model TMM500, On-street Master Controller Unit	II-36
II-8	TCT Model LMD 8000 Controller Unit	II-37
II-9	TCT Model LM100, On-Street Master	II-41
II-10	Transyt Models 1880EL Local Controller Unit and 3800EL On-street Master Controller Unit	II-44
II-11	A front panel schematic of the Model 170 Controller Unit	II-48
II-12	Major Components of Model 170 (top view)	II-50
II-13	Model 170 Conflict Monitor	II-55
II-14	Safetran Model 170 Controller Unit	II-57
II-15	Model 412B2 PROM Module	II-59
II-16	Safetran Model 179 Controller Unit	II-60
II-17	The Model 170A Controller Unit Front Panel	II-62
II-17A	PROM Module Model 412C	II-63
II-18	Model 332 Cabinet, Front View	II-67
II-19	Model 334 Cabinet, Front View	II-68
II-20	Model 919-4 Detector Unit	II-70
II-21	Model 921-2TC Detector Unit	II-72
II-22	Model 940 Detector Unit	II-73
II-23	Model 222C Detector Unit	II-73
II-24	Model 224C Detector Unit	II-74
II-25	Model 262C Detector Unit	II-75
II-26	Model TLS-1 — Traffic Logging System	II-76
II-27	Model 515B Detector Unit	II-77
II-28	Model 500 Series Detector Unit	II-77
II-29	Series 530 Vehicle Detectors	II-79
II-30	Series 224 Vehicle Detector	II-80
II-31	Model 222T Multi-Channel Detector With Timing Functions	II-80
II-32	Model TC-20 Microwave Detector	II-81
II-33	Typical Installation of Model TDW-10 Detector	II-83
II-33A	Typical Installation of Model TDN-30 Detector	II-83
II-34	Model TC-30 Ultrasonic Detector	II-84
II-35	MSI-100 Zone Dimensions	II-86
II-36	Detection Zone with the MIX Passive Infrared Vehicle Detector	II-87
II-37	Microloop Probe	II-89
II-38	Model P422T Inductive Loop Detector	II-90
II-39	Typical AUTOSCOPE™-2003 Set-up	II-91
II-40	Emtrac System	II-93

LIST OF FIGURES (Cont.)

Figure		Page
II-41	RTC Time Switch Models and Time-based Coordinators	II-98
II-42	Sonex ZDC Time-based Coordination Units	II-103
II-43	Isolator	II-105
II-44	TSC Model 204 Load Switch	II-107
II-45	SSD Model DVLS Load Switch	II-107
II-46	Model 200i Intelligent Load Switch	II-110
II-47	Model 204 Flasher	II-110
II-48	TSC SMU — 12/16 Signal Monitor Unit	II-111
II-49	SSD Guardian LCD — 12P Conflict Monitor	II-113
II-50	SSM-LE Conflict Monitor	II-117
II-51	Model 210 Conflict Monitor	II-117
II-52	ATSI PCMT-2000 Conflict Monitor Tester	II-119
II-53	DVP ILT II Loop Tester	II-120
II-54	Setcon NT-12 NEMA Controller Unit Manual Tester	II-121
II-55	Setcon Model 435B Load Switch Analyzer	II-122
II-56	Model 448 Detek Monitor	II-123
II-57	MT-1 Series NEMA Type Monitor Manual Tester	II-124
II-58	Model MT 180 Monitor Tester	II-126
II-59	LECTRO Lightsaver UPS	II-129
III-1	Basic Communication Transmission in Traffic Control Systems	III-1
III-2	Point-to-Point Configuration	III-5
III-3	Point-to-Multipoint Configuration	III-5
III-4	Daisy-Chain Configuration	III-6
IV-1	Typical Closed Loop System Configuration	IV-1
IV-2	Typical CLS Main Menu for System Start-Up	IV-3
IV-3	MARC System Architecture	IV-8
IV-4	QuicNet II System Architecture	IV-10
IV-5	Zone Monitor IV System Architecture	IV-12
IV-6	LM100 System Architecture	IV-15
IV-7	Traconet System Architecture	IV-17
IV-8	Transyt Smartways Closed Loop System Architecture	IV-19
IV-9	Wapiti's Closed Loop System Architecture	IV-22
IV-10	Sonex Escort hybrid System Architecture	IV-31
IV-11	MONARC™ System Architecture	IV-34
IV-12	MIST Configuration	IV-38

LIST OF TABLES

Table		Page
II-1	Per Phase Timing Functions	II-11
II-2	Features of Various NEMA TS1 Local Intersection Controller Units	II-23
II-3	Model 170 Controller Unit Cabinets	II-66
II-4	Detector Systems Digital Inductive Loop Vehicle Detector Models: Shelf & Rack Mounted Units	II-71
II-5	Sarasota Digital Inductive Loop Vehicle Detector Models: Shelf & Rack Mounted Units	II-78
II-6	Vehicle Detectors and Preemption Devices: Features and Operational Characteristics	II-96
II-7	RTC Time Switches and Time Base Coordinators	II-99
II-8	Solid State Devices Automatic Traffic Monitor Tester: Test Sequence	II-125
III-1	Summary of Properties of Communication Technologies	III-7
IV-1	Features of Various Closed Loop Systems	IV-5&6
IV-2	TMS Specifications	IV-26
IV-3	State-of-the Art Signal Timing Programs: Optimization, Evaluation, and Simulation	IV-40

CHAPTER I — INTRODUCTION

BACKGROUND

Urban traffic congestion is recognized as one of the most urgent transportation problems facing the Nation today. Predictions indicate that congestion will increase at least four hundred percent by the year 2005 unless significant changes are made now. Until sophisticated long-term congestion management solutions are fully developed and deployed, these changes must concentrate on utilizing and maintaining state-of-the-art traffic signal equipment and software technology.

Studies by the FHWA in 1982 indicated that about 2/3 of all urban vehicle miles of travel are on facilities controlled by traffic signals. These studies also indicated that of the total 240,000 signalized intersections in the United States, about 148,000 are estimated to need substantial upgrading of equipment, while 30,000 others simply need to be set properly to reflect current conditions. A commonly cited problem for not upkeeping signalized intersection was lack of resources and maintenance.

The benefits of basic improvement programs for signalized intersections are most often not documented and if so they are frequently taken for granted. "Before" and "After" studies have shown that the benefits of basic signal improvements can far exceed the cost of implementation and usually can pay for itself within two or three years. Among the most recognizable benefits of signal improvements are:

- reduced congestion
- higher operating speeds
- reduced fuel consumption
- reduced air pollutants
- reduced accidents
- reduced noise

To help understand and appreciate traffic flow, congestion, and benefits of signal improvements and other congestion mitigation measures, one must understand the principles of traffic flow. The basic principles of traffic flow are defined by three primary measures: 1) speed, 2) volume and/or rate of flow, and 3) density. Speed is defined as a rate of motion expressed as distance per unit time such as miles per hour (mph). Volume and rate of flow are two measures that quantify the amount of traffic passing a point on a lane or roadway during a designated time interval. Volume is usually expressed in vehicles and rate of flow is expressed in volumes per hour. Density is defined as the number of vehicles occupying a given length of a lane or roadway, averaged over time, usually expressed as vehicles per mile (vpm). Density is a parameter that is used to characterize traffic operations and reflect the freedom to maneuver within the traffic stream.

The basic relationship between these three parameters, i.e. volume, speed, and density, are illustrated in Figure I-1. Note, however, these figures are applicable only to uninterrupted flow facilities such as interstates and freeways. Interrupted flow is much more complex than uninterrupted flow since it is dominated by points of fixed operation, such as traffic signals, mid-block stops, and yields.

Although they are limited to uninterrupted flow only, the curves of Figure I-1 illustrate a number of significant points. Note that a zero rate of flow occurs under two very different conditions (source: HCM 1985):

- When there are no cars on the facility, density is zero, and rate of flow is also zero. Speed is purely theoretical for this condition, and it would be whatever the first driver would select—presumably a high value.

- When density becomes so high that all vehicles stop (speed is zero), the rate of flow is also zero, because there is no movement and vehicles cannot "pass" a point on the roadway. The density at which all movement stops is called *jam density*.

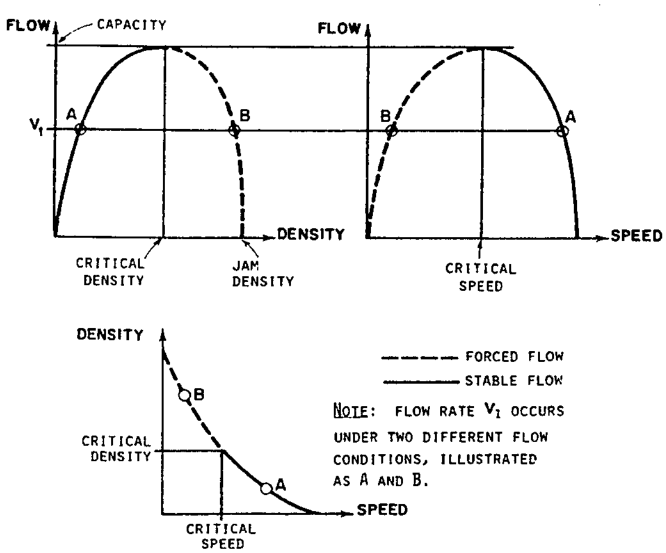


Figure I-1. Relationships Among Speed, Density, and Rate of Flow on Uninterrupted Flow Facilities (HCM 1985)

Between these two extreme points, the dynamics of traffic flow produce a maximizing effect. As density increases from zero, rate of flow also increases because more vehicles are on the roadway. While this is happening, speed begins to decline (due to the interaction of vehicles). This decline is virtually negligible at low densities and rates of flow. As density continues to increase, however, a point is reached at which speed declines precipitously. The maximum rate of flow is reached when the product of increasing density and decreasing speed results in reduced flow.

The maximum rate of flow for any given facility is its capacity. The density at which this occurs is referred to as *critical density*, and the speed at which it occurs is called *critical speed*. As capacity is approached, flow becomes more unstable because available gaps in the traffic stream are fewer. At capacity, there are no usable gaps in the traffic stream, and any perturbation from vehicles entering or leaving the facility, or from internal lane changing maneuvers, creates a disturbance that cannot be effectively damped or dissipated. Thus, operation at or near capacity is difficult to maintain for long periods of time without the formation of upstream queues, and forced or breakdown flow becomes almost unavoidable. For this reason, most facilities are designed to operate at volumes less than capacity.

The most significant source of fixed interruptions on interrupted flow facilities is traffic signals. At traffic signals, flow in each movement or set of movements is periodically halted. Thus, movement on a given set of lanes is only possible for a portion of total time, because the signal prohibits movement during some periods. Only the time during which the signal is effectively green is available for movement. For example, if one set of lanes at a signalized intersection receives a 30-sec green phase out of a 90-sec total cycle, only 30/90 or one third of total time is available for movement on the subject lanes. Thus, out of each hour of real time, only 20 minutes are available for flow on the lanes. If the lanes could accommodate a maximum rate of flow of 3,000 vhp when the signal is green, they could accommodate a total rate of flow of only 1,000 vph, as only one third of each hour is available as green. Therefore, longer green time would increase the intersection capacity, reduce stops, reduce fuel consumption, reduce noise, and attain higher speeds. Most studies, to date, have focused on reducing stops and delays, increasing travel speeds and reducing noise and fuel consumption levels. The measures taken to accomplish these goals have included signal timing and optimization, arterial progression, upgrade signal equipment, time-based and telemetry coordination, and computerized signal control and monitoring systems. Following are a few of the studies that have been reported over the past 10 years.

Studies reported by the Institute of Transportation Engineers in 1992 concluded that signal timing optimization can result in an average of 15 to 20 gallons of fuel savings per each dollar spent on improvement. Also reported were the benefits of interconnecting and optimizing previously noninterconnected signals; ITE reported an average benefit of 3 to 12% savings in fuel consumption.

Findings by the Virginia DOT and Frederic R. Harris, in 1990, as part of their Virginia Signal Timing Optimization Program (VASTOP) reported a 25.2% reduction in total delays, a 25.5% reduction in total stops, a 10.2% reduction in total travel time and a 3.7% reduction in fuel consumption at 321 intersections; 77 intersections of the total 321 intersections were isolated intersections. The studied improvements included coordination and optimization; a benefit-to-cost ratio of 200:1 was reported. Similar studies, by Frederic R. Harris, were also done in Arlington, Virginia, in 1987. Improvements included the installation of a computerized signal system as well as coordination upgrades and timing optimization at 190 intersections. This study reported the following annual reductions: 165,000 vehicle hours of total delays, 37,100,000 stops, 455,000 vehicles hours of total travel time and 90,000 gallons in fuel savings. The total annual savings were $2,144,000. The reductions in percentage for the above ranged from 11% for travel time, 23% for delay, to 29% total stops.

A study by FHWA in 1982 indicated that approximately 40 percent of the fuel consumed at signalized intersections is wasted when signals are not timed properly. The study also indicated that an estimated 5 million gallons per day could be conserved if all signals are modernized and timed properly. These remarks by the FHWA studies in early 1980 were proved to be credible seven to ten years later as a result of subsequent signalization improvement programs in the City of Daytona Beach, Florida and the City of Anaheim, California.

"Before" and "After" studies performed by the City of Daytona Beach, before and following a major signalization equipment upgrade from 1987 to 1989, concluded that traffic speeds were increased by 30 percent, accidents and noise were reduced, and traffic volumes were increased. The savings in fuel costs alone exceeded the total project costs ($250,000) in the first year. Similarly, a sophisticated traffic management system installed in the City of Anaheim, California, is expected to derive savings of 60 times the cost of 3 million dollars. Also, a California program, the Fuel Efficient Traffic Signal Management Program (FETSIM), aimed to help improve the efficiency of local traffic signals showed benefits that exceeded the costs by a ratio of 58:1. Many more cities and states have also experienced substantial benefits due to upgrading and/or retiming signalized intersections.

The above examples are a few of many realized improvements around the country. While more sophisticated and long-range solutions to urban congestion, such as Intelligent Vehicle-Highway Systems (IVHS), maybe the key to urban congestions, the implementation of the best available traffic control equipment and software technology, however, can still make immediate cost-effective improvements in the operating efficiency of existing highway systems. Moreover, it is a known fact that the current state-of-the-art traffic control technology is still far from being utilized to its fullest potential. This project is about linking and transitional technology which needs to be deployed to its fullest extent as we transition into more advanced forms of IVHS by the turn of the century.

OBJECTIVES

The objectives of this workshop are:

1. To promote cost effective solutions to urban traffic congestion by means of presenting and demonstrating state-of-the-art, leading edge electronic traffic control equipment and software including, but not limited to, traffic signal controller units, vehicle detectors, communication techniques, high-resolution computer graphics, computerized signal systems, and distributed intelligence systems.

2. To make top management and administrators aware of the role of traffic signal systems in efficient traffic management, and the importance of providing adequate levels of resources to operate and maintain these systems.

ORGANIZATION OF NOTEBOOK

This notebook is organized into six chapters.

- **I** — introduction to the workshop.
- **II** — discussion of controller unit technology, state-of-the-art National Electrical Manufacturers Association (NEMA) and Model 170 traffic controller units, auxiliary devices (input and output), controller unit cabinets, traffic control equipment testers and equipment for uninterrupted power supply and transient suppression.
- **III** — discussion of traffic signal system communication techniques such as twisted-pair cable, coaxial cable, leased and dial-up telephone services, fiberoptic cable, radio & microwave.
- **IV** — discussion of state-of-the-art traffic signal systems information management, i.e. closed loop and hybrid systems, high-resolution computer graphics and off-line and on-line signal timing plan generation.
- **V** — hands-on traffic control systems software operation. (This session will be conducted in a mobile exhibit, inside a semi-trailer/tractor combination.)
- **VI** — discussion of emerging urban traffic signal systems technologies such as controller units, vehicle detectors, communications, systems information management, etc.

GLOSSARY

Definitions of relevant terminology used in traffic control systems.

APPENDICES

The Appendix contains the following:

A. List of FHWA and NHI courses, workshops, and references.

B. List of abbreviations and acronyms.

C. List of Traffic Signal Equipment Manufacturers and Contact Telephone Numbers.

D. Blank Pages for Notes.

CHAPTER II — CURRENT TECHNOLOGY

This chapter provides information on controller unit functions and concepts of NEMA and Model 170 traffic controller units. Some of the following information is extracted from FHWA training courses.

HISTORY OF CONTROLLER UNIT TECHNOLOGY

For almost seventy-five years, electrically operated traffic signals have been in use in the United States. The earliest signals were manually operated; that is, police officers used switches to activate red or green lights. It was not long, however, before simple automatic controller units were developed to relieve the traffic officer's duties.

These first automatic controller units were electromechanical pretimed devices, using motors and gears for timing and cams with electrical contacts to change the signal displays. Often, these simple controller units were integral to a four-way signal head. Time settings were not easily adjustable, and adjacent signals could not be interconnected for synchronization purposes.

With further development, controller units began to resemble current electromechanical pretimed controller units. These featured more than one timing dial with adjustable key settings, and signal display sequences which could be varied by a programmable camshaft.

Traffic actuated controller units, which used detectors to identify traffic demand, were first developed during the late 1920's. The first detectors were microphones, located at the stop line of a minor street. Upon arriving at the stop line, motorists would blow their horns to obtain the right of way. These earliest actuated controller units were essentially modified pretimed controller units, and provided only a fixed length side street green.

To improve intersection efficiency, controller units were then developed that could extend the side street green based on vehicular demand. To accommodate the various timing devices required for this more sophisticated operation, electronic controller units, using vacuum tubes and analog timing, were introduced. Timing on these controller units was accomplished with an Resistor/Capicitor circuit — a variable resistor and a capacitor. This technique was not completely satisfactory, as both temperature fluctuations and age of the equipment created variations in the time constant.

As with radio and television technology, the development of the transistor replaced the vacuum tube in traffic controller units of the early 1960's. These controller units, using "solid state" technology, eliminated the relays, motors, and tubes found in earlier units. However, analog Resister/Capacitor timing circuits were still used, and precautions had to be taken to ensure the desired length of critical intervals (i.e., Yellows) were actually appearing on the street.

The introduction of digital technology solved the difficulty of ensuring critical interval length. Using digital techniques, timing could be referenced to the 60 Hertz line frequency of the AC power line. It was during this stage of technology that the NEMA Controller Unit Standards were first developed. At about the same time, in 1976, the States of California and New York began to develop the Model 170 concept.

There have been many advances to controller unit equipment since the initial release of the NEMA standards. Most prominent was the introduction of microprocessor-based controller units. The first generation of NEMA controller units utilized TTL Logic (Transister to Transister Logic) and followed by a Large Scale Integration (LSI) design. (LSI refers to the use of integrated circuits having more than 100 gates.) In LSI design, all controller unit operations are a function of hardware; that is, each controller unit operation is generated by a circuit, containing multiple components, located on a printed circuit board.

The introduction of microprocessors to traffic control has brought about major changes in manufacturer's product lines. Today's microprocessors are computers, capable of responding to programmed instructions, confined to a single "chip." Programming is maintained in some type of memory device, generally in PROM (Programmable Read-Only Memory) chips, and data is stored in RAM (Random Access Memory) chips.

The first computers, developed in the 1940's, used hundreds of vacuum tubes. Tubes took up a lot of space, generated great amounts of heat, and required operating voltages of from 50 to 300 volts. With the introduction of transistors, space requirements were reduced, much less heat was generated, and required operating voltages were lower. Even so, a modest computer could fill up a room.

Microprocessor development in the early 1970's centered around the introduction of the "chip." Five to ten thousand transistors could now be placed on a small plate of silicon less than .25" square, commonly called a chip. The electronics contained on the chip are called integrated circuits, or IC's. Today, denser integrated circuits (200,000 transistors or more per chip) are common.

Though a very powerful device, the microprocessor cannot stand on its own. It must have peripheral devices such as a clock, memories, and input/output buffers to comprise a functioning unit. Memories are especially important to the microprocessor. Instruction sets (or "programs") must be stored as well as fixed parameters or even intermediate values in decision making commands. There are two basic types of memory devices: Random Access Memory, or RAM, and Read Only Memory, or ROM.

Random Access Memory (RAM) allows the microprocessor to access information stored anywhere in the memory simply by designating the desired address. The most distinctive feature of RAM, however, is that the microprocessor can write or store information on the chip as well as read information from the chip. A RAM chip is connected to the microprocessor by an address bus, a read/write line, and a data bus.

The microprocessor specifies the location of the desired information in memory. The address bus conveys that information to the RAM. Next, the microprocessor specifies if the information is to be read from the RAM or written into it and sends the appropriate signal over the read/write line. Finally, the data is read from or written into the RAM through the data bus.

Read Only Memory means data can only be read, not written. It is in this type of memory that permanent or semi-permanent information is stored, such as programs for the microprocessor. Information is retrieved from the ROM in much the same manner as the RAM. There are four basic types of Read Only Memory, each of which has special characteristics which make it applicable to specific uses.

<u>ROM (Read Only Memory)</u>: This memory is programmed during manufacturing and cannot be amended afterwards. This makes it a feasible option where a large quantity of identical programs are required, such as those in mass produced consumer goods.

<u>PROM (Programmable Read Only Memory)</u>: Like the ROM, this memory cannot be changed after programming. However, it can be user-programmed once by using a device called a PROM burner. Because it is user-

programmable, it is used in applications where only a small number of the ROM's are needed and it would not be economical to have them manufactured in quantity.

EPROM (Erasable Programmable Read Only Memory): This type of ROM is very versatile because not only is it user-programmable, it can also be erased and reprogrammed. The programming is similar to that of a PROM. The erasing is accomplished by exposing the internal circuitry, through a small window in the chip, to ultraviolet light. This allows the EPROM's to be reused so that it is especially useful in situations where programs need to be periodically revised.

EEPROM (Electrically Erasable Programmable Read Only Memory): This device combines the features of both the EPROM and RAM chips. Like an EPROM, it is user-programmable. However, like a RAM, it includes a write line which permits the changing of data within the EEPROM. In its current configuration, it will not replace the RAM, because it is a substantially slower memory device. However, it is a good means to save semi-permanent data without the need for battery back-up.

In a typical controller unit assembly the microprocessor, the ROM, the RAM, the clock, and the input/output buffers, work together as a system. The microprocessor acts as the manager of that system. It receives instructions from the program stored in ROM, performs those operations using values stored in RAM or located in the input buffer, and sends any outputs to the output buffers. At the same time it is monitoring the inputs for any conditions which would require it to alter its status and perhaps go to another program for appropriate instructions.

CONTROLLER UNIT FUNCTIONS

The basic function of an intersection controller unit assembly is to alternately assign the right-of-way between two or more conflicting traffic movements. All controller unit assemblies control red, yellow, and green vehicular signals. They may control pedestrian signals. They may be based on demand or on preset timing patterns. The two basic types of intersection control are pretimed and actuated control.

Pretimed signal control repeat, cycle after cycle, on one or more preset timing plans, without regard to actual demand on the street. The older model electromechanical controller units used synchronous motors to generate timing intervals. Signal displays were generated by a camshaft which was advanced by electrical switches on timing dials.

Today's solid state digital based controller units are configured with equivalent functions. The camshaft equivalent is actually a matrix burned into EPROM, showing the state of each output (On, Off, or Flashing) for each interval. Interval length timing plans are stored in RAM.

The same type of operation is accomplished on the Model 170 controller unit by means of software programming.

NEMA controller units are supplied by the manufacturer with actuated operation already programmed. In Model 170 controller units, the program for actuated control is usually furnished by the manufacturer.

Actuated control is best suited for locations with unpredictable traffic patterns or isolated locations. Timing is varied for some or all controlled conflicting movements depending upon vehicular or pedestrian demand as determined by detectors placed in the roadway or near the pedestrian crossing.

There are three types of actuated control:

- Semi-Actuated control implies that only the secondary movements are timed relative to demand.

- Full Actuated control implies that all controlled conflicting movements are timed relative to demand.

- Volume-Density is the third form of actuated control in which the controller unit is programmed to operate with an added initial interval and a reducible gap in addition to the timing features of full actuated control.

Controller units also have phase functions. NEMA controller units range from two phase to eight phase (full control of all through and left turn movements at a cross-type intersection). Although Model 170 controller units are generically eight-phase controller units, they may be used in any two-to-eight-phase operation.

Each phase provides for timing of the functions related to that phase. Timing functions include:

- Pedestrian Timing Features
  - WALK
  - Pedestrian Clearance (Flashing DON'T WALK)

- Green timing (Non-volume-density)
  - Minimum Green (initial)
  - Passage or Extension
  - Maximums 1 and 2

- Green timing (with volume-density)
  - Added Initial
  - Time to Reduce
  - Time Before Reduction
  - Minimum Gap

- Change and Clearance
  - Yellow Change
  - Red Clearance

<u>Single Ring Controller Units</u>

The term "Ring" is defined as two or more sequentially timed and individually selected conflicting phases arranged to occur in an established order. Single-ring controller units are by definition, two to four phases in capacity.

Two-phase controller units are perhaps the most common installation. The controller unit sequence — Phase 1, then Phase 2, then back to Phase 1, and so on — is graphically shown on the top of Figure II-1 on page II-5. The Ring is the loop formed by the phases in sequence and the return to the starting point.

A three-phase controller unit, also shown in Figure II-1, follows the same format. Phase 1 is followed by Phase 2, which, in turn, is followed by Phase 3. After timing Phase 3, the controller unit returns to Phase 1. This sequence, which occurs with calls on all phases, is called the Preferred Sequence. If there is no demand for a particular phase, that phase can be skipped within the sequence.

Figure II-1 also shows a four-phase controller unit, whose preferred sequence is Phases 1, 2, 3, 4, and back to 1. Again, any of the phases in the sequence can be skipped if there is not call for that phase.

<u>Dual Ring Controller Units</u>

Dual ring controller units contain two interlocked rings which are arranged to time in a preferred sequence and to allow concurrent timing of phases in both rings. The dual ring concept is used in controller units of five to eight phases, but is best illustrated in the eight phase configuration, shown in Figure II-2A on Page II-6. The eight phase configuration is commonly known as a "quad left" operation - left turn phases are provided for all four approaches.

The preferred sequence in a dual ring controller unit consists of Phases 1 to 2 to 3 to 4 and back to 1, and, concurrently, Phases 5 to 6 to 7 to 8 and back to 5. There are, however, some constraints on the concurrent timing, and these are represented by the "barriers" in Figure II-2A.

Only phases to the left of the barrier, or to the right of the barrier, can time concurrently. Following this format, while phase 1 is active in the top ring, only phase 5 or 6 can be timing in the bottom ring.

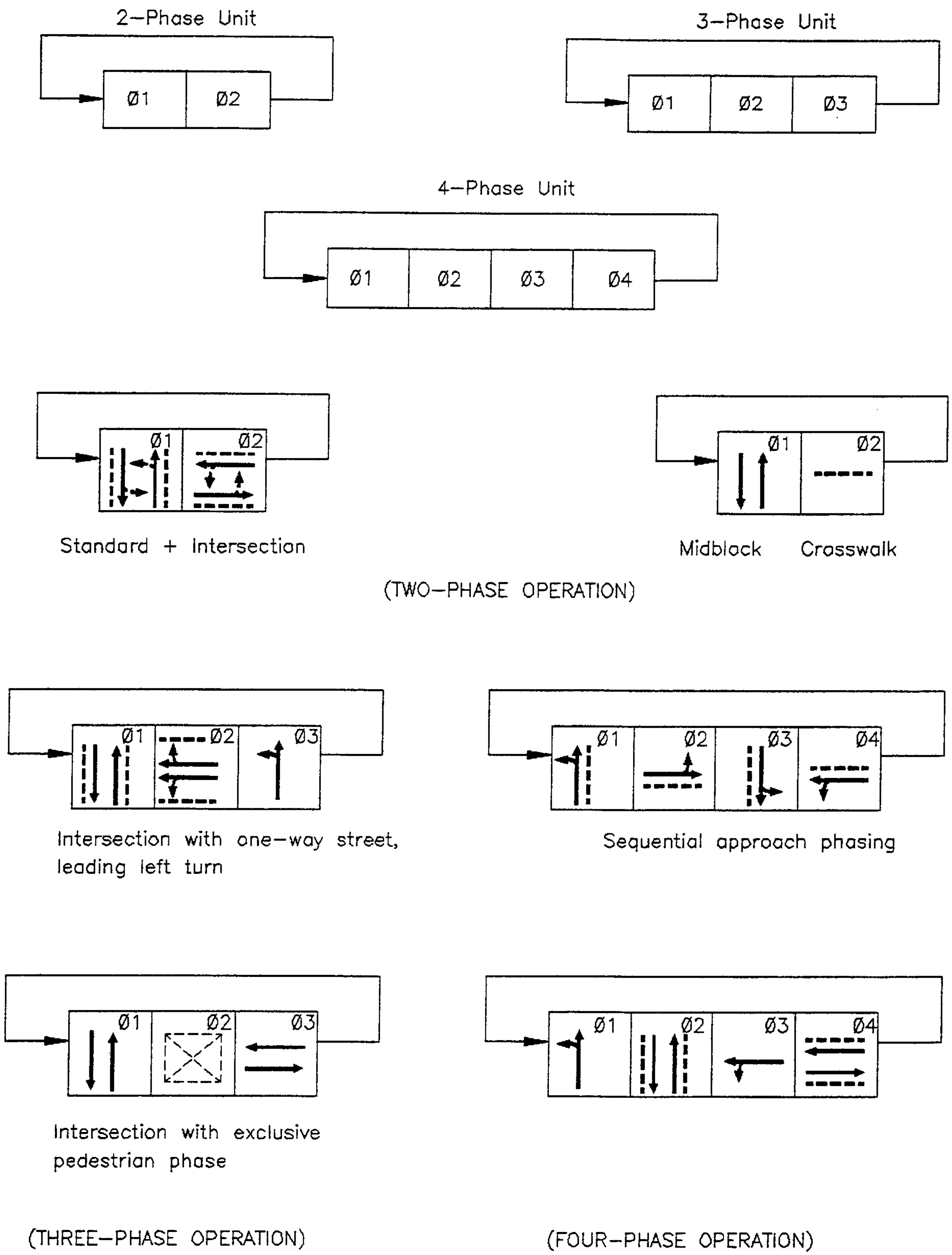
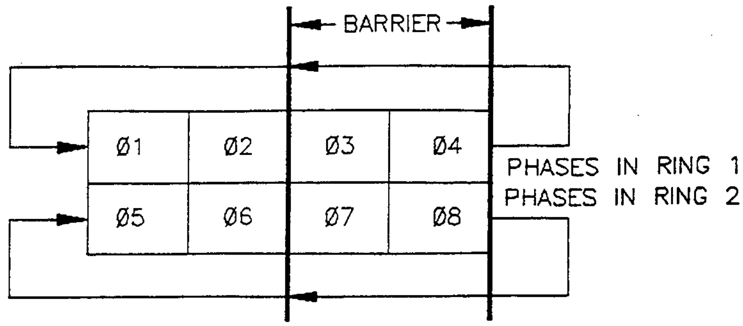
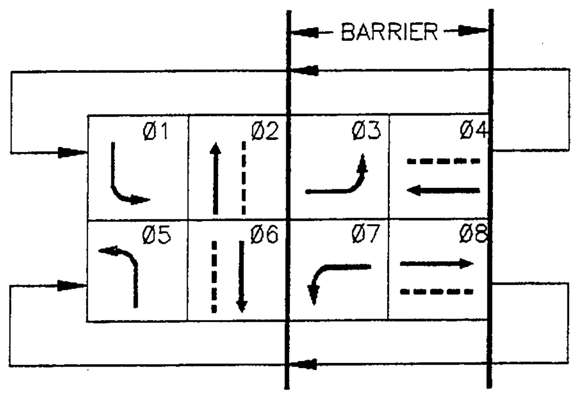


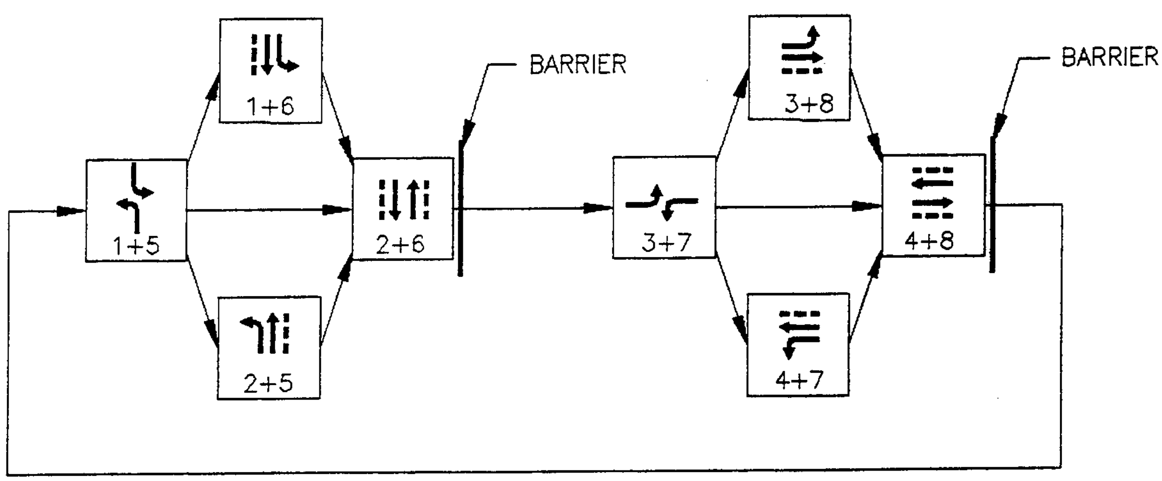
FIGURE II-1. Single Ring Controller Unit & Typical Phase Assignments



A. DUAL RING CONTROLLER UNIT



B. DUAL RING PHASE ASSIGNMENTS



C. DUAL RING OPERATION

FIGURE II-2. Dual Ring Controller Unit & Typical Phase Assignments

The applications of this operation can be more easily seen if traffic movements are added to the dual ring diagram, as shown in Figure II-2B on Page II-6. If, for example, all phases to the 1eft of the barrier are on the main street, and all phases to the right are on the side street, then phases 1 and 5 are opposing main street left turns and phases 2 and 6 the main street through movements. Similarly, phases 3 and 7 are side street lefts, and 4 and 8 are side street throughs.

It should be noted that NEMA does not assign the numbered phases to cardinal approach directions. Some states do assign directions for state-wide uniformity. In addition, NEMA does not define phases 1, 2, 5, and 6 as major street movements, but this configuration has become a common practice in the industry.

In Figure II-2C, Page II-6, the dual ring operation now becomes apparent. Opposing main street lefts start the cycle. However, if one of the two lefts has a higher demand than the other, the lesser movement's phase can be terminated and the opposing through movement started. Finally, the heavier left turn phase will terminate, and opposing main street greens will time concurrently.

However, since one ring cannot be advanced to the side street left (as the main street through would conflict with the side street left), phases 2 and 6 must terminate simultaneously to cross the barrier to phase 3 and 7. A similar operation occurs when the controller unit is in phases 4 and 8 (side street throughs), and is to advance to phases 1 and 5 (main street lefts). Of course, phases can be skipped if no demand exists for a particular phase. Controller unit operation must still conform to the sequencing and constraints defined above.

A five phase configuration, shown in Figure II-D, Page II-8, is used where left turn phases are not needed on one of the intersecting streets. In the example shown, only the phase 4 functions are used for the street movement — opposing throughs with permissive (unprotected) lefts.

A six phase configuration can be used when split side street movements are desired. In the example shown in Figure II-E, Page II-8, the main street has dual ring operation, and the side street uses the Phase 3, then Phase 4 functions for the split side street operation.

When one left turn movement in an eight phase operation is not needed, a seven phase configuration results, as shown in Figure II-F, Page II-8. In this example, only the functions of Phase 7 are not used.

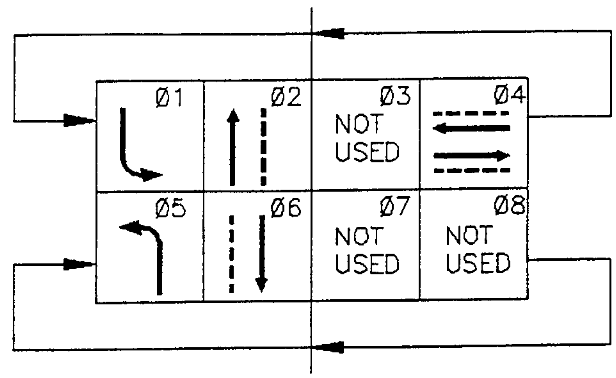
Dual ring controller units have two modes of operation known as Dual Entry and Single Entry. Dual Entry is a mode in which one phase must be in service in each ring. For example, if a call brings Phase 4 to Service, then either Phase 7 or 8 (as predetermined by either user or manufacturer programming) must also be serviced. In Single Entry operation, the phase in one ring can be serviced and timed alone if there is no demand for service in a non-conflicting phase on the other ring.

CONTROLLER UNIT CONCEPTS: NEMA AND MODEL 170

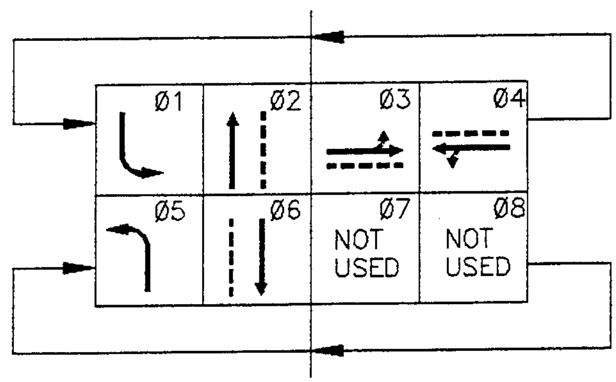
Problems experienced in the 1970's centered around the lack of interchangeability among the number of different systems being manufactured. Test procedures and quality assurance techniques varied in effectiveness and were costly to implement because of the varying systems being supplied. For manufacturers, there was the cost and trauma of developing customized designs and the manufacture of controller units to meet various specifications made the prediction of manufacturing cost difficult.

The magnitude of this problem provided the impetus for the development of two distinct approaches to resolve the problem.

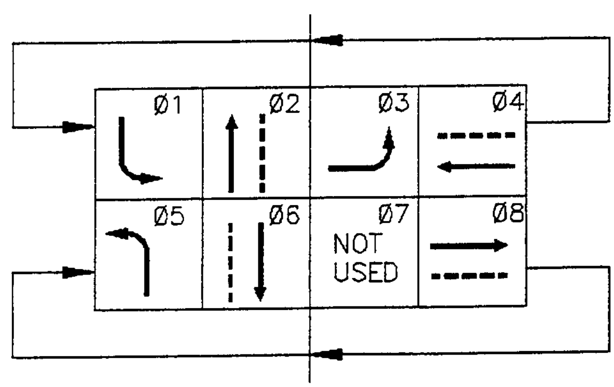
- Development of functional standards by NEMA



D. FIVE–PHASE OPERATION



E. SIX–PHASE OPERATION



F. SEVEN–PHASE OPERATION

FIGURE II-2. Dual Ring Controller Unit & Typical Phase Assignments (Cont.)

- Development of standard design and specifications by California and New York — Model 170 Controller unit specifications.

NEMA Standards

NEMA, the National Electrical Manufacturers Association, is an organization of manufacturers of various types of electrical equipment. One of the Association's primary functions is the development of standards defining a product, process, or procedure relating to electrical equipment. A NEMA Standard must be approved by at least 90 percent of the members of the appropriate subdivision before it is released by the organization.

NEMA standards are developed and funded by the manufacturers. Because of the high technology involved, this represents a considerable outlay of engineering time and expense. The NEMA Standards are completely functional. The individual manufacturers develop the hardware and software to implement the specified functions under competitive free-enterprise conditions without government assistance.

Members of NEMA are grouped into sections based upon the type of equipment they manufacture. A Traffic Control Equipment Section was formed in 1972, with the majority of the traffic signal equipment industry as members. The group identified two major problems facing their industry at that time: 1) many governmental jurisdictions were developing their own specifications for solid-state controller units, all different to some extent; and 2) equipment was not interchangeable between manufacturers, thus creating maintenance stockpile difficulties.

The Section formed a technical committee to develop a set of standards for traffic control equipment that addressed these problems. The specific goals of the committee were to:

- Develop a set of standard definitions
- Develop a set of standards detailing environmental and operating conditions for the equipment, as well as test procedures for demonstrating performance under those conditions.
- Develop interface standards for solid-state, actuated controller units including connector types and input and output terminations.
- Develop functional standards for these controller units.
- Develop standards for solid-state load switches for signal lamp circuits.

Over a four-year period, this committee developed a draft set of standards, which was then sent to a wide sampling of governmental agencies for review. The draft was revised to reflect their suggestions, and was subsequently approved by the traffic control subdivision. These standards were published in 1976 as NEMA Standards Publication TS1-1976. The Federal Highway Administration, Institute of Transportation Engineers, and International Municipal Signal Association all endorsed the use of the Standards.

Since the initial publication of the Standards, requirements for conflict monitors, solid-state flashers, and loop detectors were developed and added to the document. In addition, new interface and functional standards for controller units (Section 13 and 14) were developed and distributed as a revision to the Traffic Control Systems (TS) Standards in 1981.

In 1983, NEMA reissued the Standards, labeling it Standards Publication TS1. The previously developed standards were updated. However, a new section (Section 11) was added to define standards for loop detectors with delay or extension timing. This section and Section 7 were later combined into new Section 15 dated August, 1986.

A new section of Standards for Terminals and Facilities was released as Section 10 of TS1-1983 in October, 1985. Subsequently, NEMA reissued the standards in 1989 labeling it TS1-

1989 and superseded TS1-1983.

In 1992, NEMA TS1 was expanded by the NEMA organization by adding two control approaches to enhance the operation and functionality of the current NEMA TS1 controller unit. This expansion took place during the years of 1987 through late 1991. The standard publication of NEMA that covers the two control approaches is referred to as NEMA TS2, Traffic Control Systems, and is covered in a later section.

NEMA TS1 Standards define both timing and control functions for actuated controller units. These functions are presented on a per phase, per ring, and per unit basis. In NEMA controller units, each phase has five inputs that affect the operation of the phase. Two of the inputs are detector inputs - one for vehicles and one for pedestrians. These inputs allow detectors to place calls for the desired phase. A third input is the Hold input, which permits an external command to retain the right-of-way on active phase. This input is often used when the controller unit is operated within a coordinated system.

Other inputs are Phase Omit and Pedestrian Omit. The Phase Omit input causes the omission of a phase, even in the presence of a demand for that phase. Similarly, the Pedestrian Omit input inhibits the selection of a phase due to a pedestrian call and prohibits the servicing of a pedestrian call. These two inputs can be used for time-of-day prohibition of a movement, for creating permissive periods in coordination for generating preemption sequences, or numerous other modifying operations.

Each NEMA phase has nine outputs. Three outputs are the Red, Yellow, and Green driver circuits that generate the vehicular displays. Another three outputs; WALK, Pedestrian Clearance, and DON'T WALK, are used to generate pedestrian displays for the phase. The final three outputs are Check, Phase On, and Phase Next. The Check output indicates the call status of the phase while the controller unit is not in green for that phase. The Phase On output indicates that either the Green, Yellow, or Red Clearance for a phase is active. The Phase Next output is generated when the phase is committed to be next in the sequence, and remains present until the phase becomes active.

NEMA controller units provide means for storing a call for vehicle or pedestrian service, as required, on each phase. Minimum Recall places a recurring call for service on the phase when that phase is not in its green interval. The call appears to the controller unit as a single vehicle. Maximum Recall places a constant call for a phase as if very heavy traffic were present, thus the green timing will be extended to the maximum. When a constant call is placed, the maximum timer commences as if there were always a serviceable conflicting call, but the phase does not terminate unless there is an actual conflicting call. Pedestrian Recall places a recurring pedestrian demand for a phase and is not recycled until an opposing phase is serviced.

Almost all timing functions are on a per phase basis. NEMA requires the timing functions shown in Table II-1, Page II-11, to be provided. Care should be taken when specifying a NEMA controller unit to list all volume-density features (Added Initial, Time to Reduce, Time Before Reduction, and Minimum Gap) since they may not be provided on all phases, depending on the manufacturer.

Timing of the Green interval is dependent on whether or not the phase is actuated, and, if it is actuated, whether or not the volume density features are provided.

<u>**Program Software:**</u> Although manufacturers provide fixed function software, NEMA does not really address "software." Early NEMA controller units were not microprocessor-based. Functions were described, but handled as digital functions and not a program. The controller unit is dedicated to actuated traffic control functions, while special applications (diamond interchanges, unusual phasing, etc.) are usually accomplished through external manipulation of standard controller unit inputs by specially designed

TABLE II-1. Per Phase Timing Functions

Function	Range, Seconds	Increments, Seconds
Min Green (initial)	1 - 30	1
Passage Time (preset gap)	0 - 9	0.25
Maximum 1	1 - 99	1
Maximum 2	1 - 99	1
Yellow Change	0 - 7	0.25
Red Clearance	0 - 7	0.25
Walk	1 - 30	1
PED Clearance	0 - 30	1
Added Initial	0 - 3 per Actuation	0.125
Time to Reduce	1 - 60	1
Time Before Reduction	1 - 60	1
Minimum Gap	0 - 7.75	0.125

Source: NEMA TS1

hardware. Many manufacturers, however, are providing controller units that are more adaptable to special applications which are beyond NEMA requirements. These devices include such applications as diamond interchange controller units, traffic masters, pretime and hybrid actuated-pretimed controller units, and coordination units. These special application devices are not interchangeable with other NEMA controller units.

NEMA Standards TS1: TS1 includes the following sections:

Section 1 is definitions of words and phrases related to traffic control equipment industry as represented by NEMA (i.e. cabinet, barrier, call, controller unit assembly, force off, hold, interval, etc.)

Section 2 defines environmental standards and test procedures for intersection control equipment. It defines equipment operating standards, voltage, frequency range, temperature, humidity, transients, power service, and test procedures for the controller unit assembly which includes weatherproof cabinet, controller unit, load switches, detectors, flashers, signal conflict monitor, and alternating-current line filters.

Section 3 was superseded by sections 13 and 14, July 1984.

Section 4 was superseded by Sections 13 and 14, July 1984.

Section 5 defines the requirements for solid state load switches which are connected between the alternating-current line power and traffic signals.

Section 6 for conflict Monitors was added in response to the need for a combination signal conflict and voltage monitor capable of interchangeability between units of different sources of manufacture.

Section 7 was superseded by Section 15, August 1986.

Section 8 defines solid state flashers which are used to periodically interrupt a source of alternating-current line power for the purpose of providing flashing traffic signals.

Section 9 is reserved for future additions.

Section 10 defines minimum requirements for terminals and facilities within the cabinet. It also defines the performance and construction standards and requirements for cabinet terminals and facilities that are of the attached or non-plug-in type. Emphasis is placed on electrical requirements, cabling, supporting terminal facilities and labeling.

Section 11 Superseded by Section 15, August 1986.

Section 12 Reserved.

Section 13 is interface standards for advanced two-phase through eight phase solid-state traffic controller units. It also defines interface requirements for a class of solid-state-actuated controller units with input/output spare for future use.

Section 14 is definitions and physical and functional standards for advanced two-phase through eight-phase solid-state traffic signal controller units of the vehicle-actuated type.

Section 15 is standards for inductive loop detectors which cover the performance and design requirements of interchangeable inductive loop detector units.

The NEMA TS1 Standards rely heavily on point-to-point wire connections for all functions, as discussed earlier. A TS1 controller assembly typically has a total of approximately 325 wire connections, many of which are not used. The current hardware configuration with the Military Specification A (MSA), Military Specification B (MSB) and Military Specification C (MSC) connectors also limits the controller unit from future expansion without nonstandardizing the front panel connectors, i.e. connector Military Specification D (MSD). Furthermore the NEMA

TS1 Standards do not cover coordination, time base control, preemption, uniform code flash, internal communications, diagnostics, cabinet, and pretimed control. All of these limitations are now circumvented with the NEMA TS2 Standards.

<u>NEMA Standards TS2</u>: NEMA Standards TS2 supplements TS1 with several new features and adds entirely new performance oriented standards, i.e. controller units. Some of NEMA TS2 new features and functions include the following:

Standard Features

- Actuated and pretimed control
- Conditional service
- Additional detectors
- Delay/extension/switching detectors
- Dual entry
- Alternate phase sequences
- Start-up flash
- Automatic flash
- Dimming
- Coordination: 16 timing plans; one cycle length per timing play; one split per timing plan; three offset per timing plan
- Preemption: six inputs; six sequences
- Time base: yearly clock; daylight savings; and leap year
- Internal diagnostics: memory diagnostics; processor monitoring; conflict monitoring checking; and detector diagnostics.

Conflict Monitor (Malfunction Management Unit)

- One type, 12 channel unit only — configurable as 12 four-input channels or 16 three-input channels
- Port 1 connector
    - Communications with controller unit, as described above
    - MSA, MSB connectors downward compatible with those on a TS1 conflict monitor. Used primarily for sensing of voltages on field terminals.
    - Low voltage monitoring-monitor will be the first unit in a cabinet to sense a low voltage condition and will put intersection in flash in an orderly manner. Vice-versa on power up.

Detectors

- Rack mounted — 16 detector channels per rack, up to 4 racks.
- Port 1 connector
    - Pluggable, interchangeable bus interface unit to convert port 1 high speed serial data to format required by individual detectors
    - Communications with controller unit, as described above
    - Per channel diagnostic data: open loop; shorted loop; excessive inductance change; and watchdog failure
    - Detector reset capability
    - Operation from either 12 volt or 24 volt DC power supply

Rear Panel (Terminals and Facilities)

- Conventional load switches, flasher, flash transfer relays
- Termination points for needed functions
- Port 1 connector: communications with controller unit, as described above, and pluggable, interchangeable bus interface unit to convert port 1 high speed serial data to format required by rear panel

TS2 standards covered two types of controller units: Type 1 and Type 2. The Type 1 controller unit standards are entirely new performance oriented standards, while the Type 2 controller unit standards included a downward compatible environment whereby the MSA, MSB and MSC connectors can be used in common with the NEMA TS1 equipment. Features of the Type 1 and Type 2 TS2 controller unit standards include the following:

Type 1 TS2 Controller Unit Approach

- Display—alphanumeric display—32 characters, 2 lines minimum
- Port 1 connector
    - High speed full duplex data channel

connecting controller unit,conflict monitor (malfunction management unit), rear panel (terminals and facilities) and detectors
    - All data exchange with rear panel
    - Controller unit and conflict monitor exchange information on a regular basis, performing redundant checks on each other. Controller unit has access to all conflict monitor internal information, making enhanced event logging, remote intersection monitoring and remote diagnostics feasible.
    - All detector information, including detector diagnostics.
    - E1A-485 serial communications interface with noise immunity characteristics.
    - SDLC (synchronous data link) communications protocol with a bit rate of 153, 600 bits/second, utilizing sophisticated error checking.
    - Vast reduction in number of wires in the cabinet.

- Port 2 Connector
    - EIA-232C connector
    - Interface to personal computer
    - Interface to printer

- Port 3 Connector
    - 1200 baud, FSK serial port for on-street communications

Type 2 TS2 Controller Unit Approach

The TS2 Type 2 is the same as the Type 1 with the following exceptions:

- The MSA, MSB, and MSC connectors for the controller unit are compatible with equipment conforming with the NEMA TS1-1989 Standards Publication.
- MS connector pin-outs are configurable to one of eight modes to satisfy different applications and achieve different functionality. Default mode is pin compatible with TS1-1989.

Other standards of NEMA TS2 included the following:

- Bus interface units
- Flash transfer relays
- Cabinet
- Pretimed controller unit

For further information on the specifics of these standards you should refer to NEMA TS2 standards publication. It can be obtained by calling (202) 457-8400.

MODEL 170 SPECIFICATIONS: Simultaneously with the evolution of the NEMA Standards, the States of California and New York developed the Model 170 controller unit system. As with the evolution of NEMA Standards, the development of this new controller unit was a direct response to the problems of non-interchangeability. The system developed would be interchangeable between all manufacturers resulting in less problem with maintenance stockpiles and easing problems of procurement.

Specifications were developed by the California and New York Departments of Transportation. These were written with the primary purpose of becoming procurement documents for California and New York, and the two states agreed to use the same processor (a 6800 series processor). These specifications address hardware but not software for various applications. They do detail acceptance testing requirements and procedures. The specifications contain the following items.

- Control unit
- Conflict Monitor
- Cabinets
- Loop Detectors
- Magnetometer Detectors
- Switchpacks (Load Switches)
- Relays
- Modem
- Flashers
- Auxiliary Output File (for more loadswitches)

The primary goals of the Model 170 controller unit were to:

- Allow multiple applications, not just actuated control.
- Reduce maintenance costs and provide easier tests for initial acceptance troubleshooting.
- Develop a non-proprietary controller unit system to facilitate competitive bidding.

Goals unique to California applications also included:

- A standard controller unit and standard cabinets with standard components (detectors, flashers, load switches, monitors, etc.) that could be used at any intersection.

- A single controller unit that is adaptable to almost 100% of intersections but with some software modifications for non-typical intersections.

- Large, base mounted cabinet, with full component layout
  - 44 detector inputs
  - 16 switchpack positions

Unique New York goals also included:

- A system adaptable to 95% of intersections with no software modifications
- Smaller, pole-mounted cabinet with 16 detector inputs and 14 switchpack positions

The California Model 170 and New York Model 179 use standardized hardware but do not use standardized functions. The underlying key concept was modularity and interchangeability, with the exception of the software. It is defined as a system incorporating cabinet, controller unit, and required accessories.

All components are designed for modular mounting in a rack assembly. The controller unit is a multi-purpose microprocessor that accepts various software packages. Inputs and outputs are generally not defined by purpose, only in level and type. All hardware is interchangeable between manufacturers included controller unit, load switches, conflict monitor, detectors, and modems.

In the Model 170 concept, the user has the ultimate responsibility for making the controller unit operate. Consequently, the user must supply the software for the Model 170. The various sources to obtain this software usually include:

- User-supplied software
  - Developed in-house, such as California and New York
  - Obtained from other operating government agencies that develop software
  - Obtained from software consultants
  - Obtained from controller unit vendors

- Manufacturer-Supplied Software
  - Vendor is normally responsible for total controller unit system operation

The software can accomplish various purposes including:

- Intersection control (pretimed and actuated)
- Diamond Interchange Control
- Ramp Metering
- On-Street Master Controller Unit
- Sprinkler Control
- Weigh-in-motion systems
- Changeable message sign control
- Traffic Count Station

All of these various purposes are based on PROM programming on interchangeable PROM modules.

The latest Model 170 specifications and revisions are dated 1992 and 1989 for New York and California, respectively.

OVERVIEW OF THE NEMA CONTROLLER UNIT AND COMPONENTS

NEMA provides standards for a controller unit and a number of controller unit cabinet components. These components, including all the necessary auxiliary devices for input and output functions, are discussed below. The following discussion is only applicable to NEMA controller units that meet NEMA TS1 standards.

The NEMA controller unit is a dedicated controller unit, designed for two-to-eight-phase, dual ring, full-actuated intersection control. It is designed to be interchangeable between similar units from other manufacturers, but still allowing variations in design for appearance, operator interface, and special function operation to permit the competitive creativeness of the manufacturers.

The controller unit is designed to operate inside a weatherproof cabinet of the controller unit assembly.

<u>Major Components</u>

NEMA's TS1 Standards only cover the required functional operation of the controller unit, input and output levels, and connector types, and leave the techniques for providing the operation up to the manufacturers. Almost all of the NEMA controller units in production today are microprocessor based. The economics of developing a digital controller unit cannot compare with the new technology of microprocessor-based design.

The Central Processing Unit (CPU), which includes the microprocessor and memory devices, runs the controller unit. The microprocessor chip has not been standardized, and is selected at the manufacturer's design option. Also included as an integral part of the controller unit is the input and output circuitry, the devices that sense the state of an input or that cause the change in state of an output. Depending on the number of phases in the controller unit, the number of inputs and outputs will vary. To provide the interchangeability desired between NEMA controller units, the NEMA Standards define both interface requirements and the required functions.

NEMA has defined three standard connectors (A, B, and C) and pin assignments within those connectors. The connectors and their pin assignments have been configured in such a way to allow interchangeability throughout the full range of two to eight phase controller units.

All inputs to the controller unit operate on a ground true basis (the active state shown when a ground, or zero voltage reference is placed on the input). The operation of the controller unit program, as defined by NEMA, includes a number of inputs on a per phase, per ring, and per unit basis. The input designations were based on the planned use of external devices for functions such as preemption and coordination; accordingly, much consideration has been given to the manipulation of the normal isolated operation of the controller unit.

Outputs from the controller unit include load switch drivers (to operate the solid state relays which in turn operate the signals on the street), as well as various status indicators. These indicators on load switches show the presence of calls on each of the phases, the interval currently being timed in each ring, the phases currently being timed, and the next phase to be selected. These status indicator outputs are intended for use with the external devices described above, as a means of transferring information on what the controller unit is doing to the external devices (load switches and indicators).

<u>**Software**</u>: With the microprocessor based NEMA controller units, the software or programming necessary for operation is developed and maintained by the manufacturer of the controller unit. This software remains proprietary for the manufacturer. The user will not normally be given permission to copy or modify the software for use in other manufacturer's controller units.

<u>**Operator Interface**</u>: The NEMA Standards do not specify a particular means for the entry of timing data into a controller unit. As a result, NEMA controller units have been developed using such data techniques as pin programming, DIP switches, thumbwheels, and keypad programming. Each approach performs the same function—entering timing parameters into the controller unit.

The most prevalent means of data entry with today's microprocessor based controller units is the keypad. Unlike other techniques, in which timing values were ultimately a series of switch closures or other physical electrical contracts, keypad entered data are stored in RAM.

There are a number of advantages to keypad entry. First, keypad controller unit are much less expensive to build, particularly in relation to thumbwheel type controller units. Second, keypad data entry can provide an added degree of security, by requiring the entry of a password to gain access to memory. And third, a keypad can be used to enter coordination and preemption data on those controller units with internal functions beyond the range of the NEMA Standards.

However, there are also a couple of disadvantages with keypad entry. NEMA does not specify a standard for the entry of data through a keypad. Therefore, there is no standardization between manufacturers as to keystroke sequence or key placement. For technicians maintaining a number of different manufacturer's controller units, this can be a problem.

Also, using a keypad means that a longer time period will be required for the entry of data, or for data retrieval, as opposed to thumbwheel controller units. Determining existing data can be tedious; therefore, some manufacturers have utilized printers that can record the data that is in memory.

While each manufacturer's keypad procedures are different, there is some commonality between many of the different controller unit makes. Most use a "Phase-Interval-Value-Enter" sequence for loading data. A typical operation would be:

Press "Phase"
Press the phase number (1-8)
Press "Interval"
Press the interval number (or labeled key)
Press "Value"
Press the timing value (numeric)
Press "Enter"

Some manufacturers use one keypad, while others use two or more.

The latest advancement in data entry has been the provision of downloading techniques on many new NEMA controller units. Timing parameters can be entered on a microcomputer located at a central office or shop, and communicated, over telephone lines or interconnect, to an individual controller unit.

Downloading presents a number of potential advantages. Controller unit timings can be changed from a central site, without having to drive to the remote location. A replacement controller unit, installed during a maintenance call, could be automatically programmed to have the same timings as its predecessor, with a considerable time saving.

Controller Assembly Equipment: Auxiliary devices, necessary to interface the controller unit with its surroundings, are also located in the cabinet. These include input devices, such as detectors, and output devices, such as load switches. Major components are described in the following sections.

Backpanel: The backpanel provides the electrical interface between the controller unit and the auxiliary equipment and the intersection displays. The backpanel includes termination facilities, load switches, flashers, flash transfer relays, power distribution, overload protection devices, and various wiring harnesses.

NEMA Standards (Section 10) cover the terminals and facilities and standards do exist for certain components of the backpanel, such as the load switches, flashers, and harnesses.

The backpanel itself is usually a formed piece of sheet metal that is attached to the interior of the cabinet. There is typically a main backpanel for controller unit terminations and load switch facilities and there may also be smaller auxiliary panels, mounted on cabinet side walls, for detector lead-in termination, power distribution or other auxiliary functions.

All controller unit harness conductors are terminated on terminal strips on the backpanel. These include harnesses from detectors and the conflict monitor. Also included are coordination devices and preemptor devices. The termination area permits the electrical interface of the various pieces of equipment in the cabinet.

Load Switches: Load switches are devices used to switch power to the lamps in the signal heads. Controller unit circuitry does not have the capacity necessary to control multiple 110 volt displays. Therefore, load switches are used as relays to control the signal circuits.

NEMA Standards include requirements for load switches, calling for them to be solid state, three circuit devices, with a standardized plug connector for insertion into the backpanel. Each load switch can control the signal power for one vehicular phase or one overlap (each with Red, Yellow, and Green signals) or one pedestrian phase (for the DON'T WALK and WALK indications, with one circuit unused).

Flashers: Flashers are similar in construction and appearance to load switches. NEMA has defined three types of flashers, one with a single flashing output, the other two with alternating dual flashing outputs. All three have a standardized connector.

The flasher is an important component of the cabinet system as it provides a backup for the stop-and-go operation of the controller unit. Should the controller unit fail, or some other electrical problem in the cabinet occur, the flasher is used to illuminate the signals in the street in a flashing mode.

Flash Transfer Circuitry: The function of the flash transfer circuitry is to electrically isolate the flashing function from the stop-and-go function of the controller unit. For example, when in flashing operation, the controller unit continues to operate, outputting the appropriate load switch drivers. The flash transfer circuitry prevents the flasher output from being interfered with by the controller unit load switch outputs (i.e. so that green is not on with a flashing red, etc.).

Power Distribution and Overload Protection Devices: NEMA has standards for power distribution and overload protection (Section 10 Terminals and Facilities). Components included in this category are:

- The Grounding System, which consists of three parts:
  - The neutral bus, to which all neutral conductors are connected
  - The ground bus, to which all equipment grounds are connected and which is then connected to the ground rod
  - The logic common bus, which is the zero voltage reference point needed for the actuation of a ground true input.
- Circuit Breakers usually include a main breaker protecting the controller unit and signals and an auxiliary breaker serving the convenience outlet and cabinet light fixture.
- Overvoltage and Lightning Protection, to limit the means of ingress or potentially damaging overvoltage spikes or lightning strikes. The need and extensiveness of the protection equipment is heavily dependent upon the geographical location of the intersection. Therefore, it is not covered in Section 10.
- Mercury Contactor, which is a heavy duty relay for controller unit power to the signal bus, which, in turn, supplies the load switches with power.

Harness: Harnesses are used to connect

the various pieces of equipment to the back panel assembly. Section 10 of the NEMA Standards addresses the requirements for the type of wire to be used in the harnesses. Standardized connectors have also been defined by NEMA as well as many of the major components of the controller unit system.

Conflict Monitor

Because of the possibility of a solid state device, such as a controller unit or load switch, failing in such a manner as to give an erroneous, and possibly unsafe, indication to the street, the conflict monitor was developed and has been standardized by NEMA.

The NEMA Standard conflict monitor accepts a number of input channels, each consisting of a Green, Yellow, Red, and WALK. A channel might consist of either a phase or an overlap display. There are four types of NEMA monitors:

- Type 3 - Has three input channels preprogrammed for mutual channel noncompatability.
- Type 6 - Has six fully programmable input channels.
- Type 12 - Has twelve fully programmable input channels.
- Type 18 - Has eighteen fully programmable input channels.

The monitor determines the presence of conflicting permissive (Green, Yellow, or WALK) indications or two or more non-compatible channels, and can also sense the absence of a display (no red, yellow, or green output on a channel). In either case, the monitor causes the intersection to go into a flashing operation, and applies "STOP TIME" to the controller unit to freeze it at the point in its operation that the problem occurred.

The conflict monitor also keeps watch over the 24 volt DC voltages put out by the controller unit, as well as a true state voltage monitor signal generated by the controller unit. If a voltage problem occurs, the intersection will again be put into flashing operation.

Conflict monitor channels are programmed using a standardized programming board, with a number matrix of solder pads. When a pair of channels is determined to be compatible, a jumper is inserted at the appropriate solder pad and soldered into position. The card is designed to remain with the intersection, permitting easy swapping of conflict monitors for maintenance or testing purposes. A sample Type 12 is shown in Figure II-3.

Detectors

Demand information from vehicular or pedestrian detector is relayed to the controller unit and an appropriate action taken. Three main types of vehicular detectors are used with NEMA controller units: magnetic detectors, magnetometer detectors, and inductive loop detectors. Only the inductive loop detectors are addressed by the NEMA Standards, which has developed a set of standards for the inductive loop detector amplifiers. Pedestrian detection is accomplished through the use of push buttons.

The NEMA Standards define two basic types of loop detector configurations -- shelf mounted and card-rack mounted. The shelf mounted units are by far the most prevalent in the field, and are available in both single channel and multi-channel (2 or 4 channels) configurations. Each unit is connected by a multiconductor harness to the cabinet backpanel.

Section 11 of the NEMA Standards defines a series of loop detector sensors with internal timing capabilities. These detectors are capable of providing a "delayed call" operation in which the detector does not act on the presence of a vehicle until after a preset time limit. They are also capable of providing an "extended call" mode, in which the detector continues to output a call for a preset time after the departure of the vehicle from the loop.

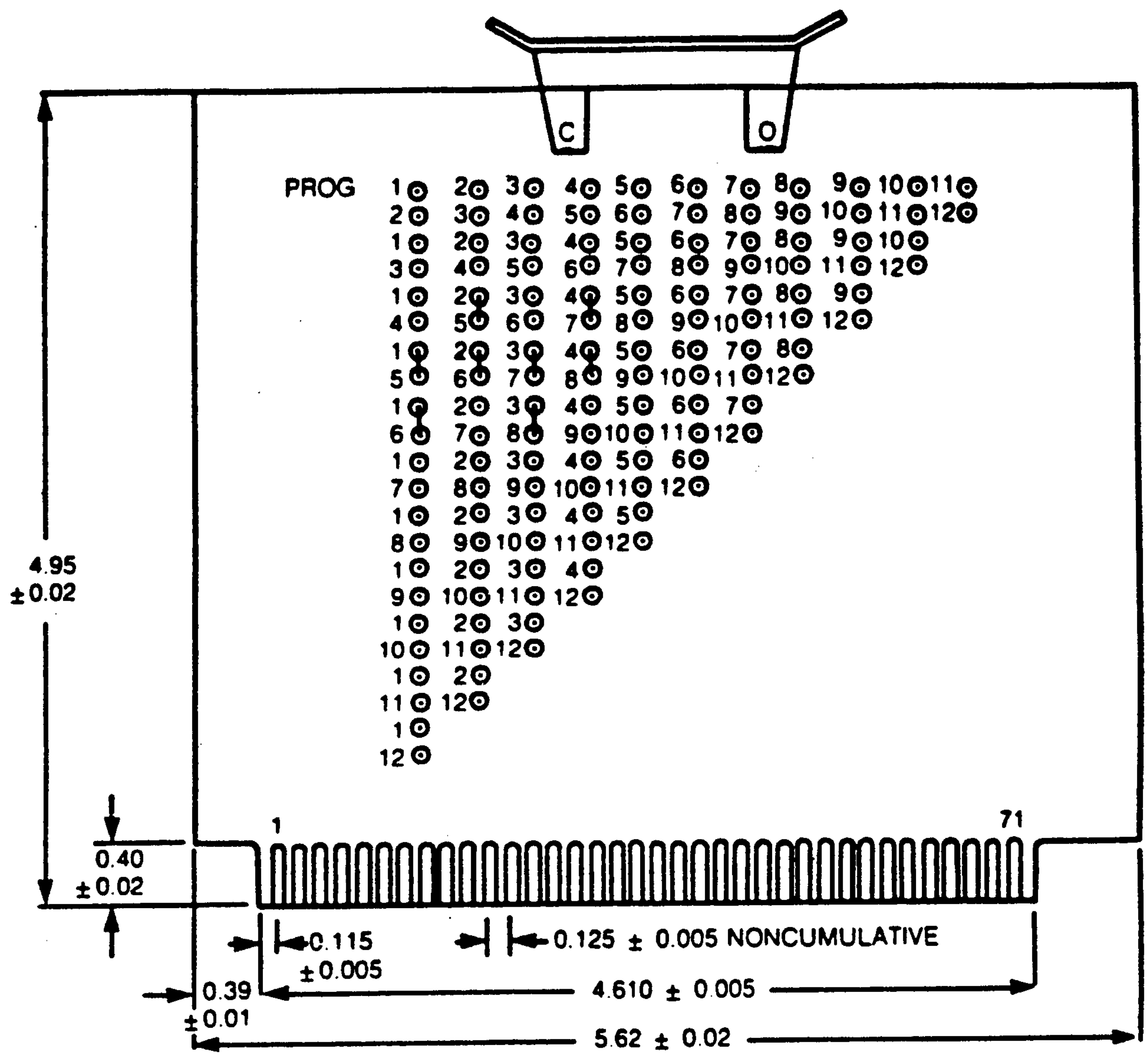


FIGURE II-3. Type 12 Programming Board Front View

Coordination

There are a number of benefits of coordinated operation on arterials. The value of coordinated operation is directly related to platoon characteristics of vehicles arriving at intersections. Significant reduction in stops and delays will result from well-defined, compact platoons. Other benefits include:

- Ability to change timing plans to accommodate predominant flow of traffic,
- Increase capacity to meet peak demands,
- Control speeds on major arterials,
- Provide gaps for crossing vehicular and pedestrian traffic at unsignalized intersections, and
- Conserve energy and improve safety by reducing stops and delays.

NEMA controller units can also be easily integrated into a coordinated system, using external coordination equipment that generates commands for the manipulation of the controller unit. These external devices run the full range, from simple, one dial, offset electromechanical synchronizers to microprocessor-based, time-based coordination devices.

Two basic NEMA controller unit inputs are commonly utilized by external coordination units in supervising local intersection controller units. These are:

- Hold: used to retain the right of way on the coordinated (or main street) phase. The momentary release of the Hold input permits the controller unit to service conflicting calls, it they exist. This momentary release of the Hold command is often referred to as the Yield command.
- Force Off: used to terminate the currently timing green interval of an actuated phase.

Other inputs that may be used in coordination, depending upon the complexity of the coordination scheme, include:

- Call to Non-Actuated Mode (CNA)
- WALK Rest Modifier
- Phase Omits
- Pedestrian Omits
- Pedestrian Movement Recycle

A number of manufacturers of microprocessor-based NEMA controller units are providing controller units with internal coordination features, in excess of the NEMA Standards. Often, time-based coordination can be provided with no changes to the standard NEMA harness wiring. However, controller units with internal coordination may not be interchangeable with controller units from other manufacturers.

Preemption

Preemption is the altering of a controller unit's normal operation to accommodate a special event or occurrence, such as the passing of a train or a fire truck. The NEMA Standards do not address the function of preemption. However, preemption can be easily accomplished by combining a NEMA controller unit with external preemption logic circuits.

External logic circuits are normally incorporated into a harness-connected package known as a preemptor. The preemptor can sense the demand for preemption, through an input or series of inputs, and the current state of the controller unit, from the various status indicator outputs described earlier. The preemptor then manipulates the signal phasing, using such standard inputs as Phase Omits, Holds, and Force Offs, to accomplish the desired operation.

Many of the microprocessor-based NEMA controller units offer the option of internal preemption sequences. As the preemption routines are developed as software and included in the basic intersection program, reliability is increased because of the elimination of the need for additional external devices. Neither the functions of internal preemption nor the connectors necessary for bringing preemption inputs into the controller unit have been standardized. Thus, different controller unit models that provide for preemption in differing ways are interchangeable relative to preemption.

MANUFACTURERS OF NEMA CONTROLLER UNITS

This workshop covers and demonstrates at least five (5) NEMA controller units. These controller units are manufactured by Automatic Signal/Eagle Signal Controls, Econolite Control Products, Inc., Traconex Systems, Traffic Control Technologies, and Transyt Corporation. The following section presents highlights and description of the above NEMA Traffic Signal Control units.

Additionally, Table II-2 on page II-23, summarizes the features of these various controller units.

AUTOMATIC SIGNAL/EAGLE SIGNAL CONTROLLER UNITS

Three NEMA traffic signal controller units are included for demonstration in this workshop. These units are the EPAC 300 actuated controller unit and the EPIC 140 pretimed solid state controller unit, and the MARC 360 on-street master controller unit. (See Figure II-4, Page II-24.)

EPAC 300 Controller Unit:

The EPAC 360 controller unit is a fully actuated two to eight phase traffic controller unit with a full complement of operational, programming, and diagnostic capabilities. The following is summary of features of the EPAC 360.

- **General Features**
  - Front Panel multi-line alphanumeric backlit display (8 lines and 40 characters per line) for all operational parameters and states
  - Fully prompted menu driven programmability
  - EEPROM memory
  - Optional EEPROM module
  - Optional overlap modules and card
  - Modular hardware design
  - Internal diagnostics with automatic and operator initiated verification of:
    - memory
    - display
    - key board
    - processor operators
    - individual inputs and outputs

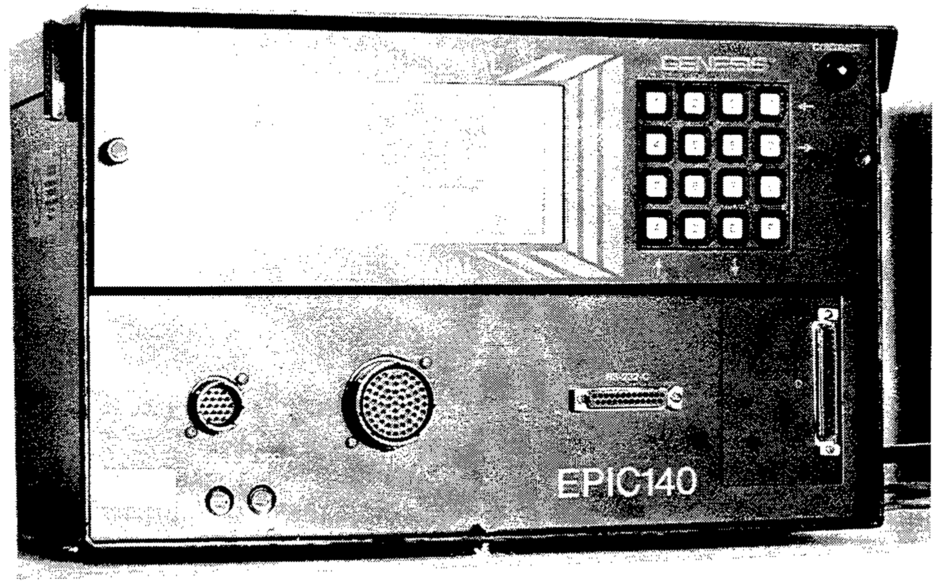
- **Per Phase Features**
  - Time Before Reduction
  - Extended Flashing Ped Clearance
  - Actuated Rest-In-Walk
  - Soft Recall
  - Selective Phase Omit
  - Selective Phase Yellow Omit
  - Conditional Service
  - Detector (stretch, delay, and switch)

- **Per Unit Features**
  - Programmed (Remote) Flash
  - Exclusive Ped Service (Phase 9)
  - Ring Configurations (Up to 4 Rings)
  - Start-Up Flash or All Red
  - Remote Sequence Modifiers (16)
  - Timed Trailing Overlaps
  - Overlap Green/Yellow Omit
  - Auto Timing of Ped Clear
  - Programmed Stop Time Reset
  - Parameter Print Out
  - Unit-To-Unit Transfer

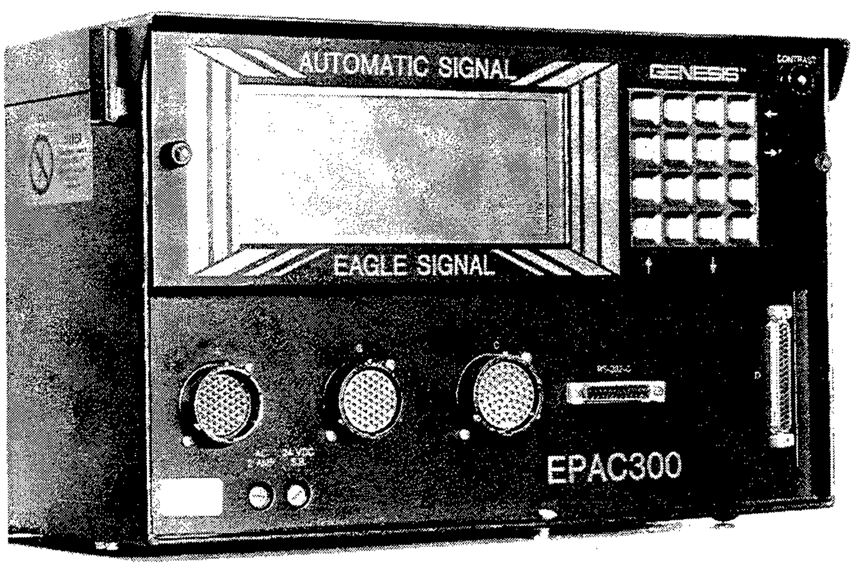
Table II-2. Features of Various NEMA TS1 Local Intersection Controller Units

Function	Manufacturer					
	Automatic Signal/Eagle Signal	Econolite	TCT	SONEX	Traconex	Transyt
Controller Unit Model	EPAC 300	ASC 8000	LMD 8000	ZDC (RCU)	TMP 390	1880 EL
Coordination						
. Cycle/Split/Offset	4/4/3	6/4/5	8/4/5	NI	6/3/5	6/16/5
. Traffic patterns	48	120	96	32	90	480
. Trsp Plans	48	20	All TRSP	32	12	
Preemption Sequences	6	6	6	3	5	6
Additional Bus Preemptors	6	4	6	3	4	None
Speed Trap Detectors	Yes	2	Yes	8	8	Yes
Detector Inputs (System & Local)	16	16	24	16	16	48
Time Base						
. Event Capacity	250	NI	200	63		200
. Weekly Programs	10	10	10	10		10
. Day Programs	99	16	15	10	48	10
. Holiday Programs	92	36	35	24		48
Front Panel Display	8 lines, 40 characters/line, LCD Display	4 lines, 40 characters/line, LCD Display	4 lines, 40 characters/line, LCD Display	1 line, 48 characters, LCD Display	2 lines, 24 characters/line, LCD Display	4 lines, 20 characters per line, LCD Display
Menu Driven	Yes	Yes	Yes	No	No	No
EEPROM Non-Volatile Memory	Yes	Yes	Yes	Yes	Yes	Yes

NI — Not Indicated



(EPIC 140)



(EPAC 300)

Figure II-4. Automatic Signal/Eagle Signal
Models: EPIC 140 and EPAC 300

- **Special Features**

  - Eight System Detector/Coordination Inputs
  - Local TRSP pattern selector
  - Detector Diagnosis
  - Detector Assignments
  - Speed Report
  - Measurements of Effectiveness
    - Green Utilization
    - Time Waiting
    - Cars Waiting
    - Volume
  - Monitor and Log Alarm/Events
  - Remote Selected Special Functions
  - Remote "Manual" Overrides
  - TBC on Loss of Communications
  - Upload and Download Data
  - Communications
  - SOLO Operation with Dialup

- **Time Base**

  - Primary Plus Nine Alternate Weeks
  - 90 Alternate Days
  - 250 Event Capacity
  - Dimming (per Phase by Phase Output)
  - Three Auxiliary Outputs
  - Eight Special Function Outputs

- **Preemption**

  - Six Preempt Sequences with:
    - Delay and Duration
    - Programmable Dwell
    - Programmable Exit
    - Programmable Cycling Dwell

  - Six Low Priority Routines

- **Coordination**

  - 4 Dial/4 Split/3 Offset
  - 48 Traffic Patterns
  - 4 Offset Correction Modes
  - Transition Cycle
  - 4 Operational Modes
    - Permissive (Vehicle and Pedestrian)
    - Yield
    - Permissive Yield
    - Permissive Omit
  - Sync Monitoring
  - Manual Control
  - Input Monitor (Walk Rest Modifier, Manual Control Enable, Stop Time Remote Flash)
  - Dial/Split to Dial/Split Copy

<u>**EPIC 140 Controller Unit**</u>

The EPIC 140 series controller is an interval oriented pretimed traffic controller unit with built-in operational, programming, and diagnostic capabilities. Below is a summary of the EPIC 140 design and operational features.

<u>Displays</u>: The EPIC 140 series backlit display (8 lines and 40 characters per line) provides visibility into program entries, timers, and status of intersection operation. Related parameters are visible simultaneously making verification straightforward. The upper left corner identifies the display and the lower line identifies cursor control and forward/backward menu selection.

<u>Programmability</u>: All programming is via a front panel 16-position keyboard and LCD display. Programming is easy and error free due to the English Language Menus. Within a menu, each parameter may be viewed and a cursor movement to that parameter makes changes easy and error free.

<u>Memory</u>: The EPIC 140 ensures the accuracy of traffic control parameters, even during power outages, EEPROM technology is used to retain all timing and control parameters. No batteries are required for retention of traffic parameters. Event logging and the time base clock utilize RAM memory for those functions with battery support.

<u>Coordination</u>: Sixteen different timing programs may be selected (one for each dial/split combination) with three offsets in each. Coordination settings and activity can

be monitored and controlled. Included are multiple corrections and sync monitoring modes as well as input monitoring and easy to program menus to reduce the number of entries and the potential for errors.

Time Base Coordination (TBC): TBC contains automatic adjustment for leap year and daylight savings changes. It provides a minimum of 250 events each capable of requesting any of the 48 traffic control patterns, three auxiliary events and dimming, TBC also provides the capability to program exception days and alternate weeks on a one-time basis over a year in advance.

Security: The EPIC 140 series provides for a user specified security code entry before data may be altered. This security code entry is never required in order to view any parameter. The EPIC 140 series also has the ability to disable security code entry requirements for perpetual access.

Diagnostics: A resident diagnostic program is standard. In addition to the extensive displays to aid in intersection setup, monitoring, and operation, the resident diagnostic program enhances the maintenance and troubleshooting of the controller unit. Many of the diagnostic routines execute automatically and continually, verifying unit integrity. Diagnostic analysis is displayed and logged in English. Automatic diagnostics begin at power up and continue as long as the unit is operating. Power up diagnostics include ROM, RAM, and processor checks. Failures will result in the unit not enabling the voltage monitor output while the display shows messages such as "ERROR: RAM TEST."

Other features of the resident diagnostic program are available at the operator's request, and when combined with an input/output monitor provide total indication of unit operation. For trend analysis, the failures are logged with date and time and remain available for display as needed.

The time base, coordination, and preemption capabilities of the EPIC 140 are identical to the EPA 300 controller unit. The obvious difference between the two units is the "per unit features" especially since the EPIC 140 is an interval oriented pretimed controller where as the EPAC 300 is a phase oriented controller unit. The EPIC 140 "per unit features" include the following:

- 4 signal plans with 32 intervals
- 4 detector groups with detector stretch and delay
- Programmed (remote) flash
- Start-up flash or all red
- Programmed stop time reset
- Parameter print out
- Unit-to-unit transfer

MARC 360 Controller Unit

The Automatic Signal/Eagle Signal Model MARC 360 Master Controller Unit is an On-Street Master unit designed for the automatic control, monitoring, and data collection of up to 32 EPAC 300 Local Intersection Controller Units. See Figure II-5 on Page II-27.

Each unit consists of a housing, a printed circuit I/O board, a Processor board, and a plug-connected power supply for easy maintenance (no extender boards or other unit exclusive test equipment is required).

EEPROM technology is used to retain all timing and control parameters. All programming is done via a 16-position front panel keypad and. Liquid crystal 8 line by 40 characters per line alphanumeric display for parameter entry and viewing.

- **Modes of Operation**
  - Manual
  - Remote
  - Time Base
  - Traffic Responsive

- **Standard Features**
  - Diagnostics

- **Coordination**
  - Commands: 4 Dial/4 Split/3 Offset
- **Time Base**
  - Primary Plus Two Alternate Weeks
  - (99) Alternate Days
  - (180) Event Capacity for:
  - Traffic Events
  - Auxiliary Events
  - Exception Dates
  - Alternate Weeks
  - Day Equates
- **Other Functions**
  - Monitor and Log Alarms
    - Traffic Responsive Channel Failures
    - Critical Intersection Failures
    - Critical Detector Failures
    - Improper Traffic Responsive Data
    - Power On/Off
    - Six Special Inputs
  - Generate Special Remote Functions
    - Eight Special Outputs
  - Respond to Remote "Manual" Overrides
  - Upload to Remote Locations
    - Parameters
    - Logs
    - Real Time Status
  - Download From Remote Locations
    - Parameters

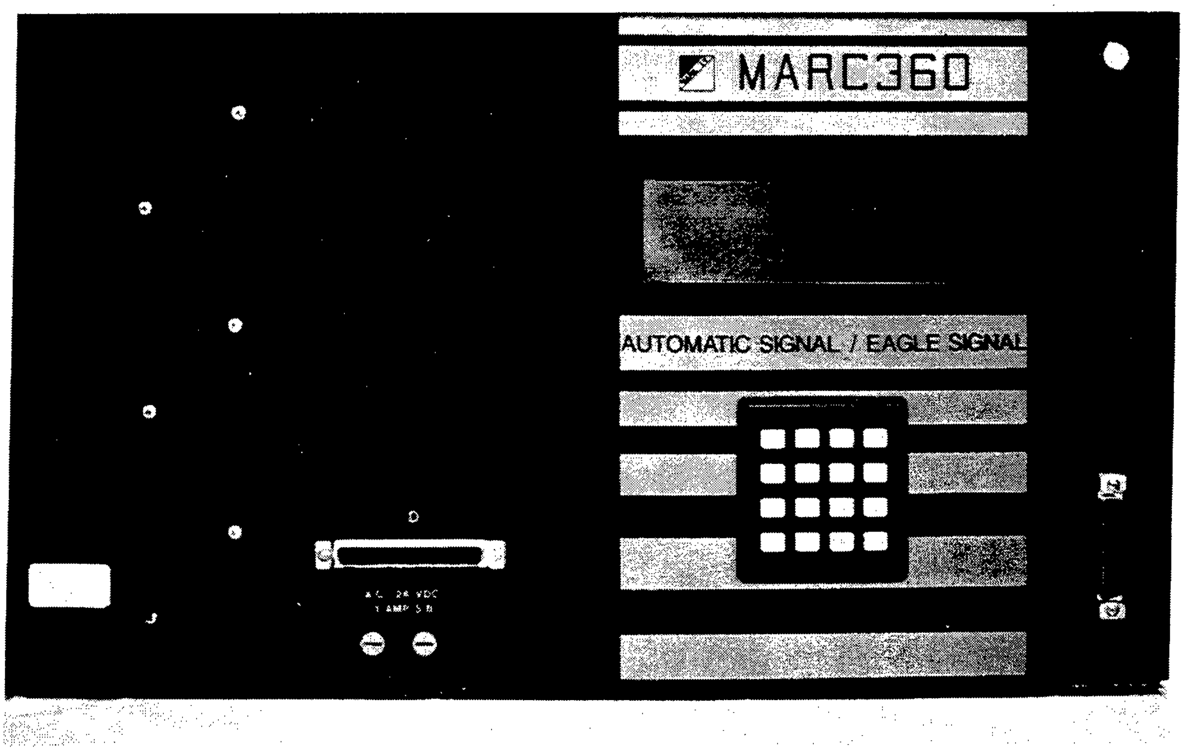


Figure II-5. MARC 360 On-street Master Controller Unit

ECONOLITE CONTROL PRODUCTS, INC.

Two Econolite traffic control units are included in this workshop. These units are the ASC-8000 and the KMC10,000 On-Street Master. (See Figure II-6, page 29.)

Advanced System Controller Unit (ASC-8000)

This controller unit functions as a semiactuated or fully actuated traffic controller unit. The ASC-8000 operates as a two-through-eight-phase controller unit with any combination of eight vehicle phases, eight pedestrian phases, six concurrent groups, two timing rings, and four overlaps. In addition to standard controller unit capabilities, the ASC-8000 provides software and hardware features that simplify programming, operation, monitoring, and maintenance. Programming is completely menu-driven and in most cases involves only ON/OFF selections and time value data entries. Increased flexibility is allowed by providing the operator with numerous programming options and enhanced coordination, noninterconnected coordination, and preemption capabilities. Real-time controller unit activity can be monitored via the eight dynamic status displays.

The ASC-8000 controller unit is made of a formed aluminum enclosure. The front of the ASC-8000 comprises two panels; the keyboard/display panel and the connector interface panel. The keyboard/display panel consists of a custom, weather and dust-proof membrane keyboard with numeric function and cursor keys and a high-contrast 4 line by 40 character liquid crystal display with electroluminescent backlighting. The connector interface panel contains two fuses (+24 VDC/1 Amp and 115 VAC/1 Amp), connectors A through D, and terminal and telemetry connectors.

The controller unit contains two electronic modules and a power supply module. An optional telemetry module is available for system applications.

Processor/Display Module: The Processor/Display module contains the microprocessor (6809), timing and control logic, and associated memory (8K CMOS RAM with battery backup, 54K PROM with optional 32K overlay). All user entered data is stored in a small plug-in 2K EEPROM data module mounted on the processor/display module. The processor/display module controls all ASC-8000 operations as determined by instructions stored in the program memory.

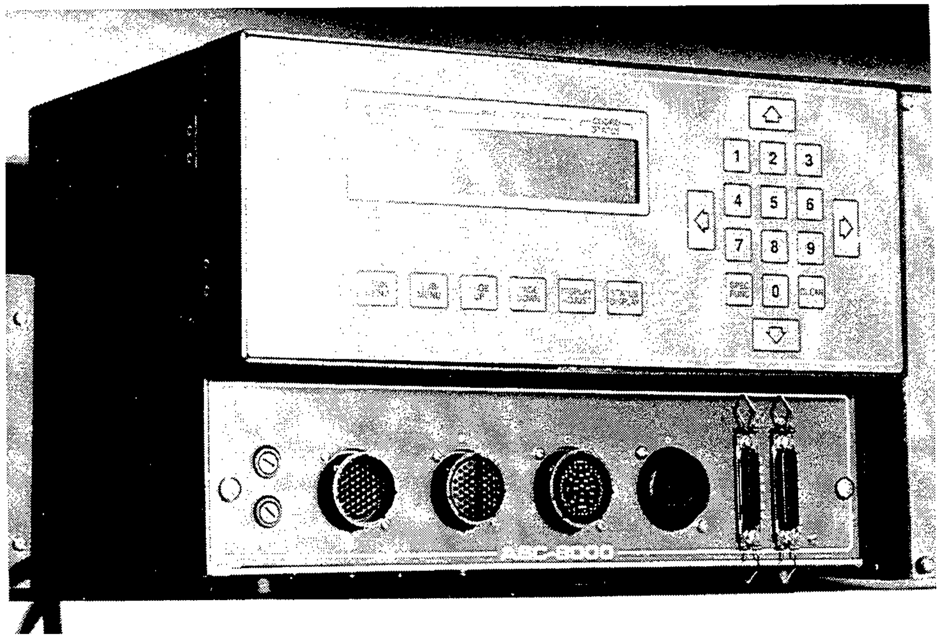
I/O Interface Module: The Input/Output Interface module links input and output information between the microprocessor and external equipment. The module contains latches for storage of information, buffers for logic level shifting between internal controller unit logic circuits and external circuits, and multiplexors for routing input data to the processor. A connector interface accepts a plug-in NEMA standard overlap programmer card for overlap phase programming. The RS232C terminal interface is used in controller unit-to-controller unit and controller unit-to-printer and controller unit-to-computer communication.

Telemetry Module: The Telemetry module is optionally used with the ASC-8000. This module transfers data between a master controller unit and local controller unit/coordinator, system detectors, and other devices in an interconnected traffic control system.

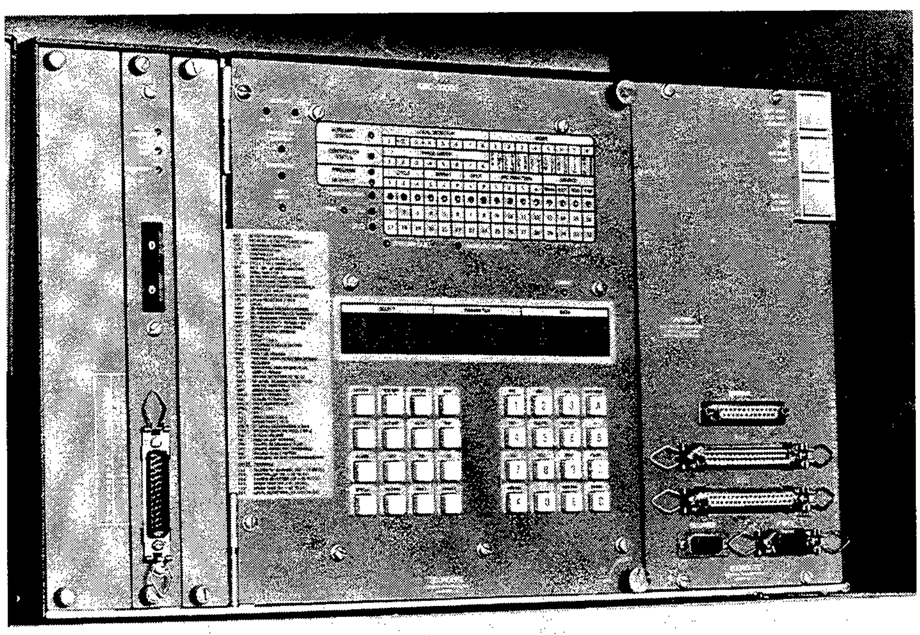
Power Supply: The power supply furnishes various DC voltages required for internal circuits, +24 VDC power used for the controller unit interface circuits, and regulated +24 VDC power for external loads and monitor circuits. The power supply is protected by fuses against current overloads.

Timing Features:

- All standard NEMA timing functions provided.
- Guaranteed minimum times for minimum green, walk, pedestrian clear, yellow, red, and red revert.



Model ASC-8000



Model KMC-10,000

Figure II-6. Econolite Models ASC-8000 & KMC-10,000 Controller Units

- Added density functions include: cars before reduction and actuations before reduction.
- Five-section, left-turn head control.
- Soft recall
- MUTCD flash with flash phases selectable from keyboard.
- Simultaneous gap termination by concurrent group.
- Power on flash or all red time.
- Dimming by phase and color.
- Three max green times for each phase.
- Dynamic extension of max time based on vehicle demand.
- Overlaps programmed from the keyboard or NEMA overlap card.
- Standard and protected-permissive overlaps.
- Program up to 12 overlap movements.
- Backup protection by concurrent group.

Coordinator Features:

- Six cycles with five offsets and four splits per cycle.
- Coordinated, lag, and omit phases can be selected for each cycle.
- Actuated or non-actuated coordinated phases.
- Pick-up cycle to provide a smooth and orderly transition from free to coordinated operation.
- Each split provides a split interval for every controller unit phase allowing coordination of up to eight-phase sequential intersection.
- Manual override.
- Manual command uses NIC sync.
- Built-in diagnostics to detect both coordination and hardware failures: coordination alarm, coordination error fail free.
- Local split demand operation.
- Dual coordination capability.
- Three methods of offset correction: Smooth transition, add-only, dwell.
- Vehicle recall, pedestrian recall, and recall to max can be selected on a by-phase basis for each cycle.
- Omit phases during coordination.
- Operates as both a local and master coordinator.
- Three permissive operations: Automatic permissive, Dual permissive, single permissive.
- Automatic calculation of yield point, permissive and force-offs from split intervals.
- Five coordination operating modes: time-based, hardwire, telemetry, time-based backup for hardwire or telemetry interconnect, time clock master/coordinator in an interconnected system.
- Plan command capability.

Preemptor Features:

- Six complete preemption sequences
- Priority status for preemptor sequences
- Guaranteed minimum green times
- Guaranteed minimum pedestrian clearance times.
- Proper overlap termination during preemption.
- Four bus preemptor sequences
- Reservice time for bus preemptors
- Preempt delay, duration, and inhibit timing in addition to green, clearance, hold, and flash interval timing.
- Priority preemptors may be linked to allow multiple track clearance movements or complex sequences.

Time-based Coordination:

- 16 day programs
- 10 week programs
- 1 year program comprising 53 weeks
- 160 program steps
- Program steps command: cycle, offset, split, free operation, MUTCD flash, dimming, max timer, and four special functions.
- Automatic compensation for leap year
- Daylight savings set to take effect on first or last Sunday in April
- Controller unit can be forced to a NIC step from the keyboard
- Cycle resync time can be set from the keyboard

- Day-of-week and week-of-year automatically calculated and displayed
- Timing accuracy:
  - With power applied, accuracy of line frequency
  - With power removed, drift less than 25 ppm.

<u>Telemetry Features</u>:

- Receipt of system command word containing cycle, offset, split, master zero, and four special functions.
- True speed measurement of vehicular traffic.
- Keyboard entry of system address and speed trap length.
- Upload/download of data base.
- Readback of intersection color status including vehicle, pedestrian, and overlaps as well as local detectors, preempt calls and activity, and local time.
- Readback of eight system detectors for volume and occupancy counts.
- Built-in diagnostics to detect failures.

<u>Detector Features</u>:

- Delay and extend timing
- Detector cross switching
- Calling detector
- Stop bar detector
- Detector disconnect (three types of operation)
- Eight additional detector inputs for a total of sixteen detectors plus eight system detectors.

<u>Utilities Features</u>:

- Copy timing data from one phase to another
- Copy split data from cycle to cycle
- Access code control
- Backlight control
- Transfer data from one controller unit to another
- Print data pages
- Clear entered data
- Enable keyboard audio feedback

<u>Dynamic Status Display Features</u>: The ASC-8000 dynamic displays show all dynamic timing parameters associated with the main controller unit functions (timing, coordination, telemetry operation, preemption, and detection). The following is a summary of display features available.

<u>Intersection</u>:

- Ring, phase, and coodination status
- Vehicle and pedestrian timing itervals
- Status of vehicle, pedestrian, and preempt calls
- Default status display

<u>Controller Unit</u>:

- Phase timing
- Density timing
- Max extension timers
- Overlap timing
- Overlap lag timing

<u>Coordinator</u>:

- Hold, force-off, and permissive periods
- Offset correction operation
- Local cycle and master cycle counters

<u>Time-based Coordination</u>:

- Real time display of program step in process
- Current weekly program
- Automatic updating of program steps
- Next program step and its execution time

<u>Telemetry</u>:

- Speed Trap speeds
- Status
- System detector calls

Preemptor:

- The timing phase, associated interval time, and color
- Delay period
- Inhibit period
- Duration time
- Preemptor flash condition plus flashing phases and color

Detectors:

- All processed detector calls

KMC - 10,000 On-Street Master:

The KMC - 10,000 is an on-street, micro-processor-based system master controller unit. The master controller unit functions primarily as a zone master providing traffic measurements and generating control commands based on operator-entered parameters. Additional functions include performance monitoring, data processing for presentation of logs and recording, and display of data for operator evaluation.

The desired operation and functions are preestablished by user requirements and are permanently stored in a programmable read-only memory (PROM). Data from the configuration PROM is transferred to read/write memory that actually controls the KMC - 10,000 operation. The user is provided with data entry routines so that system operation and functions can be changed as required with simple keyboard entries from the front panel or optional data terminal. Data in the read/write memory is retained by batteries during periods when power is removed from the controller unit.

The KMC - 10,000 also operates as a zone master connected through a modem via dial up telephone service to a monitor computer. In this application, the KMC - 10,000 provides data base transfers to/from data base files in the monitor computer and its data base and the data bases of intersection controller units connected to it by telemetry. System detector, speed logs, and event reports are transferred to the monitor computer for display and storage in archival files. Additionally, the KMC - 10,000 transfers status and operational data, on command, to the monitor-computer to provide real-time intersection and zone map displays.

The master controller unit accommodates 24 intersection controller units and 32 system detectors when connected by telemetry. Any of the first 16 detectors may be directly connected.

Coordination Plan Selection: The KMC - 10,000 controls the operation of the system by generating signals that specify the operation of intersection controller units based on processed detector data, time-of-day/day-of-week/week-of-year scheduling, external commands, or manual operator selection. The control signals specify a traffic plan that commands one of six cycle lengths, one of five offsets, one of four splits; or system free or plan commands; and up to four special functions. Plan selection can also be done in response to nonarterial demands that can specify unique traffic patterns. Capability is also provided to modify the selected program with independent split selection.

Crossing Artery Control: Provision is made for crossing arterials controlled by KMC-10,000 master controller units to be synchronized. Crossing artery synchronization is enabled as a function of time-of-day for operator specified system cycle commands. During the time that selection criteria are met, the master zero in the crossing artery will be displaced to permit uninterrupted flow of coordinated traffic on both arterials through the intersection.

Diagnostic: Extensive diagnostics and a diagnostic display capability minimizes down time. These diagnostics are particularly effective for systems connected by telemetry. Data from intersection controller units give status information that allows for rapid maintenance response to reduce adverse effects on traffic flow. Provision is made for critical master controller unit and local controller unit parameters to set an alarm output.

Telemetry (Optional): Telemetry interconnection to two data channels is accommodated by plug-in transceiver modules in an expanded KMC chassis. These transceiver modules are identical to those that plug into local KMC series controller units or stand-alone telemetry units. In addition to providing a means for communicating system commands to intersection controller units, the transceivers can also be commanded to return status from the controller units and local detectors, up to eight system detectors, and two sets of speed detectors utilizing system detectors. In the stand-alone version, the transceiver can also be used to control a speed sign in lieu of an intersection controller unit.

Modem or Local Terminal Operation: In addition to direct interface through the keyboard, the user of a KMC - 10,000 software has many options for interfacing to the system through remote and local computers and terminals. The serial interface can be configured for either connection to a modem or directly to a local terminal or printer.

The serial interface can be configured to connect a data terminal to the KMC - 10,000 master controller unit to produce reports on a scheduled or demand basis. The data that is printed out includes unscheduled events relating to plan or mode changes and to diagnostic results and scheduled reports by the operator such as system detector logs, sample period logs, speed logs, and system status. All data entry routines may be accessed through the data terminal.

Modules: Modules of the controller unit are of integrated and printed circuit solid-state design. Each module plugs into a connector on the motherboard. All modules are easily removed or replaced without the use of special tools. In addition, each module, including the power supply, is readily accessible for maintenance.

The controller unit contains a complement of modules as follows: processor, I/O interface, keyboard/display, and power supply.

Processor: The processor module contains a microprocessor IC, timing and control logic, and both program and data memory circuits. This module controls all operations of the controller unit as determined by a set of fixed instructions stored in the program memory. The microprocessor executes these instructions and performs all logic, arithmetic, and data transfer operations required to provide controller unit operation.

I/O Interface: The I/O interface module provides conditioning circuitry for signals linking the controller unit with external equipment. It also provides for interrupt control and a power-down timer to measure the time that power is off. The signal conditioning circuitry includes latches for storage of direct connected outputs, buffers for routing direct connected input data to the processor, and logic level shifting between internal controller unit logic circuits and external circuits. An interface circuit meeting EIA standard RS-232-C for serial binary data interchange is also contained on this module.

Keyboard/Display: The keyboard/display (KYBD/DSPL) module provides keyboards for programming the controller unit and displays that indicate the controller unit status and operation. The module contains a control circuit that controls both keyboard and display operation, two keyboards and their interface circuits, and both light-emitting diode (LED) indicators and alphanumeric displays.

Power Supply: The power supply module furnishes the various DC voltages required for the internal circuits of the controller unit, the +24 VDC power used for the controller unit interface circuits, regulated +24 VDC power for external loads, battery charging and control circuits, and monitor circuits. The power supply is protected against excessive current overloads by fuses.

The controller unit uses 115 volts nominal single-phase, alternating current. It operates correctly with input voltage ranging from 95 VAC to 135 VAC, with a frequency of 60 Hz.

TRACONEX INC.

TRACONEX TMP-390CJ Actuated Controller Unit

The TMP-390CJ is a completely modular, 2 to 8 phase dual ring NEMA traffic signal controller unit. (See Figure II-7.) It provides a complete set of operating programs that satisfy the requirements of a wide variety of traffic control application. Operator programmable features allow the controller unit to be configured to meet any control strategies, functions, or options needed to operate a signalized intersection as a stand-along controller unit or as part of signal system with central control.

All options and features are menu-driven and front panel keyboard selectable, and all data are displayed in "alpha-numeric" standard traffic engineering language and symbols on the front panel LCD display.

The Traconex TMP-390CJ has the flexibility to meet a variety of traffic controller unit requirements. Its fully programmable format makes the controller unit equally adaptable to pre-timed (with NEMA phases on recall), semi-actuated, full actuated, volume density, system operation, or a combination of these modes.

The unit consists of a frame and mother board with printed circuit modules which facilitates simple and rapid maintenance. All controls and displays necessary for operator interface are available on the front panel of the controller unit. The connectors for interface with the cabinet are part of each input/output module and are located on the front of the unit for ease of access. The controller unit front panel has a 4-line X 40 characters per line liquid crystal display (LCD) with an alphanumeric readout of the operating parameters and data base. This display provides 40 characters per ring, displays both rings simultaneously, and displays all data in standard traffic engineering abbreviations and symbols.

The TMP-390CJ may be configured as a 2, 4, or 8 phase NEMA controller unit by the use of the appropriate input/output modules. A 63 pin Special Function module is available which provides 32 additional inputs and 24 additional outputs for NEMA Plus features such as preemption, coordination, auxiliary detectors, phase rotation, traffic counting, system operation, and other special operation requirements.

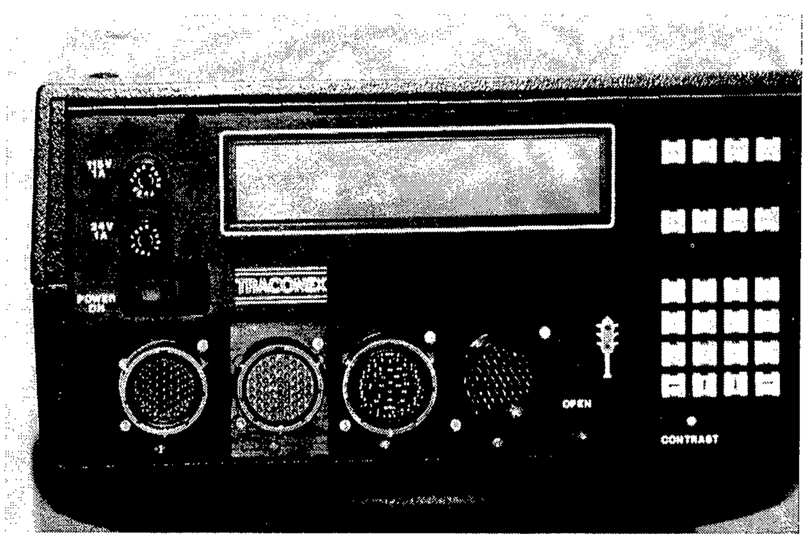


Figure II-7. Traconex Model TMP-390CJ Controller Unit

The TMP-390CJ meets the NEMA Standards for traffic signal controller units using NEMA A, B, and C connectors and provides the following NEMA Standard features and options:

For each phase
- Vehicle Call
- Pedestrian Call
- Hold
- Phase Omit
- Pedestrian Omit

For each ring
- Force Off
- Maximum 2
- Red Rest
- Stop Timing
- Inhibit Maximum Termination
- Omit All-Red
- Pedestrian Recycle

For the controller unit
- External Start
- Manual Control Enable
- Interval Advance
- Minimum Recall to All Phases
- Indicator Lamp Control
- Call to Non-Actuated No. 1
- Call to Non-Actuated No. 2
- Walk Rest Modifier

Design Characteristics: The CPU is a CMOS 8-bit, parallel processor, with an 8-bit bidirectional data bus and a 16-bit address bus. The TMP-390CJ is designed as a bus-oriented micro-computer with functional modules interconnected through a main system bus (motherboard).

The controller unit power supply is completely modular with a plug connector to the frame assembly. It produces all the voltages necessary to operate the microcomputer and, in addition, provides a 500 ma, 24V DC supply for use by external auxiliary equipment. The use of EEPROM memory devices eliminates the need for a battery to support RAM memory during power outages, and the only battery is on the CPU module for use by the clock chip to maintain time during power down.

Each input/output module is configured with 32 inputs and 40 outputs. The front panel connectors are configured to meet NEMA requirements as specified for NEMA 2, 4, and 8 phase controller units, but modules may be configured with other connectors to meet special requirements of non-NEMA controller units and NEMA Plus machines. All inputs are pulled up to 24V DC and will interpret any voltage between 16 and 24 volts as an OFF condition, and any voltage between 0 and 8 volts as an ON condition. The output ports are latched lines capable of withstanding 30 volts and sinking 200 milliamps.

The modem module is a 1200 Baud asynchronous FSK modem suitable or voice grade private lines or standard telephone lines. With a modem installed the TMP-390CJ is capable of being placed in a Traconet System which provides master control as well as complete upload/download capability of the complete controller unit data base.

A 25 pin RS232C serial communications connector is provided on the right side of the controller unit housing near the back of the unit. This communications connector provides the means to interface the controller unit with a personal computer, a serial printer, or connect an internal modem to a remote computer.

TRACONEX TMM — 500 Micro-Master Controller Unit

The TMM-500 (see Figure 7A) is as an intelligent master controller unit for arterial systems, grid systems, or other signal groups where coordinated program selection and synchronization is required. The TMM-500 is capable of selecting and generating traffic programs as selected by traffic samples, time-of-day programs, or manual control inputs. In addition, the TMM-500 is capable of interfacing its signal system with TRACONET, a computer operated traffic system manager/monitor. This option provides the capability to monitor the system operation, change master and local controller unit data bases, or observe traffic control information in map displays from any system or controller unit in a system.

The TMM-500 has the following parameters available to operate a signal system:

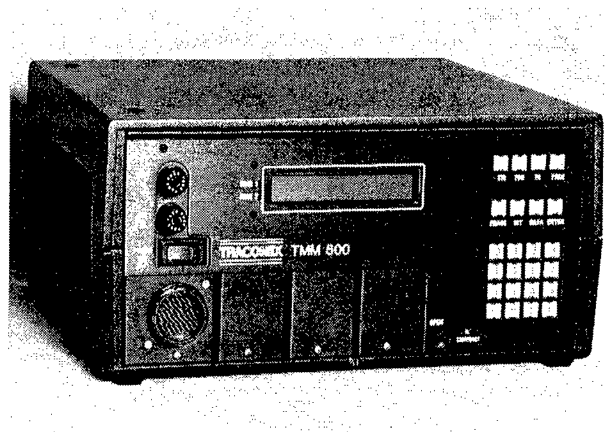


Figure 7A. Traconex Model TMM500, On-street Master Controller Unit

Outputs

- Six Cycle Lengths
- Five Offsets
- Three Splits
- Free or Coordinated
- System Flash
- Special Function Selection
- On Line Command
- Synch Output
- 48 Intersection Plans

Inputs

- Six Dial Selections
- Five Offset Selections
- Three Split Selections
- Free Selection
- System Flash Selection
- Remote Synch
- 16 Sampling Detectors
- On Line Command
- Special Function

There is no specific limit to the number of intersections that the TMM-500 can control. As long as the 16 sampling detectors can adequately represent the system under control, the master can provide system commands for any number of intersections. This is true for modem connected systems or hardwire systems or a mix of hardwire and modem connections.

In modem connected systems the maximum number of intersections that can be used as system detector sites is 31 and 31 intersections can communicate with a central TRACONET computer. Sixteen sampling detectors can be active at any time.

The TMM-500 operates the traffic signal system in one of four levels of control. These levels are:

Level Four	=	Traffic Responsive
Level Three	=	Time-of-Day (TOD/DOW)
Level Two	=	Operator Manual Selection
Level One	=	External Wired Inputs

Lower levels will take priority over higher levels.

In addition to being the third level of priority for system operating parameters, the TOD/DOW program has two other functions. It is used to enable traffic responsive selection on a parameter by parameter basis, and also as the back-up for the traffic responsive program in the event of system detector or communications failure. When the TOD/DOW programs are loaded into memory, each parameter (cycle, offset, split, free, IPL or special function) is independently enabled for traffic responsive selection. If the parameter is not enabled by TOD, then the selection is made by TOD unless there is a manual command present. This provides the operator with the option of selecting any or all of the parameters by traffic sampling.

As an example, the operator could load a morning peak hour program that would select an inbound offset by TOD, but allow the system detectors to select the cycle length and split. This could better meet the demands of an arterial that has a predictable direction of flow but a varying volume.

Another example would be the loading of a evening peak hour program that selected the beginning time for cycle, offset, and split. Then at the time a normal evening peak would be well underway, traffic responsive selection would be enabled for the duration of the evening peak. This allows unusual weather or accident conditions that can extend the length of the peak to be served, and help limit unnecessary delay when the traffic dissipates early.

<u>TRAFFIC CONTROL TECHNOLOGIES</u>

<u>LMD 8000 Controller Unit</u>

The Traffic Control Technologies LMD 8000 traffic controller unit is a 2-8 NEMA actuated controller unit using a MENU format for data entry. The unit provides traffic responsive signalized control of vehicles and pedestrians and is characterized by microprocessor control, keyboard data entry, a 40 column by 4 row back-lighted liquid crystal display, and a front fold-down panel for easy access. (See Figure II-8.)

The LMD controller unit can be programmed for either sequential or concurrent timing in various sequences from two phase semi-actuated to eight phase fully actuated applications. Timing control data are entered into EEPROM (non-volatile memory) directly through the front panel keyboard. The EEPROM data as well as real time information

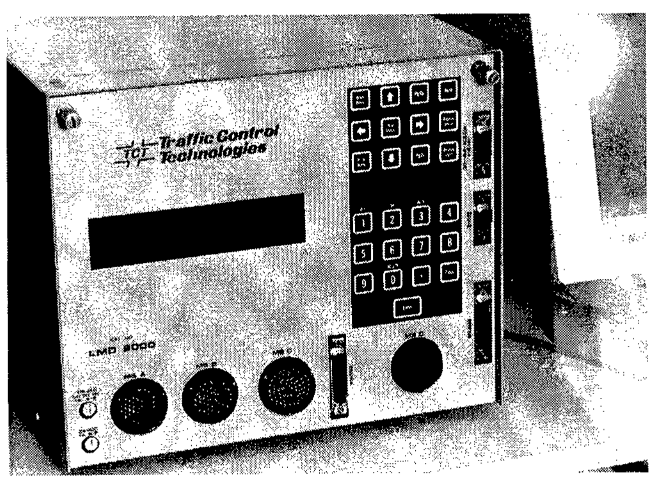


Figure II-8. TCT Model LMD 8000 Controller Unit are stored on a removable Information Memory Card (IMC) on the fold down panel. This card can be used to transfer data and the real time (time of day, date, year) from one unit to another without keystroke procedures.

Features: The LMD8000 is designed to be completely NEMA compatible, utilizing MSA, B, and C connectors in accordance with NEMA Standards. In addition to MSA, B, C, a fourth connector (MSD), can be optionally added to the basic unit to provide expanded I/O. Timing Features provided with the LMD are:

- NEMA timing entries
- Minimum Yellow
- Volume density w/Last Car Passage or Automatic Min. Gap Recall or No recall options
- Detector Memory - on or off Vehicle Recall either - extension, maximum, soft, or ped recall
- Conditional service with programmable Max time
- Phases used 1-8 on or off
- Simultaneous Gap Out - on or off
- Dual Entry wither - off, on
- Back-up timing plans for 2, 3, 4, 5, 6, 8 phase operation
- Remote MUTCD Flash by clock or MSA test input A (AC input or FSK communications with option modules).
- Five Section Head control with yellow blanking and phase restrictions (not available in early revisions)
- Phase assignable detectors, switching, stretch, delay.
- Auto-Max and max extend
- Coordination Data
- Keyboard Entered Pre-emption
- Service and Max plans
- Clock circuit control
- Flashing Don't walk through yellow

Sequences: Sequences include 2-8 phase, single ring, dual ring, combinations of single and dual, and lead/lag. The Lead/lag operation allows independent reversal of phase pairs 1 & 2, 3 & 4, 5 & 6, and 7 & 8. Selection can be on an on/off basis, by MSD inputs, or automatically by TOD or by selection of certain cycle, split and offset combinations. In the Cycle/Split select mode, up to 10 pattern changes can be selected from a choice of 16 possible lead/lag patterns.

Overlaps and Phases as Overlaps: Overlap phases can be programmed through the keyboard or by a NEMA overlap card. Delay operation is provided with self timed overlap yellow and red. Protected/permissive operation is provided via "overlap inhibit" programming. Phase output drivers can also be programmed as overlaps (with delays if desired).

Internal Time Clock: With an internal clock standard in all units, the LMD can operate in response to time of day commands based on a yearly program. This function can be used to implement various modes of operation such as night time flash, and, in conjunction with other controller units, wireless time based coordination. In this mode, each controller unit time clock simultaneously issues coordination commands.

The time clock battery back-up feature allows the clock to continue to keep time without power supplied, so there is no need to reprogram, or re-setup the time clock after power failures.

The clock is programmable by date and year with:

- 99 year calendar
- 30 day (minimum) down-time clock
- Daylight savings time automatically adjusted (on/off)
- 4 sync reference modes
- 200 day program events (a change in CSO = 1 event)
- 15 day programs
- 10 week programs
- 35 exception days, repeat by date or by DOW, WOM, MOY (such as Memorial Day, the last Monday in May)

Time based coordination: The LMD controller unit is capable of coordinated operation in response to internally generated time clock commands selecting cycle, split, and offset. In this mode the LMD is able to coordinate with other time base units without need of interconnect. Four sync reference modes are provided including; End of previous cycle, 8 independent (daily), absolute (one time), and event.

Hardwired Interconnect based coordination: This task requires optional modem connector and board. It allows full duplex communications with a closed loop system master or other central communications system.

FSK Communications based coordination: The LMD 8000 also requires optional modem connector and board for this task. It allows full duplex communications with a closed loop system master or other central communications system.

Fixed or Floating force offs: Coordination force off's can be programmed as standard "fixed" to the background cycle, or "floating". When the floating option is selected, the force-offs act more like max times, and begin with the phase green. Early starting non-coordinated phases get only the time allocated to them and no more.

Coordinated Parameters: Coordinated Parameters include the following:

8 cycles
4 splits/cycle
5 offsets/cycle
8 phase assignable force offs
8 phase assignable permissives
Coordinated phases assigned per cycle/split
Service/Max plans assigned per cycle/split
Ped permissives auto-calculated from veh permissives
Shortway/dwell/interrupter offset seeking

Displays and Keyboard: The LMD display operates in a menu format whereby the display lists, various categories from which the user may select. The base menu lists the most general category choices such program mode and run mode data. From this base menu, when a category is selected, a sub-menu appears listing further choices such as security code, controller unit, coordination, time clock, pre-emption, etc. Each sub-menu further breaks down the choices into more specific categories until the specific sections of data can be obtained. The display operates such that a user familiar with traffic terminology, but unfamiliar with the display can successfully operate the display by following menu selections.

Help screens are provided, giving a description of the functions on each system.

Security Code: An optional security code can be programmed, which when activated, allows data changes. The code automatically de-activates 10 minutes after the last user keystroke. With knowledge of the old security code, the security code can be changed or inhibited. The security code can be keyboard disabled (no code required for data entry).

Dimming: The LMD can be programmed to provide dimming operation by phase and color. Each phase/OL, G, Y, R, W, DW, PCL can be user specified to dim + half wave, - half wave or no dim. Dimming can be activated by MSA test B, MSD pin 18, or Time clock CKT 108.

Diagnostics: Built into the standard LMD unit is a set of Diagnostic Test routines. When activated these routines convert the controller unit into a hardware self-diagnostic tester, exercising boards, IC's, and components. Diagnostics harness is required for this purpose.

Interrupter Mode: When programmed for Interrupter mode and operating as a secondary, the LMD will respond to master sync pulses only. When programmed for Interrupter mode and operating as a master, the LMD will generate master sync pulses and interrupter pulses on the time clock outputs at a rate of (cycle length-2)/4

Pre-emption: All pre-emption parameters are programmable, including:

- 6 preempt inputs/sequences
- 6 preempt outs defined by sequences (flash or steady)
- "Hold only" or "sequence" options
- Priority assignable per input
- Preempt entry minimums per input programmable
- Delay before preempt per input programmable with option to omit non preempt phases the last X seconds of the delay period (programmable).
- Preempt minimum re-service time. Sets a minimum time between successive preempts (in minutes).

Custom Output Configurations ability. Special intervals allow complete control of outputs — allows "soft flash," whereby controller unit flashes load switches.

Flashing Don't Walk through yellow on entry into preemption can be specified on a per input basis.

- These can be used to define the responsiveness, priority, and repetitiveness of preemption, useful for determining the type of sequence, bus vs. railroad vs. an emergency vehicle etc.

RS232 Port: An RS232-C industry standard I/O port is provided in all LMD units serving a variety of functions, including:

- Unit to unit data transfer
- Print-out of program data (interfaces with most standard serial printers)
- Direct interface with desktop personal or lap-top computer for upload/download of program data, etc.
- Direct interface with a dial-up modem for communications over phone lines with a PC (no system master).

Communications Module: The LMD is expansible by addition of a module/board with connectors to provide remote communications. The communications provides a TDM FSK communications modem port, additional system I/O, and an additional RS232 port. When inserted, the LMD unit is capable of full duplex FSK 1200 baud data transmission over a 4 wire 3002 voice grade link. The unit would typically communicate with a system master in a closed loop type system environment. Since the module is internal to the controller unit, it has possible access to all RAM data for transmitting and receiving (depending on the software). The system I/O port (communications inputs) provides LMD system detectors 17-24 and monitor status bits. The extra RS-232 port can be used to interface with the conflict monitor while still maintaining direct dial-up capability through the standard RS-232 port.

There are 3 connectors on the Communications Module:

One 15P NEMA
One 9P Modem I/O
One RS-232

The communications module in conjunction with a system master and a personal computer provides the ability to receive system traffic commands and to use the computer, through the system master, to program the controller unit (download) or to read data from the controller unit (upload).

The computer software provides the ability to compare computer data files with data uploaded from the controller unit. Differences are highlighted for easy identification of data that has been changed. Printing of data files from the computer can easily be accomplished using standard printer and interface.

<u>Conditional Service</u>: Conditional Service is a dual ring feature, optionally selected through the front panel keyboard or enabled by input. Conditional Service allows "Conditional" service to an odd phase (left turn) after normal service to that phase; i.e., the even phases are being serviced but one gapped out. The "Condition" is established by a keyboard setting called "Conditional Service max time" which requires that there is enough time left in the still extending phase's max timer to allow this service. It also establishes a new max time on the re-serviced phase.

<u>Simultaneous Gap-Out Disable</u>: Simultaneous-Gap-Out is actually the standard mode of operation employed by a dual ring controller unit. Under this mode, two phases waiting to cross the barrier must "simultaneously gap-out" (or max out) in order to cross the barrier. This occurs because a phase resting while the other phase is extending can have its passage timer reset at any time and begin extending once again.

<u>Traffic Control Technologies On-Street Master Controller Unit LM 100</u>

The Traffic Control Technologies LM100 is a traffic responsive system master controller unit with programming means, computational processes relating to parameter selection, and communications capabilities which are used to generate cycle, split, and offset selections in a traffic coordinated system. (See Figure II-9.)

The unit selects parameters from a choice of one of 8 cycles, one of 4 splits, and one of 5 offsets. The LM 100 unit then transmits the chosen parameters to secondary controller unit locations within the system. Data is transmitted to up to 60 secondary locations, and 4 system groups, over a two pair Bell 3002 grade link using TDM FSK full duplex data transfer techniques.

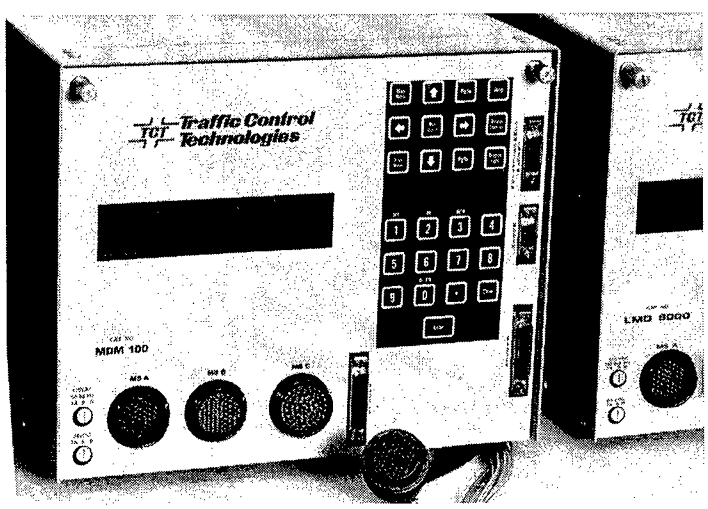


Figure II-9. TCT Model LM100, On-Street Master

Secondary locations would consist of Traffic Control Technologies "L" series type controller units, each equipped with Communications modules. Up to 128 system detectors would be reported back to the LM100 through the locals via the communication module.

The LM 100 unit supports 128 system detectors (32 maximum per system group).

Special features of the LM100 include the following:

- TRSP Operation
  - Pattern matching algorithm
    - 32 detectors per section, 24 per intersection
    - Detector signatures match C/S/O patterns
      - Volume/occupancy of speed
      - Detectors individually weighted 0-100%
    - Pattern with that best fits the current data is selected
    - Hysteresis % to keep from "hunting" between patterns
    - 48 patterns include CSO and special function bits
  - Free to system thresholds
    - Minimum total volume/minimum average occupancy
  - Forecast detection
    - Selected detectors to trigger CSO if exceed thresholds
    - Selectable sampling period
    - TOD enabled

- TOD Operation
  - 35 exception days
    - DOW/WOM/MOY/ or DOM/MOY
  - 200 events/15 day programs/10 week programs
  - Daylight savings time enable
  - Sectional functions
    - Enable TRSP
    - Enable TRSP if TRSP cycle exceeds TOD cycle
    - Enable TRSP cycle only, split only, offset only
    - Sampling periods 1,2,3
    - Enable master control (system)
    - Section UCF flash
    - Log volume/occupancy
  - Global functions
    - Alarm scheduling
      - Up to four phone numbers
      - Each alarm assigned to one of three schedules or request only or not logged
    - 3 section locking enables
    - 24 special function bits
    - Enable forecast sensor groups
    - Enable intersection to report alarms
      - Local volume counts
      - Local cycle based MOEs
      - Local computed speed and speed traps
    - Enable speed logging
    - Enable alternate vol/occ/spd log period

- Manual Override

- Special Function Bits
  - 24 per master
  - Controller programmed for response
    - Bit mapped to time clock circuits
    - LMD8000 time clock circuits
      - 4 general purpose outputs
      - UCF flash
      - Max II
      - Inhibit max per ring
      - CNA I/II
      - Min recall all phases
      - Vehicle and ped calls all phases
      - Vehicle and ped omit per phase

* Red rest mode per ring
* Omit all red clearance per ring
* Enable ped recycle per ring
* Inhibit low detector threshold
* Inhibit constant call monitor
* Enable dual entry
* Enable conditional service
* Inhibit simultaneous gap out
* Enable TBC
* Inhibit volume density per phase
* Inhibit 5 section head control
* Lag phases 1,3,5,7
* Inhibit each overlap
* Inhibit detector 1-16
* Select service plans 1-8
* Select max plans 1-8
* Call preemption sequences 1-6
* Enable local volume logging
* Activate dimming
* Enable adaptive split control
* Force to week program 10
* Force to TBC from TRSP

- Programmable response delay
- Section Linking
  - Master section selects CSO for itself and a slave section
  - TOD enabled for each link
- Run Mode Displays
  - Sectional status
  - Mode of operation
  - Number of intersections and on line and failed
  - CSO in effect, system/free
  - Selection mode of C/S/O/System
    * TRSP
    * TOD
    * Manual
    * Linking
  - Number detectors and of failed detectors
  - Cycle timer
  - Sampling period timer
  - Pattern number
  - Intersection status
    - Communication failure
    - Control mode
      * Sectional
      * Local manual override
      * Local TBC
      * Flash
  - Detector data
    - Volume/occupancy
    - Status ok or failed and why
    - Speed
  - Comm status
  - Clock status
  - Checksum status
  - Time clock circuits status
- Upload/download
  - Keyboard initiated
  - Master data
  - Any intersection
  - Portions or all of programming data
  - Alarms

TRANSYT CORPORATION

Model 1880EL Actuated Controller Unit

The Model 1880EL Traffic Signal Controller Unit (see Figure II-10) is the latest and most advanced of TRANSYT'S Modular Family of 1880 Controller Units. Featuring all new high-technology, state-of-the-art design and componentry, the 1880EL offers user flexibility in providing fully-actuated traffic control operation from 2 to 8 phases. A wide variety of phase sequences ranging from standard concurrent and sequential phasing to a number of special sequences may be implemented with the controller unit.

Of particular significance is the controller unit's new menu-driven LCD display which adds a new dimension in user-friendly controller unit operation.

The 1880EL Controller unit is of true modular construction, with all modules being removable from the mainframe via front panel thumbscrews.

Two available controller unit mainframe assemblies can be configured in various module combinations to provide advanced operational features. Standard built-in features include preemption (6 modes), time based coordination, volume density, diamond sequence, and many others.

Additionally, the controller mainframe is designed to accommodate up to two auxiliary function modules which will enable special interval operation including:

- Closed Loop System operation
- External hardwire coordination
- Other communications, with system direct-drive capability

The 1880EL controller unit is a microprocessor based unit, with the functional operation of the controller unit being stored as a "software" program in permanent "read only" memory. The standard controller unit is furnished with a program which provides the operation specified in NEMA TS1.

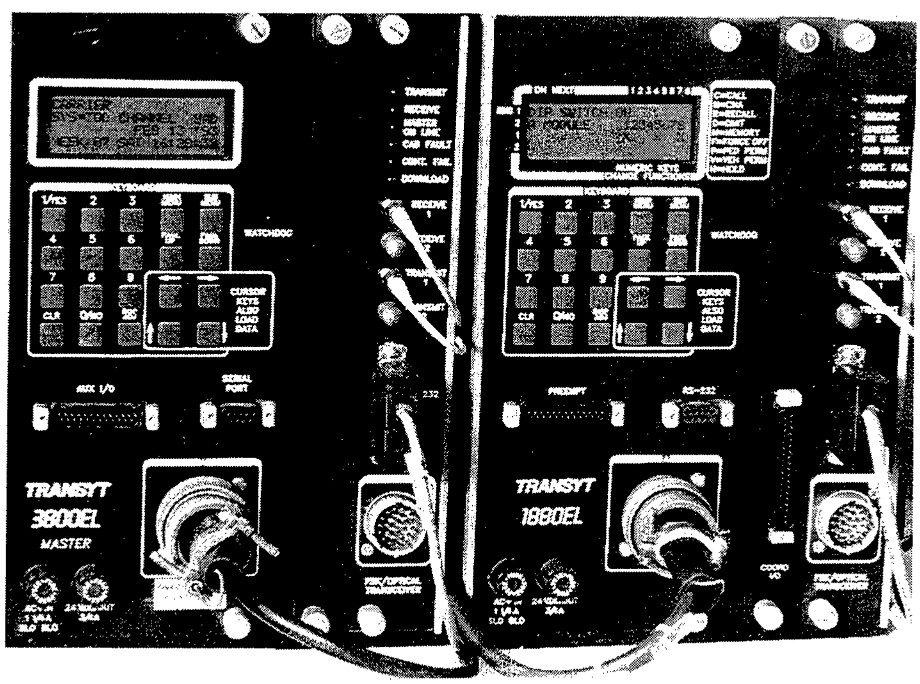


Figure II-10. Transyt Models 1880EL Local
Controller Unit and 3800EL
On-street Master Controller Unit

Timing interval settings and phase function status data such as recalls, call to non-actuated (CNA), etc. are stored in changeable "random access memory" (RAM). The 1880EL controller unit features a technologically advanced self-powered RAM which does not required a separate battery to maintain memory should a power interruption occur.

<u>Controller Unit Configurations</u>: The 1880EL controller unit can be furnished in two basic mainframe configurations.

- Two/Four Phase Mainframe - allows up to four phases of sequential operation.

- Two/Eight Phase Mainframe - allows up to eight phases of sequential or combined concurrent/sequential operation.

Common to either controller mainframe configuration is the basic Two Phase CPU - Input/Output (I/O) Module labeled the "A" Module which always plugs into the far left slot of the mainframe. This module is 5 inches wide and contains all the circuitry required for standard or volume density operation. This would include all input and output circuitry, the NEMA "A" Connector, keyboard for timing and function entry, display, the microprocessor unit, permanent program memory and random access memory for timing and function storage.

There is a small four conductor cable and connector that plugs into the back of the "A" front I/O module. This cable routes the 117 volt A.C. input directly to the power supply. Thus, only low voltage levels are present on the main board of the module and in the back plane.

Additional modules may be inserted into the mainframe to add auxiliary functions not included in the basic controller unit operation.

To facilitate the basic module and additional modules as might be required, both the Two/Four Phase Mainframe and the Two/Eight Phase mainframe include a mother-board which features "1 to 1" connections. The backplane pin connections are identical in each module slot, allowing all modules - except the Two Phase CPU-I/O "A" Module - to be plugged into any module slot. The Two Phase "A" module must plug into the far left slot.

Special features such as Time Based Coordination and Preemption are built-in to all 1880EL basic controller unit configurations and are enabled via front panel programming. A special cable connector is provided on the front of the "A" Module. This connection allows preemption input from the field as well as providing output to drive special signs or devices associated with preemption.

Additionally, an RS 232 connector is also provided on the front of the A module to enable direct interface with a printer or other peripheral devices for data input/output functions.

The smaller 1880EL configuration (i.e. two/four mainframe configuration) is furnished with a 7-1/2 inch wide mainframe and accommodates the following modules:

- A Module (basic)

- Power Supply Assembly

- B Module or Auxiliary Function Module(s) (maximum of two)

This mainframe configuration will easily accommodate up to four phases of controller unit operation by adding the optional Four Phase I/O labeled the "B" Module to the basic configuration. This module furnishes all of the additional circuitry required to provide Four Phase NEMA operation, input, output, and display and four overlap outputs. The B module is 2 1/2 inches wide and contains front panel provision for the standard NEMA Overlap Program Card. This module is normally inserted in the controller unit chassis immediately to the right of the A module.

If the B Module is not required, the small 1880EL mainframe contains space to accommodate up to two Auxiliary Function modules depending on functions. These modules would normally plug into the last two controller unit chassis slots. Machine operation is not affected by module position.

Preemption: Preemption timing functions include:

- Min. Green
- Clearance 1 Green
- Clearance 2 Green
- Dwell Green
- Clearance 1 Yellow
- Clearance 1 Red Clearance
- Clearance 2 Yellow
- Clearance 2 Red Clearance
- Yellow After Preempt
- Red Clearance After Preempt
- Special Overlap Clearance
- Special Pedestrian Clearance
- Delay Before Preemption

Inputs and Outputs: Primary electrical interface between the controller unit and other equipment of the field is accomplished via the NEMA-compatible A, B, and C connectors on the three I/O Modules.

Auxiliary electrical interface is provided between the controller unit and certain auxiliary functions via two special connectors located on the A module. The Prempt Connector enables up to six preemption inputs and several auxiliary outputs. Another special connector, the RS-232 Connector, enables controller unit interface with a number of peripheral devices including a printer.

Display: Controller unit operation and status is provided via an LCD display located on the front panel of the 1880 EL controller unit. All information is readily available using a menu-driven program, greatly simplifying user understanding and programmability of the controller unit.

General information which can be displayed includes the following:

- Phase and timing activity
- Interval and detector activity
- Overlap indications
- Special program activity (including coordination, preemption, etc.)

Basic Program Areas: The basic program areas are defined in the Main Menu which allows the user to select three basic programming tasks including:

- Display
- Data Read
- Data Entry

The Display function enables the user to observe normal operation of the controller unit, showing timing countdown information for each active phase on an interval-by-interval basis.

The Data Read function enables the user to interrogate the controller unit and determine the value and/or status of all intervals and functions within the controller unit. Values cannot be changed, however, with the Data Read function.

The Data Entry function enables the user to enter values for intervals and functions contained within the program. A flashing cursor prompts the user for appropriate programming of each value.

Interval Status Displays: The standard vehicle and pedestrian intervals can be displayed on the LCD, together with the associated timing countdown and detector status for each phase or phase pair.

Typical intervals (or interval portions) displayed include the following: Rest, Initial, Passage, Yellow, Red Clearance, Walk, Pedestrian Clearance, Gap, Maximum Max/Force

Watchdog Timer: The power supply has a "watchdog" circuit which monitors the cycling of the microprocessor. Should the device fail to cycle, the "watchdog" indicator will be illuminated and the Controller unit's volt monitor output will be automatically interrupted, causing the conflict monitor located in the cabinet to place the intersection on flash. This indicator will also illuminate when improper controller unit voltages cause a volt monitor failure.

TRANSYT Model 3800 EL On-Street Master

The Model 3800 EL master controller unit (see Figure 11-10) has the following operational features:

- Supervises the operation of a Closed Loop System and implements traffic responsive pattern selection based on actual traffic demand.
- Receives and analyzes sensor data from up to 48 system sampling sensors.
- Evaluates system traffic conditions from sensor data and selects best timing pattern from its library of up to 480 patterns.
- Directs the operation of local supervisors for up to 30 local intersections to implement the selected pattern.
- Monitors system elements for proper operation and notifies central office of conditions found.
- Utilizes volume, occupancy, and queue duration as pattern selection parameters for traffic responsive operation.
- Enables up to 12 system sensors to be routed to each parameter computational channel for pattern evaluation.
- Patterns can be selected from a combination of up to 6 cycles, 5 offsets, and 16 splits.
- Features time-of-day/day-of-week pattern selection in addition to traffic responsive selection.
    - Time-of-day override of responsive operation can be pre-programmed.
    - 99-year clock available for time-of-day operation.
- Enables the operation of single groups with differing parameters (cycle lengths, etc.) within the same subsystem.
- Tabulates and stores 24 hour count data from all system sensors throughout the system and transmits data to central office.
- Serves as communications link to upload and download intersection timing settings (internal) and pattern data from an unattended central office computer.
- Master can be linked to central office computer via autodial modem using standard telephone line, direct hardwire connection, on wireless radio link.
- Supervises Closed Loop Systems utilizing internal or external Local Supervisors.
- Keyboard activity log also available.

Design features also include:

- LCD display with backlight and adjustable viewing angle.
- Keyboard programmable, with audible enunciation of key press.
- User friendly menu-driven operation.
- Modular construction, with modules easily removable via thumbscrews.
- New increased capacity lithium powered RAM.
- HCMOS logic provides extremely high noise immunity, low power consumption, and excellent temperature ratings.
- Meets or exceeds applicable portions of latest NEMA TS1 standard.

OVERVIEW OF THE MODEL 170 CONTROLLER UNIT

A number of standardized components makeup the Model 170 approach to traffic control. These components include the controller unit, which serves as the brain of the system, and auxiliary devices for input, output, and other necessary functions.

Controller Unit

The controller unit is a multi-purpose microprocessor-based controller unit. Because it can be programmed by the user, it is used for purposes other than the control of intersection traffic signals. The controller is a modular unit in the Model 170 controller assembly and is interchangeable with standard Model 170 controller units from other manufacturers.

To provide the multi-purpose operation, the controller unit is configured as a microprocessor with a series of unassigned inputs and outputs. Software, typically supplied by software vendors, defines the purpose of each of the inputs and outputs. Therefore, the same controller unit can be used as an actuated controller unit, a pretimed controller unit, a ramp metering controller unit, an arterial master, or a sprinkler controller unit.

All controller units of a given type are designed to be interchangeable. Users can therefore expect competitive bids on equipment. Purchases can be made from several different manufacturers without concerns of interchangeability. An example is the current concept of the "closed loop" system. Because 170 controller units are not proprietary, an intersection can readily be added to the closed loop system. The user owns the rights to a software package, which can be operated in any controller unit meeting the requirements of the original specifications.

All controller units have the same basic dimensions, and are designed to mount in a standard 19-inch computer-type rack, as shown in Figure II-11. The weight of the unit is limited by specifications to 25 pounds.

For interface with an operator, the controller unit has a front panel with a defined arrangement of indicators and controls. These include:

- Six 7-segment LED numeric displays. These indicators are used to display data in a decimal or hexadecimal format (0-9 and A through F).

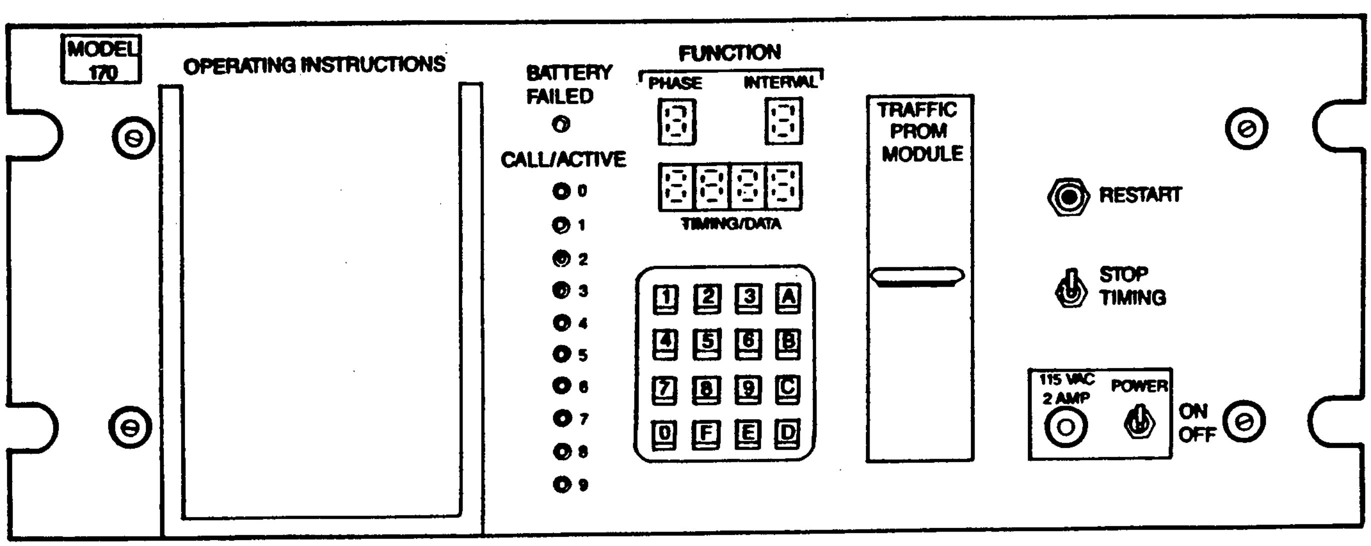


Figure II-11. A front panel schematic of the Model 170 Controller Unit

- Ten discrete LED indicators. These ten LED's, located in a vertical row, can be used to display the status of various functions.

- A hexadecimal keypad, consisting of sixteen buttons labeled 0 through 9 and A through F, for the entry of data.

- A power switch, to turn the controller unit on and off.

- A stop timing switch, to interrupt the timing of the current controller unit interval.

- A holder for a programming "cheat-sheet" is also provided on the front panel of the controller unit. As the controller unit is designed as a multi-purpose device, operating instructions are not printed on the controller unit's front panel. Therefore, this "cheat-sheet" provision is made.

Also provided on the front panel is an opening for the insertion of the PROM module which contains the software to operate the controller unit.

The controller unit is designed to operate under the conditions found in a field-located cabinet. Its specified temperature range is from -35° to +165° F, over a relative humidity range of 0 to 95 percent. Within those limits, the controller unit is required to operate on line voltages of 95 to 135 volts AC, at 60(± 3) Hertz.

<u>Major Components</u>: The major components of the Model 170 controller unit are shown in Figure II-12 on page II-50. The brain of the controller unit is located in the Central Processing Unit, or CPU. The center of the CPU is the microprocessor, which is specified to be of the "6800" family of processors. By specifying the 6800 microprocessor, a standard for software has been developed — programs developed for the 6800 will be interchangeable between similar controller units.

Also included within the CPU is a minimum of 1 K (1024 bytes) of Random Access Memory or RAM, and a crystal controller unit processor clock, which triggers the operation of the processor, operates at a specified frequency of 768 Kilohertz, providing a machine cycle time of approximately 1.302 microseconds.

The controller unit includes a downtime accumulator (DTA), which is used to determine the length of time of a power failure. The DTA records the number of minutes and seconds (up to 255 minutes, and with an accuracy of ± 1 second) of a power failure, for use by the program in updating time-of-day clocks.

The program that defines the intersection is installed, as firmware, in a PROM module that can be inserted into the controller unit through an opening in the front panel. The most common PROM module is that standard Traffic PROM module, which provides 8K (8192 bytes) of ROM memory, using eight Type 2716 EPROM's

Other special modules that can be substituted for the standard traffic PROM module. Typically known as System Memory modules, these have additional ROM and RAM capabilities, such as the 412C module with 32K EPROM and 32K zero PROM/EZPROM allowing more complex programs and greater variable data capacity.

With the controller unit being bus type of microprocessor system, the PROM module can be a convenient means of providing a hardware modification without sacrificing the interchangeability of the standard controller unit. As an example, the developers of a time-based coordination software package were concerned about the relative inaccuracy of the Downtime Accumulator, with its ± 1 second permitted variation. Therefore, a more accurate means of maintaining power outage time was added to a special PROM module, i.e. PROM 412C (Caltrans specs), permitting improved time-base coordination operation without a modification to the controller unit itself.

Although a number of these special modules have been developed, only two have been standardized. These are the Model 412C, designed to handle up to to 32K of EPROM and

MODULE/FUNCTION

POWER SUPPLY	—INTERNAL VOLTAGES +12, −12, −5, 2-5 VDC
TRAFFIC PROM	—8K BYTES OF PROM FOR PROGRAM STORAGE
—OR—	
DIAGNOSTIC PROM	—4K BYTES OF PROM FOR DIAGNOSTIC STORAGE —VOLTAGE MONITORING CIRCUIT —TEST FAILED/PASSED INDICATORS —SELECTOR SWITCHES
CPU	—6800 MICROPROCESSOR & SUPPORT DEVICES —CLOCKS
MEMORY/ DOWN TIME ACCUMULATOR	—1K BYTES OF RAM MEMORY —DTA w/CLOCK —NICAD BATTERY & CHARGING CIRCUIT
MODEM (OPTION)	—COMMUNICATION INTERFACE
INPUT MODULE	—64 INPUT LINES BUFFERING & DECODING
OUTPUT MODULE	—80 OUTPUT LINES DECODED & LATCHED
FRONT PANEL	—LATCH/DECODE/DRIVE 6 DISPLAYS —INPUT/DECODE THE 4x4 KEYBOARD —CALL/ACTIVE INDICATORS

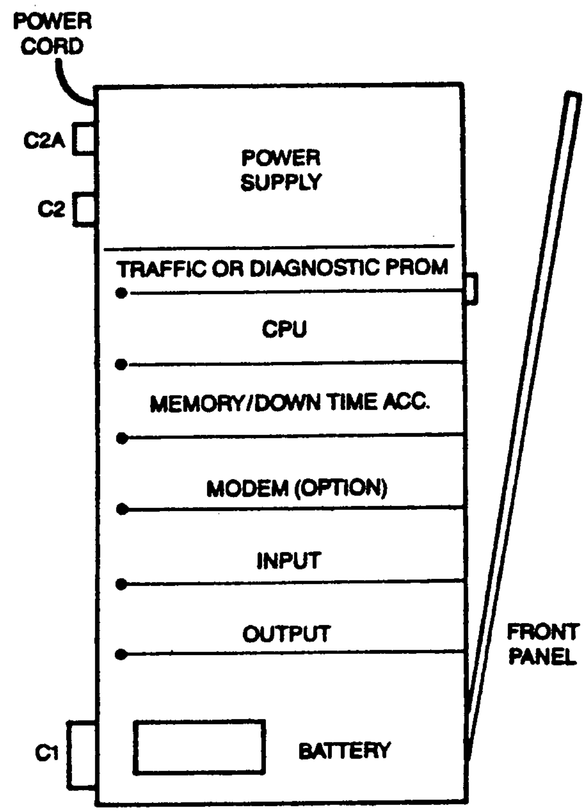


Figure II-12. Major Components of Type 170 (top view)

32K of EEPROM and equipped with the improved time keeping circuit; and the Model 414, which builds a communications interface into a module with the same memory capabilities as the 412C.

A number of inputs and outputs are required to permit the CPU to interface with field-located devices. The Model 170 has assignable ground true inputs. Ground true means that the input is activated by connection to a ground, or zero voltage, reference point. These inputs can be assigned to vehicular or pedestrian detectors, or any of a number of auxiliary devices that require an input to the controller unit.

The Model 170 also has 56 assignable ground true outputs. (In this case, the controller unit internally changes the output's voltage level to a zero reference point when the output is to be on.) These outputs can be used to operate load switches, for the illumination of signal displays in the street.

The Model 170 controller unit also has an internal power supply for the operation of the processor, memory, and display. This internal power supply is not used for the operation of external devices such as load switches which are operated by an external power supply located in the cabinet.

Provisions for data communications between the controller unit and the on-street master consist of an Asynchronous Communications Interface Adapter (ACIA). This device provides the circuitry necessary to interface the processor and memory with a modem (modulator-demodulator) for external communications. A standardized modem card (Type 400 modem) is inserted into a reserved slot in the controller unit.

Software: The software, or program, defines the operation of the controller unit, whether it is a pretimed or actuated intersection controller unit, a system master, a ramp metering device, a diamond interchange controller unit, etc. The software must be specifically written for use with a 6800 series of microprocessor.

Software is usually developed on an interactive system, the compiled and transferred to a read-only device, typically an EPROM or series of EPROM's. When a program is stored on a chip, it is often referred to as "firmware."

The program developed for a specific application assigns various functions to the inputs and outputs of the controller unit. The program acts on the inputs, such as detectors, by doing the necessary timing and processing functions, and then, changes that state of outputs, such as signals, as appropriate.

The program uses the RAM capability of the machine for the storage of user-changeable timing settings and for scratch calculations.

Operator Interface: The primary means for the operator to interface with the controller unit is through the sixteen button keypad and the six numeric and ten discrete LED displays. The specific procedures to be followed are dependent on the program installed; consequently, a card holder for a "cheat sheet" is included on the front panel.

Being a hexadecimal keyboard, there are six letters, A through F, which normally stand for the values 10 through 15. Traffic control programs rarely require the operator to manually convert to hexadecimal values, so these lettered keys can be assigned to functions. In the Local Intersection Program (LIP), A and B are used to refer to rings A and B, C is used to call coordination data, D for detector data, and F for phase data. E is used to enter changes.

The six numeric displays assist the operator in the determination of variable data. Since these displays are seven-segment units, a B would look like an 8, and a D would appear to be a 0. Therefore, when A, C, E, or F are displayed, they appear as capital letters, but a B or D appear as lower case b or d.

The ten discrete LED displays provide status information on various functions, as defined by the program. They are often used to display phase-related binary functions, such as phase enabled or detector call, or to designate the day of week in setting up time clock functions.

In the Caltrans Local Intersection Program (LIP), a base display shows the currently timing phase and interval in each ring. This base display is designated by an A and B in the top two displays, and then phase number and interval number, repeated for each ring, in the bottom four displays. Pressing an A or a B brings up a detail of the ring selected, with the top digits representing phase and interval number, and the countdown timing for the interval shown in the bottom four digits.

The method of changing timing values depends on the program in use. Again using LIP as an example, changing a phase's yellow interval requires six keystrokes, as follows:

Starting at the base display,
- Press "F", for Phase
- Press "2", for the phase number, in this case 2
- Press "E", for the interval, which by looking up on the cheat sheet, is known to be the yellow interval.
- Press "4" and then "5" for the interval length, in this case 4.5 seconds.
- Press "E" to Enter the timing change.

The provisions for an internal modem in the Model 170 controller unit permit the possibility of downloading controller unit timing parameters. This would enable the operator sitting at a central computer terminal to enter and store timing in a city-wide database, then automatically transfer the data to the controller unit.

Cabinet Rack Assembly

The controller unit and all auxiliary devices are mounted in a rack assembly which fits into the cabinet. The rack is a standard 19-inch EIA computer type rack, with drilled and tapped mounting holes distributed along the vertical rails of the rack assembly. A number of major components fit into this rack assembly, as described below.

Power Supply: The Model 170 system utilizes an external power supply, referred to as #206 and is located in the PDA #2, for the 24 volt DC needs of detectors, loadswitchs, and other auxiliary devices. The power supply is a rack-mounted assembly, usually mounted at the top of the cabinet. It provides regulated 24 volts DC, with a five amp minimum capacity. The power supply's dimensions are limited by the specifications to take up not more than 7 inches of rack height, and to extend no more than 6 inches in depth from the vertical mounting rails.

Input Files: Input files are assemblies for holding up to 14 different input-related devices, such as detectors. Each device incorporates circuitry to handle at least two inputs to the controller unit. It is in the form of a printed circuit board with a perpendicular handle. The input files are equipped with card guides for easy insertion and an edge connector for electrical interface with the harness leading to the controller unit. Each input file requires 5.25 inches of vertical rack space.

The number of input files required is dependent on the application of the controller unit assembly. For example, the LIP program requires the use of two input files. All inputs to the controller unit must be routed through the input file assembly.

The Model 170 input file can be used with three kinds of vehicular detectors. These include:

- Loop Detectors: for use with standard inductive loops imbedded in the roadway.
- Magnetic Detectors: for use with magnetic probes in conduit under the roadway surface.
- Magnetometer Detectors: for use with magnetometer probes embedded in the roadway surface. Only a two-channel model has been standardized.

The two channel loop or magnetic detector takes up the width of one card slot, while their four channel versions take up the space of two two-channel units.

A number of other inputs may be required for the operation of the controller unit. These include pedestrian push-buttons, preemption call inputs, and system interconnect. Devices called "isolators" have been developed for insertion into the input file. These devices provide a buffer between the external circuits (from outside the cabinet) and the inputs to the controller unit. Isolators have been standardized for use with the Model 170 cabinet system, as follows:

- DC Isolators — used for loop detectors and preempt inputs, come in a two-channel and four channel mode.
- AC Isolators — for interface with an AC input, such as 115 VAC system interconnect. Only a two-channel version has been standardized.

All detectors and isolators have indicators to display their operation. Detectors include the necessary controls for selecting mode of operation and tuning. Isolators include a momentary contact/lock on three way test switch for each input.

One manufacturer has developed a special emergency vehicle preemption module for use in the input file. Designed for operation with the propriety (3M Company) Opticom system, the module takes the space of an isolator and provides the necessary input to the controller unit to select a preemption routine.

Power Distribution Assembly: The Power Distribution Assembly, PDA, is a multi-function assembly mounted below the input files. Included in PDA No. 2 are:

- The Main Circuit Breaker, through which all incoming power is routed for protection. The power is then distributed to several additional breakers for branch circuits.
- The Equipment Circuit Breaker, which is a smaller rated breaker for the protection of the circuit feeding the controller unit and the ground fault protected convenience outlet.
- The Signal Bus Circuit Breakers (6), which evenly distribute and protect the AC power being fed to the loadswitches by the Signal Bus.
- The Flasher Bus Circuit Breakers (2), which evenly distribute and protect the power being fed to the flashers.
- Convenience Outlets (2), Protected by a Ground Fault Interrupter, for use be a serviceman working at a cabinet in the field.
- An outlet to plug in the power cord of the controller unit.
- Sockets (2) for the insertion of interchangeable Model 204 flasher units.
- An Auto/Flash control switch.
- Mercury Contactors (2), serving as heavy duty relays for controlling power to the signal buses.

Output Files: The Output File is an assembly that is similar in concept to the Input File, except that output devices are located here. The Output File contains sockets for up to twelve loadswitches, the flash transfer relays, and the conflict monitor.

Loadswitches: Loadswitches are modular solid state relay packages, each capable of controlling three output circuits, typically the green, yellow and red vehicular display, or the WALK and DON'T WALK pedestrian display of a phase. The standard output file holds twelve loadswitches, permitting eight-phase operation with four pedestrian movements.

The output file also contains the flash transfer relays. These are heavy duty relays that switch the field signal head wiring connections between the loadswitches and the flashers, as appropriate, for stop-and-go or flashing operation. Four flash transfer relay positions are provided in the output file assembly, with each relay controlling two vehicular displays.

The conflict monitor illustrated in Figure II-13 (page II-55) is a standardized, self-contained module that inserts into the output file assembly. Identified as the Model 210, the conflict monitor accepts sixteen channels of greens and yellows and/or WALKS and monitors for conflicts between channels. The monitor includes a removable programming board, with a matrix of diodes representing each possible channel combination. Diodes are removed for each permitted combination of channels.

The conflict monitor also keeps watch over voltages generated by the power supply, and a watchdog output generated by the controller unit software. The watchdog output, which cycles ten times a second, indicated to the monitor that the processor is continuing to run. Without the watchdog monitor, the processor could fail and cause signals to stop timing, which would not be identified by the monitor as an error.

In case of a conflict, voltage problem, or watchdog timer error, the conflict monitor will trigger the flash transfer circuitry, causing the intersection to go to flashing operation, and stop time to be applied to the controller unit. The monitor can be reset only by pressing a reset button on the front panel of the monitor module (except that, if the monitor had been triggered by a voltage problem, restoration of appropriate voltages will automatically restart the monitor).

The output file assembly takes a maximum of 10.5 inches of vertical rack space. It is located just below the power distribution assembly.

<u>Auxiliary Output File</u>: Where the needs of a specific intersection require more than the twelve loadswitch positions available in the standard output file, (such as a multi-legged intersection) an auxiliary output file can be used. The auxiliary output file is a standardized assembly which can hold six more loadswitches and two flash transfer relays.

<u>Lightning Protection and Noise Suppression</u>: One of the major features of the Model 170 system is the isolation of all inputs and outputs between the controller unit and the field. All inputs, such as detectors or pedestrian pushbuttons are routed through isolating devices in the input file. Similarly, all outputs run through loadswitches in the output file. By providing this isolation, the sensitive components of the controller unit are protected from lightning or noise intrusion.

Incoming power lines are protected from lightning or surges by a gas tube type protector, as well as a pair of Metal Oxide Varistors (MOV's). However, if lightning is a serious problem, as it would be in the southeastern portion of the United States, then additional protection is usually specified by users.

<u>Terminal Facilities</u>: Field wiring, such as cabling to signal heads or lead-ins from detectors must be terminated within the cabinet on its terminal facilities. Output wiring to the signals is terminated as a series of terminal strips on the back side of the output file assembly. Input wiring can be terminated either on panels mounted on the inside walls of the cabinet, or on the back side of the input file.

<u>Coordination</u>

Model 170 controller units can be easily incorporated into systems, by hardwire interconnect, time-based coordination, or through computer control. The capabilities of the intersection to operate within the system are dependent upon the program being used.

Hardwired interconnect covers two primary areas of communications — switched voltages, as would be used in multiple conductor interconnect; or modulated messages, using modems.

Generally, a seven-wire interconnect is used with three-dial, three-offset pretimed or actuated arterial systems, where switched AC or DC voltages are used for dial and offset selection and synch generation. Interconnect would enter the controller unit through the input file. With this approach, new Model 170 controller units could be used in an existing system with electro-mechanical or non-170 controller units.

The controller unit's internal modem capabilities can be utilized with twisted pair cabling extending between intersections. A number of programs for the Model 170 controller unit utilize this approach, including California's Basic Arterial Local Intersection (BALI) package. BALI, resident in a single EPROM, is combined with a modified LIP program (which takes only five EPROM's) for local intersection operational. With the BALI system, a master controller unit for each system is designed ,in which an additional program EPROM, the Basic Arterial Master (BAM) is inserted. The master controller unit communicates with each of the local intersections through modems and provides for traffic responsive and time-of-day operation.

The Model 170 controller unit can also provide time-based coordination features, depending on the program used. Using the Local Intersection Program from California and inserting the BALI and BAM programs creates a time based coordination controller unit. One drawback of the Model 170 has been the limited accuracy of the Downtime Accumulator, resulting in a potential error, between two adjacent units, of two seconds per power failure. As mentioned previously, the two system memory modules include circuitry to improve the operation of time based coordination.

Model 170 controller units can also be utilized in computerized systems, ranging from UTCS-type systems to closed loop, microprocessor-based systems. Most of these systems have used special controller unit software to accommodate the requirements of the system, and have used the Model 400 modem for communication.

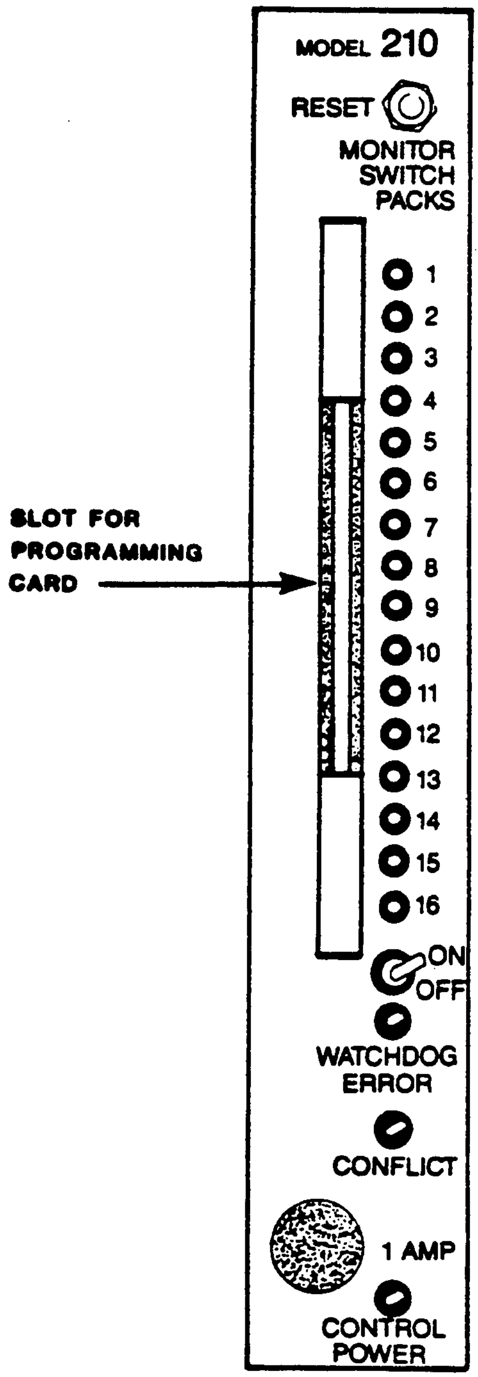


Figure II-13. Model 170 Conflict Monitor

Preemption

Preemption is the altering of a controller unit's normal operation to accommodate a special event or occurrence, such as the passing of a train or a fire engine. In the Model 170 controller unit system preemption is accomplished internally, through software routines in the main traffic control program. One or more inputs to the controller unit are designated as preempt call inputs within the software package. In the Local Intersection Program, two forms of preemptor, requiring six input channels in the input file, are provided.

Railroad preemption is activated by the passage of a train on a nearby grade crossing. In the LIP program, two railroad preemption routines are standard. One routine, when activated, calls for the track clearance interval for phase 2 and 5 (this is fixed in software, so this particular installation would have to be oriented so that phases 2 and 5 crossed the tracks). After the track clearance interval, the controller unit advanced to an all-red state, then flashes all-red until the end of the preemption.

The second rail preemption routine in LIP calls for clearing the track phases 4 and 7, then servicing only those phases that don't cross the track (1, 2, 3, and 6), until the end of preemption.

The two railroad routines are activated by two channels in the input file, served by one isolator position. A two-channel DC isolator (Model 242) would most likely be used for this purpose.

Emergency vehicle preemption is becoming more prevalent, and the LIP provides four routines, each activated by its own input in the input file. Each routine calls a combination of two phases, a through movement and its associated left turn, as follows:

Emergency Vehicle Routine A - phases 2 & 5
Emergency Vehicle Routine B - phases 4 & 7
Emergency Vehicle Routine C - phases 6 & 1
Emergency Vehicle Routine D - phases 8 & 3

Inputs can be generated through isolators, particularly if route preemption (with interconnect) is used. If vehicle mounted devices, such as Opticom, are used, a special module may be available for insertion into the input file.

MANUFACTURERS OF MODEL 170 CONTROLLER UNITS

At least three companies manufacture Model 170 controller units in the United States. These companies are Safetran Traffic Systems, Inc., Signal Control Corporation, and Dynatrol.

The following section describes the functional characteristics of the Safetran and Signal Control Model 170 controller units. Both controller unit systems are included in the mobile exhibit.

SAFETRAN MODEL 170SV CONTROLLER UNIT

The Safetron Model 170SV is a general purpose microprocessor. It is based on the Motorola family of 6800 microprocessors. The Model 170SV is designed specifically to meet CALTRANS requirements. The Model 170SV uses standard prom module and model 400 modem, as specified by the Specifications. (See Figure II-14.)

The Model 170SV uses an eight (8) bit microprocessor and it operates at 768KHZ. Some of the Model 170SV features include.

- operates in a hostile environment
- vertical board design
- accepts two plug-in communications modules
- connectors specified by address rather than by function
- memory map defined by specification
- data entry method defined by specification
- utilizes memory mapped I/O

Applications: The Model 170SV is designed to operate as either a local controller unit or a master controller unit supervising simple or complex traffic control requirements. The Model 170SV is capable of operating two to eight-phase intersections. Some of the most recent applications of the Model 170SV include:

- Master/Local traffic signal controller unit
- Ramp metering controller unit
- Sprinkler controller unit
- Highway surveillance
- Environmental controller unit
- Diagnostics controller unit
- Sequential off-ramp controller unit

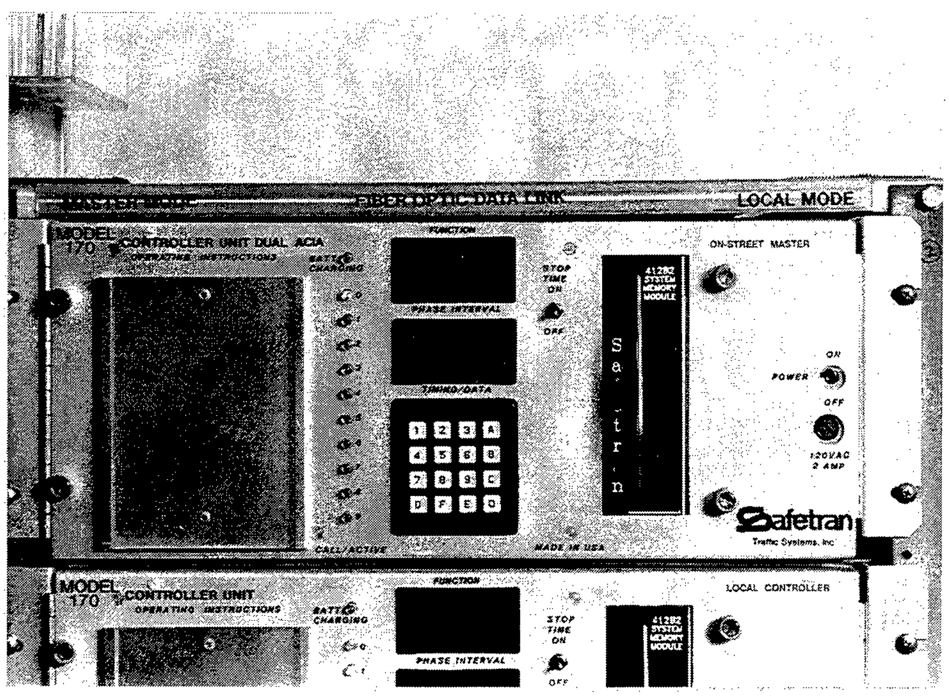


Figure II-14. Safetran Model 170 Controller Unit

Module Design: All modules have been designed to increase reliability, reduce maintenance and lower power consumption, and are mounted in a vertical plane to facilitate heat dissipation. A unique module and chassis design ensure proper positioning of each module. All modules may be extended, for maintenance purposes, using extender cards.

CPU Module: The CPU houses the MPU, the dual independently programmed ACIA for communications, up to 32 K of battery backed RAM, decode logic and bus drivers. An option allows the installation of up to 32K of EPROM on the CPU thus eliminating the requirement for the Prom Module. This feature reduces the complexity and total power consumption of the 170SV controller unit.

Input Module: The single input module draws heavily on CMOS technology. Lightning protection devices have been added to enhance surge protection. All input circuits are resident on this module to facilitate maintenance. In addition, the power start up and battery power circuitry are located on this module.

Output Module: The single output module contains the entire output circuitry of the Model 170SV. Operation can be easily diagnosed by simply exchanging output modules.

Power Supply Module: The Model 170SV is equipped with a liner power supply. All components of the power supply, including capacitors, transformers, and power transistors, are located on this removable module. Connection between the power supply and the mother board is via a floating 15-pin and socket power rated connector. Power consumption is about 40 watts and it requires 115 VAC, 60 Hz cycle.

Chassis: A printed circuit mother board assembly provides reliable interconnect between the modules. A separate bus for the I/O increases noise immunity. In addition, separate logic ground paths are supplied from the power supply to each module. Vertically mounted, the input/output connectors are located on the back of the Model 170SV. To facilitate the installation of the Prom Module, card guides are extended to the front panel. A hinged front panel is held in place by four thumb screws. When closed, the front panel prevents the modules from backing out of the connectors. The Model 170SV may be equipped with two communication modules. An optional connector and module can be added to optically isolate the I/O bus.

Standby Power: The Model 170SV is supplied with rechargeable batteries, which supply standby power to volatile memory devices and the down time accumulator circuitry.

Safetran Model 412B2 Prom Module: The model 412B2 prom module provides the user with a platform to interchange data and programs for the Model 170SV controller unit. The Model 412B2 prom module provides reliable operation, with reduced components and low power consumption requirements. The 412B2 supports 32K EPROM and 32K RAM or NOVRAM (total 64K memory map) while addressing the full 64K range of the 170 controller unit. The 412B2 can be installed in all 170 controller units and based on the software requirements, configured to operate with most software packages. (See Figure II-15, page II-59.)

The 412B2 provides several convenient and useful features for the Model 170 users. There is a mechanical device to prevent the insertion of the module upside-down, thus eliminating damage to the module. There are three sockets that accept up to three 28 pin memory devices. The standard configuration allows for 1-27256 EPROM (32K) 1-62256 RAM (32K) or 1-1235 NOVRAM (32K), and a third memory device can be installed in the middle socket when required by software. HCT drivers are used in the 412B2 to increase noise immunity. A battery clip and on/off storage switch can be supplied. A lithium battery (one "AA" cell) installed in the clip will provide extended back-up to on board RAM.

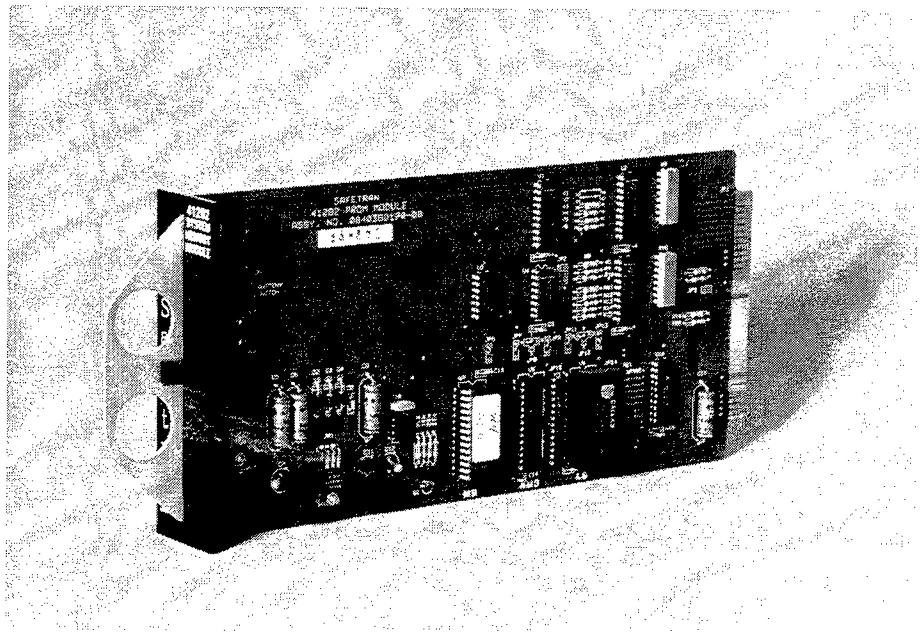


Figure II-15. Model 412B2 PROM Module

SAFETRAN MODEL 179 CONTROLLER UNIT

The Model 179 Microcomputer is an MC6809 microprocessor based unit that is capable of addressing 1 MEG 8-bit words. Memory in the Model 179 varies as installed on the prom module. The Model 179 meets the NYDOT requirements. The standard NYDOT requirement is 16K RAM memory, 96K EPROM memory, and 8K EEPROM memory installed in the prom module. (See Figure II-16, page II-60.)

Application: The Model 179 Microcomputer is designed to operate as a master controlling multiple systems or as a local intersection controller unit capable of directing the simplest two-phase intersection up to a full diamond interchange under system control.

Volatile Memory Back-Up: The Model 179 has a battery back up system, affords the use of either EEPROM or NOVRAM devices, super capacitors and operates an accurate time clock in the event of a prolonged power failure. The battery is trickle-charged during normal operation to ensure top performance when required.

Communications: The Model 179 is designed specially for multiple communication. As a standard there are two RS-232-C communications ports which are routed to the rear of the controller unit on both C2 type connections, a 25 pin D connector, and an 8 position terminal block. The BAUD rates are user selectable from 300 to 19K. In addition there are four RJ-11 telephone type connectors on the rear of the Model 179 that may be attached to up to four optional internal communication modules installed in the Model 179 via the SS-50 bus. The Model 179 will accept both the Model 602 or the Model 612 internal communication modules thus allowing for up to either four ports of Bell 212 dial up connections or eight ports of Bell 202 direct line modems, or several combinations of both.

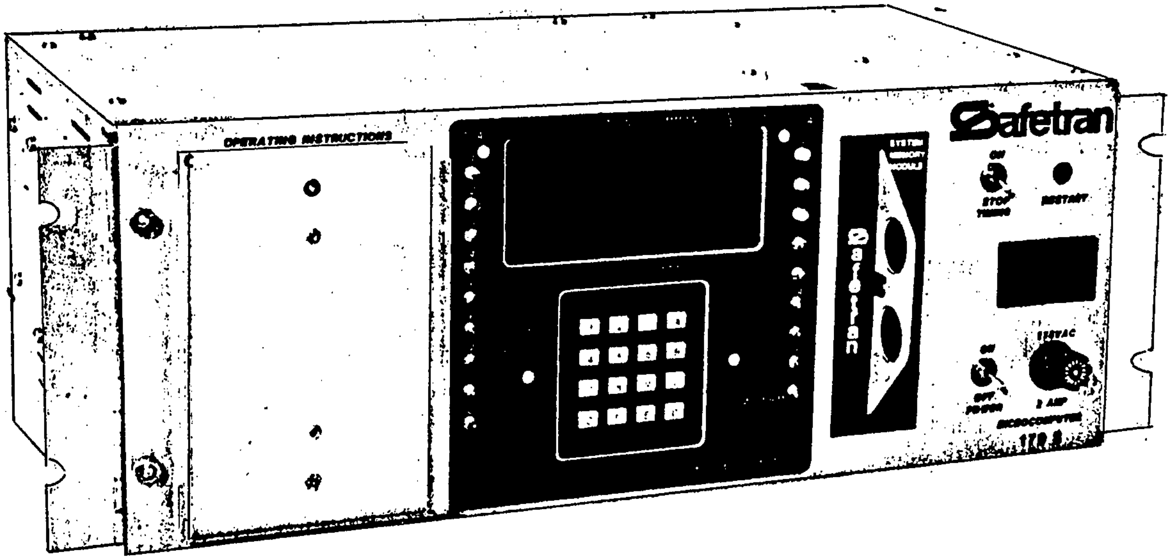


Figure II-16. Safetran Model 179 Controller Unit

Input/Outputs: The Model 179 provides 44 inputs and 56 outputs with capability of expansion via the insertion of optional I/O modules into the SS-50 Bus connection.

New Hardware Features: There are several new hardware features that enhance the operation of the Model 179. There has been added a missing pulse detector that can detect missing AC pulses. This will allow software to more accurately control clocks during time based operation. Bank switching of memory devices has been added to allow for addressing memory location beyond the 1 MEG level. The downtime accumulation circuit has been expanded to account for up to a 5 day power outage and still continue to operate to ± 100 parts per million accuracy. A four port Programmable Event Time has been included to allow for more accurate speed and classification counting as well as to relieve the software during its timing routines.

SIGNAL CONTROL 170A CONTROLLER UNIT

The model 170A Dual ACIA Microcomputer is an MC 6802 microprocessor-based unit that is capable of addressing 65,535 bytes, 8-bit words. Memory in the Model 170A is comprised of 52K total memory, composed of various combinations of EPROM and Static RAM.

The Model 170A is designed to meet the CALTRANS Traffic Signal Control Equipment Specifications dated January 1989 and Addenda through March 1991.

The 170A controller unit has many options that are not required by the CALTRANS January 1989 Specification. Foremost among them are the availability of 4 ACIA communications ports and several memory configurations, one of which is a bank switching mode that lets you double the available memory. The parts count in the Model 170A controller unit is reduced as much as possible and the total board count is cut to 6 PC boards. This means that there are less parts to fail and fewer connections to wear out. The use of high-speed CMOS where possible means the 170A controller unit will run cooler and be more immune to noise. The power supply uses dc-to-dc converters to pre-regulate the voltages in the power supply which increases efficiency and enhances the noise immunity. The Model 170A controller unit uses less than 30 watts of power. A view of the Model 170A front panel is shown in Figure II-17, on page II-62.

The 170A controller unit will accept all 412C and 414 Program Modules and other pin compatible memory modules. It will also accept the Model 400 Modem and the new Dual Modems that fit in the same slot.

<u>Applications</u>: As mentioned earlier, the Model 170A controller unit has a broad range of applications ranging from a local intersection controller unit, a full diamond interchange controller unit, on-street master controller unit, loop counter, or a sprinkler control controller unit.

<u>Module Design</u>: The Signal Control Model 170A controller unit is modular in design and is comprised of the following plug-in modules.

- CPU Module
- I/O Module
- Program Module
- Power Supply Assembly
- Front Panel (Display/Keyboard)

Optional modules also include a model 400 modem and/or dual modem module.

The 170A controller unit chassis assembly consists of the following:

- CPU Motherboard Assembly
- C1 Assembly
- Rear Panel Input/Output Connector Assembly
- Communication Assembly
- Card Cage Assembly

<u>CPU Module</u>: The CPU is the heart of the Model 170A controller unit. It consists of the following:

- 6802 microprocessor unit
- 6850 asynchronous ACIA communications adaptors
- RS232 interface to connector C2 and the Model 400 Modem
- RS232 interface to connector C20
- Interface to the CPU Motherboard Bus and Program Module
- Interface to the I/O Module
- Interface to the front panel Display Board

Power supplies, address, data, and control buses for the Display Board and I/O Module are supplied from the CPU Module via the Front Ribbon Cable Interface labeled P1.

<u>Input/Output Module</u>: The Input/Output Module provides the interface between the processor and all C1 connector and Front Panel related input and output lines. It contains battery backed logic

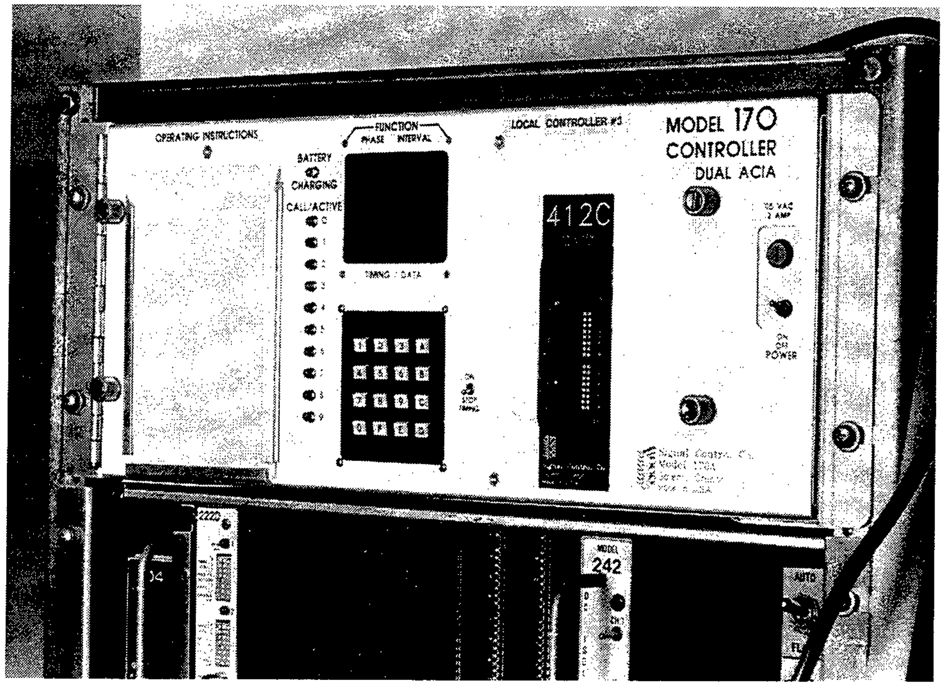


Figure II-17. The Model 170A Controller Unit Front Panel

to log AC power loss duration (Downtime Accumulator) and control intersection display initialization upon power restoration (Restart Timer). This board plugs directly into the C1 connector board assembly and controls the 56 outputs and 44 inputs available at the connector. It also regulates the front panel display and keyboard operations. Its edge connector (P2) is dedicated to C1 connector interface, while power, data, address and control inputs and outputs utilize P1, the front ribbon connector, which connects the CPU Module. The display board interface is conducted through connector C3.

Prom Module Model 412C: The 412C Program Module is designed to be installed in the Model 170 traffic controller unit to extend the versatility and range of the controller unit. The 412C Program Module offers ample memory and other features to perform tasks that range from local intersection control to complex master traffic control systems.

The 412C Memory Module is a direct replacement for the 412C/64 and 412/128 Memory Modules as described in the Caltrans specifications. The only difference is in the method employed to generate the memory chip select signals on the board. See FIgure II-17A on page II-63.

The total address range of the Model 170 Traffic Controller MicroProcessor Unit (MPU) is 64K bytes. 12K bytes of memory addresses are reserved for use of the controller unit internally, reducing the total useable Program Module memory range to 52K bytes.

In addition to memory, the Program Module offers a Real Time Clock Adjust circuit (RTCA), battery voltage monitor, and programmable switches to identify the intersection and active program features.

Features of the 412C Module are summarized below.

Memory Capacity:	Approximately 52K total memory, composed of various combinations of EPROM and Static RAM.
Random Access:	6264 8K x 8-bit COMOS RAM, 120 ns.
Memory (RAM):	62256 32K x 8-bit CMOS RAM, 120 ns. 1225 Nonvolatile RAM. (On-chip battery.)
Real-Time Clock:	24-stage resettable binary counter.
Adjust:	Read in 6-bit increments. Used to update software time-of-day clock after power outage.
Program Switches:	Two 8-bit DIP switches. Function assigned by software.
Battery Monitor:	Microprocessor may access battery condition via 8-bit port.

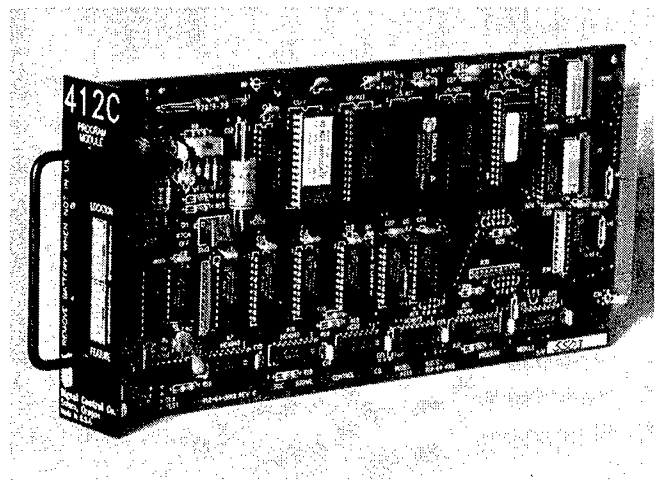


Figure II-17A. PROM Module Model 412C

Power Supply: The 170A controller unit power supply unit forms the right side panel of the controller unit case. The ac Power Switch and fuse are located here, and protrude through the front panel access opening. The ac power cord is located on the rear panel. The power supply can be detached by removing four screws.

The power supply provides all regulated dc voltages required to operate the 170A. The supply contains circuitry to measure the ac power line voltage, and reset the microprocessor in the absence of proper operating voltages. All dc supplies operate from a high-isolation linear power transformer. Its input is protected by a 3-conductor shielded power cord, current limiting resistors, 3 metal oxide varistors, a 2A fuse, and noise filter capacitors. The current limiting resistors are critical, since they are chosen as much for their inductance as their resistance.

Both the ac power inputs and power supply outputs are routed through connectors for ease of maintenance. In most cases, because of the ample service loop provided in the Power Supply Output Cable, the supply need not be electrically disconnected from the 170A for servicing. An additional hole is provided in the side panel to support the printed circuit board in a vertical position for ease of troubleshooting.

Front Panel Display and Keyboard: The front panel is hinged to the left side of the main chassis. It may be detached from the chassis by the removal of hand-operated fasteners and disconnecting the C3 ribbon cable and the battery harness to facilitate servicing. It contains or allows access to all controls and displays required by the operator to observe and control the 170A. A 4-inch by 6-inch operating instruction card holder is provided on the left side. An opening to facilitate removal or insertion of the Program Module eliminates the need to open the front panel for this purpose.

The 170A Display consists of six (6) seven-segment readouts, located near top-center of the front panel behind a contrast-enhancing red filter, and a column of eleven (11) discrete LEDs located on the left side. The Keyboard is centrally located beneath the Display, with the Stop Timing Switch to its immediate right. The Keyboard permits decimal and hexadecimal data entry for purposes of viewing or changing operational parameters.

The Stop Timing Switch is read by the microprocessor through an input port with its function being dependent on the software installed in the 170A controller unit. In normal operation, the Stop Timing Switch will halt the controller unit timing routine and prevent changes of interval.

The AC Power Switch, and the AC power fuse are mounted on the Power Supply Assembly, which is located on the right side of the controller unit. An opening located on the right side of the Front Panel provides access to the switch and fuse. The AC power cord is mounted to the rear of the Power Supply Assembly.

CONTROLLER UNIT CABINETS

This section discusses the specifications for NEMA and Model 170 controller unit cabinets.

A cabinet is an outdoor enclosure for housing the controller unit and associated equipment such as input and output auxiliary devices. With NEMA, the size and type of cabinet was not standardized and, therefore, the size and type of cabinet is still dependent on the manufacturer, the type of controller unit to be housed in the cabinet, and/or any user-specific requirement. NEMA TS2, however, has included specifications and standards for cabinet type, material, size, and mounting detail. A complete description of the specifications can be found in NEMA TS2 publication. The Model 170 cabinet, however, has been standardized, and at least four size cabinets are commonly used throughout the country. See Table II-3, page II-66.

In general, controller unit cabinets are fabricated from aluminum alloy. Cabinet sizes are usually dictated by the type of mounting and number of input and output devices. Almost all cabinets, however, have provisions for waterproof protection, latches and locking mechanism, police compartment, supporting rack or shelving assembly, finish and surface protection, mounting hardware, natural and/or mechanical ventilation, wiring, control panel assembly, convenience receptacle, lighting fixtures, terminal blocks, surge arrestors, and suppressors.

The following are descriptions of the most widely used standard Model 170 cabinets.

California Type 332 Cabinet

Specifications for the California 332 cabinet call for a base-mounted, anodized aluminum cabinet equipped with both a front and back door. The 332 cabinet is the primary cabinet for use with the Local Intersection Program. It provides the most space and easiest access of any of the standardized cabinets. It is illustrated in Figure II-18.

The cabinet stands 64 inches high 24 inches wide and 30 inches deep. The front door allows access to all controls: the controller unit front panel, the module side of the input and output files, and the front of the power distribution assembly with its circuit breakers and flash control switch. The rear door provides access for all wiring connections. A police panel, with a switch for putting signals on flash, is located on the external side wall of the cabinet. A fan is built into the roof of the cabinet, with exhaust vents coming out from under the roof, eliminating a major source of rain intrusion.

The cabinet assembly is heavy, due to both its size and material, and the rack assembly inside. To permit easy lifting of the cabinet into location, lifting plates or eyes are required on the top side of the cabinet, so that a small truck-mounted crane can be used to assist.

California Type 334 Cabinet

The Type 334 cabinet share the same external sheet metal dimensions and appearance as the Type 332 cabinet. However, this cabinet has been designed for use as a ramp metering controller unit cabinet, and therefore has a different combination of internal components. (See Figure II-19.)

With this cabinet, only one input file is installed; the output file and power distribution assembly have been combined into a single component. As there is no need for a conflict monitor, this function has been eliminated, with the exception of the watchdog monitor.

California Type 336 Cabinet

The Type 336 cabinet is intended as a condensed version of the Type 332 cabinet, for use with the Local Intersection Program. It stands only 38 inches high, but has the same horizontal dimensions as the Type 332 (24 inches wide by 30 inches deep).

Table II-3. Model 170 Controller Unit Cabinets (*)

CABINET TYPE	SIZE (INCHES) H	W	D	SHIP. WEIGHT	NO. OF L/S'S	DOUBLE DOOR	TYPE OF MOUNTING[2]	INPUT SLOTS[3]	NO. OF FLASHERS	NO. OF FIR'S	CABINET SPEC.	RACK SPEC.	VEHICLE PHASES	PED. PHASES	OVLPS.
332	66	24	30	300	12[1]	YES	B	28	2	4/5	CALTRANS	CALTRANS	8	4	4[5]
336	36	24	22	265	12	YES	B, S, P	14	2	4/5	CALTRANS	CALTRANS	8	4	0
336 S	46	24	22	280	12[1]	YES	B, S, P	14	2	4/5	SPECIAL	CALTRANS	8	4	4[5]
330	51	20	18	200	14	NO	B, S, P	14	1	7	NYDOT	NYDOT	8	4	2
303	36	20	17	145	6	NO	S, P	7	1	2/3	SPECIAL	SPECIAL	4	2	0
333	54	43	26	450	12[1]	YES	B	28	2	4/5	SPECIAL	CALTRANS	8	4	4[5]
337	36	20	17	165	6	YES	S, P	11	1	3	SPECIAL	SPECIAL	4	2	0
334	66	24	30	290	3	YES	B	14	0[4]	0	CALTRANS	CALTRANS	3	0	0
336 B	36	24	22	260	6	YES	S, P	14	1	2	CALTRANS	CALTRANS	4	2	0
336 W	38	22	20	265	12	YES	S, P	14	1	4	SPECIAL	CALTRANS	8	4	0

(*) - SOURCE: SAFETRAN TRAFFIC SYSTEMS INC.

(1) 6 ADDITIONAL LOADSWITCHES CAN BE PROVIDED WITH AN OPTIONAL MODEL 420 AUXILIARY OUTPUT FILE
(2) B - BASE MOUNTED, S - SIDE OR BACK OF POLE MOUNTING, P - PEDESTAL MOUNTING
(3) EACH INPUT SLOT WILL ACCEPT A 2-CHANNEL INPUT DEVICE
(4) FLASH OPTION IS AVAILABLE
(5) FOUR THREE-COLOR OVERLAPS ARE AVAILABLE WITH ADDITION OF AN OPTIONAL MODEL 420 AUXILIARY OUTPUT FILE

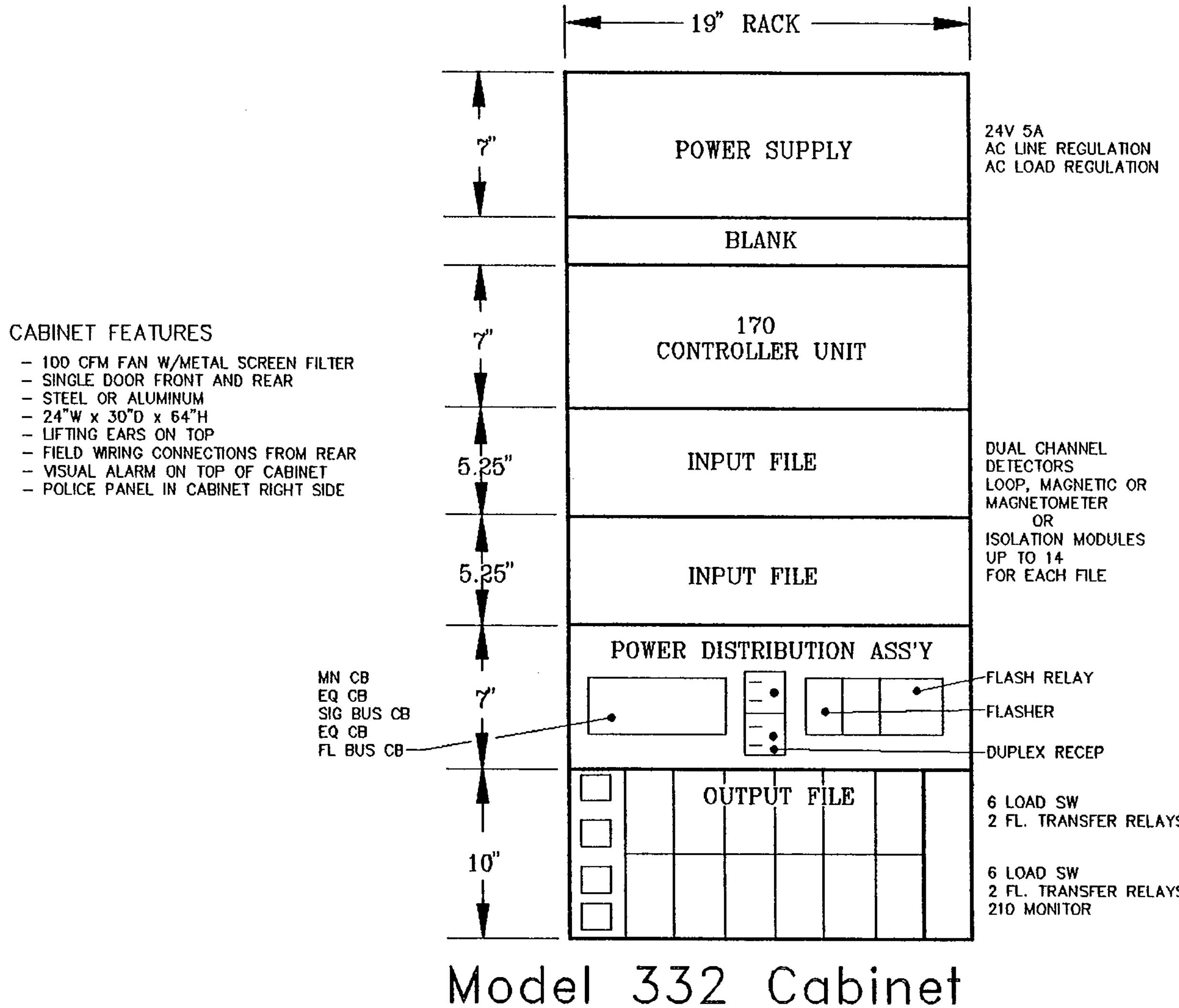
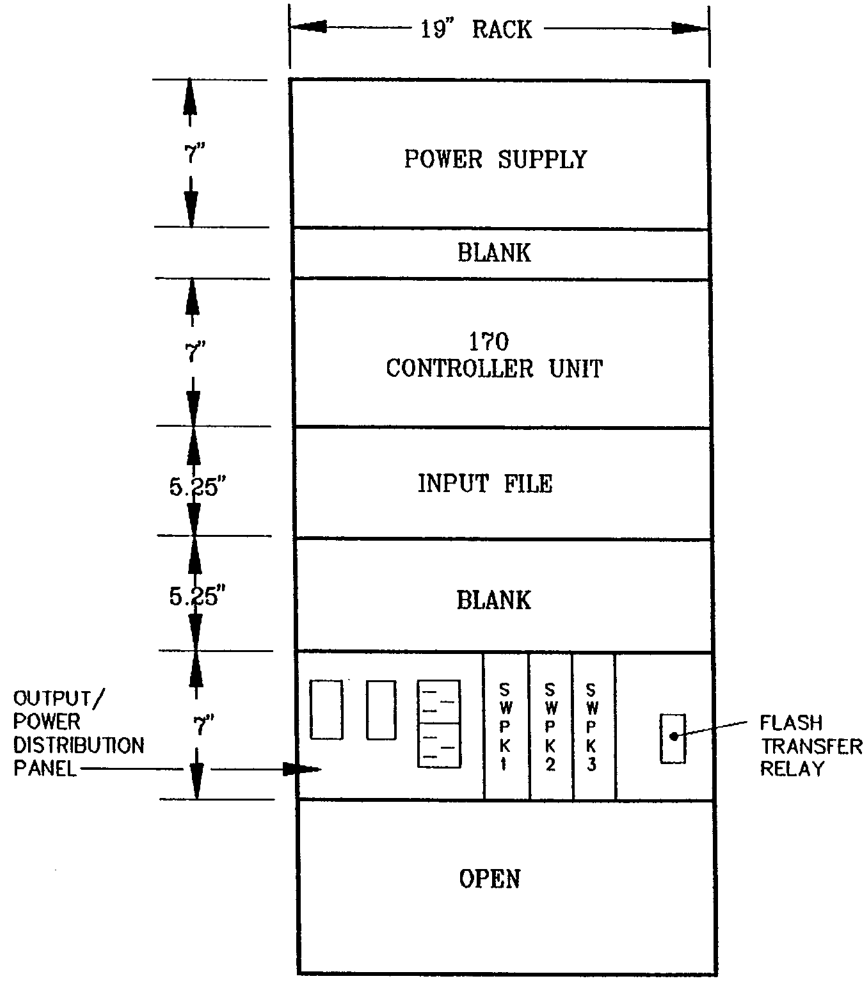


Figure II-18. Model 332 Cabinet, Front View



Model 334 Cabinet

Figure II-19. Model 334 Cabinet, Front View

The Type 336 cabinet is designed for either pole, pedestal, or pad-mounted. As it is a double door cabinet, when mounted on the side of a pole it presents a somewhat awkward appearance because its long dimension extends out from the pole. It has also been described as too heavy to realistically mount it on top of a pedestal pole. Therefore, perhaps its greatest use has been as a base-mounted cabinet.

To conserve on its vertical height, some rearrangement of components of the Type 332 was required for the Type 336. The PDA#2 now includes the power supply in the PDA, in accordance with Caltrans specifications, 1989. In addition, the auxiliary output file, if needed, would not fit into a Type 336 cabinet.

New York Type 330 Cabinet

The Type 330 cabinet reflects New York's approach to the Model 170, in developing a system that would satisfy 95 percent of the state's traffic signal installation needs. Therefore, the Type 330 cabinet is smaller and has fewer components than California's Type 332 cabinet. The cabinet is designed for pole, pedestal, or base-mounted installations.

The 330 is a single door cabinet, and stands 51 inches high. The internal rack assembly includes a sliding shelf for the controller unit so that the rear-mounted connected can be attached while the controller unit rests on the shelf. The input and output files are configured for only 14 load switches and 16 detector inputs, which is considered sufficient for most New York applications.

Because of its differences in configuration with the 332 cabinet, the Type 330 cabinet requires a different software package than Caltrans Local Intersection Program. New York has developed an Isolated Traffic Actuated Program, TAPS, for use with the 179 controller unit and Type 330 cabinet.

Non-Standard Cabinets

One of the most frequently heard complaints about the standardized cabinets is their size, particularly for a downtown area. For jurisdictions desiring to replace aging electromechanical pretimed controller units with a Model 170, while maintaining an existing two-phase operation, a Type 332 cabinet seems to be overkill. In response to this identified market need, several manufacturers of Model 170 equipment have developed their own cabinets. Typically, these cabinets are small, pole-mounted cabinets with limited input and output facilities, appropriate for operation of a two or three phase signal with pedestrian displays. However, these cabinets are not standardized, and may present a procurement program if a particular design is desired.

AUXILIARY INPUT DEVICES

Input auxiliary devices for controller unit assemblies include detectors, time switches, time-base coordinators, preemptors, and isolators.

A vehicle detection system, defined by NEMA standards as "... a system for indicating the presence or passage of vehicles," provides input for traffic-actuated signal control, traffic responsive system control, freeway surveillance, and data collection systems. The three main types of vehicle detector systems used in current traffic engineering practices are inductive loops, magnetic and magnetometer detectors. Recently, however, other detector types such as infrared, microwave (radar), ultrasonic, optical and radio have evolved specifically for special operating conditions such as preemption, small area detection, light rail detection, etc.

This workshop includes inductive loop detectors, magnetic detectors, microwave detectors, ultrasonic detectors, radio detectors, and optical detectors. Below are descriptions of these systems and their respective manufacturers.

Inductive Loop Detectors
- Detector Systems
- The Peek/Sarasota

Microwave Detectors
- Microwave Sensors
- Whelen Engineering Company

Ultrasonic Detectors
- Microwave Sensors

Optical/Infrared Detectors
- 3M Company

Radio Detectors
- Econolite Control Product Inc.

INDUCTIVE LOOP DETECTORS

Detector Systems Inc.

Table II-4 summarizes all characteristics of the Detector Systems detectors that are exhibited in this workshop. Figure II-20 depicts a single channel digital inductive loop detector, model 919-4.

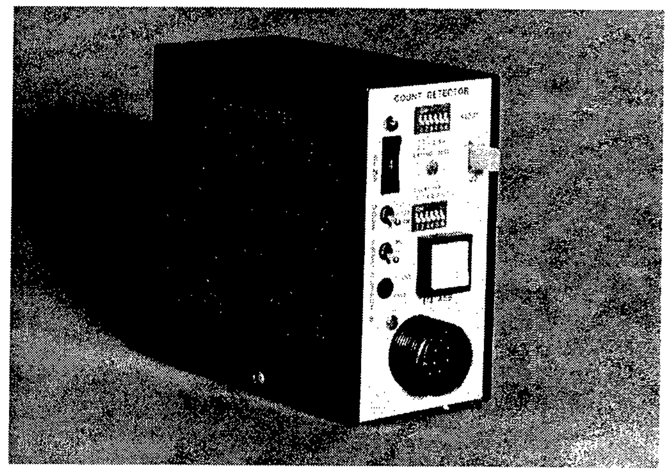


Figure II-20. Model 919-4 Detector Unit

Model 919-4 Single Channel Digital Inductive Loop Vehicle Detector: The Model 919-4 unit is a shelf-mounted one-channel digital inductive loop vehicle detector with timing functions and AccuCount™ outputs.

- The AccuCount™ pulse output enables accurate counting of vehicles entering the loop even when preceding vehicles remain present over the loop.

- The AccuCount™ works with a single, long rectangular loop or a Quadrupole loop of any size. Also works with four 6' x 6' loops wired in series.

TABLE II-4. DETECTOR SYSTEMS DIGITAL INDUCTIVE LOOP VEHICLE DETECTOR MODELS: SHELF & RACK MOUNTED UNITS

	Model 919-4	Model 921-2TC	Model 940	Model 222C	Model 224C	Model 262C
No. of Channels	1	2	4	2	4	2
Sensitivity levels per channel	10	9	9	9	9	9
No. of operating frequencies per channel	3	3	3	3	3	3
Modes for detection output per channel	3	3	3	3	3	2
Delay time range (sec.)	0 - 63	0 - 63	None	None	None	0 - 63
Extension time range (sec.)	0 - 15.75	0 - 15.75	None	None	None	0 - 15.75
LED Detect indicator	Yes	Yes	Yes	Yes	Yes	Yes
Transformer isolation of loops	Yes	Yes	Yes	Yes	Yes	Yes
Self tuning	Yes	Yes	Yes	Yes	Yes	Yes
Used for vehicle count simultaneously	Yes	Yes	No	No	No	No
Response time (MS)	1 to 64	4 to 128	4 to 256	5 to 160	5 to 160	4 to 128
Separate output for vehicle count	Yes	Yes	No	No	No	No
Recommended loop geometry size	4 - 6' x 6' in series	Quadrupole or single rect.	Any Size	Any Size	Any Size	Any Size
Toggle switches for frequency and mode, on front panel	Gold Contacts	Gold Contacts	Gold Contacts	Gold Contacts	Gold Contacts	Gold Contacts
Lightning protection	Yes	Yes	Yes	Yes	Yes	Yes
Intermittent or Failed loop LED indicator (Winky-Blink)	Yes	Yes	Yes	Yes	Yes	Yes
Thumbwheel switch for sensitivity setting	Yes	Yes	Yes	Yes	Yes	Yes
Manual reset required if intermittent or failed loop self-heal	No	No	No	No	No	No
Loop Inductance Range (μH)	20 - 2500	20 - 2500	20 - 2500	20 - 2500	20 - 2500	20 - 2500
Mounting Type	SHELF	SHELF	SHELF	RACK	RACK	RACK
Loop Feeder Length (Ft)	≤ 5000	≤ 5000	≤ 5000	≤ 5000	≤ 5000	≤ 5000
Unit with Timing Functions (Delay time and extension time)	Yes	Yes	No	No	No	Yes

- The MS and Molex connectors on the front panel both provide output "B" connections.

- The "Winky-Blink" loop monitor remembers and indicates intermittent and failed loops.

- If intermittent or failed loops self heal, the detector will resume normal operation without requiring a manual reset.

- Thumbwheel switch for sensitivity settings.

- Three selectable modes for Output A:
  - Pulse, max 2 seconds
  - Presence, normal hold time of 4 min. minimum and 30 min. maximum
  - Presence, long hold time of 4 min. minimum and 90 min. maximum

- Digital Delay and Extension Timers (Output A only):
  - Delay time range is 0 to 63 seconds in 1 second steps
  - Delay is indicated by the LED flashing at 4 Hertz
  - Delay inhibit control is available on pin J
  - Extension time range is 0 to 15.75 seconds in 0.25 second steps
  - Extension is indicated by the LED flashing at 16 Hertz

- Complete low power C-MOS digital design

<u>MODEL 921-2TC Digital Inductive Loop Vehicle Detector</u>: Figure II-21 shows the front panel of another multi-channel shelf-mounted detector unit. This unit has the following features:

- Two detector channels in a single unit
- This advanced detector enables the user to obtain accurate vehicle counts from very long loops
- AccuCount™ works with a single rectangular loop or a Quadrupole loop of <u>any size</u>
- The AccuCount™ output provides a separate pulse for each vehicle entering the loop detection zone
- Three selectable modes per channel
  - Pulse (max. 2 seconds)
  - Presence (4 minutes min. and 90 minutes max.)
  - Count (AccuCount™)
- Digital delay and extension timers for each channel:
  - Delay time range is 0 to 63 seconds in 1 second steps; times set with dip switches
  - Delay is indicated by the LED flashing at 4 Hertz
  - Delay inhibit control is available on pin J
  - Extension time range is 0 to 15.75 seconds in 0.25 second step
  - Extension is indicated by the LED flashing at 16 Hertz
- Complete low power C-MOS digital design

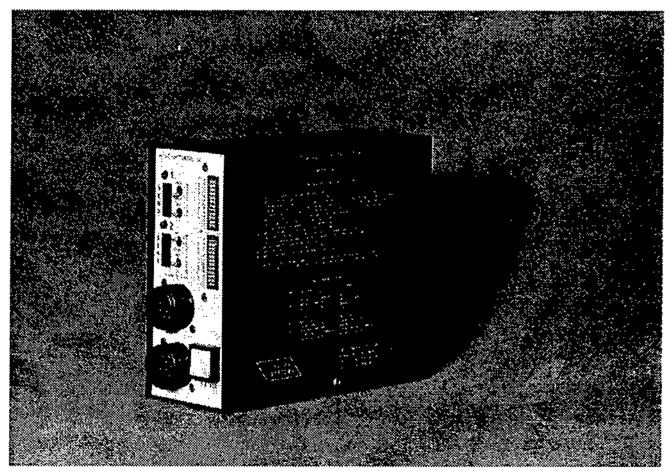


Figure II-21. Model 921-2TC Detector Unit

<u>MODEL 940 Four Channel Digital Inductive Loop Vehicle Detector</u>: Another unit shown in FIgure II-22 is a four-channel inductive loop vehicle detector. It features the following:

- Four channels, shelf-mounted, in a compact package with all controls on front panel
- 3 selectable modes per channel:
  - Pulse, max. of 2 sec.
  - Presence, normal hold time of 4 minutes min. and 30 max.
  - Presence, long hold time of 4 minutes min. and 90 max.
- Loops are sequentially scanned, which helps eliminate crosstalk
- Self tuning and complete environmental tracking
- Wide inductance range (20-2500 microHenries)

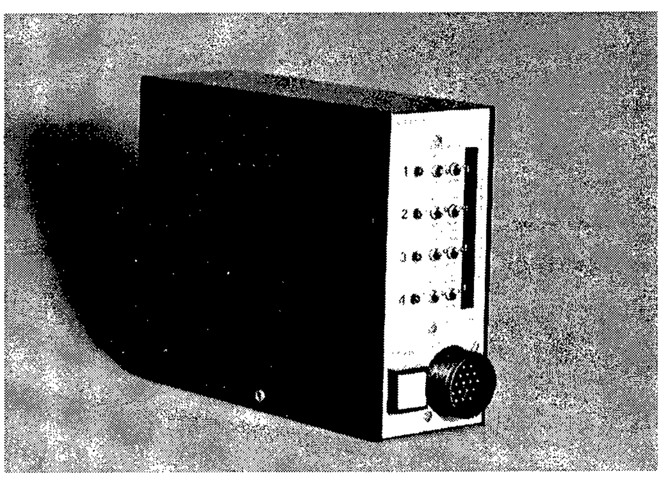


Figure II-22. Model 940 Detector Unit

- Standard four channel MS connector
- Low power C-MOS digital design
- High intensity, red LED indicators
- Lead-in cable lengths up to one mile from controller unit
- Relay or optical coupled solid state output

<u>Model 222C Two-Channel Digital Inductive Loop Vehicle Detectors</u>: The Model 222C, shown in Figure II-23, is a two-channel rack-mounted unit and it features the following:

- Thumbwheel switches for sensitivity settings eliminate confusion and mistakes associated with DIP switches
- Nine levels of sensitivity per channel, over an extended range, cover every situation

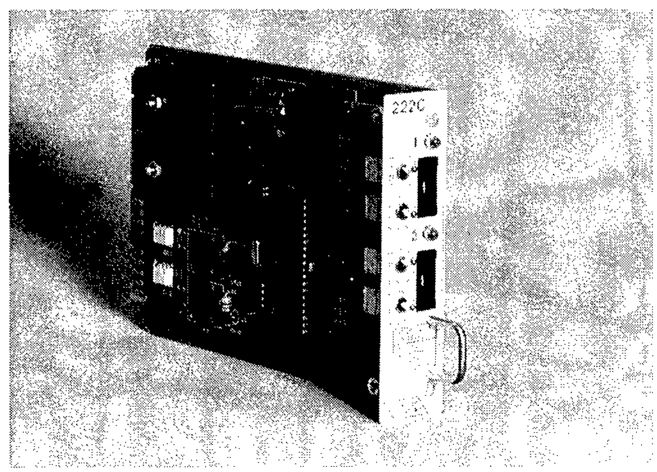


Figure II-23. Model 222C Detector Unit

- Gold contact toggle switches, on front panel for frequency and mode selections, increase reliability

- Three selectable modes per channel
  - Pulse
  - Presence, normal hold time
  - Presence, long hold time
- Three loop frequencies per channel permit complete elimination of crosstalk
- Two detector channels in a single unit
- The Winky-Blink™ loop monitor remembers and indicates intermittent and failed loops
- If intermittent or failed loops self heal, the detector will resume normal operation without requiring a manual reset
- Loops are sequentially scanned, which helps eliminate crosstalk
- Self turning and complete environmental tracking
- Complete low power C-MOS digital design
- Operates on a single DC power supply
- Transformer isolation for loops
- Red, high intensity LED "Detect" indicators
- Loop Inductance Range of 20 to 2500 MH

<u>Model 224C Four Channel Digital Inductive Loop Vehicle Detector</u>: The 224C unit, shown in Figure II-24, is a four channel rack-mounted digital inductive loop detector. It features the following:

- Thumbwheel switches for sensitivity settings.
- Nine levels of sensitivity per channel.

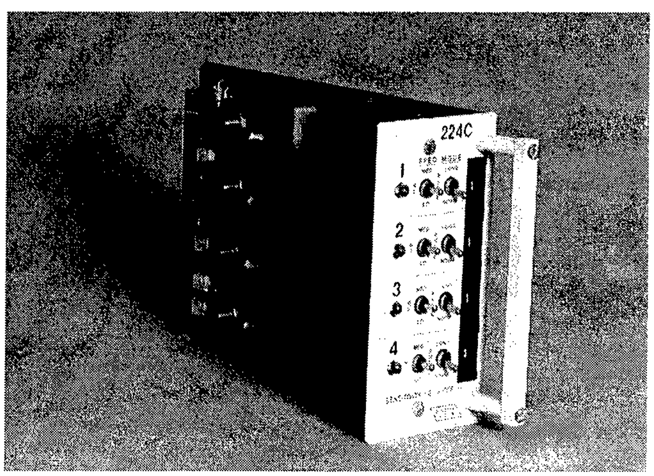


Figure II-24. Model 224C Detector Unit

- Three selectable modes per channel:
  - Pulse
  - Presence, normal hold time
  - Presence, long hold time
- Three loop frequencies per channel permit complete elimination of crosstalk
- Four detector channels in a single unit
- Loops are sequentially scanned, which helps eliminate crosstalk
- Self tuning and complete environmental tracking
- Complete low power C-MOS digital design
- Operates from a single DC power supply
- Optically coupled output circuits
- Transformer isolation for loops
- Red, high intensity LED "Detect" indicators

<u>Model 262C Two-Channel Digital Inductive Loop Vehicle Detector</u>: (See Figure II-25.) Features of the Model 262C detector unit include:

- Two detector channels in a single unit; rack-mounted
- The Winky-Blink™ loop monitor remembers and indicates intermittent and failed loops
- If intermittent or failed loops self heal, the detector will resume normal operation without requiring a manual reset.
- Loops are sequentially scanned, which helps eliminate crosstalk
- Thumbwheel switches for sensitivity settings
- 9 levels of sensitivity per channel
- Gold contact toggle switches on front panel for frequency and mode selections, increase long term reliability
- Three loop frequencies per channel
- Two selectable modes per channel:
  - Pulse
  - Presence
- Digital delay and extension timers for each channel:
  - Delay time range is 0 to 63 seconds with 1 second steps

- Delay is indicated by the LED flashing at 4 Hertz
    - Delay inhibit control is connected to ch. 1 - Pin 1 and ch. 2 - Pin 2
    - Extension time range is 0 to 15.75 seconds in 0.25 second steps
    - Extension is indicated by the LED flashing at 16 Hertz
- Self tuning and complete environmental tracking
- Complete low power C-MOS digital design
- Operates on a single DC power supply
- Transformer isolation for loops
- High intensity LED indicators

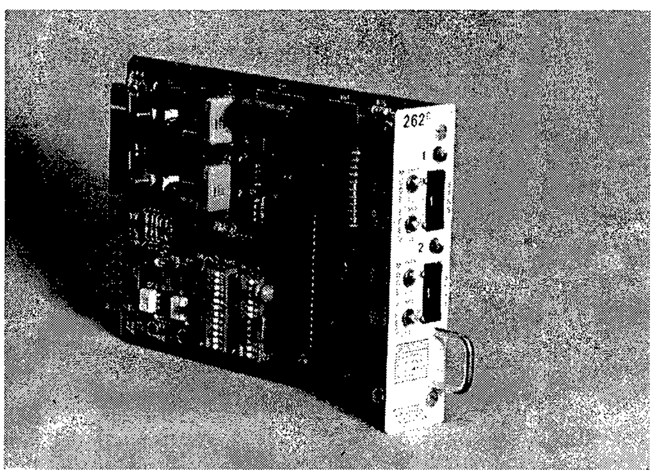


Figure II-25. Model 262C Detector Unit

__Model TLS-1 Traffic Logging System__: The Traffic Logging System (TLS-1) hardware consists of a microprocessor unit to collect, time stamp, and store data in an unattended manner. (See Figure II-26.) After the data collection, the unit's stored data can be uploaded to a personal computer via an RS-232 cable. The unit accepts a new operating program, operational parameters, and the date and time from a download with a personal computer via an RS-232 cable. After a download, data collection is automatic and does not require an operator to reset or start operation once the unit is plugged into an interface harness. The unit automatically starts collecting data of the type and method selected at the correct time, based on the operational parameters selected at download. These include:

- Type of data collection: any combination of count, split timing or event logging
- Sample intervals of 5, 15, 30 and 60 minutes.
- Collection of split timing data in total for sample interval or by cycle.
- Selection of reference input for split/cycle data collection
- Month, day, year, day of week, hour, minute and second information

The unit does not lose stored data from an interruption of power; only the current sample being collected is affected. After a power interruption, data collecting automatically starts at the proper time. At the start, and if a power failure occurs, the re-start of data collection and time will be logged.

Monitor will inhibit operation if the internal logic supply falls below minimum operating requirements. The unit has an internal timer (watch dog timer) that will reset the unit upon failure of the software to properly execute. Below is a summary of features of the TLS-1.

- User friendly menu-driven software
- 32K bytes internal program/data memory
- 28 input channels
- Low cost way to obtain data
- Easy hookup in traffic cabinet
- All timing done digitally (.005 second resolution)
- "Watchdog" timer monitor
- Data retrieval in field or office (only a cable & lap-top or PC required)
- Data/Program/Clock protected for 10 years
- Input interface draws no power from controller unit + 24VDC supply

- Can be used in either NEMA or 170 cabinets
- Small size: 5.0" W x 1.5" H x 5.25" D

The TLS-1 unit downloads and uploads directly with a serial cable without an external interface box. Serial connection is facilitated with a female 15-pin "D" subminiature connector on the cable side. The connector retainer is a TRW/Cinch super "D" snap-on type.

The personal computer side of the cable is a 9 or 25 pin "D" subminiature connector as required.

The Traffic Logging System personal computer software provides the operator interface to the TLS-1 hardware. The PC software is menu-driven and provides the following:

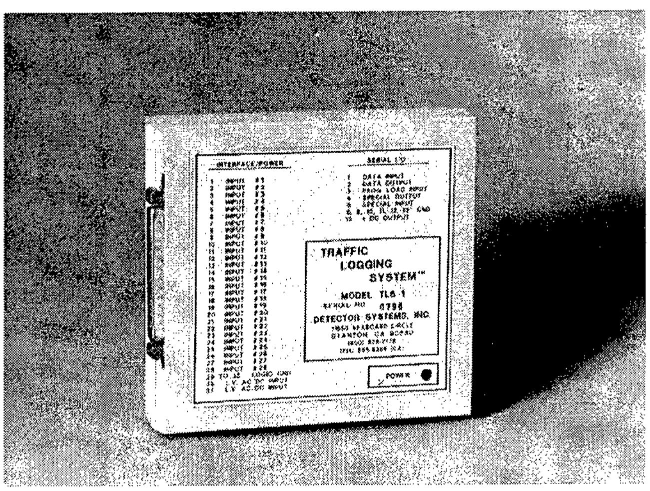


Figure II-26.
Model TLS-1 — Traffic Logging System

- Download to initialize the TLS-1 hardware with its operating program, type and method of data collection.
- Upload of data collected by the TLS-1 and storage to disk.
- Count thresholds.
- Output of data file to printer or text file.
- Graphic display of data on an EGA or VGA color monitor with day and week graphs.
- Selective listing of data files by month and year.
- Color or monochrome display operation.

The TLS-1 unit software provides

- Sample periods of 5, 15, 30 and 60 minutes
- Split logging of 8 data channels with either total by interval or by cycle.
- Count logging of 8 data channels.
- Event logging of 12 data channels.

SARASOTA AUTOMATION INC.

Features and operation characteristics of the Sarasota Detectors are summarized in Table II-5.

MODEL 515 B/MS Detector Unit: The SARASOTA 515B, shown in Figure II-27, is a single channel, shelf-mounted, inductive loop using the latest microcomputer technology to provide sensitivities and response times substantially independent of loop size. Failsafe circuitry quickly identifies open or short circuit loop faults and is backed up by a "self healing" feature which enables the detector to revert to normal operation once the fault condition is removed, subject to presence time.

Another advanced feature of the 515B is the inclusion of crosstalk filter to minimize problems at installations where several identical size loops are in close proximity.

The 515B is a flexible high performance detector suitable for use in a wide range of vehicle detector applications where single channel shelf mounted unit are desired.

Model 500 Series (516B OR 516T OR 517B) Detectors: The 500 SERIES Multi-Channel detectors offer a choice of two or four channels in a single compact shelf mounted unit. (See Figure II-28.) Designed for high reliability the microprocessor based circuit includes a crystal timing reference guaranteeing accurate and repeatable operation over long periods. The SARASOTA software provides continuous environmental tracking even when a vehicle is present as well as providing fixed presence time for small signals.

Delay and Extension Timing is offered as an option on the dual channel unit with the ability to use either or both and to accept external control signals. As all switch settings and detector values are read by the microcomputer on each scan, it is not necessary to reset the detector following changes in switch settings.

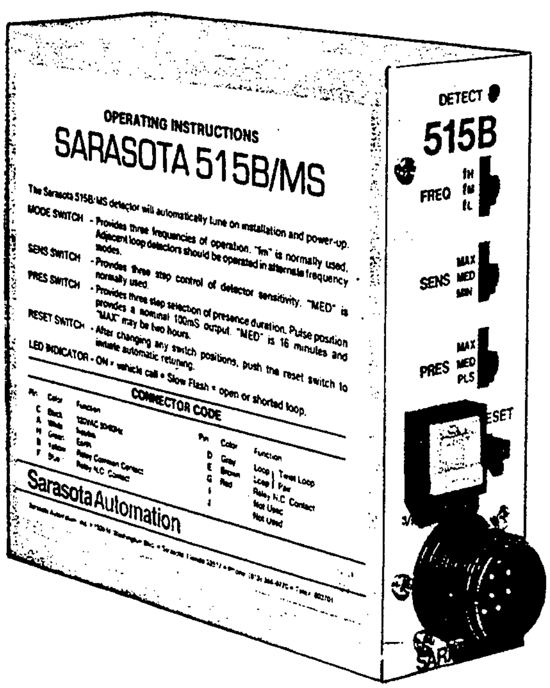


Figure II-27. Model 515B Detector Unit

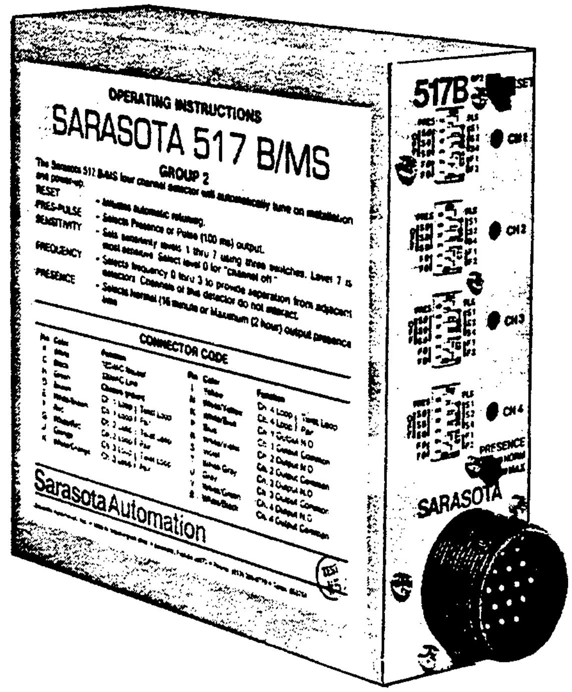


Figure II-28. Model 500 Series Detector Unit

TABLE II-5. SARASOTA DIGITAL INDUCTIVE LOOP VEHICLE DETECTOR MODELS: SHELF & RACK MOUNTED UNITS

	Model 515B	Model 500 Series	Model 536 & 537	Model 224/222	Model 222T
No. of Channels	1	2 - 4	2 - 4	2 - 4	2 - 4
Sensitivity levels per channel	3	7	15	7	15
No. of operating frequencies per channel	3	4	4	2	4
Modes for detection output per channel	3	3	2	2	2
Delay time range (sec.)	None	0 - 31	0 - 63	None	0 - 63
Extension time range (sec.)	None	0 -7.5	0 - 15.75	None	0 - 15.75
LED Detect indicator	Yes	Yes	Yes	Yes	Yes
Transformer isolation of loops	N.S.	N.S.	N.S.	N.S.	N.S.
Self tuning	Yes	Yes	Yes	Yes	Yes
Used for vehicle count simultaneously	No	No	No	No	No
Response time (MS)	N.S.	3 - 4	3 - 4	20 - 100	2 - 4
Separate output for vehicle count	No	No	No	No	No
Recommended loop geometry size	Any Size	Any Size	Any Size	Any Size	Any Size
Switch type for frequency and mode, on front panel	Dip	Dip	Dip	Dip	Dip
Lightning protection	Yes	Yes	Yes	Yes	Yes
Intermittent or Failed loop LED indicator (Smart-Flash)	Yes	Yes	Yes	Yes	Yes
Switch type for sensitivity setting	Thumb	Dip	Dip	Dip	Dip
Manual reset required if intermittent or failed loop self-heal	No	No	No	No	No
Loop Inductance Range (μH)	20 - 2000	20 - 2000	20 - 2000	20 - 2000	18 - 2500
Mounting Type	Shelf	Shelf	Shelf	Rack	Rack
Loop Feeder Length (Ft)	≤ 1000	≤ 1000	≤ 5000	≤ 1000	≤ 5000
Unit with Timing Functions (Delay time and extension time)	No	Yes (Optional)	Yes	No	Yes

N.S. - Denoted not states

Model 530 Series (535B) Single Channel and (536B, 536T & 537B) Multi-Channel Loop Vehicle Detectors: The 530 series, shelf-mounted, vehicle detector (see Figure II-29) compensates for marginal loop conditions, providing on-site and/or remote diagnostics to identify present and intermittent loop failures. Standard innovations include Present and Historical fault indicators discriminating between Open Loop, Shorted Loop, and sudden 25% changes in loop inductance.

Fast, predictable response times facilitate accurate speed and occupancy measurements. An RS232/RS485 communications option is also available for remote control and monitoring of the detector and loop. Internal addressing allows a single serial interface unit to address up to 16 detectors thus allowing remote diagnostics of up to 64 different channels or loops at an intersection via telemetry.

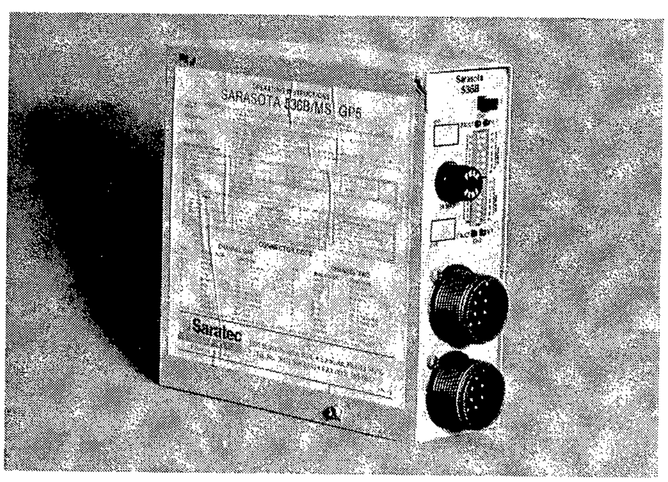


Figure II-29. Series 530 Vehicle Detectors

Specific Features of the 530 series include:

- Separate fault LED's per channel
- .01% Sensitivity
- Sensitivity boost for small and high vehicles
- Fifteen (15) sensitivity selections
- Four (4) frequency selections
- High crosstalk and noise immunity
- Consistent operate and release delays
- Present and historical fault indication
- Optional RS232/RS485 serial communications

Models 222/224 Multi-Channel Modular Loop Vehicle Detectors: The Group 5 series of the 224 multi-channel modular loop vehicle detectors use the latest LSI and microcomputer techniques. (See Figure II-30.) Comprehensive failsafe for open or short loops is backed by a "self-healing" feature which allows the detector to automatically resume normal operation once a fault condition is corrected. Additionally, as all switch settings and detector values are read by the microcomputer on each scan, it is not necessary to reset the detector following changes in switch settings.

Specific features of the Model 224 digital inductive vehicle loop detector include

- multi-channel detectors
- seven sensitivity levels
- two operating modes: pulse and presence
- two operating frequencies
- LED detect and fault indicators
- RS 232 communications serial interface

Other specific features are summarized in Table II-4.

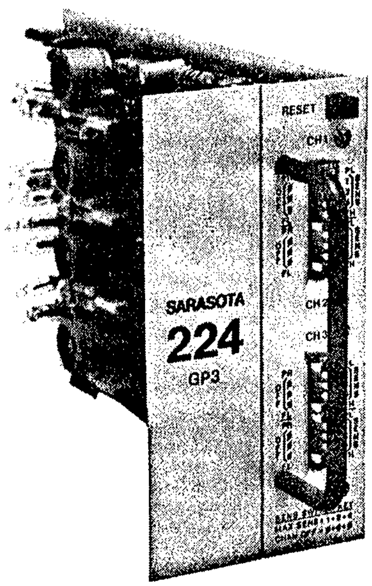


Figure II-30. Series 224 Vehicle Detector

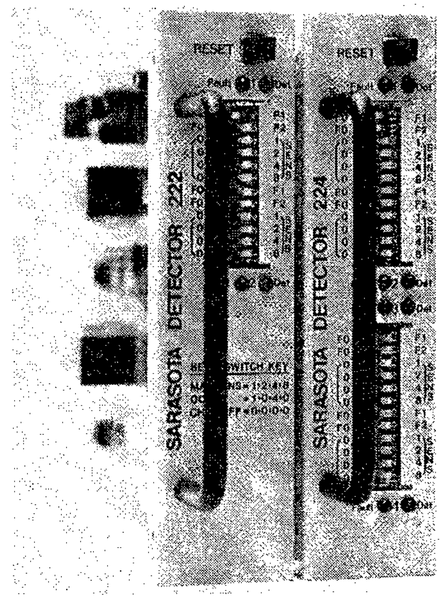


Figure II-31. Model 222T Multi-Channel Detector With Timing Functions

<u>Model 222T Multi-Channel Vehicle Detector with Timing Functions</u>: The Model 222T is a multi-channel vehicle detector with timing functions. (See Figure II-31.) This unit has fifteen sensitivity levels, four frequency selections, two operating modes, delay and extend timing functions, and sequential scanning capability to eliminate crosstalk. Specific features of the model 222T include:

- Separate Fault LED's per Channel
- Higher Sensitivity to .01%
- Sensitivity boost
- Optional RS232/RS485 serial communications
- Relay or Optical Coupled Outputs
- Pulse or Presence Modes
- Fast Response Times

In addition, Peek/Sarasota has a communications/diagnostics software that is capable of remotely diagnosing of up to 64 detector inputs and changing all front panel settings except for the frequency settings. The software is menu driven and user friendly. The software supports a 9600 communications baud through a single communication module.

MICROWAVE DETECTORS

Microwave Sensors Inc.

Model TC-20 microwave detector: This unit detects traffic moving in only one direction using a very low power microwave beam. A single unit can cover more than one lane of traffic. It may be less expensive to install and maintain than loop detectors, since it requires no traffic diversion and has more immunity to damage from ice, salt or heavy vehicular traffic.

The Model TC-20 detector has a wide range of uses. When an underground loop is damaged, traffic actuation can be achieved in minutes using side-fire operation. The unit is ideal also for bridge repair work, which necessitates lane close down, since it is easily removed and re-used when the job is completed.

The Model TC-20 detector is small in size and its anodized aluminum finish does not require painting. The universal mounting bracket, L.E.D. indicators, pattern adjustments and 4 conductor wiring make installation simple. Five different operating frequencies are used eliminate crosstalk between units. Monitoring circuits for relay and transceiver failure will cycle the controller unit to recall.

There are two methods of installing the TC-20 detectors:
a) Side-Fire Detection
b) Overhead Detection

Side-fire operation is the most widely used. (See Figure II-32 on page II-80.)

- Locate a pole near the intersection approach
- Mount the detector 12′ to 18′ above the pavement
- Aim the unit toward the flow of traffic
- Run a 4-conductor cable to the controller unit cabinet, with two wires to 10 to 24 VAC power and two wires going to detector inputs.

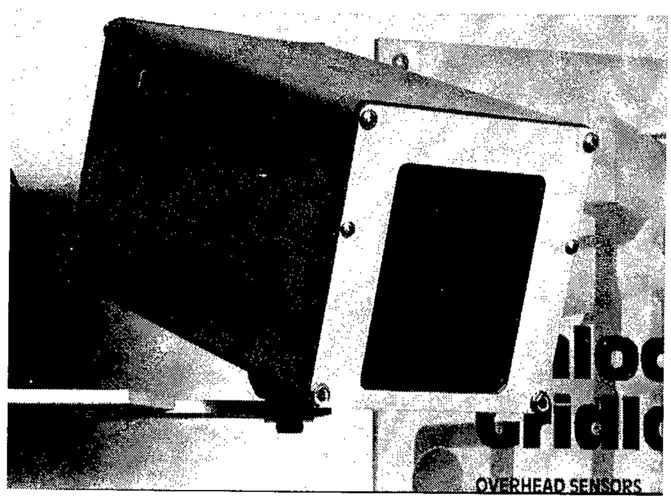


Figure II-32. Model TC-20 Microwave Detector

WHELEN ENGINEERING

Model TDW-10 and TDN-30 Microwave Detectors: The TRACKER™ TDW-10 microwave detector is a cost effective vehicle detector for new freeway management applications. A wide angle, low power microwave radar beam provides vehicle detection across as many as four lanes of highway. (See Figure II-33.) The TDW-10 detector detects the speed and presence of any moving vehicle that is in the beam pattern.

State-of-the-art technology allows a single TDW-10 to process real time traffic speeds for use in freeway management or other speed/traffic flow applications. The TDW-10 determines the speed of the general flow of traffic, in the detection area, through the use of Doppler radar techniques. Since the radar detects in only one direction, it can distinguish between opposing lanes on the freeway (i.e. northbound vs. southbound).

Outside of freeway management applications. TDW-10 can be used to activate speed warning signs by comparing vehicle speeds to field selectable thresholds.

The TRACKER™ TDN-30 is a narrow band vehicle detector. A narrow, low power microwave radar beam is used to identify a detection area. Lane specific vehicle detection is achieved by mounting the TDN-30 detector over the center of each lane of the freeway. (See Figure II-33A on page II-83.) Overpass structures and sign bridges are typical of existing mounting locations.

The real power of the TDN-30 is its ability to establish individual vehicle speed, based on Doppler shift radar techniques. This information can be transmitted via an RS-232C port (modem, fiberoptics, etc.) to a Traffic Operations Center. With true speed data, the TDN-30 can also pulse a pair of closures to emulate a pair of loops that are configured for speed collection.

The TDW-10 & TDN-30 vehicle detectors require no underground wiring and very little maintenance. Both units are completely enclosed in a weather-tight, high-impact plastic housing and are not affected by snow, rain, fog, or dirt.

For more conventional traffic control applications, either model can be used as a simple "passage" or "advanced" detector.

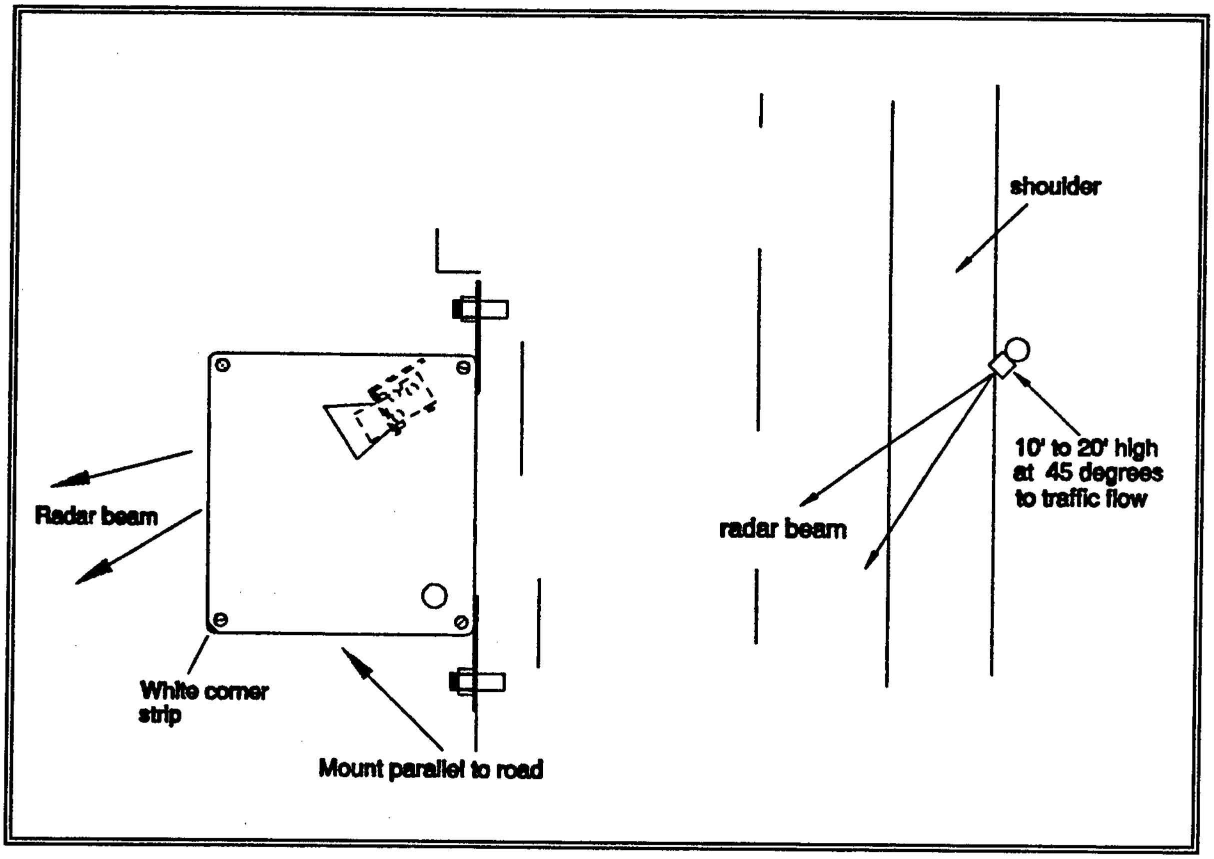


Figure II-33. Typical Installation of Model TDW-10 Detector

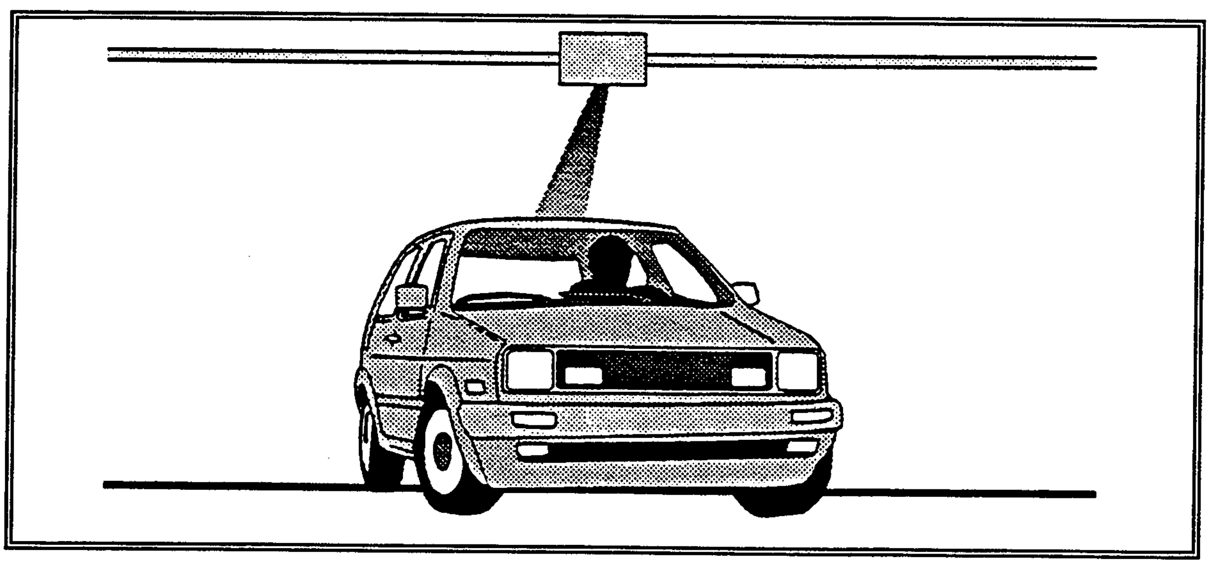


Figure II-33A. Typical Installation of Model TDN-30 Detector

ULTRASONIC DETECTORS

Microwave Sensors, Inc.

Microwave Sensors Model TC-30 Ultrasonic Presence Detector: The Model TC-30 presence sensor is a low-cost device designed to detect the continuous presence of an object within its detection pattern. This sensor is ideal for detecting vehicle presence in a right-turn lane from a sidefire mount or for detecting presence in an individual vehicle or pedestrian lane from an overhead mount.

The TC-30 may be less expensive to install and maintain than in-ground loop or magnetic detectors because it is installed overhead and is not in physical contact with the traffic it is detecting.

The presence sensor features solid-state circuitry for longer life and incorporates a fail-safe mode to cycle the controller unit to recall in the event of a power loss to the unit. It also features an LED that will assist the installer in setting the pattern range.

There are two methods of installing the TC-30

1) Overhead (overhead mast-arm mount)
2) Side-Fire (side-of-pole mount)

Overhead operation is the most desirable, and can be followed as follows:

- Locate a mast arm directly over the lane you are going to cover.
- Mount the detector 12′ to 24′ above the pavement. (See Figure II-34.)
- Aim the unit directly down to the ground.
- Run a 4-conductor cable to the controller unit cabinet, with two wires to 10 to 24 VAC power and two wires going to the detector inputs.
- Range TC-30 out until detector receives a return echo from the ground, then turn back range two to three feet (2′ to 3′) to allow for expansion and contraction of the pattern.

Side-Fire operation is ideal for right-turn lanes; installation can be followed as follows:

- Locate a pole near the lane approach.
- Mount the detector 12′ to 24′ above the ground.
- Aim the unit directly down into the lane so that it will be looking directly at the sides of vehicles.
- The remainder of the installation is identical to overhead operation installation.

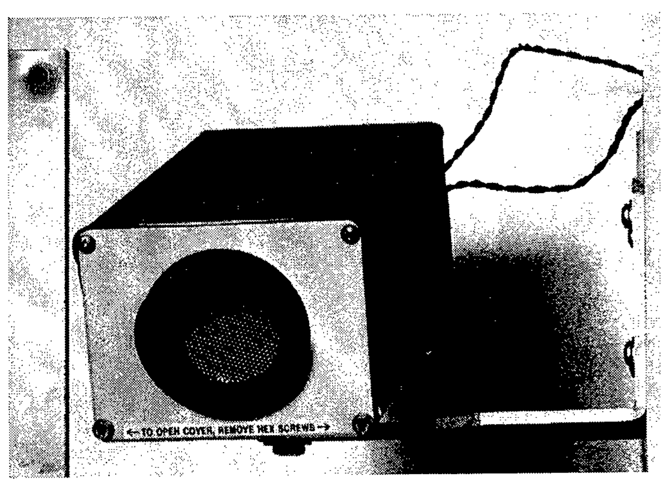


Figure II-34. Model TC-30 Ultrasonic Detector

INFRARED DETECTORS

Microsense Corporation

Models MSI-100 Active Infrared Detector: The MSI-100 is a presence infrared detector device that combines infrared sensing with advanced real-time digital signal processing to produce a traffic detection system.

In operation, detection zones are illuminated with harmless, low power infrared light. The infrared light reflected from vehicles traveling through the zone of detection is focused onto a complex sensor matrix. A microprocessor analyzes the received signal to reliably determine the presence of a vehicle. All environmental shifts are tracked automatically so that changes in ambient lighting and adverse conditions do not affect operation.

Typical applications of this unit include stop bar vehicle presence detection for traffic signals, vehicle counting and queue detection. The extendable detection zone can be used to emulate existing long loop systems.

The unit is designed to accommodate mounting heights of between 15 and 30 feet. Multiple units can also be installed within the same intersection without interference. No interaction occurs between units provided the zones of detection do not overlap. The optical system design provides sharp edged zones of detection giving excellent adjacent lane rejection. Specific features of the Model MSI-100 detector include:

- True Presence Detection
- Extendable Detection Zone
- Excellent Zone Definition
- Replaces Inductive Loop Systems
- Fast Response Time
- High Immunity to False Detects
- Easy to Install
- High Reliability
- Weatherproof Enclosure
- Maximum Range of 100 feet

The MSI-100 Active Infrared Detector has two contiguous zones of detection as shown in the diagram below, Figure II-35 on page II-85. Sighting along the top of the unit during installation will provide an aimpoint at approximately the far edge of the Zone 1.

The diagram on Figure II-35 is a representation of the effective detection zones of the MSI-100 detector. The effective zones are defined as between 1.5 and 5 feet above ground level. Monitoring height, aim angle, tilt and shape of road surface affects the actual zone of detection.

Pattern of Detection: The detection pattern of zone 1 emulates a 6 ft. x 6 ft. loop at a range of 30 feet from the base of the mounting structure with a mounting height of 20 ft. Zone 2 increases the detection zone to emulate a 14 ft. x 6 ft. loop. Maximum effective range of this detector is 100 ft.

Installation: The unit may be mounted to a pole or mast arm within the range of 15 to 30 feet high. The unit mounting should be rigid. All mounting bolts should be tight so as to prevent false detections occurring due to the unit itself moving.

The unit is aligned by aiming along the top of the unit at the far edge of zone 1; zone 2 selection will extend the detection zone beyond the aimpoint. Aiming the unit down will bring the area of detection closer to the unit; aiming the unit up will cause the detector to see vehicles further from the unit up to an effective maximum of 100 feet. The unit may be installed to detect vehicles passing through the zone of detection in any direction. Detection may be achieved up to 100 feet but shorter distances are recommended.

Select a medium sensitivity setting (the switch is marked 1-16) and observe operation. If certain vehicles are not being detected then raise the sensitivity by one setting (toward 16) and again observe operation. Always use the lowest sensitivity setting which gives acceptable performance so as to reduce the possibility of false calls.

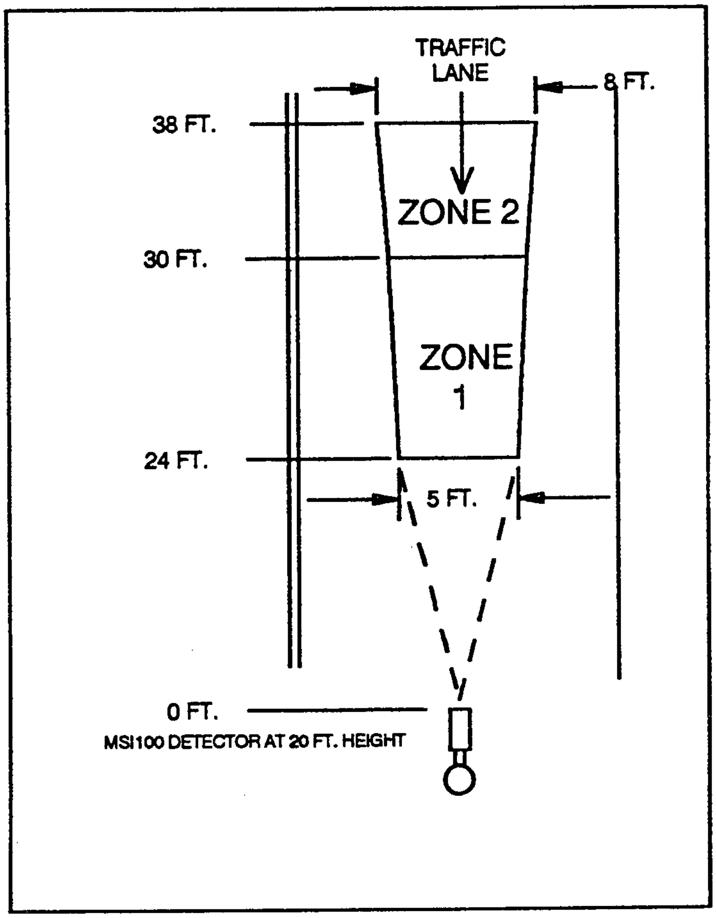


Figure II-35. MSI-100 Zone Dimensions

Microsence Model MIX Passive Infrared Vehicle Detector:

The MIX detector is a Passive (motion) infrared detector. Lens configuration provides "point and shoot" detection of moving vehicles within a 3° zone of detection which may be up to 300 feet away from the unit. Wider detection zones are available by selecting the optional medium or short focal length lenses. To eliminate adjacent lane detection when detecting vehicles over 100 feet from the unit, the long focal length lens option should be selected. For detection close to the unit, e.g. for sidefire detection, the medium or short focal length lens option should be used.

The MIX is used for detection of vehicles approaching a traffic signal or approaching a gate and may be mounted for straight-on detection (in line with the traffic flow), or a sidefire detection (perpendicular to traffic flow). In some installations the MIX may be used for counting vehicles or for mid-block system detection. Multiple units may be used to cover the same or adjacent areas of detection without interference or crosstalk.

Specific features of the Model MIX include:

- motion detector
- range up to 300 feet
- speed and count detector
- adjustable range and conve of detection

Installation: The unit mounting must be rigid. All mounting bolts should be tight so as to prevent false detections occurring due to the unit itself moving. The unit is aligned by aiming along the top of the unit at the center of the lane, or area of detection desired. If vehicles in more than one lane are to be detected, then aim at the center of the area to be covered. Aiming the unit down will bring the area of detection closer to the unit, aiming the unit up will cause the detector to see vehicles further from the unit up to a maximum of 300 ft. (See Figure II-36.)

The unit may be installed to detect vehicles approaching along the line of sight (straight-on detection) or sidefire detection. For straight-on detection the unit must be rigidly mounted to a pole or bridge. Detection may be achieved at up to 300 feet but shorter distances are recommended for quick response to traffic and minimization of false calls, this type of mount is especially good for exclusive left turns or traffic counting applications.

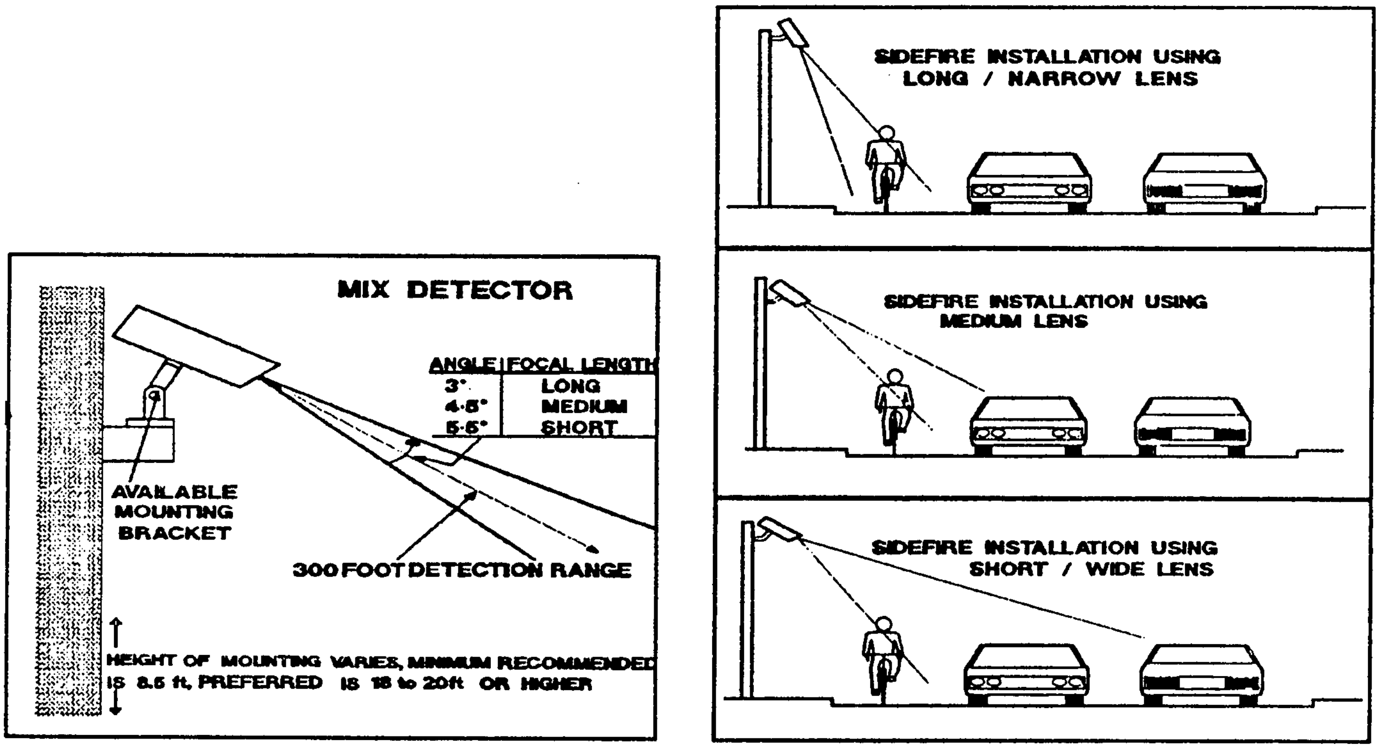


Figure II-36. Detection Zone with the MIX Passive Infrared Vehicle Detector

SCHWARTZ ELECTRO-OPTICS INFRARED DETECTOR (AUTOSENSE)

A new type of overhead vehicle detector capable of sensing a vehicle's presence, passage, speed, and classification has been developed by Schwartz Electro-Optics Inc., under FHWA's Small Business Innovation Research program. The overhead detector uses infrared laser to achieve excellent sensing zone definition which results in high vehicle detection accuracy. Test results from Orange County, Florida, demonstrate that 99.4 percent of all vehicles are reliably detected.

The detector uses a pulsed time-of-flight laser-range finder to detect moving or stationary vehicles. A dual fan-shaped beam of 904 nm (10^{-9}m) radiation emitted by a diode-laser array is directed toward the vehicles. Although most of the radiation is specularly reflected away, a small amount is diffusely reflected back to the detector where it is detected by a pair of light sensors. The round-trip propagation time of the laser pulse is proportional to the range of the vehicle. Vehicle presence is indicated by a reduction in the range reading from the road surface. Vehicle speed is computed from the measured time interval between the interceptions of the two laser beams. A microprocessor in the detector is used to determine a vehicle's presence, passage, speed, and classification. A date/time clock is used to tag the data to provide vehicle count and average speed for each hour of the day.

3M COMPANY
CANOGA MICROLOOP VEHICLE DETECTOR

The Canoga microloop is a small cylindrical, passive transducer of earth's vertical magnetic field intensity into inductance. (See Figure II-37.) It transforms changes in magnetic field intensity into inductance changes which can be sensed by loop detector units. Intended for point detector (passage) applications, 1, 2 or 3 microloops installed across a lane will replace a typical 3 turn 6' x 6' wire loop for those applications. The number of probes required per lane and their optimum cross-lane position is determined by the lane width and the size (height) of vehicles to be detected. As a general rule, if some portion of a vehicle passes over a probe it will be detected. A single probe centered in a lane will detect most vehicles, however two or more at 3' to 4' intervals are preferable for detection of small motorcycles and bicycles. Probes are usually located vertically in 1" holes and 16" to 24" below the roadway surface. Microloop probes can also be connected in series with other microloop probes or conventional wire loops.

Features

- Small size: Probes fit in 1" diameter holes, lead-in cable fits in 1/4" sawslot.
- Could replace 6' x 6' wire loops. Used, in passage detection applications, for speed measurement, advance detection, and counting.
- Reduced installation costs: Less than 1/3 the sawcut of a 6' x 6' loop.
- Less surface damage: Ideal for use in poor pavements, brick or cobblestone surfaces, temporary construction zones, etc.
- Works in high iron environments. Works on or under bridge decks.
- Flexible: May be series connected to other microloop probes or conventional wire loops.
- Low inductance: Allows up to 10 micro-loops per channel with "Canoga" units.
- Reliable: Buried probes are unaffected by temperature changes, water, snow, ice or pavement deterioration.
- Accurate: Unique operating characteristics radiate no magnetic fields therefore can resolve closely spaced vehicles and reject adjacent lane vehicles to improve count accuracy.

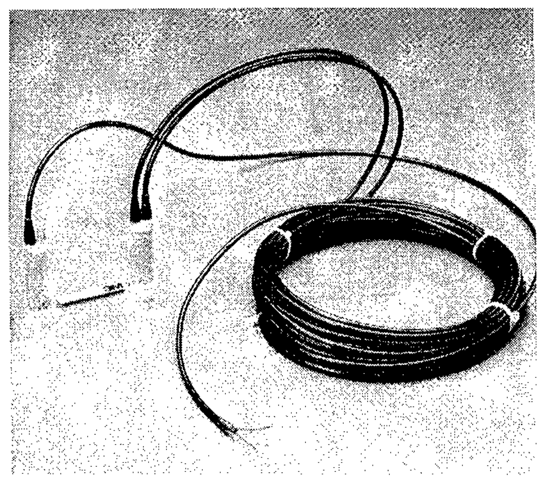


Figure II-37. Microloop Probe

CONOGA
TWO-CHANNEL LOOP DETECTOR MODEL P422T

The P422T is a high-performance, two-channel, plug-in digital inductive loop vehicle detector which includes versatile digital output timing. (See Figure II-38.) It is powered by unregulated 24 volt direct current. Circuit board programming switches select "delay" and/or "extension" and "time." Digital integrated circuits control output timing. Indicators flash to distinguish periods of delay and extension timing. Special circuits allow external inputs to control "delay" and/or "extension" timing by enabling or disabling the timers on a per channel basis. The P422T has six independently selectable modes of operation for each channel: presence, presence with delay, presence with extension, presence with both delay and extension, pulse and pulse with extension. Selection of pulse or presence mode, channel reset, off and sensitivity for each channel is controlled by a 16-position thumbwheel switch. A "remote reset" circuit allows an external ground level signal to reset all presence indications except a failsafe "open loop" call. An "open loop test" switch allows rapid field verification of loop or lead-in system integrity by recalling from memory and displaying previous faults (Opens) on channel indicators.

Specific features of the Model P422T include:

- Wide-angle, hi-visibility LED's.
- Thumbwheel control for selection of pulse, sensitivity, presence, channel reset & off.
- 8 sensitivity choices designed to detect all licensed vehicles in loops with specific turns and/or alternative splice combinations, and lead-in length over 1000'.
- Automatic self-tuning and continuous environmental tracking.
- Instant, automatic recovery from intermittent opens and/or multiple shorts plus power failures.
- Open loop test switch displays previous faults (opens) on channel indicators while continuing to process and output valid detections.
- Minimum presence hold times — auto 60 mins., motorcycle 4 mins.
- No loss of peak-hour continuous traffic. Vehicle movements restart hold-timers.
- Optically coupled solid-state outputs rated at 50VDC.
- Remote reset input on card edge connector.
- Dipswitch selects delay and/or extension and time.
- Extended tuning range accommodates small vehicle detection capability in loops of various sizes, shapes and configurations including Microloop probes.

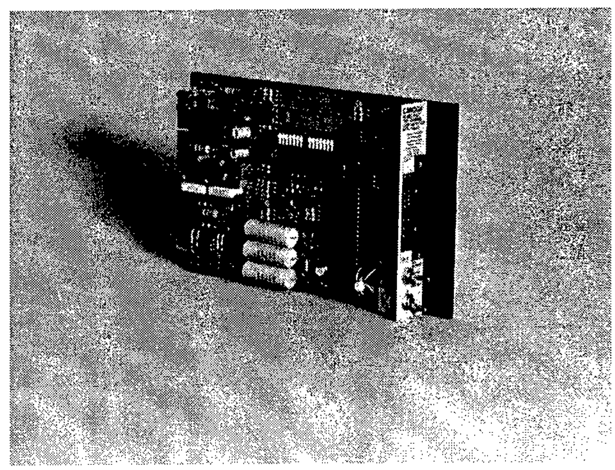


Figure II-38. Model P422T
Inductive Loop Detector

- Multiple channel scanning method totally eliminates crosstalk within a unit.
- Transformer isolated loop inputs tolerate single point leakage or short to ground.
- Failsafe, non-resettable output and indication with multiple shorts to ground and open (broken) loop, lead-in or home-run cable.
- Digital integrated circuits control delay and extension output timing.
- Input circuits enable or disable both delay and/or extension timers.
- Indicators "Flash" to distinguish output timing in process.

ECONOLITE VIDEO VEHICLE DETECTION SYSTEM

AUTOSCOPE™2-2003 is a wide-area vehicle detection system which uses video image processing to replace inductive loops in multiple lanes and multiple directions of traffic. It accepts inputs from up to six video cameras overlooking the roadway and the detectors are drawn graphically on a video monitor using a mouse. Different types of detectors can be selected, and the detection zones may be placed anywhere and in any orientation within the combined field of view of the cameras. Special speed trap detectors can extract vehicle speed and vehicle classification as defined by length.

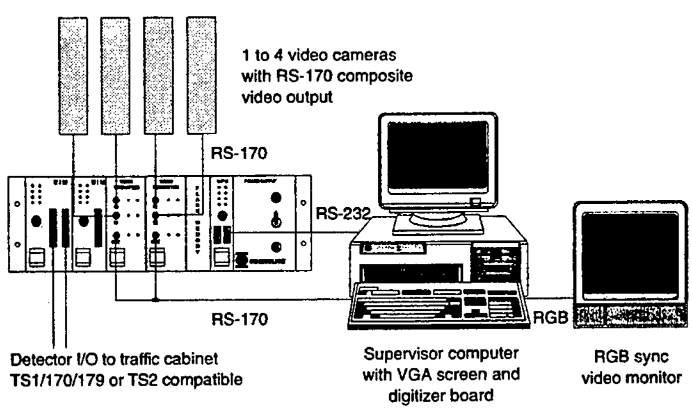
AUTOSCOPE™-2003 is designed for outdoor installation in a traffic cabinet. It meets NEMA TS1/TS2 and 170/179 environmental requirements. It provides a minimum of 60 detection zones assignable to up to 64 detector outputs, which can be connected directly to a controller unit. Detection zone capabilities include count, presence, directional, speed trap, extend/delay, and boolean logic detection functions. A system with four suitably located cameras can replace the inductive detection subsystem of even a large eight-phase intersection, from the loops to the loop amplifiers. AUTOSCOPE™ can also capture traffic data on a per-detection or per-time interval basis for later analysis.

The AUTOSCOPE™-2003 offers several benefits, including:

- Freedom from loop installation and maintenance
- Visual feedback (real-time)
- Site flexibility (tunnels, bridges, rail, etc.)
- Advanced detection strategies
- Easily modified detection zones
- Economical solution to large/complex intersection or freeway surveillance applications

Applications of the AUTOSCOPE™-2003 include: intersection control, freeway surveillance, incident detection, traffic surveillance/quantitative data collection from video signals (tape or real time video) and special studies such as counts, speeds, occupancy, classification, and headways.

The interface to the AUTOSCOPE™ is through a Supervisor computer system (shown in Figure II-39). The hardware requirements for the supervisor computer consist of a 386/486 class PC compatible computer, MS-DOS 5.0, Microsoft Windows 3.1, VGA monitor, 4 MB of RAM, 1.44 MB floppy disk drive, 20 MB of free space on a hard disk drive, mouse, AUTOSCOPE™ supervisor digitzer board, and RGB sync monitor.



The supervisor computer is used for detector programming and data analysis. The video monitor shows vehicle detections as they occur.

Figure 11-39. Typical AUTOSCOPE™-2003 Setup

PREEMPTION SYSTEMS

Econolite Control Products, Inc.

Model Emtrac Radio Preemption System:
EMTRAC™ is a preemption system which uses digitally-coded spread-spectrum radio at 902-908 MHZ to command a green signal for vehicles through signalized intersections. It is ideal for emergency vehicles, where it speeds response time, reduces traffic accidents, and saves lives. It can also be used to improve the productivity of buses, snow plows and other service vehicles by minimizing the time waiting at red signals. Two priority levels are assignable.

Emtrac provides a preemption range from 100 to 3,700 feet and avoids line-of-sight limitations. State-of-the-art spread-spectrum radio avoids the need to apply for an FCC site license, as required for conventional fixed-frequency radio. In spread-spectrum radio, a narrow-band signal is swept over a broad portion of the frequency spectrum, with digital synchronization between the transmitter and receiver modules.

Physically, the EMTRAC system consists of a transmitter with a directional antenna and an electronic auto-compass in each vehicle, and a receiver with and omnidirectional antenna at each intersection. The direction of preemption can be set automatically by the auto-compass, which senses the orientation of the vehicle. It can also be set manually from the transmitter and can be different from the direction of travel of the vehicle. This feature allows congested traffic to be cleared in any direction.

The transmitter, receiver and auto-compass are microprocessor based. A laptop computer with menu screens is used to program all devices and to retrieve logged data via an RS-232 interface.

Vehicle Hardware: The transmitter is a compact unit (see Figure II-40 on page 92) that is normally bracket-mounted on the dashboard of the vehicle. Its front panel provides six membrane switches, each with an associated LED indicator lamp. A switch marked AUTO activates the autocompass. Switches marked NORTH, EAST, SOUTH, WEST can override the auto-compass to manually set the direction of preemption. Two independent 12V lines are required to power the transmitter. Normally one of these lines is wired to a parking brake sensor of to a driver-side door sensor to automatically terminate preemption calls when the vehicle is parked.

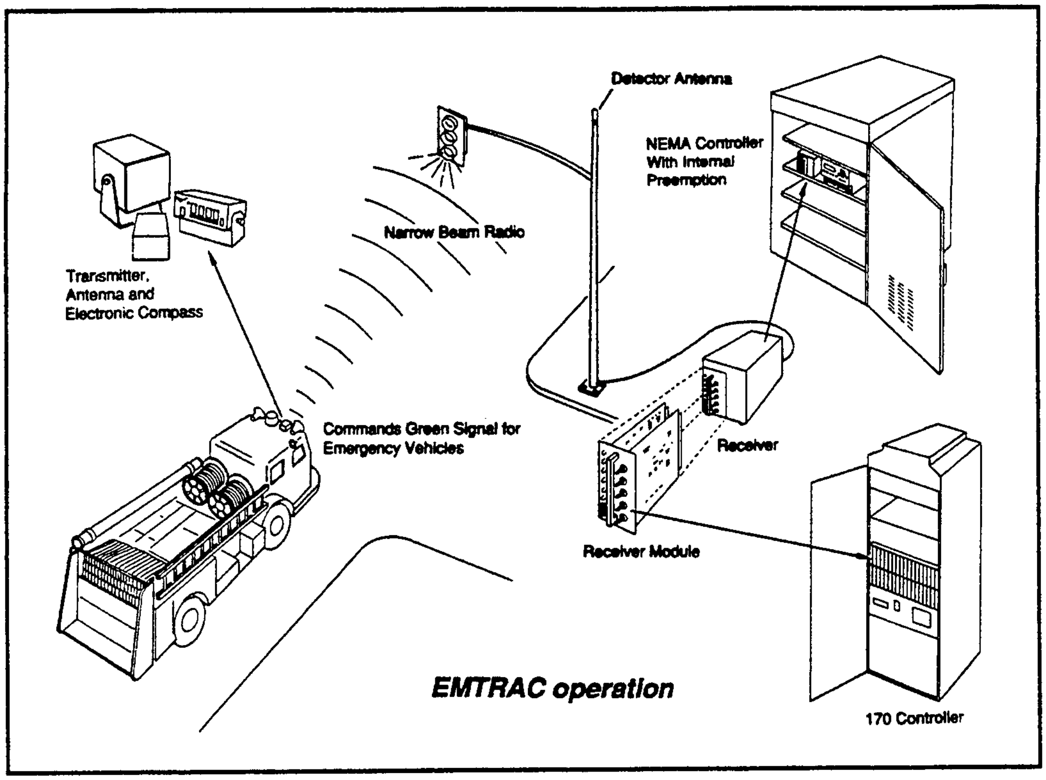
The vehicle antenna is directional so as not to preempt side streets.

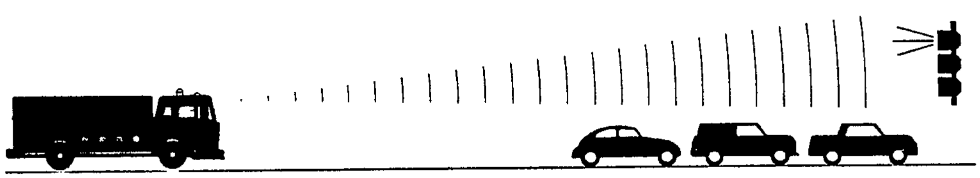
Intersection Hardware: Emtrac is available in two receiver versions. Both are designed for installation in a traffic cabinet and meet NEMA/170 environmental and electrical specifications. Model SS1600RS is shelf-mountable and for use with NEMA controller units with a built-in preemptor. Model SS160RM is for installation in a NEMA or 170 detector rack, with power provided by the backplane.

Four preemption outputs are standard, each with two priority levels. Level 1 is normally assigned to high-priority emergency vehicles; level 2 is for low-priority buses. For diagnostic purposes, LED lamps on the front panel indicate the preempt direction and priority level.

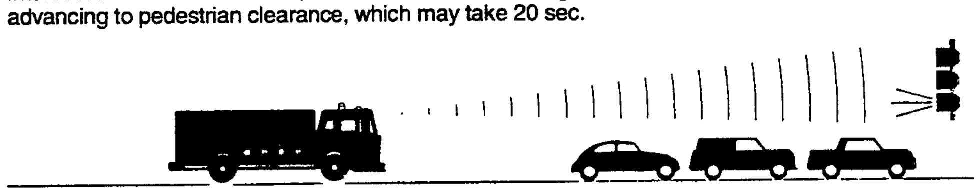
The intersection antenna is omnidirectional and is normally mounted on the pole closest to the traffic cabinet. Field wiring is limited to a single RG-58 coaxial cable.

System Software: A DOS-compatible, portable computer is used to set up the EMTRAC transmitter, receiver and auto-compass. The exact auto-compass split points to change from north to east, east to south, south to west, and west to north are programmable. Setup is easy and menu-driven. The computer also can be used to retrieve time and date-stamped preemption logs.

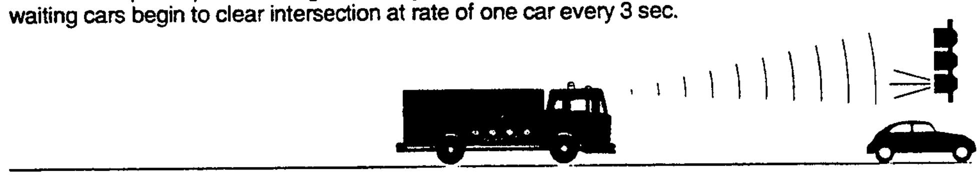




At 0 sec, radio preemption signal from emergency vehicle traveling at 35 mph (51 ft/sec) reaches intersection from distance of 2,400 ft. Traffic controller begins terminating opposing vehicle phase by advancing to pedestrian clearance, which may take 20 sec.



20 sec after preemption call, signal turns green. Emergency vehicle is 1,027 ft from intersection. Six waiting cars begin to clear intersection at rate of one car every 3 sec.



38 sec after preemption call, last of waiting cars clears intersection. Emergency vehicle is 450 ft from intersection and is able to proceed without stopping or slowing down. High speed, heavy traffic and congested intersections all require long preemption distances, which are best achieved with radio.

Figure II-40. Emtrac System

3M COMPANY

Opticom Priority Control System: The Opticom priority control system is a preemption system which uses optical signals to command a green signal for designated vehicles approaching the intersection. The Opticom system has three basic components:

An optical emitter on the vehicle to generate optical signals. An optical detector near the intersection to receive optical signals and transmit an electronic impulse to the phase selector.

A phase selector in the controller unit cabinet to process the electronic impulse and manipulate the controller unit to provide a green signal.

The system provides priority service on a first-come, first-serve basis. Once the first priority vehicle calls the system, it prevents other vehicles from entering calls until the first vehicle clears the intersection.

Specific features of the 3M Opticom system include:

- Enhanced traffic control during an emergency
- Standard signal displays reduce confusion and accidents
- Quickly returns to normal operation for safe, efficient traffic control
- Adaptable to customized traffic management systems
- Better emergency service
- Improved response range lowers cost of emergency services
- Visualization of priority control for improved safety
- Reduced liability through safer operation
- Potential for lower litigation costs
- Can contribute to lower insurance rates

Operation: An emitter switch, controlled by the emergency vehicle operator, activates the Opticom system for the duration of the response route. The activated system interfaces with the controller unit to give emergency vehicle priority over other traffic by providing a safe "green light" corridor along the response route.

If a signal is already green, the controller unit holds the display until the emergency vehicle clears the intersection. If the signal display is red, the Opticom system directs the controller unit to provide a green light, thus clearing stacked up traffic, before the emergency vehicle arrives at the intersection.

The controller unit is returned to normal operation after the emergency vehicle passes through the intersection.

The Optical Emitter Assembly consists of an emitter with mounting brackets, an emitter control switch with mounting bracket, and wiring to connect to the vehicle battery.

The emitter control switch supplies coded crystal-controlled pulses to the emitter when activated by the driver. To operate the Xenon gas-filled tube in the lamp assembly, the emitter converts 12 VDC battery voltage to the required high voltage. The emitter, mounted at the front of an emergency vehicle, produces and transmits a flashing optical signal.

The Optical Detector receives the optical signals produced by the Opticom system emitter. These optical signals are transformed by the detector into appropriate electronic impulses, which are transmitted via cable to the phase selection equipment in the controller unit cabinet.

The detector is mounted at or near the intersection in a location which permits an unobstructed line-of-sight to vehicular approaches. Detectors are bi-directional so two may be adequate for control of a two-phase intersection.

Additional detectors may be required at intersections with more than two priority directions or uniquely configured streets.

The Phase Selector supplies power to and receives electronic impulses from an Opticom system detector. When detector signals are recognized as valid, the phase selector causes the controller unit to hold or advance to the desired green display. The phase selector assigns priority traffic movement on a first-come, first serve basis. Each channel is connected to select a particular traffic movement from those normally available within the controller unit. After serving a priority traffic demand, the phase selector will release the controller unit phase timing to normal operation.

Table II-6 on page II-96 summarizes all features and pertinent data related to the detectors and preemption equipment discussed in this section.

Table II-6. Vehicle Detectors and Preemption Devices: Features and Operational Characteristics

	Detectors						Preemptors	
	Microsense		Microwave Sensors	Whelen Engineering		Microwave Sensors	3 M Company	Econolite Emtrac
Detector Type	Active Infrared	Passive Infrared	Microwave	Microwave		Ultrasonic	Optical	Radio
Series	MSI-100	MIX	TC-20	TDN-30	TDW-10	TC-30	Opticom	Emtrac
Permanent Installation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Temporary Installation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Installation	pole or overhead 15-30	pole or overhead	Sidefire or overhead (8' - 20')	Overhead (10'-20')	Overhead (10'-20')	Sidefire or overhead (8' - 20')	Overhead	Overhead
Operating Frequencies	N.S.	N.S.	5	N.S.	N.S.	5		
Adjust. Detection Pattern	Yes	Yes	Yes	N.S.	N.S.	Yes		
Adjust. Dectection Angle	Yes	Yes	Yes	No	No	Yes		
No. of Lanes Covered	> 1	> 1	≥ 1	1	> 1	1	> 1	> 1
Pavement Cuts Required	No	No	No	No	No	No	No	No
Hold Time (Sec.)	1800	N.S.	0.05 to 5	N.S.	N.S.	0.05 to 10		
Response Time (MS)	20	N.S.	165	N.S.	N.S.	0.25 sec.		
Range (Ft.)	100'	300'	3' - 100' @ 16°	(10' - 20)'	100' - 200'	3' to 24'		
Finish	N.S.	N.S.	Anodized Alum.	Plastic	Plastic	Anodized Alum.	-	-
L.E.D. Indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Relay Contacts & Amp	Heavy duty @ 3 amps	Heavy duty @ 3 amps	Form C, rated @ 2 amps	Opto-Isolator	Opto-Isolator	Form C rated @ 5 amps	N.S.	N.S.
Output Extension Timer (Sec.)	N.S.	N.S.	0.5 to 7.5	N.S.	N.S.	0.5 to 10	N/A	N/A
Field Adjust.: Range & Time Delay	Yes	Yes	Yes	N.S.	N.S.	Yes	Yes	Yes
Power	24 DC or 115 AC	24 DC or 115 AC	10 to 24 VAC	11 to 15 VDC	11 to 15 VDC	10 to 24 VAC	N.S.	N.S.
Frequency	-	-	10.525 GHZ	N.S.	N.S.	49.7 KHZ	N.S.	N.S.
Uses: Count, Queue, Presence, Passage, Speed	Pr, Ct, Qu	Pa, Ct	Passage	Pas., Sp.	Pas., Sp.	Presence	N/A	N/A
Vehicle Indentification	No	No	No	No	No	No	Yes	Yes
Component Failure LED	No	No	Yes	Yes	Yes	Yes		
Fail-Safe Recall-Closed Relay	N.S.	N.S.	Yes	N.S.	N.S.	Yes		
Sensitivity Levels	16	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Transient Protection	Yes	N.S.	N.S.	Yes	Yes	N.S.		

N.S. — Denotes Not Stated N/A — Not Applicable

TIME SWITCHES

A time switch is a device used to select modes of operation of traffic signal system pattern in a manner prescribed by a predetermined time schedule. Applications for a time switch include school warning signs, traffic signal flashing operation, special conditions or traffic events, etc.

The following is a description of various sophisticated types of time switches (see Figure II-41 on page II-98), manufactured by RTC Manufacturing, Inc. Also, Table II-7 on page II-98 summarizes all features of RTC time switches.

RTC MANUFACTURING, INC.

AP21 Series Time Switch: The series of AP21's are single circuit, calendar programmable solid state time switches. They are used for switching electric circuits according to a pre-set time and date program. The AP21's AUTO PROMPTING alpha-numeric display make programming fast and simple. The transfer feature allows the operator to program one AP21T and transfer that program to any other AP21T or to an AP21TR. The AP21DC draws its power from any 12 volt DC supply making it ideal for solar powered locations.

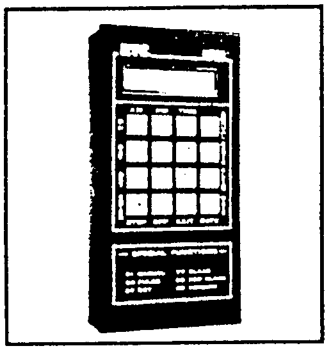
Standard Features of the AP21 include:

- 16 character, alpha-numeric, easy to read Liquid Crystal Display (LCD). Optional back-lit display available.
- Automatic Daylight Savings Time (DST) compensation.
- DST data entered from keyboard — makes future DST4 changes quick and easy.
- Time of Day entered in 12-hour format.
- Automatic Leap Year compensation.
- 48-hour capacitive memory back-up — no batteries to replace.
- The display "Auto Prompts" the operator through the programming process.
- 16 powerful program steps.
- Single Day, Week End, Week Day, or Every Day programming capability for each program step.
- 10 Holiday Skip Plans — Each skip plan prevents the time switch output from activating on a specific day or consecutive days.
- Program Transfer from one AP21T to another, from an AP21T to an AP21TR, or from a PC to an AP21T or AP2TTR.
- SPDT Relay Output rated at 15 Amps at 115 VAC resistive load.
- Manual operation of the relay output from the keyboard.
- Optional DC version will operate from any 12 Volt DC power source.

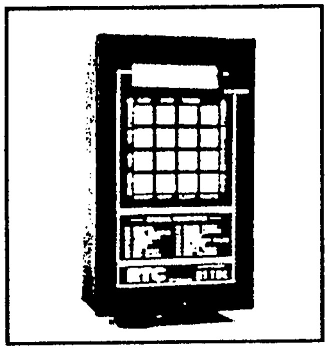
AP21TR Time Switch: RTC Manufacturing, Inc. has designed this time switch small enough to fit into any traffic enclosure. The Model AP21TR measures only 2" X 2 1/2" X 4" yet has the power for annual programming and more. Programming the AP21TR is simple. The operator enters up to 16 program steps, 10 holiday skip plans, and DST changes using an AP21T (transfer model) Time Switch or a Laptop (PC) type computer and downloads the program to the AP21TR Time Switch.

Because the AP21TR Time Switch is programmed from an AP21T or a Laptop computer, the AP21TR comes standard without a keyboard or LCD display. This saves the purchaser more than 40% over the cost of an AP21T. Also, without a keyboard, it would be impossible for an unauthorized person to make timing changes to the AP21TR thus providing additional security to the operation of the time switch.

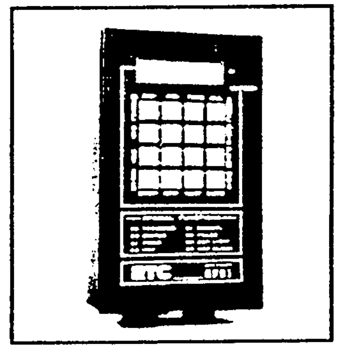
AP21 Time Switch



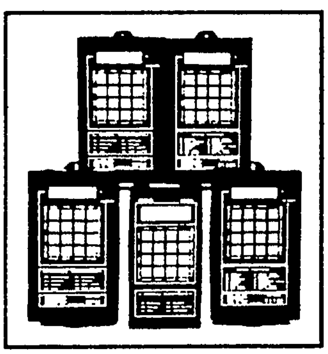
81TBC Time Base Coordinator



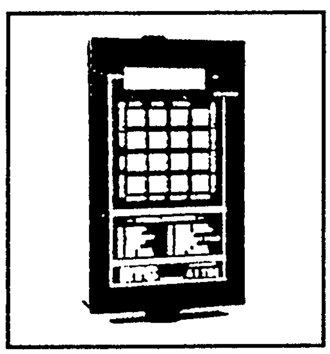
AP81 Time Switch



Standard Features



41TBC Time Base Coordinator



AP41 Time Switch

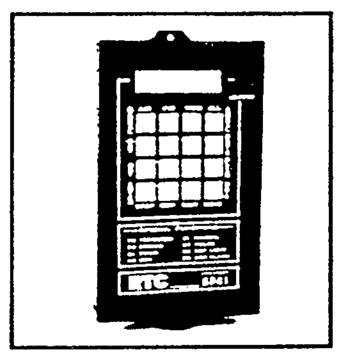


Figure II-41. RTC Time Switch Models and Time-based Coordinators

TABLE II-7. RTC Time Switches and Time Base Coordinators

			RTC Time Switches			RTC Time Base Coordinator*	
Series	AP21	AP21TR	AP41	AP81	AP21T	41TBC	81TBC
Display (Liquid Crystal Display, LCD)	1-line 16 char./line	No	2-line 16 char./line	2-line 16 char./line	1 line 16 char./line	2 line 16 char./line	2 line 16 char./line
Automatic Daylight Savings Time (DST)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time of Day - 12-Hour Format	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Automatic Leap Year Comp.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
48-Hour Capacitive Memory Back-up	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Timing Plans (Daily and/or Weekly Programming)	1	1	10	10	1	10	10
No. of Program Steps per Timing Plan	16	16	20	20	16	20	20
Menu Driven Programming Procedure	Yes	No	Yes	Yes	Yes	Yes	Yes
Special Event Programming (Day) for each Program Step	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Annual Programs for Yearly Programming	N/A	N/A	20	20	N/A	20	20
Program Transfer from One Unit to Another	No	From AP21T or PC	Yes	Yes	Yes	Yes	Yes
Print-out, Hard-copy, Feature	No	Yes, from PC	Yes	Yes	Yes, from PC	Yes	Yes
No. of SPDT Relay output (rated at 15 amps)	1	1	4	8	1	4	8
Manual Operations of the relays from the keyboard	Yes	No	Yes	Yes	Yes	Yes	Yes
No. of Circuits	1	1	4	8	1	4	8
No. of Skip Plans	10	10	N/A	N/A	10	N/A	N/A
Number of Cycle Length (30 to 254 seconds)	N/A	N/A	N/A	N/A	N/A	6	6
Number of Offset Values per Cycle	N/A	N/A	N/A	N/A	N/A	10	10
Interrupt Pulse Operation from Keyboard	N/A	N/A	N/A	N/A	N/A	Yes	Yes
Programmable Pulse Width	N/A	N/A	N/A	N/A	N/A	Yes	Yes
User Defined Re-Sync of the Unit from Keyboard: TOD, External, Manual	No	N/A	N/A	N/A	N/A	Yes	Yes
Programmable from Laptop (PC) Computer	No	Yes	No	No	Yes	No	No

N/A — Denotes Not Applicable * — TBC units by Sonex and TCT are described on pages II-101 and II-104)

II-99

Standard features of the AP21TR Time Switch include:

- 48 Hour Capacitive Memory Back-up
- SPDT (single pole double thrown) Relay Output, 15 Amp Contacts
- Separate Indicators for:
  - Power ON
  - Power Fail
  - Relay Status
- Plug into a Standard 8 Pin Octal Base

The AP21TR Time Switch has the power for annual programming, and is designed for easy installation, programming, and maintenance.

The AP21TR Time Switch is ideal for controlling school zone flashers, placing signalized intersections on flash at night, or any other ON/OFF function that the end user may have.

<u>RTC AP41 Time Switch</u>

The AP41 is a four circuit, calendar programmable solid state time switch. See Figure II-41. It is used for switching electric circuits according to a pre-set time and date program. It has the ability to run up to ten (10) different day/week plans to accommodate different school calendars and/or traffic patterns throughout the year. The AP41 AUTO PROMPTING alpha-numeric display makes programming fast and simple. (See Table II-7 on page II-98.)

<u>RTC AP81 Time Switch</u>

The AP81 is an eight circuit, calendar programmable solid state time switch. The eight circuits can control up to 8 different output functions such as cycles and offsets. It is used for switching electric circuits according to a pre-set time and date program. It has the ability to run up to ten (10) different day/week plans to accommodate different school calendars and/or traffic patterns through-out the year. The AP81 AUTO PROMPTING alpha-numeric display also makes programming fast and simple. (See Table II-7 on page II-98.)

<u>TIME BASE COORDINATORS</u>

Time-base coordinators (TBC) are devices programmed to implement different signal timing patterns at different times during the day. With TBC there is no hard wire interconnect cable between intersections. The coordinator device uses the power frequency provided by the local power company, i.e 60 Hz, as its time base. A battery, or capacitor back-up built in the TBC device, is usually used to maintain clock timing when power failure occurs.

<u>RTC MANUFACTURING, INC.</u>

<u>RTC 81 TBC Time Base Coordinator</u>: The 81TBC is an eight circuit, calendar programmable solid state time base coordination unit. It is used for time based interconnect operation of traffic signal controller units to provide maximum vehicle progression according to a pre-set time and date program. It has the ability to run up to ten (10) different day/week plans to accommodate different traffic patterns throughout the year. The 81TBC AUTO PROMPTING alphanumeric display makes programming fast and simple. (See Table II-7 on page II-99.)

<u>RTC 41TBC Time Base Coordinator</u>: The 41TBC is a four circuit, calendar programmable solid state time base coordination unit. It is used for time based interconnect operation of traffic signal controller units to provide maximum vehicle progression according to a pre-set time and date program. It has the ability to run up to ten (10) different day/week plans to accommodate different traffic patterns throughout the year. The 41TBC AUTO PROMPTING alpha-numeric display makes programming fast and simple. (See Table II-7 on page II-99.)

SONEX CORPORATION

Sonex Zero Drift (ZDC) TBC: The ZDC microprocessor based Time-Based Coordination unit. The unit is designed to communicate by telephone or by user owned cable network with the central computer and the local intersection controller unit. The unit provides the communications, decoding, error checking, monitoring and second by second control and "Stand-by TBC" operation for solid state and mechanical controllers. The brain of the ZDC-UTCS unit is the CPU module which contains the CPU, memory, control and timing logic. The remaining modules contain the power supply, I/O circuits, communications interface and display module. NEMA and Model 170 ZDC TBC units are shown in Figure 11-42 on page 103.

Sonex ZDC TBC is unique in design and application, since it has a different design philosophy than other current TBC units. For example, Standard TBC devices use the same 60 hertz frequency, generated by the power company, as a reference for keeping time. When some intersections lose power, other manufacturers must rely on crystal oscillators for their 60 hertz reference. Because the power lines do not generate a stable 60 hertz (they could be off as much as 7 seconds before the power company readjusts the frequency), the intersections with power will be referencing a different frequency than those without power, and therefore will be out of synchronization when power is returned. Sonex, however, uses its Zero Drift Technology. Zero Drift Technology uses a patented method to pick up to 60 hertz frequency that is constantly radiated by the power lines. Therefore, both the intersections, with and without power, are still referencing time from the same source, and will stay synchronized.

Standard Features: ZDC provides the following features for each and every intersection in the system:

- Eliminates time drift and always maintains offsets between intersections.

- Keeps all intersections online, all of the time, regardless of the condition of the computer or communications network.

- Supports any standard NEMA and most Pretimed controller units by any manufacturer, including 170 controller units.

- Locally stores all of the data required to control an intersection (dials/splits/offsets).

- EEPROM storage ensures the database is never lost.

- Maintains a perpetual calendar that adjusts leap year, fixed and floating holidays and Daylight Savings Time.

  The ZDC's calendar negates the need for yearly reprogramming.

  Supports 24 fixed or floating holidays.

- Supports 10 definable weekly schedules.

  Up to 10 different weekly schedules can be defined in a year.

  Each day of each weekly schedule can be assigned to any of 10 definable daily schedules.

  Each daily schedule can be divided into 24 separate time periods.

  Each time period can be assigned to any of 34 timing plans, 32 of which are user definable.

- Supports 34 timing plans.

  Two plans are reserved for "FREE" and "FLASH."

  The other 32 plans, consisting of a cycle length, an offset and split time settings, are completely user definable.

Each setting can be defined from the appropriate minimum to 255.

- Provides intersection monitoring and local storage of all events.

  The last 63 events and 5 power failures are stored in memory.

  All event and power failure logs include the date and time of occurrence, and the end time if applicable.

  All stored information is accessible through the central computer or by means of a laptop computer connected directly into the ZDC via an RS-232 port.

<u>Events Include</u>:

- **Conflicts** — Built in software monitors up to 8 phase greens for conflicts. If desired the ZDC will place the intersection into Flash when a conflict is detected.

- **Preempt Conditions** — Ability to monitor up to 3 preempt inputs. Records the phase the intersection was in when preempt occurred and the phase it was in when preempt was removed.

- **Police Flash** — Monitors the police panel switch, and records when it is activated and when it is deactivated.

- **Offset Transitions** — All transitions, no matter what the cause, are recorded.

- **Detectors** — Up to 16 detectors can be monitored. In addition to volume and occupancy data, detector failures are also recorded.

- **Calendar** — The date and time are recorded whenever they are downloaded from central.

  At midnight, the date is recorded to assure the traffic engineer that the proper time of day schedules will be used.

- **Cabinet Door Open** — Monitors and records when the cabinet door is opened and closed.

- **Manual Command Overrides** — Records each time the ZDC is commanded to change timing plans or provide some other service via operator or master command.

- **Controller Unit Stuck** — The length of time an intersection is in each phase is monitored. If one or more of the side street phases become equal to the maximum dwell time, the event is recorded.

- **Special Functions** — Depending on system configuration, activity on special function inputs can be recorded.

- Route Preemption

- Coordination Failure

- Supports user assignable special function inputs.

  There are two VAC and six VDC inputs that can be assigned by the traffic engineer for whatever purposes desired. Some examples include the monitoring of conflict monitors, school signs, variable message signs, and water levels for flood control.

- Supports user assignable special function outputs.

  There are 8 special function outputs. These can be assigned to whatever the traffic engineer desires, such as turning on school signs, controlling variable message signs, placing calls on phases, and controller unit street lighting.

  Special functions can be invoked on either a time of day or phase basis.

- User friendly 48 character liquid crystal display and keyboard entry.

  All programming, if desired, can be done directly on the ZDC unit via the two 20 key keyboards.

  Status information is displayed on the units 48 characters display.

- Supports an internal modem for system communications.

  The internal modem is used with wire or dedicated telephone mediums. Baud rates of 2400 bits per second are attainable.

- Supports an RS-232 port.

  Used for communication to a lap top computer for easy, on-site, database uploading and downloading.

  Also used for linking the ZDC to the central computer when system communications other than twisted pairs are used. This includes the Sonex S90-05 CATV RF Modem, over the air RF modems and fiber optics. Baud rates of 19,200 bits per second are attainable.

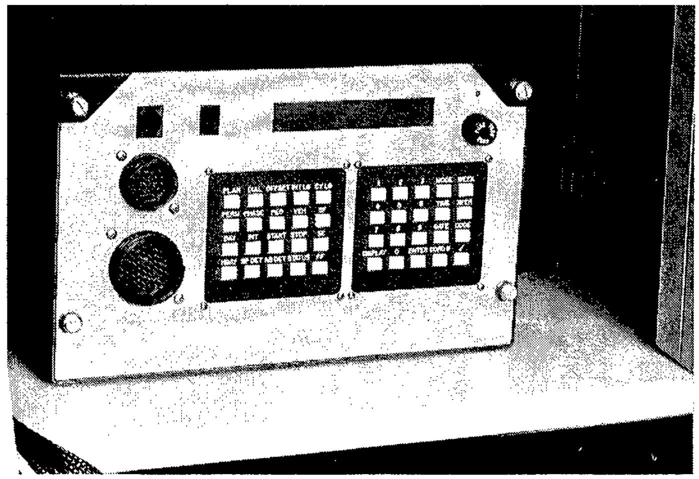
- Supports a second RS-232 port.

A second RS-232 port is available for special applications.

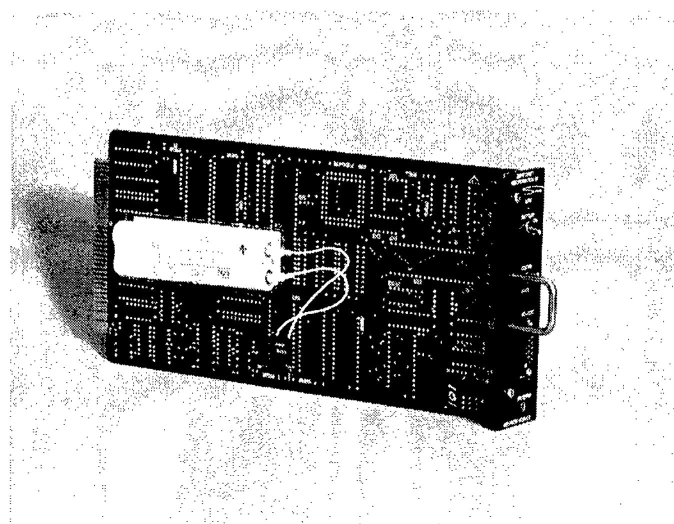
- Allows for the use of security codes.

This feature, when invoked, prevents any ZDC database from being changed. It can, however, still be viewed without the security code being entered.

The code can be uploaded and downloaded from other computers that can communicate with the ZDC.



(a) NEMA Model



(b) Model 170 ZDC

Figure II-42. Sonex ZDC Time-based Coordination Units

TRAFFIC CONTROL TECHNOLOGIES

Traffic Control Technologies LTC Series TBC: The LTC TBC is a compact, shelf mounted unit and is available in two configurations to accommodate a variety of applications. The LTC1 has 12 DC inputs and outputs for use with NEMA controller unit and an additional 16 AC inputs and outputs for pre-timed controller unit or hard wire applications.

Each unit provides a keyboard and three liquid crystal displays for data entry and readout, a connector, plus a printer jack and data transfer plug, and an additional connector for AC inputs and outputs. The unit's coordination features include 4 cycles, 3 offsets per cycle, and 4 splits. Six permissive periods and 8 forceoffs per each split allow a variety of coordination schemes. Since 3 sync reference techniques are provided the unit can be integrated into most existing systems.

Application: The LTC series coordinator units can be used for a variety of applications including:

- Stand-alone time base coordinator for NEMA, solid state pre-timed, or electromechanical controller units.
- Secondary coordinator in a hard-wired interconnect system.
- Master coordinator to drive interconnect (system master).
- General purpose yearly time clock device.

The units provide a yearly program for which events can be chosen on a time-of-day, day-of-week, week-of-year basis. The highly accurate clock relies on power line frequency for normal operation and is battery backed (2.4 VDC battery) to within ± 0.005% during power outages. Daylight savings adjustments, when desired, are automatically implemented in accordance with Federal guidelines.

Operation: LTC Series units can be wired into most new or existing cabinets and use standard external functions to provide coordinated operation. For NEMA controller units, these would include phase greens, holds, force offs, and veh/ped omit. For a solid state pre-timed or electromechanical controller unit, the LTC2 would provide AC level cycle, split, and offset commands (including sync pulses).

The LTC units are easily programmed using simple keystroke procedures and alphanumeric liquid crystal displays.

The liquid crystal displays are used for both programming of the unit as well as providing status indications of inputs, outputs and coordination parameters such as permissive periods and force-off points.

Data can be transferred from unit to unit using a simple plug-in cable, or easily printed out using the optional printer unit. Program functions include the following:

- 200 day program events
- 15 day programs
- 10 week programs
- 35 exception days
- 30 cycle/split/offset plans

Coordination Outputs include:

- Force-offs
- Hold
- Phase Omits
- Ped Omits
- System

ISOLATORS

Isolators are devices used to isolate AC and DC current and act as surge suppressors. They are typically used with push buttons, preemption, telemetry, and detectors.

The PDC Model DCI-82 Dual Channel D.C. Isolator is designed specifically to meet the California Department of Transportation, Model 242

Specifications. Each channel of the D.C. Isolator presents a true signal (ground closure) at the output of its optical coupling device when a contact closure causes an input voltage of less than 8 VDC, for longer than 5 milliseconds. A transition from a true to a false signal at the output shall occur when the respective contact closure causes an input voltage of greater than 12 VDC.

All electronics are provided on a single-sided P.C. board with an aluminum front panel. See Figure II-43. provided with a solder mask, silkscreen identifying all component locations and is conformally coated to resist adverse environmental conditions.

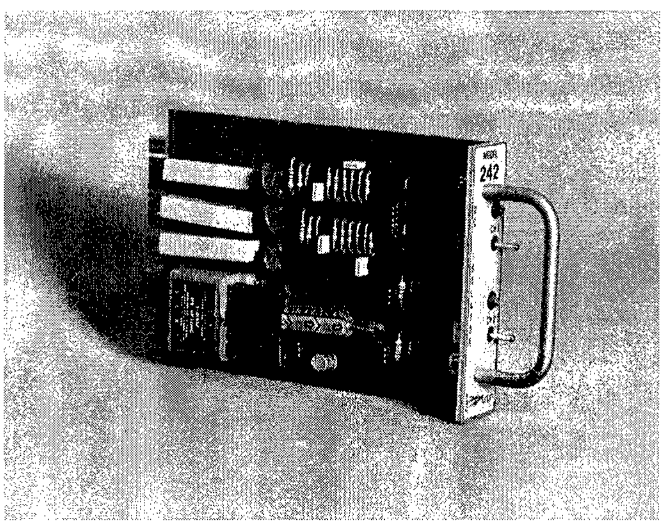


Figure II-43. Isolator

AUXILIARY OUTPUT DEVICES

Controller unit output devices include load switch drivers, flashers, isolators and conflict monitors.

A Load switch is a device used to switch power to the lamps in the signal heads on the street. Controller unit circuitry does not have the capacity required to control multiple 110 volt displays. Therefore, load switches are used as relays to control the signal circuits.

A flasher is a device used to open and close signal circuits at a repetitive use, as it provides a back-up for the stop-and-go operation of the controller unit.

A Conflict Monitor is a device used to continually check for the presence of conflicting signal indications and the absence of proper voltages at the RED signal field connection terminal and to provide an input in response to a conflict. It is also capable of monitoring for the presence of satisfactory operating voltages of the controller unit and within itself.

Although there are several manufacturers of the above devices, this workshop, however, includes some of the most commonly used equipment, as follows:

Load Switches

- Traffic Sensor Corporation (TSC)
- Solid State Devices (SSD)
- Hi-Tech Switches, Inc.

Flashers

- Solid State Devices (SSD)
- Traffic Sensor Corporation (TSC)

Conflict Monitors

- Solid State Devices (SSD)
- Traffic Sensor Corporation (TSC)
- Eberle Design, Inc. (EDI)
- Signal Control Corporation (SCC)

LOAD SWITCHES

Traffic Sensor Corporation

TSC Model 200 Load Switch: The MODEL 200-OI LOAD SWITCH meets NEMA TS1-1989, New York D.O.T. Model 170, and California D.O.T. Model 170 requirements. This ensures availability of one standard part for maintenance of all load switches. The MODEL 200-OI LOAD SWITCH has LED indicators on the a.c. output circuitry in addition to the d.c. input indicators for more accurate and complete status information than previously possible. (See Figure II-44 on page 107.) The standard load switch version has bicolor LED output status indicators which indicate when a load switch channel conducts normal full-wave output by emitting orange light. Faulty positive half-wave output, or intentional positive half-wave operation through the use of signal lamp dimmers, is indicated by a green light being emitted. Faulty negative half-wave outputs, or intentional negative half-wave operation through the use of signal lamp dimmers, is indicated by a red light being emitted. This bicolor LED feature identifies faulty photocell and timeclock operation as well as time setting errors by emitting a different color of light when the photocell or timeclock is ON. Additionally, missing or burned-out signal lamps and open field wiring are apparent because the output LED will be lit without the corresponding input LED being lit. Illumination of an output indicator without illumination of the corresponding input indicator may also be a sign of a locked load switch output ON. An "optional version" of the MODEL 300-OI LOAD SWITCH having standard LEDs on the outputs instead of the bicolor LEDs is available for use with certain conflict monitors unable to detect missing or burned-out signal lamps unless a high voltage is present on load switch outputs.

Solid State Devices

SSD Diagnostic Vehicle Load Switch (DVLS): This Load Switch uses three modular solid state relays to accomplish load switching. See Figure II-45 on page 107.

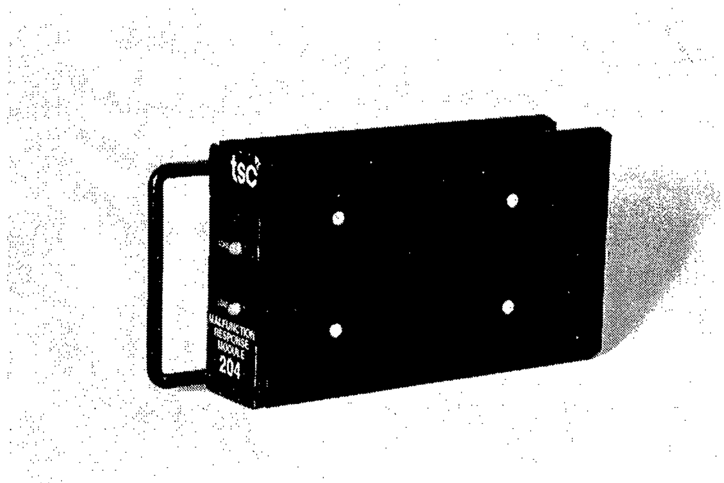


Figure II-44. TSC Model 204 Load Switch

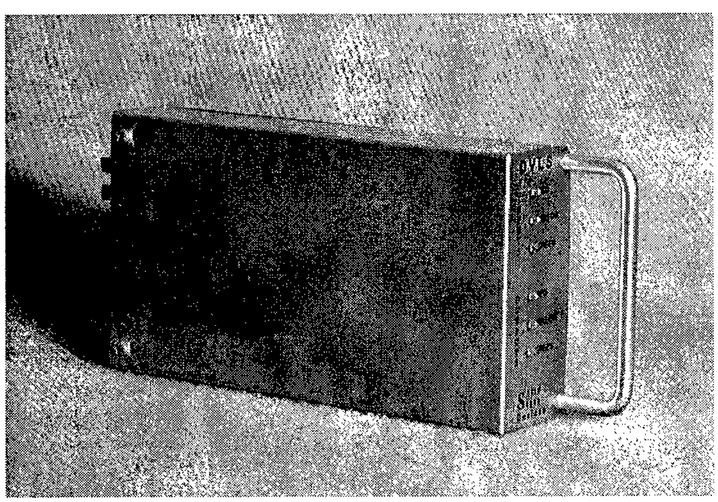


Figure II-45. SSD Model DVLS Load Switch

An input signal voltage between 0 and 6 volts dc causes the load switch to indicate an input signal "ON" condition. An input signal greater than 16 volts shall cause the load switch to indicate an input signal "OFF" condition. Both positive and negative half wave signals are sensed.

An alternating current voltage of greater than 70Vac RMS sensed at the output terminal causes the load switch to indicate an output signal "ON" condition. An alternating current voltage of less than 50Vac RMS sensed at the output terminal causes the load switch to indicate an output signal "OFF" condition. Both positive and negative half-wave signals are sensed.

Removal of AC power from terminal 1 for a period greater than 60ms causes all front panel indications to remain latched at that present condition. All indications will remain in this "latched" condition until an alternating current voltage greater than 95Vac RMS is applied to terminal 1 for greater than 400mS. Normal indicating operation will then resume.

With the DVLS you can tell instantly by observing the input and output LED indicators if any of the following conditions occur, since all failures are locked in visibly.

- controller unit signal is incorrect
- load switch is in error
- stray voltage in the field wiring
- a conflict monitor error exists

The DVLS is interchangeable among NEMA & Model 170 controller unit and it meets NEMA TS1-1989. The power supply required for the DVLS is 24 VDC.

<u>Hi-Tech Switches, Inc.</u>

<u>Model 200i Intelligent Load Switch</u>: With its patented backup capability this load switch will keep an intersection running rather than operating in a flash mode. The model 200i load switch has an on-board microprocessor which continually monitors for component malfunctions and compensates for them before the intersection is forced to go into flash. The model 200i load switch automatically tests its own backup circuits to assure backup capability when needed. The front panel LED displays (see Figure II-46 on page 110) show the status of all main circuits as well as all backup circuits. The model 200i load switch provides an output which can be used to trip an alarm in case of a component failure in the load switch.

Standard features include:

- Full backup capability for any shorted or open electrical circuits.

- On board microprocessor senses any circuit faults and substitutes a backup in less than 100ms.

- Signals remain fully operational if any or all primary Red, Yellow, or Green driver circuits malfunction.

- Backup circuits are monitored during normal operation to assure capability to provide backup if primary circuits fail.

- Fault signal is generated if either primary or backup circuits are defective.

- Status lights provide a visual indication of any malfunction.

- Manual test routine to facilitate repair.

The Model 200i Intelligent Load Switch™, by preventing flashing operation of the signals due to load switch failure will:

- Improve safety
- Reduce expensive overtime
- Reduce congestion
- Improve air quality
- Reduce liability
- Reduce insurance costs

FLASHERS

Traffic Sensor Corporation

TSC Model 304/304-15 Flasher: This flasher meets NEMA TS1-1989, New York D.O.T. Model 170 requirements. It is available with a bicolor light emitting diode (LED) and internal dimmer. These flashers need not be operated in the Reduced Power Mode unless so desired. The bicolor LED output status indicators indicate full-wave output to a load (Bright Mode Operation) with an orange color. Faulty positive half-wave output to a load, as may occur through flasher failure, and Reduced Power Operation are indicated by a green color. Faulty negative half-wave output to a load is indicated by a red color from the LED. (See Figure II-47 on page 110.) In addition to normal flasher operation, the flasher may be operated so as to supply positive half-wave power to loads. Reduced Power Operation is activated by applying an a.c. common signal using a photoelectric cell in series with a solid state time clock. During Reduced Power Operation, approximately 46% of the energy consumed during full-wave operation will be saved.

A similar flasher device is also available from Solid State Devices, Model 204.

CONFLICT MONITORS

Traffic Sensor Corporation

TSC SMU-12/16 Signal Monitor: The TSC Load Mangement System (LMS) incorporates the SMU – 12/16 Signal Monitor Unit (see Figure II-48 on page II-111) to perform in excess of NEMA requirements ensuring safe and reliable operation of the intersection by:

- measuring load currents to know when signal lamps fail
- monitoring and comparing controller unit driver outputs with load switch outputs to know which equipment fails
- continuously monitoring flasher unit outputs before and after "flash" operation of the intersection to know that the flasher unit is operating properly
- eliminating electrical transients from being generated by flash transfer relays to prevent their destruction as well as that of other cabinet electronics.

Special Load Sensing Switches measure load currents permitting detection of the loss of a single incandescent bulb. A simple harness is used so that no cabinet rewiring or modification is necessary. With this harness, the Signal Monitor Unit is also provided with controller unit driver output status which is compared with load switch outputs to confirm proper operation of traffic signals. This allows identification of which equipment has malfunctioned saving valuable maintenance personnel and equipment time. The single harnessing used also connects the SMU-12/16 with the Malfunction Response Modules (flasher units) so that the flasher outputs may be continuously monitored for their proper operation before and after they are put into service. Failure of Malfunction Response Modules can be communicated to another location via modem or RS232 connections as well as retained within internal memory for retrieval when a field service technician services the controller unit assembly. A convenient "MESSAGE" indicator is used to call attention to changes in logged information as well as to necessary maintenance. When flash transfer relays are required to transfer signal lamp loads to Malfunction Response Modules, generation of high voltage transients caused by arcing of contacts is avoided. This prevents damage to electronic equipment within the controller unit assembly and to flash transfer relay contacts such that their replacement is virtually eliminated. The TSC LMS uses extensive self-testing of internal hardware as well as checking RAM and EEPROM memory locations, optical isolation of alternating current field voltages from internal monitor circuitry, and greater precision of measuring field voltages. Each information record logged into the monitor contains the date, time, all active channel, temperature, 24 V supply

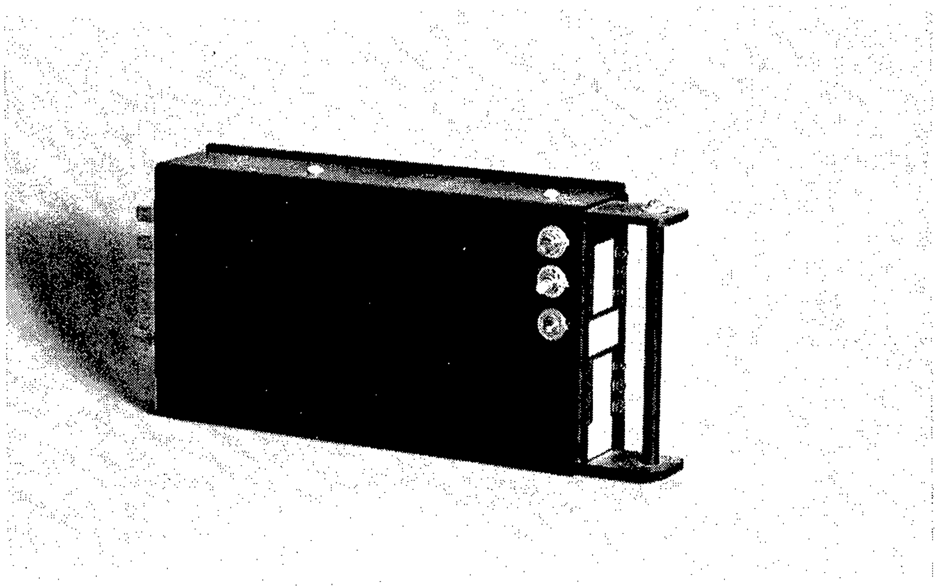


Figure II-46. Model 200i Intelligent Load Switch

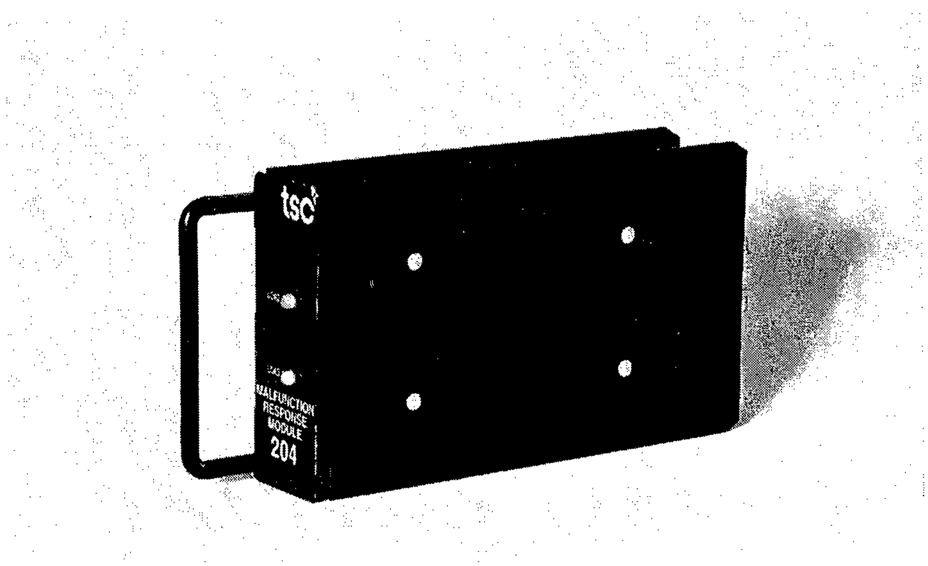


Figure II-47. Model 204 Flasher

supply and ac line voltages, and the monitored message/fault with the corresponding channels.

A description of the TSC LMS is included below.

- <u>Load Management System</u>: The Load Management System is a complete system for monitoring field wire voltages and load currents which does not require any rewiring of cabinet facilities which have been properly wired to NEMA TS1-1989 requirements. This system compares load switch input signals with field wire voltages and monitors flasher output operation independent of flash transfer relays. Each Load Management System includes one SMU-12/16 Signal Monitor Unit and one Load Interface Unit Model LIU 16-2.

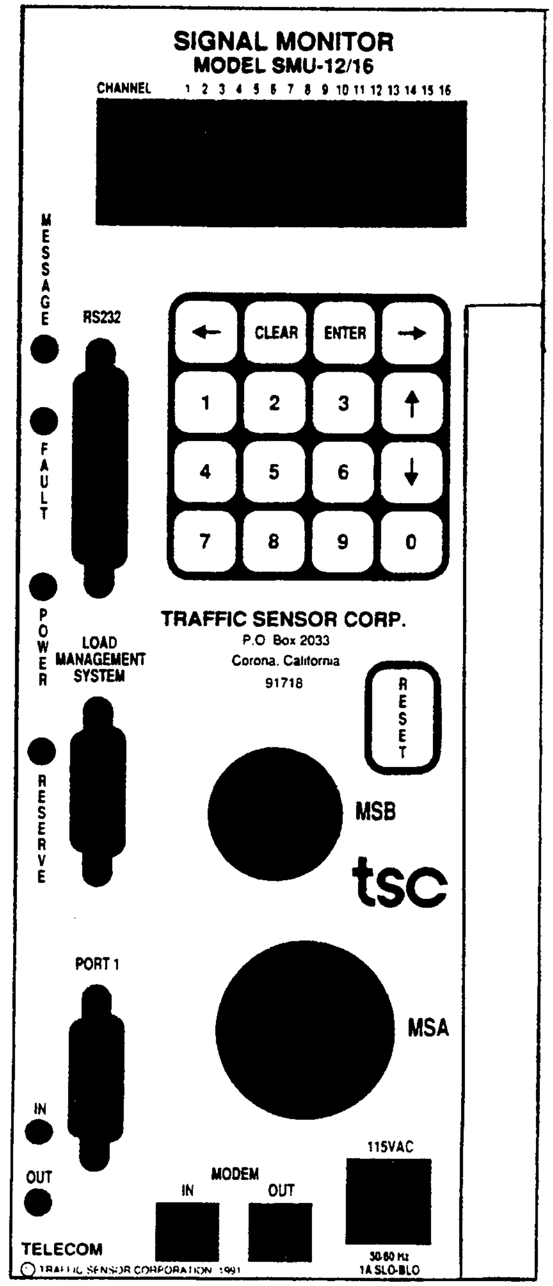


Figure II-48. TSC SMU — 12/16 Signal Monitor Unit

- **SMU - 12/16 Signal Monitor Unit**: This Signal Monitor Unit is configured with 12 channels having 4 inputs/channel and can perform all NEMA TS1-1989 voltage monitoring functions plus monitoring extended NEMA functions such as minimum yellow change time from 2.7 to 16 seconds in 1 second increments for each channel individually with failures selectable as a FAULT or as a MESSAGE logged to separate memory records. Each memory record retains up to 100 entries with time, date, all active channel signal inputs, temperature, measured 24 volt supply and ac line voltages, and monitored message or fault with the corresponding channels. The Signal Monitor Unit has a DB25 female RS232 connector and a DB15 female connector on the front panel. A 20 character/line, 4 line backlit liquid crystal display is also provided on the Signal Monitor Unit with a 16 keypad array and separate RESET keypad for front panel entries. Load switch inputs can be compared with field wire voltages. Flasher outputs can be monitored independent of flash transfer relays. Load currents can be monitored to detect loss of signal loads as small as 20 watts. A type 170 signal monitor model is also available from TSC.

- **Load Sensing Switches**: The TSC load switches meet all applicable requirements of NEMA TS1-1989 standards. Three light emitting diode indicators are provided for the input circuits and 3 bicolor light emitting diode indicators are provided for the output circuits with the indicators arranged in two columns on the front face. The input indicators are on the left with the corresponding output indicators on the right for each channel. A handle of 1/4" diameter round stock is mounted on 3.5" centers. Load current sensing is accomplished within the Load Sensing Switches such that detection of the loss of a single 20 watt load is possible from 89 to 135 volts, 60 ± 3 Hertz. The Load Sensing Switches supplies the ON/OFF status of each Load Sensing Switch input circuit (3 inputs/unit) to a Load Interface Unit. 25 amp minimum power solid state switching devices are used to switch loads.

- **Malfunction Response Modules**: The TSC flasher units contain load current sensing and are capable of being connected to the Load Interface Unit. Two bicolor light emitting diode indicators on the output circuits are provided. Malfunction Response Modules are capable of providing half-wave power to loads upon application of an ac common control signal not exceeding 30 milliamps. 25 amp minimum power triacs are used to switch loads.

- **LIU 16-2 Load Interface Unit**: The Load Interface receives load current measurements from up to 16 Load Sensing Switches and 2 Malfunction Response Modules. A simple menu-driven set-up procedure from the Signal Monitor Unit shall be used to assign Load Sensing Switch positions with channels. A female DB-15 connector shall be used to provide load current and controller unit driver output status information to the Signal Monitor Unit.

Solid State Devices

SSD Guardian LCD-12P Signal Monitor: The Guardian LCD-12P Conflict Signal Monitor (see Figure II-49 on page II-113) meets all NEMA TS1 specifications for conflict monitors, and provides enhanced fault detection and logging features beyond those requirements. It supports standard features: conflict detection, absence of signal (dark signal head), monitoring of two 24V power supplies, monitoring of the controller unit voltage (CVM), and indication of adequate AC power supply. It is compatible with standard NEMA program cards, with LED indicator for program card ajar. Enhanced features include added fault detection including PLUS features and yellow failure detection, enhanced status display capabilities (i.e. display of all field inputs, menu driven user interface), logging of fault and power history, communication capabilities, and extensive support for diagnostics.

As per TS1 specification, the LCD-12P is equipped with two relay outputs designated start-delay and fault relay. When power is applied to the monitor, both will be asserted. If a minimum flash setting of greater than zero is selected, then after 2.5 seconds, the start delay relay will be de-asserted. Similarly, if no latched fault is active, after the expiration of the minimum flash time, the fault relay will be de-asserted and the control of the intersection will be transferred to the controller unit. If the minimum flash setting is zero, then the start delay relay and the fault relay will be de-asserted immediately. If the monitor detected a latched fault before the previous power outage, the fault relay will continue to be held closed until reset from fault.

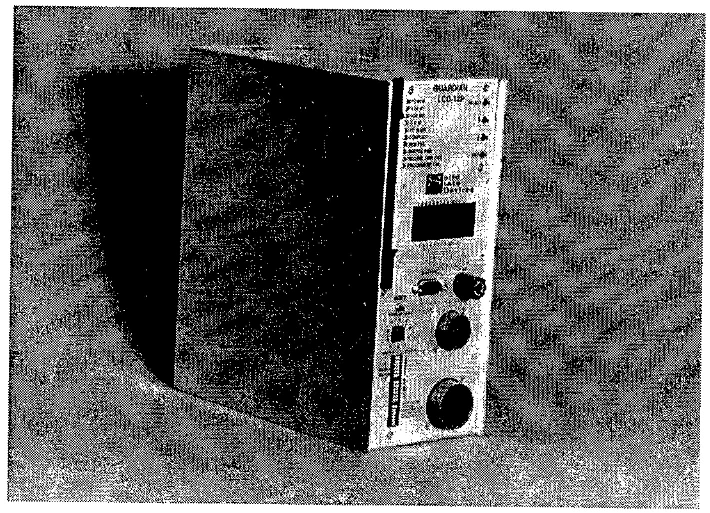


Figure II-49. SSD Guardian LCD-12P Conflict Monitor

If any of the failures described below, occur, the monitor will close its fault relay, thereby causing the intersection to go into a flashing mode. In order to aid service technicians, the monitor will display on its LEDs the status of the intersection and DC power supply inputs. If the status of phase inputs caused the detected fault, the status of phase inputs at the time of fault will also be displayed. For latched failures, the monitor will remain in this state until the Reset is activated. For non-latched failures, the monitor will remain in fault until the condition that caused the fault has been removed, or until the reset key is pressed.

NEMA extended functions built in the LCD-12P signal monitor detect switch fail conditions, i.e. multiple indications on a single channel (i.e. green-yellow, green-red, yellow-red). Also flagged as a switch failure are WALK ONLY conditions where a WALK signal is on by itself. The plus functions detect a wider range of possible controller unit and load switches malfunctions than provided by NEMA TS1. Extended functions enforce rules for incorrect signal displays as established by the M.U.T.C.D.

Front Panel Displays of LCD-12P Monitor include the following LEDs:

POWER	Illuminates under normal operation. Flashes during the startup MINIMUM FLASH period, and during AC voltage.
+24 #1	Illuminates if the input level to +24V I monitor drops below the necessary level.
+24 #2	Illuminates if the input level to +24V II monitor drops below the necessary level.
CVM	Illuminates if the input level to the Controller Unit Voltage Monitor input drops below the necessary level.
PC AJAR	Illuminates if the Program Card isn't seated properly in the connector. The monitor will assume no permissive phases.
CONFLICT	Illuminates if conflicting signals are detected.
RED FAILURE	Illuminates if a DARK signal head is detected.
SWITCH FAIL	Illuminates if a Switch Output Failure is detected and the PLUS ENABLE switch has been enabled for that channel. (If a Red Failure occurs on a channel that is enabled for the PLUS function, both the RED FAILURE and SWITCH FAILURE indicators will illuminate)
YELLOW TIME FAIL	Illuminates if a yellow interval is skipped or a short yellow failure is detected.
PROCESSOR FAIL	Illuminates if the processor fails to trigger internal watchdog circuitry.
PROGRAM CARD	Selected non conflicting phases by use of soldered-in jumpers.
RESET	Used to reset the monitor after detection of a fault condition.
MINIMUM FLASH	Selects the minimum flash delay following restoration of AC power. The delay varies from 4 to 12 seconds at one second intervals, or it may be 0 seconds (instant mode).
SELECT	Selects the main menu or current menu selection.
UP ARROW	Move cursor up one menu item or increase a number.
DOWN ARROW	Move cursor down one menu item or decrease a number.
EXIT	Exit from a sub menu to the main menu, or from the main menu to the appropriate status display.
COM PORT	RS232, 9 pin Male "D" shell connector used for connection to printer or computer.
LCD DISPLAY	16 columns x 4 rows Liquid Crystal Display used to present monitor status and menu commands.
FUSE	1 AMP fuse used for over current protection.
MS CONNECTOR	Military Specification connectors containing all field wiring terminations.

EBERLE Design INC.

Model SSM - 12 LEPR Conflict Monitor: The SSM-12 LEPR conflict monitor has the following features:

- Meets all standards specified in NEMA publications TS-1-1989, Part 6.
- Liquid Crystal Display (LCD) show full intersection status with an active Red, Yellow, Green and Walk indicator for each channel. (See Figure II-50 on page II-117.)
- Real Time clock marks the time and date the monitor is triggered by a fault condition. Unit stores a complete datalog of previous faults and AC+ interruptions in non-volatile memory.
- Display mode shows compatibility card and monitor switch configuration.
- Detects faulty sequencing of signals on a per channel basis, i.e. short or absence of yellow interval and/or simultaneous dual indications.
- Monitors AC+ line voltage for brown-out and power interruption.
- Front panel options for +24V, walk disable (for red monitoring), and controller unit watchdog input.
- CMOS logic provides high noise and transient immunity. Precision voltage comparators and temperature compensated references provide accurate front end detection. Internal diagnostics.

COMMUNICATION FEATURES: Optional ports transfer time and date, intersection status, and previous fault datalog. AC+ datalog, compatibility card and monitor configuration to a PC, printer, or controller unit.

- SSM-LEP series eliminates printer cables by using a non-intrusive IR optical link to a convenient and low cost hand held printer.
- SSM-LEPR series uses an RS-232C port to link with a PC or serial printer.
- SSM-LEC series will upload to a controller unit for remote interrogation or archiving. Unit also links to a PC or serial printer.

Signal Control Corporation

Model 210 Conflict Monitor: The Signal Control Company's Model 210 Conflict Monitor is a 16-channel plug-in module which when installed into an output file in a 170 type cabinet, provides a method of detecting conflicting signal indications. (See Figure II-51 on page 117.) The monitor is a digital device that will place the intersection into a flashing condition whenever any one or more of the following conditions exist:

- Conflicting green, walk, or yellow signals for up to 16 channels.
- Absence of a program card, with cabinet door closed.
- Absence of a watchdog signal from the controller unit.
- Absence of the cabinet 24V power supply.
- Absence of AC power to the monitor unit.
- Blown front panel fuse.

The monitor front panel contains 19 solid state indicators of which 16 indicate the active signal circuits and three that indicate a conflict watchdog timer error or loss of the 24V cabinet power supply.

The monitor unit is programmable by a removable program card that provides a means of assigning conflicting signal indications by a diode matrix and omission of the yellow signal circuits to the monitor unit by diodes. The compatible channels are enabled by removing appropriate diodes.

The front panel design includes the following:

Reset Pushbutton:	Resets output relay and internal timers on the monitor units.
Conflict Indicator:	Illuminated when the cabinet 24V power supply is above 18 volts.
Power Indicator:	Illuminated when a conflict in signal indications is detected.
Channel Indicators 1 through 16:	Illuminated when the input channel is on, also indicates the input channels that were on at the time an error was detected.
Fuse:	1/4 amp 3AG type, slow blow.
Internal Settings:	Watchdog timer enable switch. • Conflict time • 24 V power loss delay

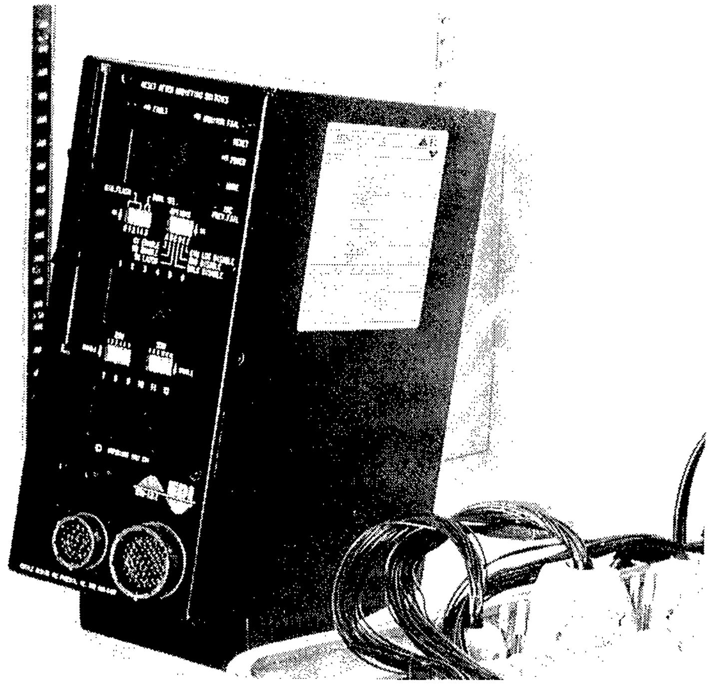


Figure II-50. SSM-LE Conflict Monitor

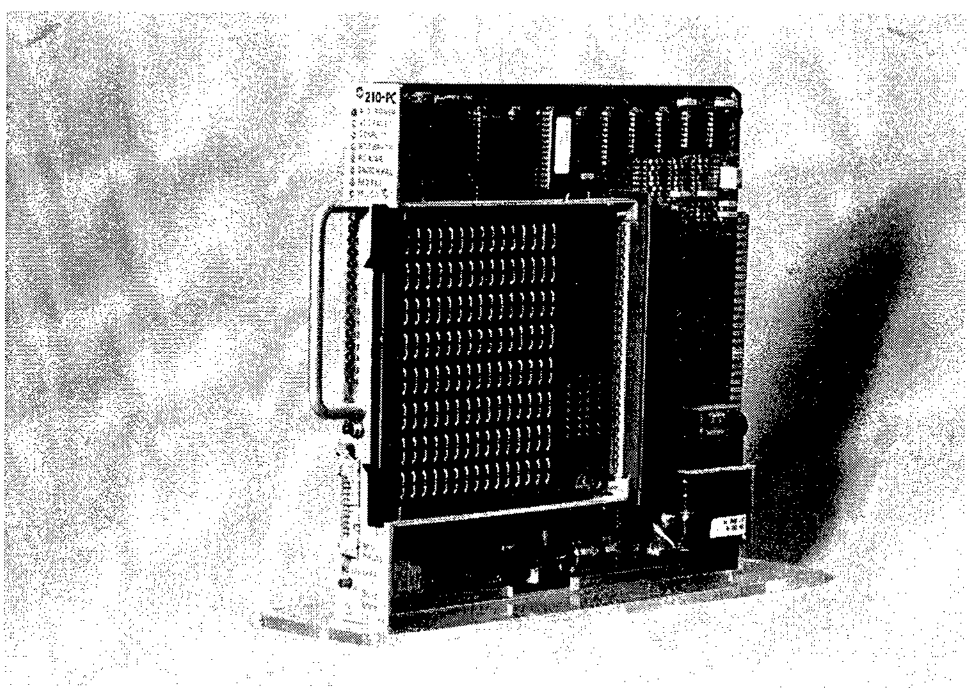


Figure II-51. Model 210 Conflict Monitor

TRAFFIC CONTROL EQUIPMENT TESTERS

Traffic control equipment testers are solid state devices that are used to perform on-line or off-line testing and simulation of NEMA and Model 170 controller unit, functions, vehicle loop detectors, conflict monitors, load switches, flashers, isolators, etc.

This section describes traffic control testers manufactured by ATSI, DVP, Inc., Setcon Technologies, Inc., Eberle Design, Inc., and Solid State Devices.

ATSI PCMT-2000 CONFLICT MONITOR TESTER

The ATSI PC-based conflict monitor tester (PCMT-2000) is designed to provide input conditions to NEMA and 170-type specified conflict monitors, to test virtually all parameters specified by NEMA TS1 and the Caltrans Specifications. See Figure II-52.

A test report in the form of a disk file is produced for each monitor tested, indicating the test description of any test failed by the monitor. A header is provided at the top of each test report, where the operator identifies himself, the monitor being tested by manufacturer, model number, and serial number, the location where the test is being performed, and any additional information specific to the monitor or testing procedure. Time and date information, derived from the PC's internal clock, is automatically attached to the test report by the PCMT test program.

The PCMT software is menu-driven, with on-screen instructions and prompts. Aside from the operator's entry of header information and adjustment of the local line voltage, the tester automatically generates the tests with little operator intervention. For each test, the tester produces the test conditions, evaluates the monitor's response, and records any response found to be in disagreement with the specifications.

Testing proceeds with a minimum of idle time: a 12-channel NEMA monitor is subjected to 320 Standards tests in about nine minutes; a 210 monitor undergoes 265 Standards tests in about eight minutes. Standard and extended tests include the following:

Standards Tests

This test group includes system/timing and conflict/voltage tests in accordance with NEMA or Caltrans standards. System/timing and conflict/voltage tests can be tested separately or together as the Standards group. These tests are as follows:

System/Timing Tests (NEMA 12 — 43 tests; 210 — 39 tests)***

Transfer Relay	Start Delay	DC Monitor Inhibit
Conflict Transfer	Conflict Latch	LED Indicators
Redfail Transfer	Redfail Latch	Red Enable
24 V DC Transfer	24 FDC Autoreset	Interlock
CVM Transfer*	CVM Autoreset*	Power Interrupt
Initial Flash*	Watchdog*	

(All standards—specified indicators.)

Conflict/Voltage tests (NEMA 12 — 276 tests; 210 — 224 tests)***

70 V Red	48 V Red	15V Sinusoids
25V Sinusoids	15V+ Rectified	15V- Rectified
25V + Rectified	25V- Rectified	115V AC thru 1500pF

Permissives Tests (NEMA 12 — 594 tests; 210 — 480 tests)***

This test group provides conflicts on all possible channel pairs to verify the monitor's programmed permissives. Green/green permissives can be tested separately or as part of the complete permissives group. The tests are as follows:

Green/Green Conflicts	Green/Yellow Conflicts	Green/Walk Conflicts*
Yellow/Yellow Conflicts	Yellow/Green Conflicts	Yellow/Walk Conflicts*
Walk/Walk Conflicts*	Walk/Green Conflicts*	Walk/Yellow Conflicts*

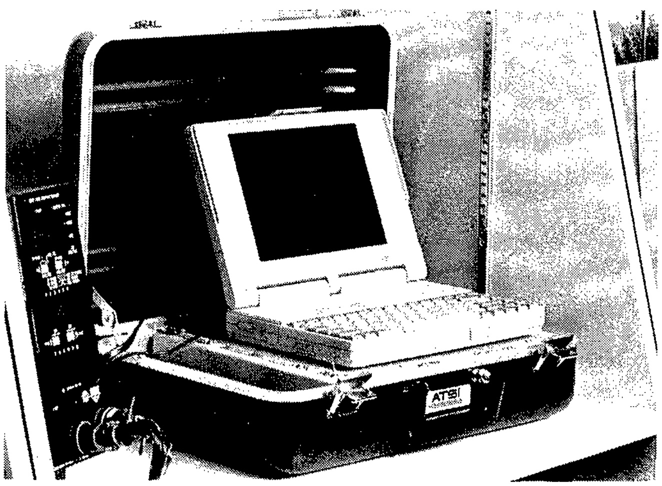


Figure II-52. ATSI PCMT-2000
Conflict Monitor Tester

Extended Tests (NEMA 12 — 64 tests; 210 w/reds — 80 tests)***

This group tests the commonly available extended features offered by most monitor manufacturers. The operator can select from the following test selections:

Short Yellow Clearance	Dual Display (R/G)	Dual Display (R/Y)
Dual Display (G/Y)	Dual Display (R open/G)**	Watchdog*
Latching CVM Fault	Latching DC1 & DC2 Faults	Dark Signal Head*

*for NEMA monitors only
**for 210/220 monitors only
***number of tests

DVP, Inc.

The DVP Inductive Loop Tester (ILT) II uses digital signal processing and sampled data techniques to quickly diagnose faulty inductive loop detector systems; it can also be used in acceptance testing of new inductive loop installations and for preventive maintenance.

Failures of inductive loops can be caused by a variety of problems. The loop windings may become shorted from work or stressed insulation or may break or short to ground. Connectors to the loop may corrode, or the loop wire itself may deteriorate or break. The lead-in wires may become damaged through corrosion. Any number of failures may eventually occur through the hostile environment, road modifications, or deterioration over time. These failures, though relatively infrequent, will eventually occur. For this reason, reliable test equipment is required for routine maintenance to detect failing or failed loop circuits.

This portable, handheld instrument (See Figure II-53) has a measurement accuracy of 0.02 percent because of a unique digital signal processing technique for making measurements and displaying and interpreting the results. The instrument can measure loop inductance, percent change of inductance, i.e. sensitivity , pulse duration (time of response), quality factor (a measure of efficiency), and resistance, and do so at frequencies from 10 to 100 KHz, thereby covering the operating frequency range of all commercial loop detector electronics. The instrument can also measure the operating frequency of the loop and its detector electronics after they have been connected together—something that has not been possible before. The capability to measure the inductance change caused by a variety of vehicles (such as bicycles or high-bed trucks) as they cross the loop allows the required sensitivity of the detector to be accurately adjusted.

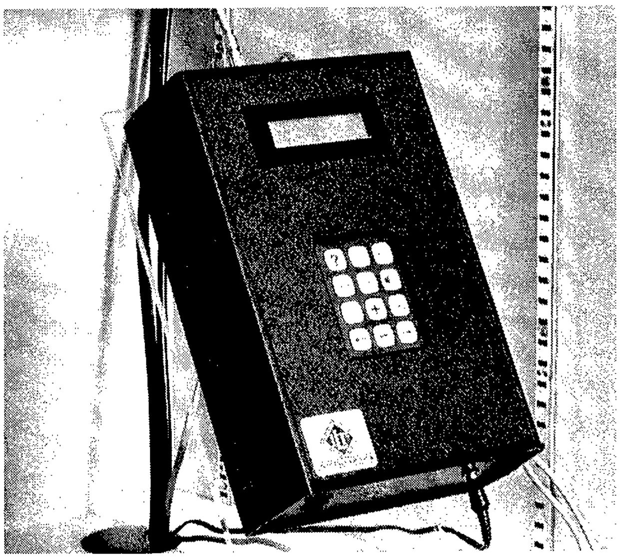


Figure II-53. DVP ILT II Loop Tester

SETCON Traffic Control Equipment Testers

SETCON has three testing devices included in this workshop. These devices are: 1) a NT12 NEMA Controller tester, 2) a Model 435B Load Switch Analyzer and 3) a Model 448 Deteck Remote Monitor. The following is a description of each of these devices.

NT-12 Advanced NEMA Controller Unit Manual Tester: The NT-12 (see Figure II-54 offers the signal technician one of the most effective tools he can get to evaluate the operation of NEMA Extended Function controllers. It enables him to simulate any controller function at his command thus expediting trouble shooting. While he is more likely to make a comprehensive check of a controller in the shop, the portability of the NT-12 permits conducting the same procedures in the field.

With the NT-12's "Extended Functions" section, connection can be made to a wide variety of NEMA controllers with a "4th Connector." It provides selectable access to the controllers 4th connector pins, which include such features as additional overlaps, standard and special pre-emption features, system coordination functions, local coordination, master coordination functions, and local/master download functions. Other features of the NT-12 unit include:

- The Extended Functions section has 36 switches, 32 LED indicators, a cycle generator and 2 adapter connectors (D and E). Each may be selected and connected to any pin in the 4th connector. Adapter cables route the Extended Function switch of LED to the desired pin.

- Overlay templates are available with special labeling to match different controller models. The Plastic template sheets are designed to fit over the Extended Function switches and LED's. The Controller functions can be labeled to order or with a felt tip marking device.

- A power line interrupt test feature, adjustable from 0.1 to 1.1 seconds, verifies that the controller responds correctly to short power interruptions.

- Switch commons are isolated and selectable by row. They may use mixed voltages (AC & logic ground) on the same controller if required. Row 1, 2, 3, 4 and 5-9 are isolated and accessible thru the D connector. For example: Row 1 may be connected to cycle generator normally closed (NC) contacts to provide sync on the offset inputs to the controller while the other switches are returned to ground.

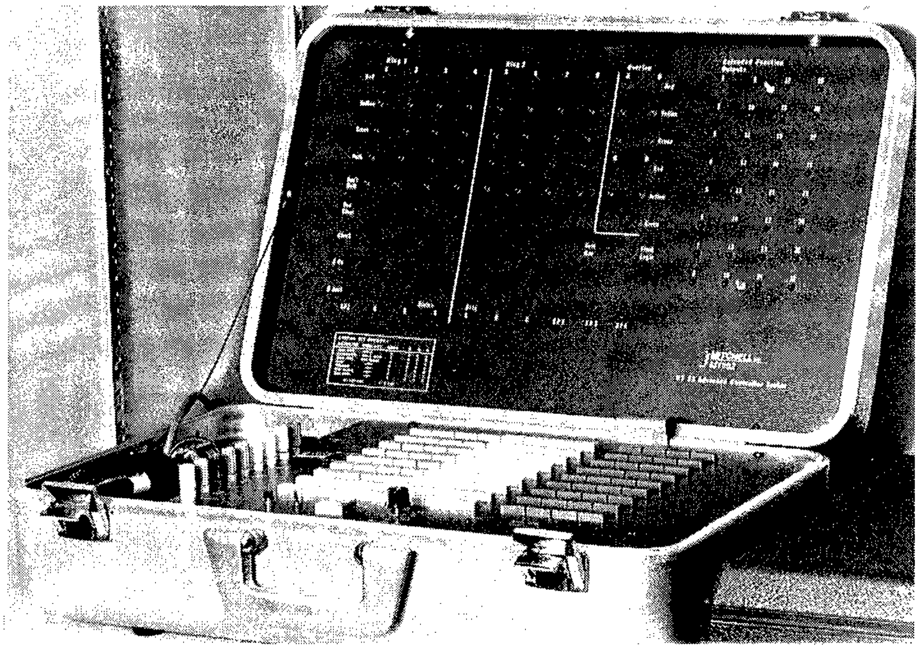


Figure II-54. Setcon NT-12 NEMA Controller Unit Manual Tester

- A cycle generator is provided so the controller can be "synched" to an external source or to provide a simple system detector test input. Two outputs are available: isolated relay contacts and logic level. The outputs are available on connector D. An LCD panel display shows elapsed cycle time. The standard display is phase oriented. The tester has its own display power supply, no controller power is required.

The NT-12 is supplied in a conveniently sized aluminum carrying case. Lightweight and portable, it is an efficient tool for both bench and intersection control test and repair.

Inputs:

Per Controller	Per Ring	Per Phase
Call to Non Act 1 & 2	Max Inhibit	Veh Det
Test A & B	StopTime	Ped Det
Minimum Recall	Force Off	Hold
Walk Rest Modifier	Red Rest	Phase Omit
Manual Advance	Omit All Red	Ped Omit
Manual Control Enable	Ped Recycle	
Lamps Off	Max 2	
External Start		

Outputs:

Flashing Logic	Status Bits	Red, Yellow, Green
Voltage Monitor		Walk, Don't Walk
Overlap A, B, C, D		Phase On
Red, Yellow, Green		Phase Next
		Phase Check

Power Interrupt Test:

Adjustable from 0.1 to 1.1 seconds

Cycle Generator:

0 to 499 sec count up timer, with LCD cycle count display
Sync pulse 2 sec.
Cycle on/off switch
Display latch switch (freeze count)
Solid state output
Isolated relay output (NO and NC contacts)

Test Points:

Neutral
Com Line
Sync In
Sync Out
24 V: (contr. 24 volts)

<u>Setcon Model 435B Load Switch Analyzer:</u>

Loadswitches, flashers and transfer relays can be conveniently checked on the model 435B Load Switch Analyzer. The test is initiated by inserting a device into the appropriate connector provided on the panel. A four scale meter with ranges of 0-30 volts DC, 0-30 ma DC, 0-10 and 0-50 ma AC is provided to monitor voltage and current. (See Figure II-55, page II-122.)

A flasher when inserted in its receptacle runs continuously and the AC output current is monitored. When a transfer relay is under test its contacts are checked for continuity and the AC output current is monitored.

Of the three devices the 435B checks, the load switch is the most sophisticated and is really what the analyzer is geared to test. In the AUTOSCAN mode, the 435B sequentially tests each of the load switch output circuits. It tests for proper turn on of the active circuit and tests for excessive current in all circuits. Readings are taken once per minute to check for leakage current. Scanning tests may be run on one circuit for long periods of time or you may sequence all three circuits.

The load switch circuits are individually tested in the manual mode. The sequencing time is 2, 4, 8, or 16 minutes/step. There is a green, yellow and red indicator for each circuit plus a flashing fault indicator. When a fault is detected the 435B will latch the fault condition, stop the sequencing process and disconnect the 10 amp load. Following a fault detection, it is necessary to manually reset the analyzer before proceeding. With the LED indicators, the panel meter and fault indicator, specific problems are quickly identified.

The procedures may also be done in the manual model and stepped through at the operators desired rate.

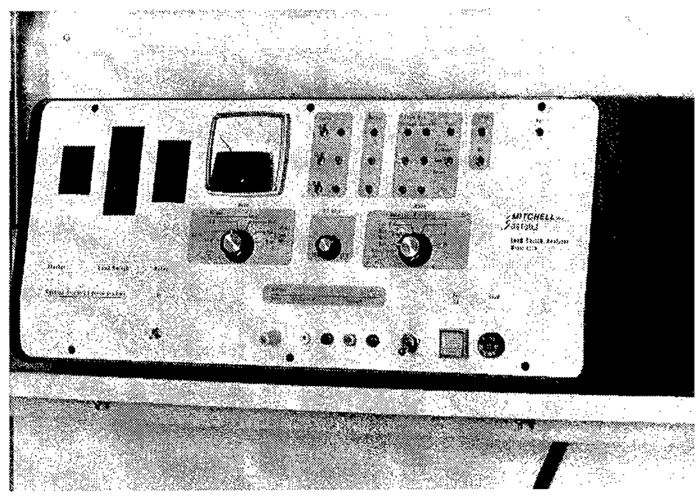


Figure II-55. Setcon Model 435B Load Switch Analyzer

<u>SETCON Model 448 Detek Monitor</u>: The Model 448 Deteck is a portable two piece short range transmitter/receiver pair (see Figure II-56). A base unit is connected to a preselected circuit in the controller cabinet, i.e. across the output terminals of the detector, via a pair of leads. The 448 Detek takes the 24 volt inputs to the controller from the detectors and converts them into a transmitted audio-signal which is received by the handheld unit. When a vehicle passes over a loop, it causes a contact closure thus generating a tone in the remote handset unit. The technician can be located up to 1200 feet

away. The tone information is transmitted on channel A thru E of the 49 megacycle band with limited power. No license is required. The transmitter/receiver pair meet FCC rules.

The handset is powered by a standard 9 volts Drycell Battery which will provide 30 hours or operation. The model 448 Detek can operate on circuits up to 120 volts AC or DC.

The transmitter is powered by 8 each AA Nicad Rechargeable Batteries. Since the transmitter is only ON during transmission the batteries are estimated to last several months before recharging.

Both the transmitter and handset have low battery indicator lights.

Features:

- Single Person operation.
- Locates detectors quickly.
- Battery operated.
- 1200 foot range.
- Works on both AC & DC contacts.
- High impact ABS plastic carrying case.
- Convenient lightweight portable size.
- Complies with FCC rules.
- Low battery indicator on both transmitter and receiver.
- Locking type test points on transmitter.
- Can be used to verify many other remote contact closure applications.

Benefits:

- Permits the technician to be in close proximity to the detection loops which are being checked.
- Permits one person, using a distance wheel, to completely "map" all loop locations and distances.
- One person can check detection on a lightly traveled direction or turn since he candrive the intersection himself using the 448's remote unit.
- Heavily traveled intersections can be quickly checked using the Model 448 utilizing the traffic itself as an actuation medium.

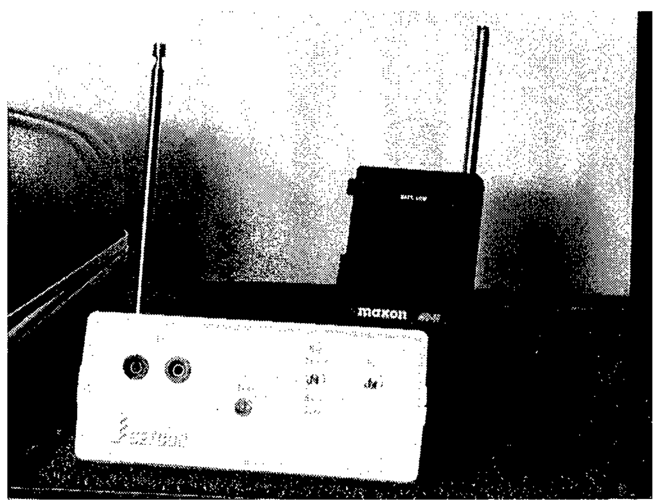


Figure II-56. Model 448 Detek Monitor

EBERLE DESIGN, INC.

EDI MT-1 NEMA Tester

EDI's testing equipment include the MT-1 NEMA Type monitor tester. (See Figure II-57.) This tester is displayed in the trailer jointly with the Eberle Design SSM-LE Conflict/Voltage monitor. Generally, the MT-1 tester is used for testing Type 3, 6, and 12 channel signal monitors. Tests can be conducted manually by selecting and pressing the proper bottoms or toggle switches on the front panel.

Features:

- Rugged field-oriented enclosure
- Tests all input levels of NEMA standards
- Separate voltage level vairacs for AC + power to monitor, AC + to Red inputs, AC + to Green, Yellow and Walk inputs
- Built-in AC voltmeter for setting variac output levels
- Provisions for external meter
- Full and half wave (positive and negative) test capability for Green, Yellow and Walk inputs
- 450 msec and 500 msec power interrupt test
- Monitor unit output indicators
- External reset

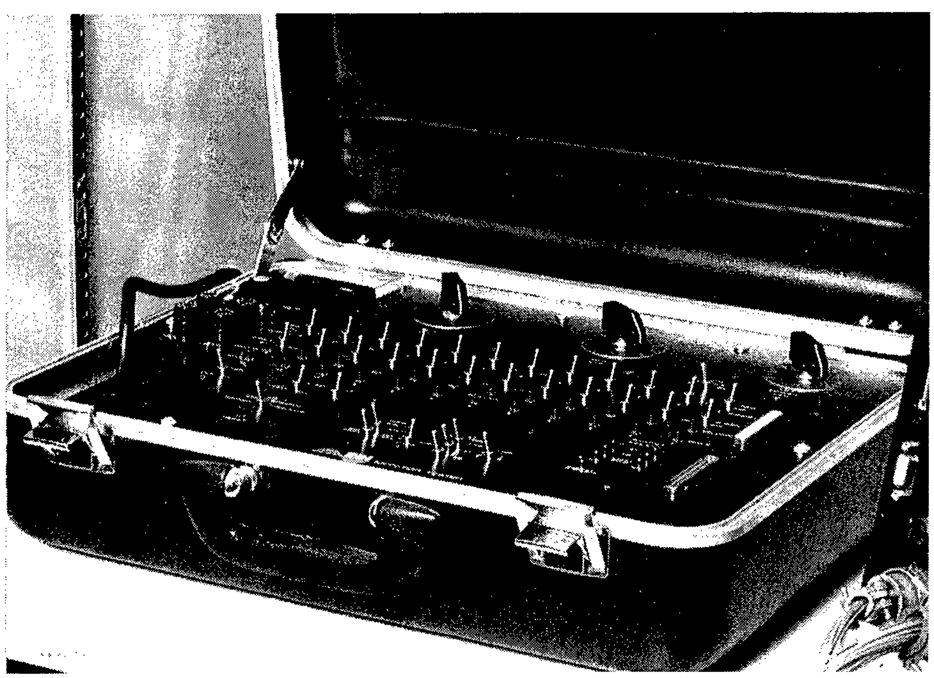


Figure II-57. MT-1 Series NEMA Type Monitor Manual Tester

Solid State Devices

Traffic Monitor Tester: The MT 180 Automatic Traffic Monitor Tester (see Figure II-58) provides complete testing, either on the bench or at the intersection, of traffic signal monitors; results of tests can be printed for a complete testing and performance report. The following test sequences are available with the MT-180:

Table II-8. Solid State Devices Automatic Traffic Monitor Tester: Test Sequence.

NEMA Monitors		170 Monitors
Start-up Delay	Capacitor Test	Fault Relay
Fault Relay	25 V Full Wave	24 Volt Test
CVM	25 V Positive Half Wave	50. mS power outage
24 Volt I	25 V Negative Half Wave	Ground Isolation
24 Volt II	Channel to Channel Conflict	AC off to Fault Time
24 Volt Inhibit	Walk Only	Conflict Retained After Power Outage
500 ms power outage	Green - Yellow Switch Failure	System 170 AC+ Voltage Thresholds
450 ms power outage	Green - Red Switch Failure	Watchdog
Ground Isolation	Yellow - Red Switch Failure	Red Enable
AC off to Fault Time	Short Yellow	50V Red
Conflict Retained After Power Outage	Green - Yellow Conflicts	70V Red
Red Fail Retained After Power Outage	Green - Walk Conflicts	15V Full Wave
Red Enable	Yellow - Walk Conflicts	15V Positive Half Wave
50V Red	Yellow - Yellow Conflicts	15V Negative Half Wave
70V Red	Walk - Walk Conflicts	25V Full Wave
15V Full Wave	Permissives	25V Positive Half Wave
15V Positive Half Wave		25V Negative Half Wave
15V Negative Half Wave		Channel to Channel Conflicts
		Green-Yellow Switch Failure
		Green-Red Switch Failure
		Yellow-Red Switch Failure
		Short Yellow
		Green-Yellow Conflicts
		Yellow-Yellow Conflicts
		Permissive Card Test

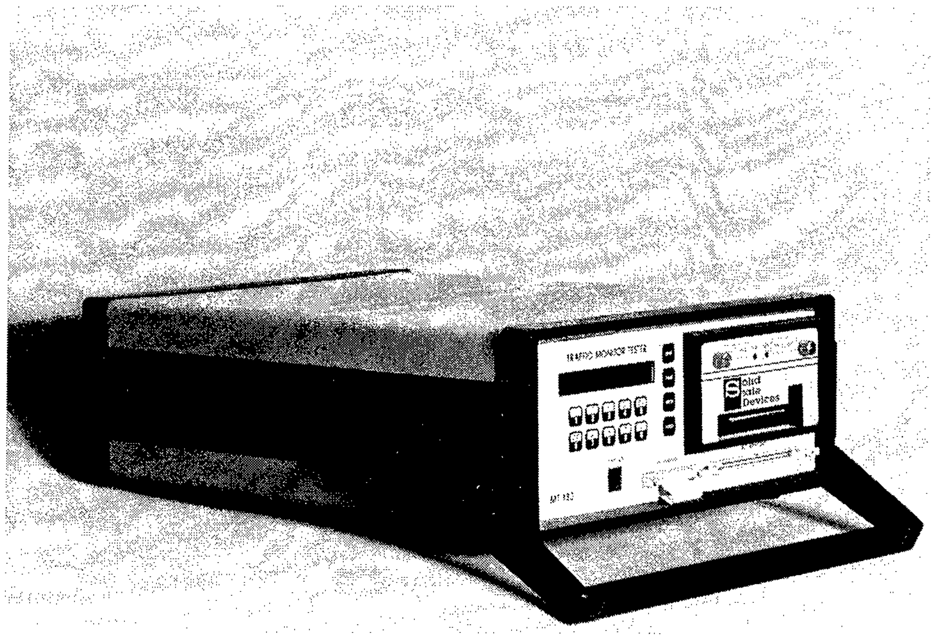


Figure II-58. Model MT 180 Monitor Tester

MT 180 Features:

- Built-in power supply
- LCD screen
- Not load dependent
- Microprocessor based
- Does not have to be turned off before changing monitors
- Menu driven
- Plus test is an intregal part of test problem
- Time all test included in program
- Internal printer, no need to carry large printer to field
- Can run single test
- Performs brownout testing
- Keyboard input for serial #, Operator ID, Site Location
- CALTRANS approved
- Complete NEMA or 170 test

UNINTERRUPTED POWER SUPPLY DEVICES/TRANSIENT SUPPRESSION DEVICES

Traffic signal systems are vulnerable to a wide range of power disturbance, i.e. voltage spikes, electrical noise, overloading, brownouts, etc.). To circumvent some of these problems, NEMA TS1 has developed standards for power distribution and overload protection (Section 10 Terminals and Facilities). Highlights of the standards include:

- The Grounding System consists of three part as follows
  - The neutral bus, to which all neutral conductors are connected.
  - The ground bus, to which all equipment grounds are connected and which is then connected to the ground rod.
  - The logic common bus, which is the zero voltage reference point needed for the actuation of a ground true input.

- Circuit Breakers shall include a main breaker to protect the controller and signals and an auxiliary breaker to serve the convenience outlet and cabinet light fixture.

- Overvoltage and Lighting Protection, devices shall be installed to limit the means of ingress or potentially damaging overvoltage spikes or lightning strikes.

- A Mercury Contactor, which is a heavy duty relay for controller unit power to the signal bus, which, in turn, supplies the load switches with power.

With Model 170, lighting protection and noise suppression is also considered.

One of the major features of the Model 170 system is the isolation of all inputs and outputs between the controller unit and the field. All inputs, such as detectors or pedestrian pushbuttons are routed through isolating devices in the input file. Similarly, all outputs run through loadswitches in the output file. By providing this isolation, the sensitive components of the controller unit are protected from lightning or noise intrusion. Incoming power lines are protected from lightning or surges by a gas tube type protector, as well as a pair of Metal Oxide Varistors (MOV's).

NEMA standards and Model 170 systems as shown above offer some protection from lighting and noise suppression but only for mild conditions. Where Lightning is a serious problem such as the case in the southeastern region of the United States then additional protection should be required. Uninterrupted Power Supply (UPS) equipment and transient suppression devices can mitigate serious lightning and electrical noise suppression problems which are beyond the capability of standard NEMA or Model 170 systems.

The following section describes at least one of the most widely used UPS equipment, i.e. LECTRO Product and several noise suppression and filtering devices manufactured by EDCO, Inc.

LECTRO Lightsaver Uninterruptable Power Supply (UPS)

Description: Lightsaver is an on-line uninterruptable power supply (UPS) which produces no-glitch, true sine wave 120 VAC standby power in case of AC power failures or severe brownouts. Its primary purpose is to keep traffic moving through power failures, thus reducing safety hazards to motorists and reducing legal liability to municipalities. It also conditions normal AC power by producing a true sine wave 120 V output over the entire NEMA range from 95 V to 135 V and suppresses spikes and surges caused by lightning and switching transients, thus reducing equipment failures and false trips of the CMU.

Operating Modes: Lightsaver operates in two modes, i.e. normal line and stand-by operation.

Normal line operation: The heart of the LightSaver circuit is a ferroresonant transformer, which isolates the input from the output and passes through a clean, voltage-regulated 60 Hz sine wave. During normal operation with utility power, any spikes or transients are attenuated by a factor of 1000:1, thus eliminating problems due to noise on the power line. The output voltage is regulated to 120 V +3% for utility voltages from 95 to 135 V, thus providing both brownout and overvoltage protection.

While operating from utility power, LightSaver recharges its batteries after each usage at the maximum safe current to minimize recharge time. It then maintains a temperature-controlled float voltage at minimum current to maximize battery life.

Standby Operation: Should the utility voltage fall below 95 V or drop out altogether, an invertor starts in about one-quarter cycle (4 ms) to maintain continued output power to the traffic system using battery power. Synchronizing circuits assure that the invertor comes on in-phase with the last utility power cycle, and a crystal oscillator maintains a constant 60 Hz line frequency during standby operation.

When the utility voltage returns to the restart level, a programmable restart delay assures that the line voltage has stabilized before returning LightSaver to normal line operation. During this delay, the invertor phase is synchronized with the utility line to avoid any disturbance when the transformer is reconnected to the line and the invertor is switched off.

Three standby operating modes are programmable by plug-in jumpers:

Flash mode standby: Here the intersection operates in Uniform Code Flashing (UCF) mode for approximately 30 minutes, upon going to standby. This mode maximizes the battery operating time by minimizing the number of lights that are on at the same time.

Reduced load standby: The intersection operates on full load for a board-programmable period of time (0 to 18 minutes), then in UCF mode. This mixed mode provides a median battery operating time.

Full standby: The intersection operates on full load for almost twenty to thirty minutes until the Low Battery Point is reached. It then operates in the UCF mode for 1 minute before shutdown. This mode provides the longest normal traffic control.

Physically, LightSaver consists of an electronics cabinet, which houses a ferroresonant transformer and the electronics, and a battery cabinet, which houses 12 V gel-cell batteries. (See Figure II-59, page II-129.) Mounting kits are available so that these two cabinets can be attached to the outside of an existing controller cabinet, be mounted on their own concrete pad, or be attached to a utility pole.

Electronics cabinets are available in versions rated 5 KVA, 3 KVA (25 A at 120 V) and 2 KVA (16.7 A at 120 V). The 3 KVA unit will handle most 8-phase intersections, but it is wise to measure actual current draw with a clamp-on ammeter. The 2 KVA unit is recommended for smaller intersections and for lane-control signals. Battery cabinets are available for 4 or 8 gel-cell batteries. At the full 25 A, 120 V output of the 3 KVA unit, the nominal duration of standby power is 30 minutes with 4 batteries and 60 minutes with 8 batteries. For currents less than 25 A, multiply these times by 25/I.

Technical Features: The LightSaver is suitable for outdoor traffic control application and differentiate it from conventional standby and UPS power systems.

Outdoor Rated: The LightSaver cabinet is gasketed for outdoor installation and meets NEMA specifications for operating temperature, humidity and utility voltage. The aluminum cabinets are corrosion resistant and rugged. The wall thickness is 0.190" for the housing and 0.125" for the door.

NEMA-Level Signals: All input/output signals meet NEMA specifications. Standard signals are Phase 2 and Phase 6 inputs, Standby Mode output and Uniform Code Flash (UCF) output. Thirteen additional optically-isolated NEMA outputs are available through an optional Status Monitor Board to allow comprehensive remote diagnostics. Ten LED diagnostic lamps are standard. (Phase 2 and Phase 6 green, low battery, restart delay, normal, standby, overload, check battery, current limit, float voltage, and charge.)

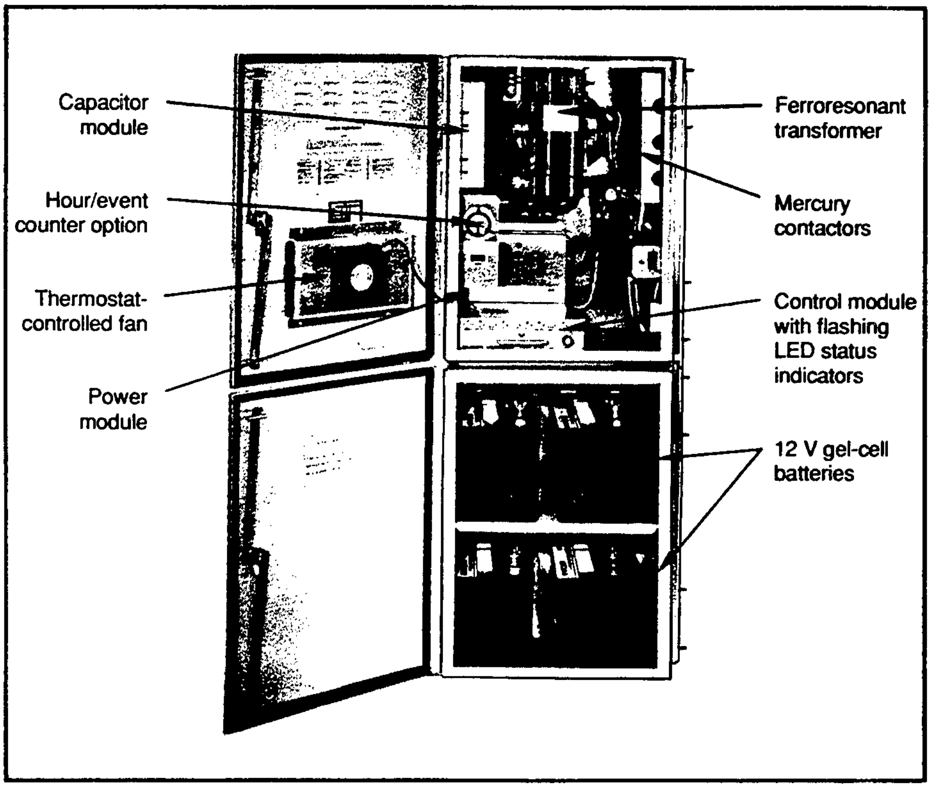


Figure II-59. LECTRO Lightsaver UPS

UPS & Standby: The invertor of LightSaver is only energized when needed for standby operation. This provides longer component life and higher power efficiency than conventional UPS systems, where the invertor is always on line. A proprietary 60 Hz synchronizing circuit allows the transfer to standby without the use of a transfer relay. This avoids the time-outs and switching transients associated with standby systems.

Gel-Cell Batteries: LightSaver uses state-of-the-art, long-life, 100 AH, deep-cycle gel-cell batteries, which are totally maintenance-free and are guaranteed not to leak, spill or stratify in stationary applications. The batteries trickle charge during normal operatin from utility power lines.

Fail-Safe Provision: In the event that the ferroresonant transformer or the electronics should fail, LightSaver automatically defaults to a fail-safe mode, connecting the traffic system to utility power. This is accomplished by de-energizing three fail-safe relays. The transfer to fail-safe takes less than 400 ms, so that all controllers meeting the NEMA TS1 or TS2 standards will continue to operate as though no power interruption had occurred.

Possible Applications: The following is a list of candidate applications of the Lectro Lightsaver UPS:

- Geographical areas which are subject to frequent lightning storms and power interruptions.
- Geographical areas with electrically-noisy electrical power and brownouts.
- Critical intersections, such as urban intersections which control the access to a bridge or tunnel, where a power failure would cause massive traffic tie-ups.

- Intersections with preemption, which are near a fire station or on the usual path of emergency vehicles.

- Intersections at railroad crossings, where signals are used to protect motorists from the path of onrushing trains. Such signals may include NO RIGHT TURN and NO LEFT TURN blankout signs.

- Overhead lane-control signals, where a power failure could lead to head-on collisions.

- Illuminated warning signs at hazardous locations, such as main flashing RED SIGNAL AHEAD diamond sign preceding a blind intersection.

- Illuminated signs which direct motorists at complex intersections.

- Variable Message Signs which warn motorists of emergencies and hazardous traffic conditions.

- Reversible one-way detours, bridges and tunnels, where the motorist cannot see the other entrance. The detour may be at a temporary construction site with frequent power interruptions, and the LightSaver system may be portable.

- Intersections with a system master which controls and arterial or network, as the loss of the master would cause loss of communications within the entire system.

- Intersections at remote locations, where a field service call would be expensive.

SUPPRESSION EQUIPMENT

EDCO Transient Surge Protection Equipment

For Traffic Control Systems EDCO's products include protection devices for vehicle loop detectors, signal cables, Model 170 Traffic Controller Cabinets, NEMA Traffic Controller Cabinets, communication cables, AC Service, etc. The following is a description of some of these surge protection devices.

EDCO SRA-6LCA Series: The SRA-6LCA is a three-terminal vehicle loop detector surge protector device, two of which are connected across the signal inputs of the detector for differential mode protection, and the third terminal is grounded to protect against common mode damage. All three terminals are connected inside the cabinet.

Features:

- Lightning protection for vehicle loop detectors
- Differential and common mode surge protection
- Designed for digital detectors
- Automatic recovery
- Epoxy encapsulated
- Installs easily

EDCO SRA-6LC: The SRA-6LC is also a vehicle loop detector surge protector. It is installed as close as practical to the point where the detector loop wires enter the controller cabinet. Best performance is by shortening the flexible leads as much as possible, and providing the lowest possible impedance to ground. Use one SRA-6LC unit for each loop detector to be protected.

Features: (Same as SRA-6LCA.)

EDCO SHP300-10: The SHP300-10 is a hybrid suppressor. It is designed to provide surge protection for alternate current (AC). The SHP 300-10 meets NEMA Transient specifications. The maximum clamp voltage of the protector maximum (even at 20KA) is under 350 volts, which provides nearly a 50% safety margin when coordinated with NEMA TS1.

Features:

- Nanosecond response
- Maximum clamp voltage 340V
- Blocks high speed transients
- Remove high energy surges
- Incorporates series choke
- 120 VAC single phase

EDCO SHA-1210: The SHA1210 is a filtering hybrid surge suppressor. It absorbs power line noise and switching transients that other suppressors and RFI filters pass through. In addition, this unit offers better lightning protection than the standard SHA-1201. The SHA-1201 can replace the RFI filter when high attenuation of noise above 25 MHz is not required. The SHA-1210 is an AC service protector and it is specifically designed for Model 170 Traffic Controller cabinets. The performance level is similar to the popular ACP-340 unit, which is used on NEMA cabinets.

EDCO 1201 Series: The SHA-1201 is specifically designed for Model 170 Traffic Controller cabinets that require power neutral to remain isolated from cabinet earth ground. Protection is provided both between phase to neutral, and neutral to ground.

Features:

- No follow current
- 40 nanosecond response time
- Automatic recovery
- 120 VAC, 60 amp service
- Epoxy encapsulated

EDCO PC-642 Series: The PC-642 model is a plug-in surge protector designed to protect data communication cables/systems from transient suppression. PC-642 surge protectors are dual pair (four wire) modules with PC8 connector. It incorporates hybrid suppression technology. One unit can be used for 4-independent signal lines or two independent signal pairs.

Features:

- Multi-stage protection
- Lightning protection for low voltage signal lines
- Differential protection
- Common mode protection
- Low capacitance option
- Plug-in module
- Automatic recovery
- Fast response time, < 1 ns.

EDCO ACP 340: ACP 340 is a filtering surge protector used with NEMA Controllers to absorb power line noise and switching transients that other suppressors and RFI filters pass through. The ACP 340 surge protector helps eliminate memory loss in NEMA controllers.

ACP 340 offers better lightning protection than standard protection devices and can replace the RFI filter when high attenuation of noise above 25 Mhz is not required.

EDCO SPA-60B Series: The SPA-60B is an economical method of protecting circuitry associated with 120 VAC interconnect signal line commonly used in traffic control systems.

Features:

- Reduces costly damage to electrical/electronic equipment
- Clamps overvoltage surges caused by lightning or switching transients
- Responds in nanoseconds
- Automatically recovers after surge is dissipated
- Very economical
- Ideal for 120 VAC interconnect
- Handles repeated surges

SIMEON

CPM + 2 Surge Protector: This device, consisting of two high speed fuses in a clear plastic envelope, clamps on directly to Bell 66 terminals. One fuse is fast acting; however, it is inappropriate for AC lines. These low cost devices are ideal for low voltage communication lines. This device is superior to encapsulated suppressor since the clear housing shows when blown, unlike the failed hybrid suppressor.

CHAPTER III — TRAFFIC CONTROL SYSTEM COMMUNICATION TECHNIQUES

Communication is the transfer of information from one location (the source or transmitter) to another location (the destination or receiver). See Figure III-1. The path over which the information flows from transmitter to receiver is called the transmission link or channel. The make-up of the transmission link is known as the communications medium, and may consist of a physical connection (waveguide) or air-path.

Information about the communications theory, principles of operation, network configuration, transmission characteristics, and communication hardware is well covered in the FHWA "Communications Handbook for Traffic Control Systems." This section includes only definitions of terms and concepts of communication media that are commonly used with traffic control systems. For more details on specific subjects, refer to the aforementioned publication.

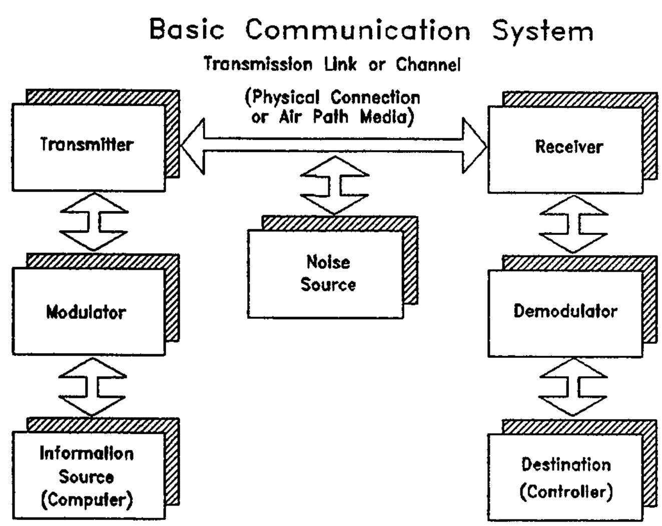


Figure III-1. Basic Communication Transmission in Traffic Control Systems

DEFINITION OF TERMS

Electronic Communications: is the type of communication systems whereby the signal is transmitted over the channel as electrical energy and propagated in the form of a sinusoidal wave.

Wave Length: is the distance between successive peaks of the energy wave.

Frequency: is the number of cycles per second measured in Hertz (Hz). One Hz equals to 1 cycle per second.

Speed of Wave: This speed varies with the transmission medium. In free space the wave travels at a speed of light, i.e., 300 million meters per second.

Amplitude: is the strength of the carrier wave.

Transmission Link: is defined as the path over which the information flows from a transmitter to a receiver.

Channel: Same as a transmission link.

Medium: is the make-up of the Transmission Link; could be air path or a physical connection such as twisted pair.

Simplex Transmission: is the flow of information in only one direction (e.g. commercial radio and television broadcasts)

Half-Duplex Transmission: is the flow of information in either direction, but the link operates in only one direction in a given time frame (e.g. C.B. radio).

Full-Duplex Transmission: is the flow of information in both direction simultaneously.

Microwave Link: is a link that utilizes frequencies greater than one gigahertz, i.e. a billion hertz.

Bandwidth: is the information — carrying capacity of a transmission link.

Attenuation: is defined as the degradation of the signal transmitted; measured as a ratio of the received signal strength to the transmitted signal strength.

Voice Grade Channel: is a channel that transmits human voice data at frequencies between 300 and 3000 Hz — provides the easiest recognition of human voice.

Video Channel: is a channel that is used to surveillance images such as for closed circuit television (CCTV). Video channels usually operate at frequencies of 6MHz for inbound videos such as from field cameras to television monitors at central. Outbound data channels operate at smaller frequencies since no full-motion video is required.

Data Channel: is a channel that used to provide telecommunication of control commands and monitoring information between the central computer and various field hardware and/or remote peripherals.

Digital Communications: is the type of communication systems that utilize discontinuous signals; information is carried in patterns of discrete binary digits (bits) which have a value of 0 or 10.

Byte: is a word of data, consisting of 8 consecutive bits.

Asynchronous Transmission: is a serial data transmission format whereby the signal is held at a constant level or state until the data are to be sent.

Synchronous Transmission: is a serial data transmission format whereby long strings of bits are transmitted in succession — one sync character is sent at a time.

Modulation: is the process by which the binary digital information is superimposed on the sinusoidal wave form of the carrier wave.

Amplitude Modulation (AM): is the type of modulation which changes the strength of the carrier wave, using a signal of larger amplitude to represent the 1 condition and a signal of lesser amplitude to represent the 0 condition.

Frequency Modulation (FM): is the type of modulation that uses a center frequency that is shifted to a higher frequency to represent one, and a lower frequency to represent zero.

Frequency Shift Keying (FSK): is the digital frequency modulation (FM) — most commonly used method for transmitting digital data in traffic control systems.

Phase Modulation (PM): is the type of modulation that varies the phase of the carrier wave relative to a constant-phase reference signal. PM is known as phase shift keying (PSK) — used for high speed transmission.

Noise: is any unwanted form of energy caused by an external source, e.g. power line splices, lightning.

Interface: is distortion created within the communication system itself, e.g. cross-talk.

Throughput: is defined as the capacity of the channel, measured in bits per second (bps). Throughput is made of the data being transmitted and the overhead which is all of the necessary addressing, synchronization, and error detection bits.

Data Communication Equipment (DCE): is the communication hardware that provides the interface between the traffic control equipment and the communications media, e.g., modems, remote communication units and front end processors.

Data Terminal Equipment: is the traffic control equipment connected to the DCE, e.g., signal controllers, central master computer and remote computers.

Modem: is a device that serves as the interface between the computer and the transmission link, and between the field hardware and the transmission link to modulate and demodulate the transmitted and receiving signal, respectively.

Radio Frequency (RF) Modem: used for transmitting data at radio frequencies over a media such as coaxial cable — capable of supporting very high data rates.

Amplifier: is a device used to improve the transmission quality of systems that require communications over long distances — used often with cable television or leased telephone systems. Amplifiers receive the incoming transmission and retransmit it at a higher power level.

Repeater: is a device used for the purpose of regenerating the signal being transmitted — generally consist of a modem and a microprocessor; used frequently with fiberoptic systems.

Multiplexing: is a communication technique which allows information to be transmitted between multiple sources and/or destinations — it ensures that the data transmitted over the common medium reaches the intended device.

Frequency Division Multiplexing (FDM): is a multiplexing technique which breaks the total available bandwidth into a series of channels, each of which occupies a portion of the band and acts as a separate and independent communication path between the transmitter and receiver.

FDM is used with coaxial networks because of its compatibility with the transmission of TV channels and data channels on the same cable.

Time Division Multiplexing (TDM): is a multiplexing technique which divides the total available time on the communication medium into discrete segments or time slots. Each device attached to the communications medium is assigned a specific time slot for the transmission of its data — commonly used with UTCS systems whereby the central master computer controls all communications (centralized system architecture).

Polling: is a centralized communication process initiated at the central master computer. The master transmits a message to a specific controller and the addressed controller receives the transmission and provides an appropriate response. The computer performs this process sequentially, polling each controller in turn for its response at a specified rate, e.g. once per second.

Bit Rate: is the measure in bits per second (bps) of the digital information being transmitted and received.

Baud Rate: is the rate at which the actual traffic control data bits are transmitted.

Twisted Pair Cable: consists of individually insulated copper wires twisted in a figure 8 pattern into pairs and combined into a shielded cable; it is available in standard pairs 6, 12, 18, 25, 50, 75, ... etc.

Coaxial Cable: consists of a center conductor within an outer cylindrical conductor, separated by a dielectric material. The center conductor is typically copper clad aluminum. The dielectric may be either a gas or a solid.

Fiberoptic Cable: is a very thin cylinder of glass which has very low attenuation properties at certain infrared frequencies. A fiber optic cable is constructed of two concentric cylinders: inner section (core) and outer section (cladding).

Radio Communications: is transmission of radio frequency (RF) electromagnetic energy through space.

ALTERNATIVE COMMUNICATION SYSTEM CONFIGURATIONS

Two basic communication configurations are commonly used in Traffic Control Systems: 1) centralized system with direct computer control of all field hardware, and 2) distributed system.

Centralized system: In this system, the central computer performs all processing functions required for system control and processing. The local hardware performs only simple load switching and minor timing logic. For this system configuration, vehicle detectors transmit data detector information and, if it is in a traffic responsive mode of operation, selects an appropriate timing pattern for use by the traffic signal and/or ramp meter controllers. This timing information is transmitted to the controllers as once-per-second control commands (e.g. HOLD, FORCE-OFF, YIELD, FLASH, etc.) The controller, in turn, transmits its current state (e.g., phase green, preempt, ramp signal status, etc.) once every second. The computer processes this information to verify that the field components are functioning properly in response to the transmitted commands. An example of this type of central system is a typical UTCS traffic signal system.

Distributed system: In a distributed system, the processing functions are significantly removed from the central computer such that it is used primarily as a clearing-house for system information, operator interface, and display functions. The local field hardware possess intelligence and are coordinated by a series of field-located zonal processors. These zonal processors, or field masters, perform monitoring and surveillance functions, and communicate with the local field hardware in a manner similar to the central system with downloading and uploading. The zonal processors communicate preprocessed data to and from the central processor on an as-needed basis. An example of this system configuration is a distributed master (closed-loop) and hybrid signal system.

NETWORK CONFIGURATIONS

Networks can be organized in three different configurations:

- Point-to-Point
- Point-to-Multipoint
- Daisy-chain/closed loop

Point-to-Point Network: In a point-to-point (Figure III-2), a separate transmission link is provided between the central facility and each field location. For every link there is one transmitter and one receiver. A special application of point-to-point is trunking. A trunk is distinguished by the large amounts of data transmitted between the source and the destination, and the fact that there are no drops between them. An example would be a transmission link connecting the central computer with a remote area computer. (The area computer, in turn, might serve a local distribution network consisting of multiple field drops connected to the area computer.)

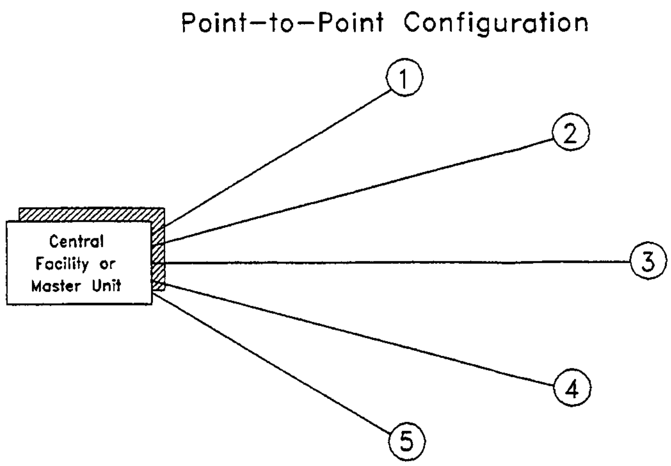


Figure III-2. Point-to-Point Configuration

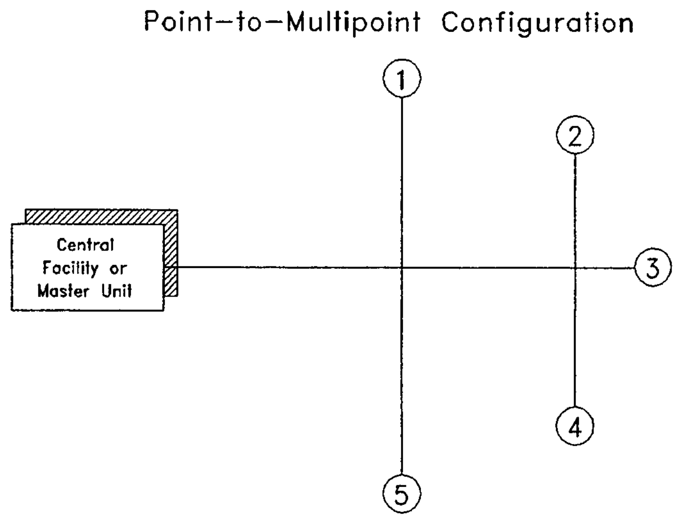


Figure III-3. Point-to-Multipoint Configuration

Point-to-Multipoint Network: In very large communication networks, point-to-point can result in an untenable number of cables being returned to the central facility and a corresponding increase in costs. One alternative is a point-to-multipoint scheme as shown in Figure III-3. Point-to-multipoint combines two or more receivers on the same transmission link, thereby reducing the total number of channels in the system. Because of the presence of multiple receivers on the same channel, a method is necessary for establishing communication between the information source and the proper receiver; this is accomplished through multiplexing.

Daisy-chain network: Another alternative is to interconnect the various drops with a series of point-to-point links. This "daisy-chain" configuration is shown in Figure III-4. The information is received by the first location, which demodulates the signal for its use, and then remodulates the signal and transmits the information to the second location; and so forth. A potential problem with a daisy-chain configuration is that a communication failure at one location will disrupt all succeeding transmissions to the remaining locations in the network. To minimize this problem, a ring configuration is often employed such that communications can occur in either direction of the loop, thereby circumventing the failed location.

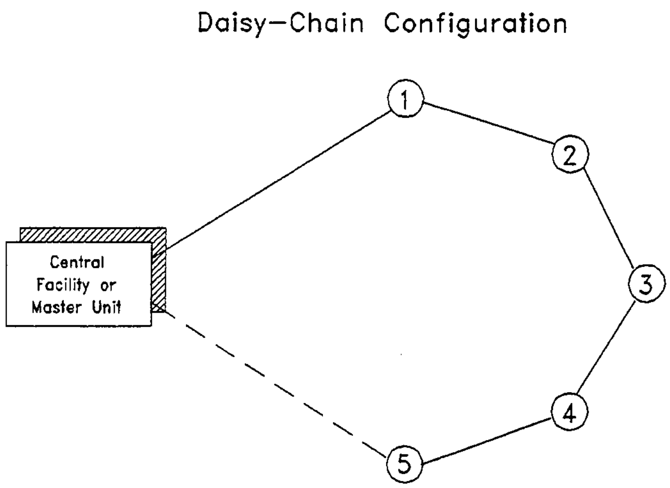


Figure III-4. Daisy-Chain Configuration

TYPES OF COMMUNICATIONS INFORMATION

The communications network for a traffic control system must provide for the transmission of one or more of the following types of information:

- voice
- video
- data

Voice circuits or "channels" are often included in the communications network to permit an operator at the central facility to talk with personnel in the field to facilitate maintenance and system debugging. Two-way voice call-box systems have been included in several freeway control systems for motorist aid. Highway Advisory Radio (HAR), which consists of a low-powered AM transmitter matched to either a roadside cable or a series of vertical antennas, have also been used in conjunction with freeway surveillance systems to provide highway and traffic-related messages to the driver using his/her AM car radio. As previously noted, a voice channel requires a minimum bandwidth of 2700 Hz.

Video channels are included in traffic control systems for closed circuit television (CCTV) surveillance. The bandwidth of the inbound video channels (from the field cameras to television monitors at central) is usually 6 Mhz per camera in order to provide full-motion video. An outbound data channel, consisting of a much smaller bandwidth than the inbound channels, is usually employed for camera control (tilt, pan, zoom, etc.).

Data channels provide for the telecommunication of control commands and monitoring information between the central computer and various field hardware. Data channels are also necessary for communications between the central computer and remote peripherals (e.g., CRT in the maintenance shop). The bandwidth requirements of data channels are dependent on several variables, including the type and quantity of data to be transmitted, the rate at which the data needs to be transmitted, the number of drops (i.e., intersections, ramp meters, etc.) on each multipoint channel, and the required accuracy of the data.

In general, centralized systems, with their once-per-second data requirements, require a transmission link with a larger bandwidth, and/or a greater number of transmission links as compared to alternatives.

COMMUNICATIONS MEDIA

Communication media consist of physical and air-path links. The physical links generally are twisted pair cable, leased telephone facilities, coaxial cable, Community Antenna Television (CATV), fiber optic cable, or Leased Telco digital data channels. Air-path links, however, generally consist of radio, cellular radio and microwave. A summary of each technique's characteristics is shown in Table III-1. For further details and descriptions of communication media, refer to

Table III-1. Summary of Properties of Communication Technologies*

FEATURES	TWISTED WIRE PAIR CHANNELS	LEASED VOICE GRADE CHANNELS	SWITCHED VOICE GRADE CHANNELS	FIBER OPTICS CHANNELS	CATV (COMMUNITY ANTENNA TELEVISION) CHANNELS	LEASED DIGITAL CHANNEL SERVICES	AREA RADIO NETWORKS (OWNED)	TERRESTRIAL MICROWAVE	SPREAD SPECTRUM RADIO
1. Media	Copper wire	May vary along length but usually copper wire pair at user interface points	May vary along length but usually copper wire pair at user interface points	Glass or plastic fibers	Coaxial Cable	Various	Atmosphere	Atmosphere	Atmosphere
2. Principal Multiplexing/ Modulation Technique Used	Time Division Multiplex (FSK)	Time Division Multiplex (FSK)	Time Division Multiplex (FSK)	Time Division Multiplex	FDM for channels. TDM for data on a channel	Time Division Multiplex, modulation technique varies	Time Division Multiplex, modulation technique varies	Time Division Multiplex, modulation techniques varies	Various modulation techniques. Time Division Multiplex. Code Division Multiplex.
3. Carrier Frequency Band	300 - 3,000 Hz	300 - 3,000 Hz	300 - 3,000 Hz	850 - 1,550 nanometers	5 - 350 MHz	Baseband and various carrier bands	161 - 174 MHz 406 - 430 MHz 450 - 470 MHz 928 - 960 MHz	928 MHz - 40 GHz	902 - 928 MHz
4. Bandwidth/ Channel Bandwidth	Will exceed 2.7k HZ for most systems	2.7k Hz	2.7k Hz	Various	6 MHz/channel. Channel may be further subdivided for data transmission	Various	25 KHz channels	Varies	Varies
5. Data Rates per Channel	1,200 - 3,100 bps/ second. Higher rates possible with different modulation technique	1,200 bps or higher	1,200 bps or higher	Up to 2.4 GBPS	Up to 7.5 MBPS based on channel subdivision	Ranges from 2.4 KBPS to upwards	9.6 KBPS	Up to 7.5 MBPS depending on channel allocation	200 KBPS (typical)
6. Transmission Range or Repeater Spacing	9 to 15 miles	Service level provided by communications lessor to a standard	Service level provided by communications lessor to a standard	Rarely a limitation when drop/insert units used at communication hubs or drop points	N/A	N/A	Several miles	Range varies and may extend to several miles depending on frequency and other variables	0.5 miles to several miles
7. Government Regulation of Channel or Service	None	Tariffs filed with State	Tariffs filed with State	None	None	Tariffs filed with State	Fcc licensing of channels for each network	FCC licensing of channels except for channels in 31 GHZ band for each installation	No license in the 902-928 MHz band for the network
8. Types of Information Supported	Data, voice, slow scan TV	Data, voice, slow scan TV	Data, voice, slow scan TV	Data, voice, analog TV, Codec	Data, voice, analog TV, Codec	Data, voice, Codec	Data	Data, voice, video	Data, Codec
9. Owned or Leased	Owned	Leased	Dial up lines	Owned	Leased	Leased	Owned	Owned	Owned
10. Constraints on Use	—	Proximity of telephone service to field controllers	Compatibility with intermittent operation. Proximity to controller	—	Proximity of CATV cable to field controller	—	Channel availability, line of sight in 900 MHz band, multipath sensitivity, geometrics	Channel availability, line of sight, availability, multipath sensitivity, geometrics, weather	Line of sight, geometrics, protocol compatibility

*Reprinted from FHWA Communications Handbook for Traffic Control Systems, Nov. 1992.

CHAPTER IV – TRAFFIC CONTROL MANAGEMENT SYSTEMS

This session presents information about two common types of traffic control systems: closed loop and hybrid systems. The closed loop system is a distributed processor traffic control system with control logic distributed among three levels: the local controller unit, the on-street master, and the office central microcomputer.

The hybrid system, however, falls in between the traditional UTCS and the closed loop system. The hybrid system is generally broader in scope, i.e. it can control and monitor more intersections and arterial sections than the closed loop system. The hybrid system can also poll and transmit information at a rate of once per second as opposed to once every 30 seconds or one minute with typical closed loop systems.

CLOSED LOOP CONCEPT

Typically, a closed loop system consists of a three-level hierarchy: 1) local controller unit, 2) on-street master controller unit, and 3) an IBM PC or compatible central computer. The latter is the highest level of all three since it facilitates receiving and transmitting data and information from and to the field equipment, i.e. local and on-street master controller units. A typical configuration layout of the closed loop system is shown in Figure IV-1.

The closed loop structure is comprised of six interlaced components: system detectors, local control equipment, local controller unit to on-street master controller unit communications, on-street master controller unit, on-street master controller unit to central computer communications, and central office computer. Each of these components is described below.

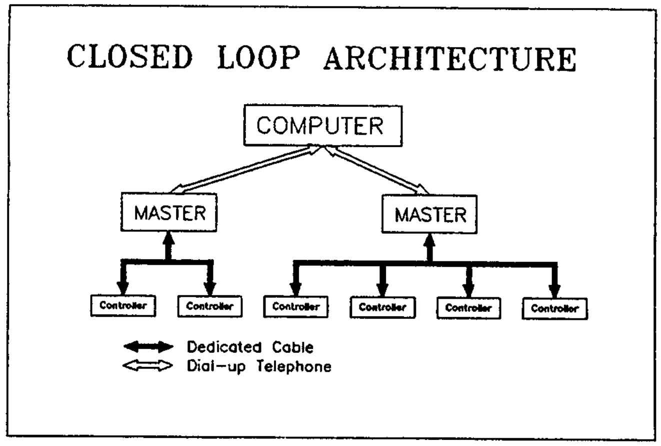


Figure IV-1. Typical Closed Loop System Configuration

<u>System Detectors</u>: Detector outputs consists of either a vehicle presence or pulse duration. These two outputs subsequently are used to derive several important variables such as vehicle volume, occupancy, speed, queue length, etc. Volume and occupancy are the most used variables for traffic systems because of their sensitivity to traffic flow and demand. Occupancy is used to measure the percent of time the detector

is indicating a vehicle presence; it can range from 0 to 100 percent. With traffic responsive operation, for example, detector data, i.e. volume and occupancy, are used to analyze the existing traffic conditions and to select the timing plan best suited to these conditions. Typically, a closed loop system can handle at least 16 detectors. System detectors are usually placed upstream of the system intersection to avoid stopped queues and driveways. The placement of system detectors should also take into consideration the technique used to select timing plans using the detector data.

Local Control Equipment: Local control equipment consists of the external communication and supervising control interface devices, and the internal devices which consist of communications, time-base coordination, and local controller unit data base modification.

A typical controller unit can handle four cycles, four splits and three offsets — a total of 48 traffic timing patterns.

Controller Unit-To-Master Communications: Generally, all closed loop systems use a 1200 bps, FSK, TDM communication protocol. Most systems use leased telephone lines, twisted pair cables, coaxial cables and some even use fiber optic cables. The most used application of all, however, has been City-owned twisted-pair cable.

Most closed loop systems can facilitate a maximum of 32 individual controller units per one on-street master controller unit. Typical communication commands between the on-street master and local controller units include addressing and echoing back, change timing plans, and data changes to the database. Return messages from the local controller unit to the on-street master usually include status data, signal display data, and detector data. Because of the amount of information and data received and transmitted by and from the on-street master, and the 1200 bps communication channel virtually all closed loop systems poll once every minute or 30 seconds. This procedure allows sufficient capacity for downloading and uploading data to and from the local controller units.

On-Street Master: With the closed loop system, an on-street master is generally used to receive, store, and process detector outputs, select matching timing plans, and monitor equipment operation. The traffic responsive control mode, when in operation, uses assigned detector groups. Typically, all detectors are assigned to groups. There is one cycle group of 12 detectors and there are two offset groups, one for inbound and one for outbound with a maximum of 12 detectors in each group. Additionally, there are two split groups, main street and cross street, with a maximum of 12 detectors in each group.

A cycle length is usually selected by the on-street master controller unit, by comparing either the highest, second highest, or average value of all detectors in the group with pre-determined values stored in the on-street master controller unit for each of the number of cycle lengths, normally four.

The selection of the offset associated with a selected timing plan is similar to the cycle length selection, except it uses a ratio of directional distribution, e.g., ratio of the highest inbound detector to the sum of the highest detector measure in both directions, and it compares it to pre-determined ratios stored in the controller unit.

The selection of the split associated with a selected timing plan is similar to the selection of a cycle length or an offset except the procedure uses the two-split groups of detectors on the main street and side street as well and it favors the highest values of all detector groups.

Master-To-Central Communications: The majority of the closed loop systems use dial-up communications between the central computer and the on-street master controller unit. This form of communication requires a separate telephone drop for each on-street master controller unit. Three common forms of communications between the central computer and the on-street master controller unit are: system command, download data, and time-base

```
MAIN MENU

1.  Set time and date
2.  Display Intersection
3.  Modify Master Database
4.  Modify Controller Database
5.  Modify Coordination Data
6.  Modify System Parameters
7.  Monitor System
8.  Prepare Reports
9.  Exit to DOS

Enter Selection [ ]
```

Figure IV-2. Typical CLS Main Menu for System Start-Up

synchronization. Communications can be scheduled by time of day, event or by operator interface.

Typical communications commands include conflict monitor report, system detectors status, uploading data, time synchronization for all TBC, system or intersection displays, time-space/progression diagram, etc. Communications is done via a menu driven/prompted procedure. (See Figure IV-2.)

<u>Central Computer</u>: The closed loop system office central computer typically consist of an IBM PC/AT compatible microcomputer, 512 KB RAM, two-360 KB memory disk drive, 20 MB hard drive, EGA or VGA color monitor, communication and output ports, mouse, serial ports, communication modem, and an 80-column printer.

The central computer, as mentioned earlier, is used to set time and date, download and upload to and from on-street master computer, modify master database (event schedule, TRSP parameters, detector processing parameters, data logging and event logging), view in real-time local intersection and system displays, create systems and intersection graphics, modify controller unit and coordination data, modify system parameters, and monitor system and prepare/print reports.

MODES OF OPERATION

Three control modes are typically found with most closed loop systems: Time of Day (TOD), Manual, and Traffic Responsive (TRSP).

<u>Time-of-Day</u>: With this mode the controller unit can automatically select and implement a pre-specified traffic signal timing plan and sequence (cycle/offset/split) based on the time-of-day, day-of-week, and/or time-of-year.

<u>Manual</u>: The operator specifies the pattern number of the desired traffic signal timing plan and sequence using the computer console.

Traffic Responsive: The computer automatically select a predefined traffic signal timing plan which is best suited to accommodate the current traffic flow conditions in the signal network. The pattern selection and implementation is accomplished through a traffic flow data matching technique which is executed every five minutes on the five-minute mark.

Two other control modes have also been claimed by closed loop system vendors. These modes are:

Controller Unit Parameter Set (CPS) Mode: The operator may specify the cycle length, split, and offset of a particular controller unit. The controller unit will operate with the specified control parameters until the CPS Mode is released and a new signal timing plan is called for by a Manual Mode.

Critical Intersection Control (CIC) Mode: In this mode the controller unit splits are adjusted once-per-cycle at controller units which are instrumented for Critical Intersection Control. The split at any controller unit is apportioned according to the ratio of traffic demand on the conflicting intersection approaches. Occupancy data is not considered with CIC mode.

CLOSED LOOP SYSTEMS

The following section summarizes the features of eight (8) NEMA and Model 170 closed loop systems, as follows:

- MARC by Automatic Signal/Eagle Signal
- Zone Monitor IV by Econolite Control Products, Inc.
- LM100 system by Traffic Control Technologies
- ZDC by Sonex Corporation
- TRACONET by Traconex, Inc.
- SMARTWAYS by Transyt Corporation
- QUICKNET II by BI Tran Systems Inc. (Model 170)
- TRAFFIC VIEW by Wapiti Micro Systems Corporation (Model 170)

A summary of these systems is shown in Table IV-1.

Other closed loop systems that may exist include those by Naztec, Ketronics and Computer Services.

Table IV-1. Features of Various Closed Loop Systems*

On-Street Master Controller Unit	Automatic Signal/Eagle **Marc 360**	ECONOLITE **KMC - 10,000**	TCT **MDM 100**	SONEX **S 80**
Controller Units Per Master	32	24	60	64
On-Street Masters per PC	256	240	16	14**
System Groups per Master	2	1	4	10
Controller Units per PC	8192	5760	960	896**
System Detectors Per Master	64	32	32 per section/ 128 per master	32
Control Modes	(TOD, DOW, TOY) Manual, TRSP, Flash	(TOD, DOW, TOY) TRSP, Manual, Flash	(TOD, DOW, TOY) TRSP, Manual, Flash	(TOD, DOW, TOY) Manual, CIC, TRSP, Flash
Field Communications . Master to Central PC . Master to Local Units	. Dial-up . Twisted-pair, Fiberoptic, Radio, Coaxial & Telephone	. Dial-up . Telemetry, Twisted pair, fiberoptic, leased telephone	. Dial-up, RS-232, Leased Cable . Telemetry, Twisted pair, fiberoptic, leased telephone	. Dial-up . Twisted pair, fiberoptic, coaxial
Central Computer	. IBM Comp. PC-XT . 512 K Bytes RAM . 360 K Bytes Disk Drive . 10 M Bytes HD . RS-232C output ports . MS DOS 3.0 . CGA, EGA or VGA color monitor . Hayes Comp. 1200/2400 modem . 80 column printer	. IBM Comp. PC AT . 512 K Bytes RAM . 360 K Bytes Disk Drive . 20 M Bytes HD . Communication & output ports . MS DOS . EGA or VGA Color Monitor . Hayes Smart Modem 300/1200 . 80 column printer	. IBM PC XT/AT . 640 K Bytes Ram . 360 K Bytes Disk Drive . 20 M Bytes HD . Communication output ports . MS DOS . EGA or VGA Color Monitor . Hayes or UDS modem . 80 column printer	. IBM PC XT or AT . 256 K Bytes RAM . 360 K Bytes Disk Drive . 10 or 20 M Bytes HD . RS 232 Port . MS DOS . EGA or VGA color monitor . Sonex modem . 80 column printer
Reports (Local alarms, MOEs, Communication and/or Detector failures, conflict monitor report, controller status, detector count logging, power failure, etc.)	Yes	Yes	Yes	Yes
Time Space Diagram	No	Yes	No	Coordinated green up to 32 intersections
Monitoring . Local intersections . System map	Yes Yes (EGA & VGA)	Yes Yes	Yes Yes	Yes Yes
Max. No. of Reporting Events Stored	?	255		4 Days
Event Capacity for Time-base Traffic Patterns	180		200	Unlimited
On-Line Timing Generation	No	No	No	No

*Information presented above is obtained from published technical information generated by individual manufacturers. ** — PC Dependent

Table IV-1. Features of Various Closed Loop Systems (Continued)

On-Street Master Controller Unit	TRACONEX **TMM 500**	TRANSYT **3800 EL**	BI TRAN **MODEL 170**	WAPITI **MODEL 170**
Controller Units Per Master	31	30	32	48
On-Street Masters per PC	31	99	16	Unlimited
System Groups per Master	1	1	1	1
Controller Units per PC	961	2970	512	Unlimited
System Detectors per Master	16	48	256	32
Control Modes	(TOD, DOW, TOY) Manual, TRSP, Flash	(TOD, DOW, TOY), Free Manual, Pre-empt, TRSP, Flash	(TOD, DOW, TOY) Manual, TRSP, Flash	(TOD, DOW, TOY) Manual, TRSP, Flash
Field Communications .. Master to Central PC . Master to Local Units	. Dial-up . Twisted-pair, Fiberoptic, Coaxial	. Dial-up . Twisted pair, Radio, Fiberoptic	. Dial-up, Leased Lines . Twisted Pair	. Dial-up . Twisted pair, fiberoptic . Any RS232 device
Central Computer	. IBM PC XT/AT . 512 K Bytes RAM . 360 K Bytes Disk Drive . 20 M Bytes HD . Output ports . MS DOS . EGA or VGA Color Monitor . Printer	. IBM System 2 PC	. IBM PC XT or AT . 640 K Bytes Ram . 1.2 K Bytes Disk Drive . 10 M Bytes HD . RS 232 Port . MS DOS . EGA or VGA Color Monitor . Hayes Modem . 80 Column Printer	. IBM PC XT/AT . 512 K Bytes RAM . 360 K Bytes Disk Drive . 20 M Bytes HD . CGA or EGA color monitor . Printer
Reports (Local alarms, MOEs, Communication and/or Detector failures, conflict monitor report, controller status, detector count logging, power failure, etc.	Yes	Yes	Yes	Yes
Time Space Diagram	No	Yes	No	No
Monitoring . Local intersections . System map	Yes Yes	Yes Yes	Yes Yes	Yes Yes
Max. No. of Reporting Events Stored	NI	NI	NI	200
Event Capacity for Time-Base Traffic Patterns	NI	200	NI	64
On-Line Timing Generation	No	No; Comp. w/AAP	No	No

NI — Not Indicated.

AUTOMATIC SIGNAL/EAGLE SIGNAL INC.

Master Area Responsive Control (MARC) System

This closed loop system uses the MARC360 as the on-street master controller unit and the EPAC300 as the local 2 to 8-phase controller unit. The MARC can interface with up to 256 on-street masters, with 1 to 32 local controller units per master and 64 system detectors. A total of 8,192 controller units can be supported with the MARC. Each master controller unit can control two independent groups of controller units with a maximum total of 32 controller units for both groups.

The MARC system supports 4 cycle lengths, 4 splits and 3 offsets – a total of 48 different timing plan patterns. Supported control modes include time-of-day (TOD), Day-of-week (DOW), time-of-year (TOY), Manual flash, pre-empt, traffic responsive (TRSP), and local time base coordination.

The office central computer uses an IBM PC/XT compatible with a minimum configuration of 10 MB hard drive. (See Table IV-1), and a color monitor. Display features include intersection and detector status, master time base status, TRSP operation, local coordinated greens, and system mapping of user-created intersections.

The MARC reporting capability includes master and local reporting features. Master reports include system critical alarms, master alarms, communication failures, group pattern changes, TRSP pattern changes, system detector logs and offline/online history. Local reports include local alarms, MOEs, communication failures, detector failures, system detector loops, speed trap logs and conflict monitor reports.

The MARC system is currently installed in several cities including Fortworth, TX; Howard County, MD; and West Virginia; North Carolina; and Huntington, WV.

A pictorial presentation of the MARC system architecture is shown in Figure IV-3, page IV-8.

MARC 360 ARCHITECTURE

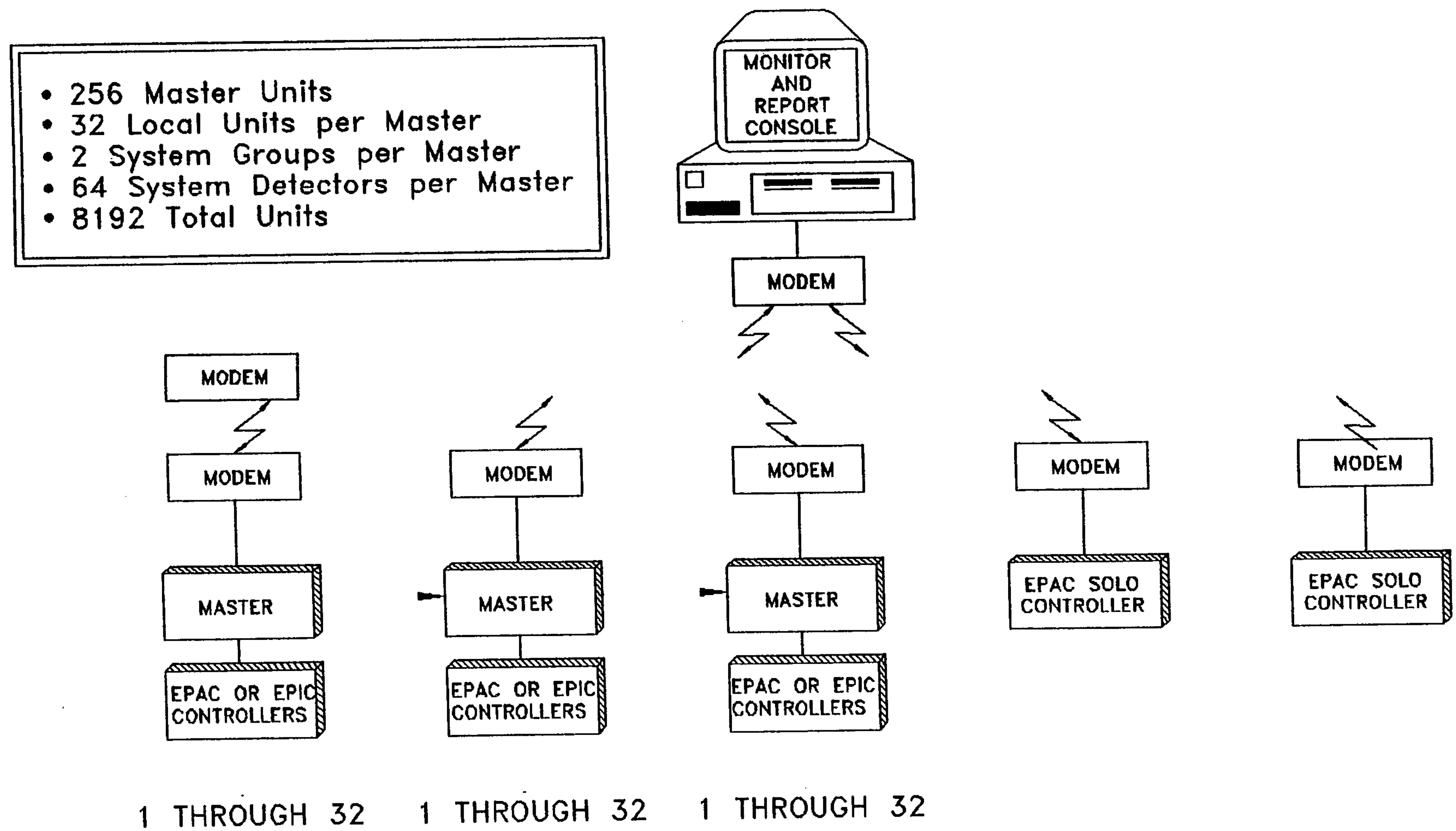


Figure IV-3. MARC System Architecture

BI TRAN SYSTEMS, INC.

QUICNET II Closed Loop System

The QuicNet II System is a LAN-based multi-users traffic surveillance and management system. The primary hardware components of QuickNet II are desktop personal computers with color graphics capability. QuickNet II typically uses Model 170 controller units as on-street masters and local controller units, respectively. QuickNet II can interface with up to 16 on-street master, 32 local controller units per each master, and a total of 512 local intersections. Eight system detectors are supported at each local controller unit.

QuicNet II supports 9 cycle lengths and splits and 3 offsets — a total of 27 different timing plan patterns. Control modes supported by QuickNet II include TOD, DOW, TOY, Manual and TRSP.

The central office computer is an IBM PC/AT or compatible host computer with a minimum configuration of MS DOS 3.0, 1.2 MB (5¼") or 1.44 MB (3½") floppy disk drive, 10 MB fixed disk drive, EGA or VGA monitor, 640 Kb memory, 1-serial and 1-parallel ports, and Hayes compatible modem.

QuicNet II display capability features real-time aerial view of intersection dynamics with user-created intersection layout, real-time display of individual detector actuation status, arterial dynamics, system-wide status display. QuicNet II reports include alarm history, operations, detector data, real-time split monitor, system detector status, purge report, and system event schedule.

A pictorial presentation of QuicNet II architecture is shown in Figure IV-4.

QuicNet II System Architecture

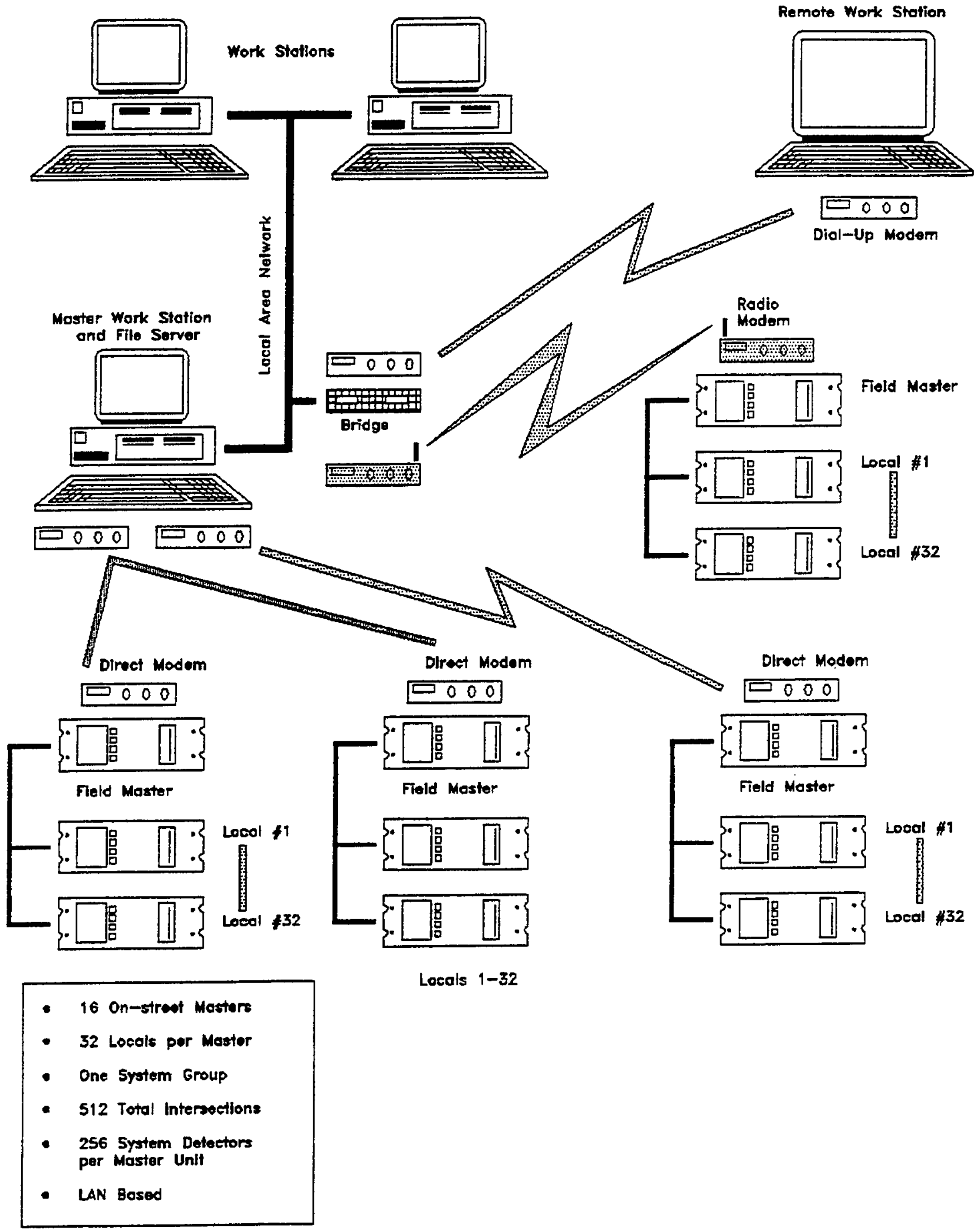


Figure IV-4. QuicNet II System Architecture

ECONOLITE CONTROL PRODUCTS, INC.

ZONE MONITOR IV

The Zone Monitor IV closed loop system uses the KMC-10,000 as the on-street master controller unit and the ASC 8,000 as the local 2 to 8 phase controller unit. The Zone Monitor IV can interface with up to 240 on-street masters, with 1 to 24 local controller units per master — a total of 5,760 intersections. Zone Monitor IV can also support up to 32 system detectors and determine speed from up to 8 speed traps for each on-street master.

Zone Monitor IV supports 6 cycle lengths, 4 splits, and 5 offsets — a total of 120 different timing plan patterns. Supported control modes include TOD, DOW, TOY, manual and TRSP. By early 1992, about 1,000 on-street masters (KMC-10,000) had already been installed nationwide.

The office central computer consists of an IBM PC/AT or compatible processor with a minimum configuration of 512 KB RAM, a floppy disk drive, a 20 MB hard disk, an EGA or VGA monitor, a mouse, a 2,400 bps Hayes-compatible modem, and an 80-column printer for hard copy reports. Display features of the Zone Monitor IV include Zone map display, intersection display, green band (time-space) display, split-timing and cycle display.

Zone Monitor IV reporting capability includes event log and failure reports, up to 255 events, status reports, 15, 30, or 60 minute detector logs and plots at 6, 12 or 24-hour log intervals for up to 32 system detectors, and split monitor reports. Other reporting features include detector failure up to 32 detectors, power failure, intersection flash, flasher failure, controller unit timing, time check failure, user-designated alarms, and local storage up to 100 events in the intersection Monitor II.

Zone Monitor IV uses dial-up telephone lines for communications between the central computer and on-street masters — a separate telephone drop is required for each master controller unit — and a 1200 Baud, TDM/FSK telemetry cable to communicate between the masters and local controller units. An external Hayes-compatible 1200 or 2400 bps modem is required for each master unit. Zone Monitor IV also supports the direct connection of KMC -10,000 masters over private lines at 2400 bps with electronic line switching by an external data port selector. The copper wiring may also be replaced by fiberoptic cables with an RS-232-to-fiber modem at each end.

An illustration of the Zone Monitor IV system architecture is shown in Figure IV-5.

Zone Monitor IV is currently installed and operational in several states and local jurisdictions including City of York, PA; Maryland State Highway, Baltimore County, MD; Georgia; Ohio; Kentucky; Indiana; North Carolina, etc.

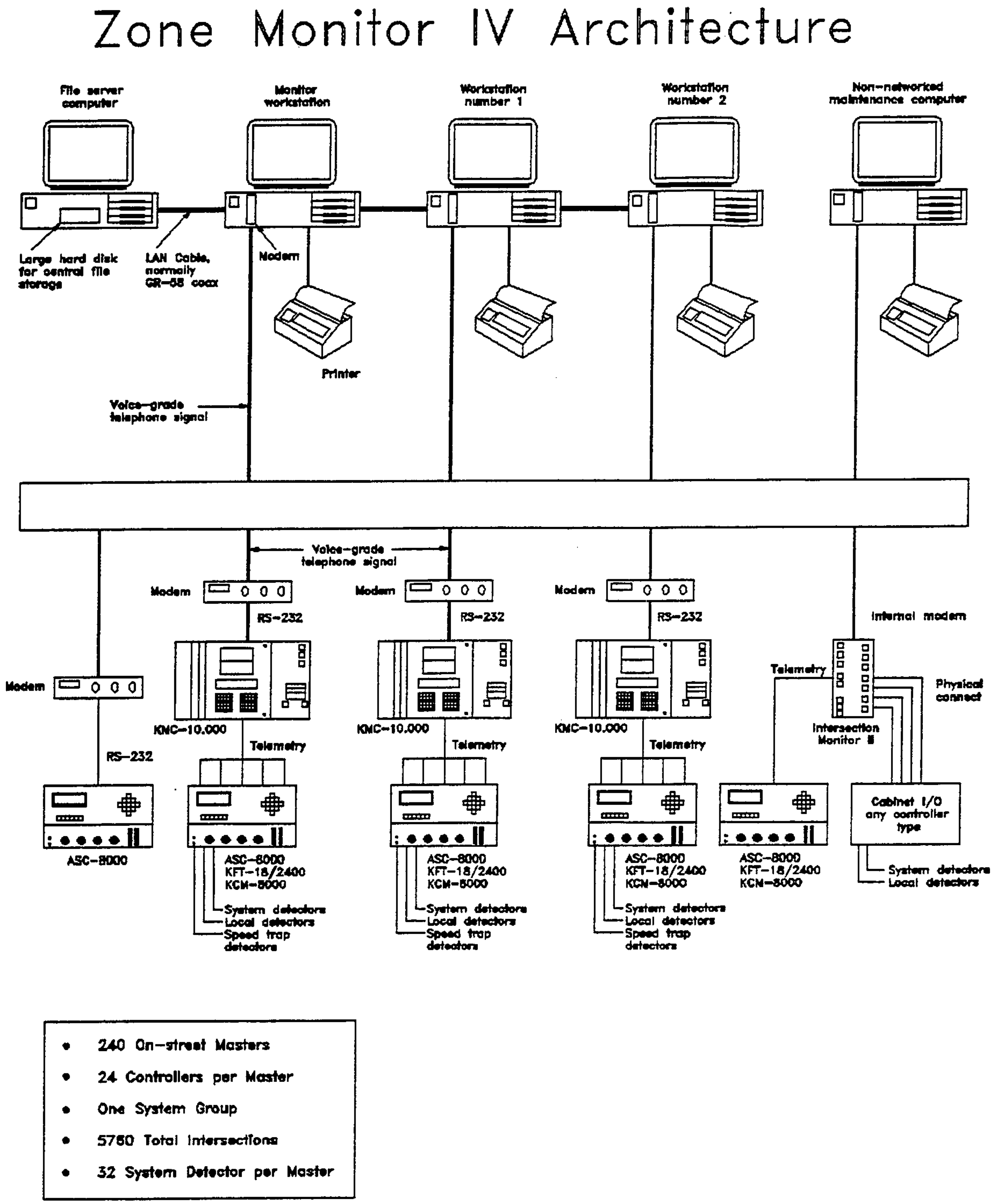


Figure IV-5. Zone Monitor IV System Architecture

SONEX CORPORATION

ZDC CLOSED LOOP SYSTEM

The ZDC system uses the Sonex S80 controller unit as a street master and the Zero Drift Coordinator (ZDC)/interface unit as the local controller unit. The ZDC unit, however, functions in the capacity of a 2-phase controller unit if not complemented by an 8-phase NEMA or a Model 170 controller unit. The ZDC system commands simultaneously a maximum of 14 field master controller units and up to 64 local ZDCs per field master — a total of 896 intersections.

The ZDC system can support up to 64 different cycle lengths; it can also control NEMA single and dual ring controller units, Model 170 controller units, fixed-time solid state, electro-mechanical, and PR controller units. The ZDC can monitor up to 16 detector inputs, three preempt indicators, all phase displays, and can command and monitor up to 8 special functions in two modes of operation. The field master can also hold up to 4 days of volume and occupancy data for up to 64 system detectors.

The central computer system is a colorgraphic based MS DOS computer. This unit is an IBM PC/AT, XT, or compatible processor. The ZDC operates using a minimum of 10 MB hard disk drive and requires 256 KB of memory. The arterial map processor allows up to 100 customized displays for each arterial.

The ZDC system reporting capability features arterial and intersection status reports (MOEs, intersection number, name, address, colored status, green phase display, current pattern, cycle, offset, and split), power failure report, event status report (last 63 events), volume and occupancy report (last 3 five-minute samples for all 16 detectors).

Display features of the ZDC system include real-time green phase displays, status indicators, threshold display of system detectors for both volume and occupancy, presence for intersection detectors, intersection and arterial display. Intersection graphics are updated once-per-second.

Communications between the central PC and field masters are via dial-up telephone lines. The ZDC can communicate with only one field master at one time — the PC can only support one serial port at one time.

Communications between the local ZDC units and field masters are via two-wire or four-wire circuits operating at 1200 baud, TDM/FSK. Up to 31 intersections can be supported on a single circuit in this configuration. The ZDC system also supports coaxial cables, radio, and up to 56,000 baud communication speeds using Sonex's high speed RD modems.

TRAFFIC CONTROL TECHNOLOGIES, INC.

LM100 System

The LM closed loop system uses the TCT MDM 100 controller unit as its field master and the LMD 8000 as its local intersection controller unit. The LM system can command up to 16 field masters, with up to 60 intersections per field master, and 4 sub-sections per field master. The LM System, therefore, can control up to 960 intersections from the central office.

The LM system supports 8 cycle lengths, 4 splits per cycle, and 5 offsets per cycle; it also supports up to 32 system detectors per section and up to 24 detectors per intersection. Supported control modes include time base (TOD, DOW, TOY) up to 200 events, 15 day programs and 10 week programs, TRSP, and manual override.

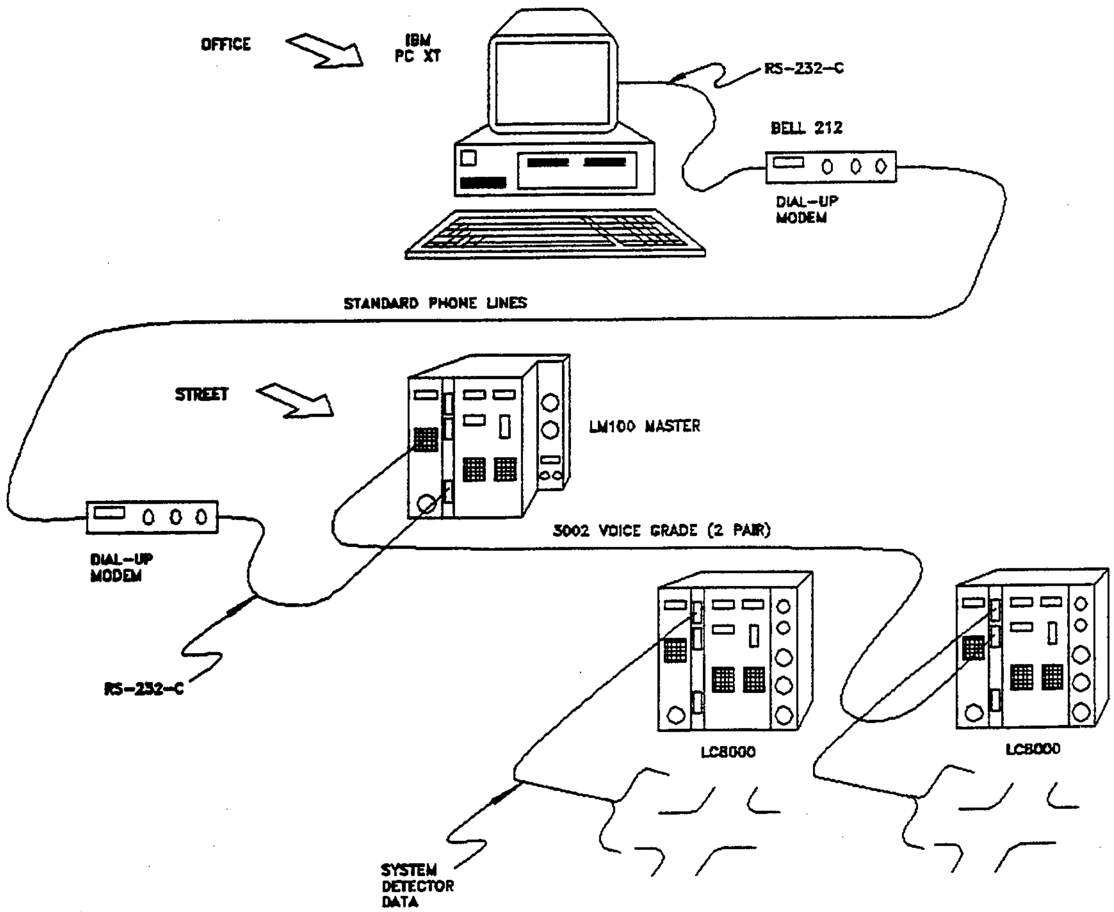
The central computer is an IBM PC/XT or compatible processor with a minimum configuration of 640 KB RAM, 20 MB hard disk, 360 KB disk drive, serial and parallel ports, 256 KB of RAM color monitor (EGA or VGA), printer and Hayes 1200 band modems.

Reporting features of the LM system include field master reports (system detector volume and occupancy), system pattern changes, detector failures (local and system), pattern error alarms, telemetry status, intersection off line, status of 8 user-defined system inputs and local controller unit reports (diagnostic failure, conflict monitor status, preempt sequence, cycle failure, detector status, MOEs, volume logs, etc.)

Display features include real-time intersection displays (phase or overlap indications, all detectors, local flash status, preempt status, cycling status, current timing plan (cycle, split, offset), pedestrian phases, conflict monitor status, and sectional display (main street green up to 8 intersections) speed traces in both directions, master cycle timer, number of intersection on line and in flash, number of sectional detectors failed, current clock and TRSP selection (cycle, split, offset), active section and mode of selection and status of 8 user defined section functions.

The LM system communicates with field masters via dial-up telephone lines. Each master controller unit has a NEMA modem port (TDM/FSK). Communications from the field master to locals is via a dedicated (leased or agency owned) two pair cable interconnected between modem ports of the respective units. A pictorial presentation of the LM closed loop system architecture is shown in Figure IV-6.

LM 100 System Architecture



- 16 On-street Masters
- 60 Locals per Master
- 4 System Groups per Master
- Total of 960 Intersections
- 128 System Detectors per Master
- 32 System Detectors per System Group

Figure IV-6. LM100 System Architecture

TRACONEX, INC.

TRACONET CLOSED LOOP SYSTEM

Traconet uses the TMM-500 controller unit as its field master and the TMP-390 unit as its local controller unit. Traconet can command up to 31 field masters with 31 local controller units per each master — a total of 961 intersections. Traconet also supports 16 system detectors for traffic responsive operations.

Traconet supports 6 cycle lengths; 5 offsets, and 3 splits — a total of 90 different timing plan patterns. Additionally, Traconet supports 12 TRSP timing plan profiles stored in the TMM-500 field master. Traconet control modes include time-based, manual and TRSP.

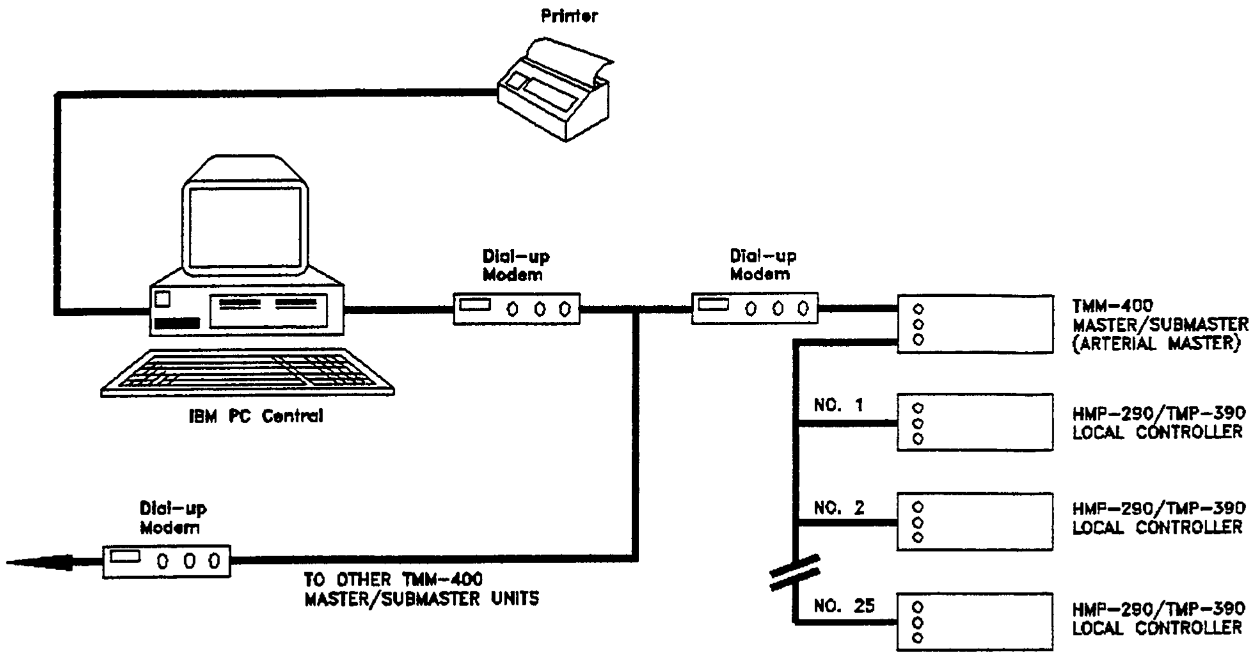
The Traconet central computer is an IBM PC/XT or compatible processor. The central computer functions as a disk-based clearing house for information and a central editing/reporting station, and as Traconet's overall monitor and system data logger.

Traconet display capability includes real-time monitoring of intersection and system map displays, real-time phase and timing display, and detector status. Similarly, Traconet offers excessive reporting features such as event reports, local and master controller unit report, data base changes, conflict monitor report, etc. All intersection and system map graphics are user-created including vehicle phasing, pedestrian phasing, detector symbols and intersection display.

Communications between the central PC and TM-500 field masters are done via dial-up telephone lines using one 212 dial-up modem for each master. Hardwire and modem interconnect interfaces are supported with the TM-500 for communications between the field master and local controller units. Communications via modem interface allow more intersections to be controlled per each master. Typically, the TMM-500 master communicates with 31 local controller units via dedicated four-wire telephone line, using 202 modems.

A system architecture of the Traconet closed loop system is depicted in Figure IV-7.

TRACONET System Architecture



- 31 On-street Masters
- 31 Local Units per Masters
- One System Group
- Total of 961 Intersections
- 16 System Detectors per Master

Figure IV-7. Traconet System Architecture

TRANSYT CORPORATION

SMARTWAYS

Smartways uses Transyt 3800 EL as the field master controller unit and Transyt 1800 EL as its local controller unit. Smartways can control up to 36 field masters, 30 local controller units per each field master, and up to 48 sampling detectors per field master. Additionally, up to 8 sampling detectors can be monitored per each local controller unit. The total number of intersections that can be controlled and monitored with Smartways is 1080.

Smartways supports 6 cycle length, 16 splits and 5 offsets. A total of 480 timing plan patterns can be selected; supported control modes are time base, manual, TRSP, fully-coordinated back-up and free/flash.

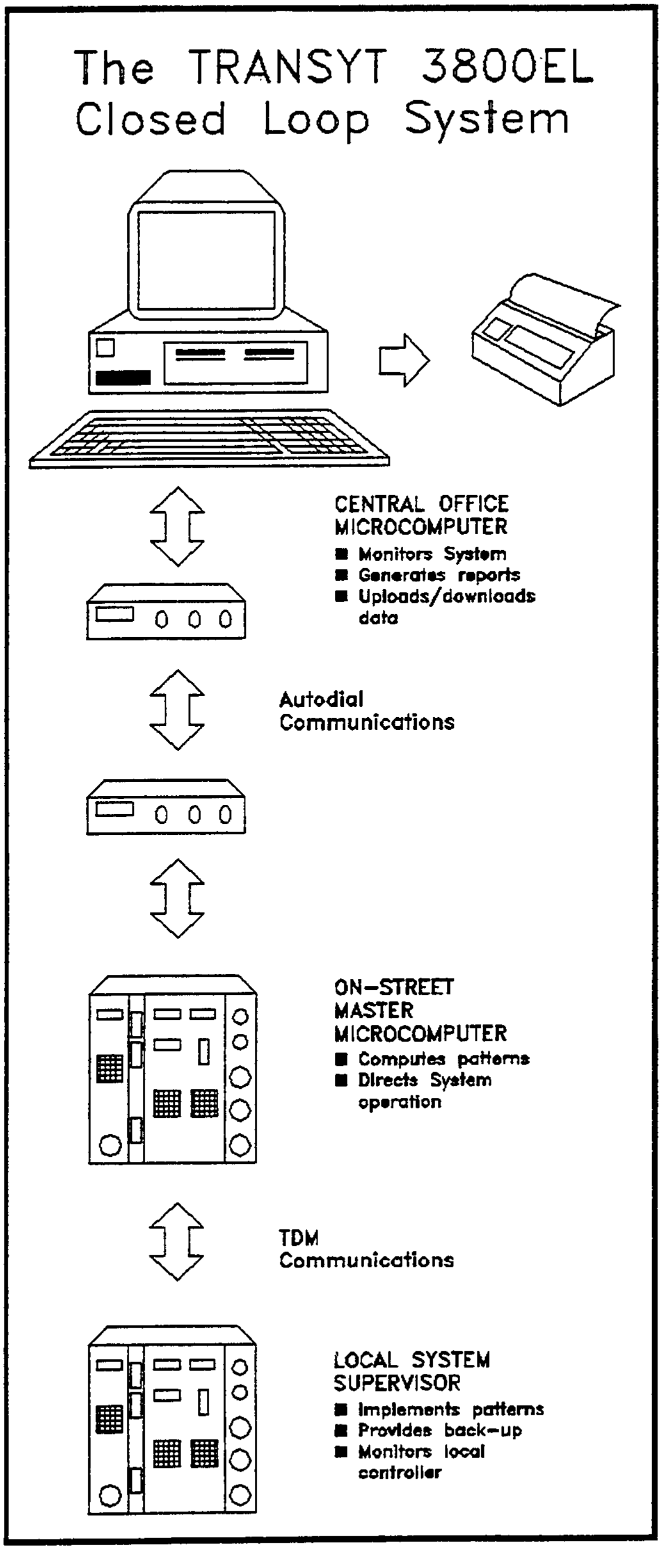
The central computer is an IBM system 2 personnel microcomputer, with high speed hard disk and a color monitor.

Smartways has a generous display features including intersection and system maps and real-time displays.

Smartways supports auto dial-up communications on standard telephone lines between the central office computer and field masters, and twisted pair wires (2-pair) for communications between the field master and local controller units. Fiberoptic communications is also supported.

Smartway system architecture is shown in Figure IV-8.

Transyt closed loop systems have been installed at 77 locations nationwide, including Florida, Alabama, South Carolina, Oklahoma, Ohio, Georgia, Illinois, Virginia, New Jersey, Colorado, Texas, Tennessee, New York, etc.



SMARTWAYS System Architecture

- 99 On-street Masters
- 30 Locals per Master
- One System Group
- Total of 2970 Intersections
- 48 System Detectors per Master

Figure IV-8. Transyt Smartways Closed Loop System Architecture

WAPITI MICRO SYSTEMS

TRAFFIC VIEW CLOSED LOOP SYSTEM

The Traffic View closed loop system uses Model 170 controller units as its field master and local controller units as well. Traffic View uses W70SM as its on-street master program and W41KS as its Model 170 actuated program for local controller unit.

The on-street master program (W70SM) has the following features:

- Up to 48 local intersections can be controlled by one on-street master controller unit.
- Supports up to 32 system detectors for traffic volume and occupancy data collection.
- Provides system with real time clock reference pulses.
- Maximizes traffic flow to respond to peak traffic hours, or peak traffic flow.
- Detector diagnostics.
- 8 programmable outputs.
- 18 coordination plans.
- 9 programmable special event functions by time of year.
- 48 programmable functions by time of day.
- System operation and failures recorded.
- System reverts to time base backup if communications fail.
- System controls actuated and fixed time 170 controller units.
- System operates in all 170 controller units.
- System operates on fiberoptic modems, or 400 type modems.

Similarly, features of the local actuated program (W41KS) for local Model 170 controller units include:

- 8 independent programmable pedestrian outputs.
- 8 programmable overlaps, with outputs assignable to any load switch.
- 3 separate timing plans with separate phasing, input and output re-assignment, and extended outputs are available by time of day.
- Records vehicle counts for 12 phase detectors with a minimum duration of 95 hours.
- 4 vehicle and 1 railroad fully programmable pre-emption.
- Timing data backed up by EEPROM and NAVRAM contained on prom module.
- 18 coordination plans, plus free and flash functions.
- 64 time of day and week entries.
- 9 yearly event functions.
- Actuated coordinated phasing.

Traffic View software provides interface with either program (W70SM or W41KS and few others) whereby the traffic engineer or technician would have the ability to:

- Observe the operations and conditions of a local intersection as they occur.
- Change a local intersection's timing data from your office.
- Read a local intersection's timing data from office.
- Error check intersection's timing data against information stored in office computer.
- Print timing reports from local intersections.
- Reports the status of the signal system.
- Diagnose failed controller units from office or shop.
- Read detector status and provide reset capabilities.
- Retrieve stored information of accumulated system operation and failures.
- Print reports of traffic volume data from local intersections.
- Interface with other programs and main frame computers.
- Control an unlimited number of master and local 170 controller units.
- Limit access to system to appropriate personnel.

Traffic view requires the following system hardware for its central PC, field master and local intersection controller units:

- **Central computer**
  - Microcomputer, IBM PC compatible
  - Auto-dial modem (1200 Baud)
  - Color monitor, CGA compatible
  - Printer

- **Field Master Controller Unit**
  - Model 170 controller unit with dual ACIA and 2 K of ram on controller unit CPU board
  - Auto-dial modem central computer link
  - Model 400 modem, local controller unit link
  - System memory module, with 32 K of EPROM, 30 K of RAM, and 4 K or EEPROM, located on prom module

- **Local Intersection Controller Unit**
  - Model 170 controller unit with 2 K of ram on controller unit CPU board

Communication for traffic view can be effected by standard dial-up telephone lines with 12002 BD auto-dial modems or dedicated communication lines. Dedicated lines may be standard telephone lines or fiberoptic lines. Fiberoptic lines will require fiberoptic modems at each intersection.

Figure IV-9. illustrates the system architecture of the Traffic View closed loop system.

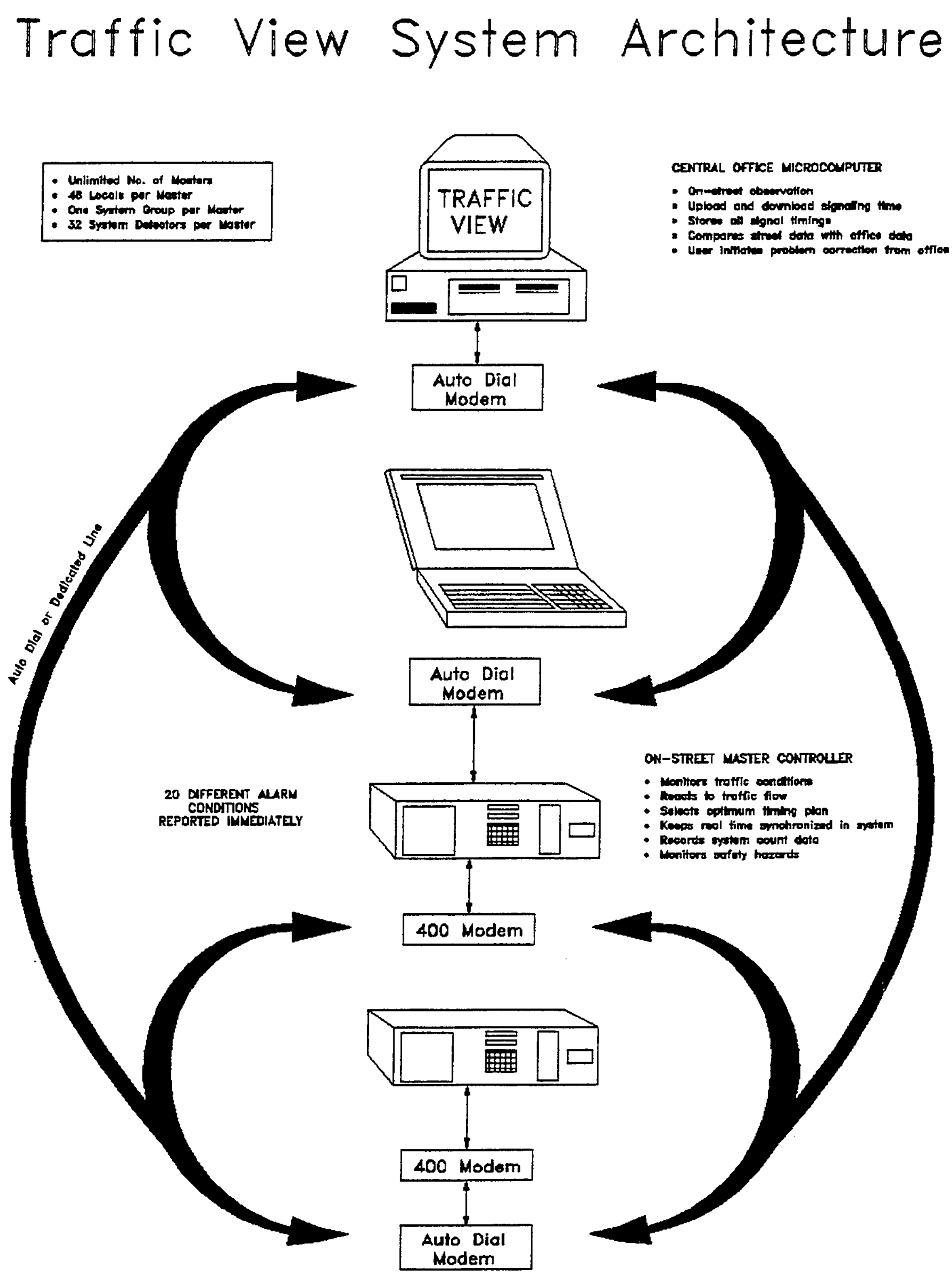


Figure IV-9. Wapiti's Closed Loop System Architecture

HYBRID TRAFFIC CONTROL SYSTEMS

As indicated earlier, hybrid traffic signal systems are identical to closed loop systems except they are broader in scope, communications, reporting, and graphics capability. Some of the distinguished features of a hybrid system, in general, include the following:

- Uses core of UTCS
- Once-per-second polling
- Uses mini and/or super microcomputers
- Uses a multi-tasking operating system
- Compatible with NEMA or Model 170 controller units
- No field masters required
- Functions as either a centralized or distributed system
- Enhanced graphics
- Enhanced reporting
- Uses a file server network (LAN)
- Commands up to 250 intersections per single processor
- Proprietary software

Hybrid systems described below include TMS by Frederic R. Harris; Series 2000 by JHK and Associates; ESCORT by Sonex Corporation; MONARC by Automatic Signal/Eagle Signal; and MIST by Farradyne Systems, Inc.

FREDERIC R. HARRIS, INC.

TRAFFIC MANAGEMENT SYSTEM (TMS)

Description: TMS is a centralized traffic control concept under which the second-by-second controller coordinated and phase command responsibilities are removed from the central computer and "distributed" among the field hardware. TMS supports and fully utilizes on-street, state-of-the-art, intelligent controllers and remote communication units.

The number of controller units with which the TMS can interface is unlimited. Some recently designed systems have been sized for as many as 1,100 intersections. This number can, however, be easily expanded for larger control networks.

TMS has the capability of communicating with controller units of various makes and models through an internal modem or an external Remote Communication Unit (RCU). All the features and capabilities of large centralized systems (including multi-user access) are provided with the TMS but instead of the second-by-second transmission of phase control commands, the timing plan data is downloaded to the local controller unit itself. The stored timing plans are then implemented through plan selection commands sent from the central computer to each controller unit or selected via intelligence stored at the local controller unit cabinet. System detector data is collected and transmitted back to the computer at various rates and using various methods depending upon the vendor and communication protocol selected.

The TMS approach is suitable for interfacing with Intelligent Vehicle Highway System (IVHS) elements. The TMS approach of distributed processing makes it adaptable for control of ramp metering systems, changeable message signs, incident detection, etc. through Type 170 controller units or other intelligent devices. The RCU's may also include time-based coordination capabilities. If valid communication with the central is lost, the intersection automatically reverts to local time-based control using the updated timing plans stored at the intersection; therefore, there is little or no discontinuity in progression despite the length of the communication disruption. Thus, without special setup, backup coordination is inherently available for each intersection. While downloaded/uploaded parameter data is transmitted to/from the computer and the local controller unit locations on an as-needed basis, return messages (e.g. phase green status, conflict flash,special functions, etc.) are transmitted from all controller units to the central computer on a once-per-second basis. This permits independent and continuous monitoring of failures by the central computer as well as full, system-wide graphic representation of real-time controller unit status on a high-resolution color graphics monitor.

The primary user interface is through PC-based workstations. The traffic engineer communicates with the system through these workstations at two levels: 1) via the SoftPanel pull down window command processor and status displays, and 2) via the color graphics subsystem, which invokes the graphic system representations requested by the user. The user may also interface with TMS via the computer system's video display terminal and keyboard. Through this terminal, the user has the ability to control the computer system and its resources via the vendor-supplied operator communications interface.

System Architecture and Specifications: Central site hardware for TMS is comprised of both general data processing equipment and some specialized equipment selected specifically for traffic control systems. Table IV-2 summarizes the TMS specifications.

The TMS mini or super-micro computer platform could be any of the following:

- Concurrent
- Data General
- Mod Comp
- Digital Equipment

TMS operates under a single copy of an operating system which controls all of the processors in a multiprocessor configuration to optimize the utilization of the hardware and software. A multiprocessor-based system is able to execute simultaneously, multiple tasks on multiple processing units.

System Operation: The TMS can operate and interface with both Model 170 and NEMA controller units, by using Remote Communication Units (RCU). TMS is designed, however, primarily to utilize the capabilities of Type 170 controller units. All intersection controller units are monitored second-by-second by the central software, via the TMS communications hardware/software subsystem.

Operating Modes: The TMS operates in four different modes, as follows:

- Central Manual (MAN) mode
- Central Time of Day (TOD) mode
- Central Traffic Responsive (TRSP) mode
- Local (LOC) mode

Users Interface: The TMS is a command-driven interface, integrated with a window driver package for simultaneous displays of pull-down menus. the TMS interface command processor, referred to as the SoftPanel, is the primary interface of the user.

TMS Reports and Displays: The TMS has several reports available at the user's request. These reports include:

- System Status
- Intersection Status
- Intersection Operation
- Detector Status
- Failure Summary

Similarly, the TMS has several real-time display features, including:

- Intersection display
- Area map display

The base maps for these displays are generated using AutoCad software.

Current Installations: The TMS is currently installed and operating in several states and cities including the following:

- Austin, Texas (365 on-line intersections using Model 170 controller units)
- Ft. Worth, Texas (260 on-line intersections using NEMA/RCU controller units)
- Honolulu, Hawaii (290 on-line intersections using Model 170 controller units)
- Nashville, Tennessee (378 on-line intersections using NEMA/RCU controller units)
- Pittsburgh, Pennsylvania (under construction, 90 Model 170 controller units)

Table IV-2. TMS Specifications

Central Computer	Mini or Super-micro Mainframe (i.e. Concurrent, Modcomp, DEC, Data General)
No. PC-based Workstations	20
Special Functions	16 Total 8 with Timing Plans 8 with Special Function Schedule
Minimum Workstation Configuration	486/33 Mhz 120 MB Hard disk minimum for RGS 8 MB RAM minimum for RGS 300 MB Hard disk minimum for CAD 16 MB RAM minimum for CAD
Graphics Display Generation	DXF (CAD) files xBase Compatible Data Base
Compatibility	Can be interfaced with • IVHS system components • Different closed loop systems • Other centralized control systems
Number of Control Sections	500
Detectors	Up to 16 per intersection
Number of Intersections Controlled	Up to 4,096
Communication Media	Twisted-Pair, Fiber-optic, Coax, Microwave, Spread Spectrum Radio
Communication Frequency	Once per second with each intersection
Security	Password Limited User Access Capabilities

Source: Frederic R. Harris

JHK & ASSOCIATES

Series 2000

The Series 2000 Computerized Signal System is designed as a distributed processing system. Many of the computations and data processing responsibilities normally associated with centralized systems — such as detector data processing and real time transmission of inter-section timing and control commands (FORCE-OFF, YIELD, etc.) — have been removed from the central computer and distributed among the system hardware (e.g., local interface, central communications, and operator workstations). This, in turn, has a significant impact on the design requirements of the central control hardware and of the control center.

The user interface is supported by either microcomputer workstations or more traditional CRT terminals. The workstation concept allows the user to add more peripherals in the future without impacting the main computer. Additionally, intelligent workstations can provide processing capability for remote analysis of data and development of timing plans. Workstations can be IBM PS/2 or AT-compatible with keyboard, color monitor, and printer.

The main difference between Series 2000 and more traditional traffic control software packages is the method of data communications and signal control. Instead of the traditional second-by-second transmission of signal control commands (e.g., HOLD, FORCE-OFF, etc.); with Series 2000, complete timing plan data (i.e, cycle, split, offset) are downloaded to and stored in local controller units or remote communications units (RCU). The appropriate timing plan is implemented by a PLAN SELECT command sent from the central computer to each controller unit once every second. The local controller or RCU also preprocesses system detector data over a one-cycle or one-minute period before transmitting the information back to the computer. This results in reduced computer processing requirements.

Series 2000 can command up to 1000 controller units and 1000 system detectors, with up to 100 independent sections. Each section can control between 1 and 100 controller units, and each controller unit can accommodate up to 12 system detectors and up to 8 local detectors. The system is designed to operate on a continuous basis with or without operator supervision or interaction. In the event of a power failure at the control center and upon power resumption the system will restart automatically with the TOD clock maintaining the correct time.

Series 2000 can interface with standard NEMA, solid-state digital pre-timed, and electro-mechanical pre-timed controller units via an intelligent RCU; and also can interface with Model 170 and 179 controller units and Traconex TMP390 controller units via an internal interface device.

Series 2000 supports a total of 32 timing plans, plus flash and free operation for each controller unit. All controller units operating on the same cycle length use the same offset synchronization reference point regardless of the timing plan number in effect or the section in which they are located; this facilitates coordination across section boundaries.

Series 2000 also supports four timing plan selection modes: manual, TRSP, central TOD schedule, and local TOD schedule mode (TOD, DOW).

Reporting features of the Series 2000 system include:

- Global Failure Analysis: presents an analysis of the failures in the system broken down by device type (as specified by user), showing total current failures and average smoothed time-between-failure for all such devices.

- Global Failure Summary: presents a system-wide list of all failures, indicating the reason for the failure and the time of failure.

- Global Status: presents the current control state of the system and all defined sections. Information includes desired and actual modes of operation, plan number in affect, and number of failures in each section (by type), and status of scheduler override.

- Time Consistency: uploads the current time from each local controller and compares it to the central computer's time.

- Section Detector Summary: presents current detector status about all system detectors within a section.

- Section Status: displays the current operational characteristics of the section and the status of all intersections within the section.

- Intersection Status: presents the current state of an intersection, including previous cycle, offset, and phase times; traffic control mode and plan number; current phase green time counter; system and local detector information; and general configuration data.

- Multiple Intersection Tracer: displays current green phase return data for several intersections simultaneously.

- Communication Status: shows the status of communications on the selected channel.

Graphic display features of the Series 2000 include high-resolution real-time customized software, using 1024 x 1280 pixel resolution with up to 16 million colors. Graphics displays are structured in a five level hierarchy, as follows:

- **Level 1 (Title Screen)**: a static display which is brought up automatically when the color graphics workstation is turned on. Clicking the mouse anywhere on the screen will advance the display to the next level.

- Level 2 (Index): a static display listing all of the signalized intersections and their numbers, with a dynamic color coded indication of each one's respective status. Clicking the mouse at special locations on the screen will advance the display directly to any level 3, 4, or 5 screen

- Level 3 (System Map): a display showing a map of the City, including expressways, major roadways, and section boundaries. The map also dynamically shows that status (on-line, standby, failed, etc.) of al controller units (color coded). Clicking the mouse anywhere within a section boundary will advance the display to the next level.

- Level 4 (Section): a series of screens depicting each section of the signal system. Each screen incorporates dynamic information along with a static map of the section showing streets, signalized intersections, and detector locations. The dynamic (i.e., real time) information on these screens includes:

  - Status of controller units and system detectors (e.g., off-line, on-line, failed. Each condition is represented by a different color in the filled circle at the center of each signalized intersection).

  - Green and amber for all phases at each controller unit. Reds are typically not shown.

  - Traffic flow characteristics at system detectors showing volume, occupancy, and average speed over and under a threshold value. The thresholds are variable and are selected by the user through the keyboard.

Clicking the mouse at a designated location on the display changes from one section to another (i.e., an adjacent section). Clicking the mouse at any one of the intersections will advance the display to the next level.

- Level 5 (Intersections): a detailed display of each intersection with both static and dynamic information displayed. The static information includes the geometrics of the intersection and other desirable features such as pavement markings. The dynamic information includes graphic representations of each directional display for vehicles and pedestrians (e.g., red arrows, yellow arrows, red stop bard), and a header containing information on equipment status and the current timing plan (e.g., timing plan number, cycle length splits, offset, cycle counter, interval counter, etc.). The dynamic information changes in real time in accordance with the monitor messages.

As mentioned earlier, communications are maintained on a once per second basis. However, only monitoring data are returned at this frequency; controller unit commands are issued on an as-needed basis. This procedure reduces the communication loading. Communication between the central computer and the local controller units are full duplex.

Users of the Series 2000 include the cities of Portland, Oregon; Sioux City, Iowa; Eugene, Oregon; Springfield, Oregon; Sacramento, California; Lakeland, Florida; Tucson, Arizona; JFK Airport, New York; Scottsdale, Arizona; Chula Vista, California; Pasadena, California; San Jose, California; New Haven, Connecticut; Greensboro, North Carolina; and White Plains, New York. The number of controlled intersections in these systems ranges from 35 to 350.

SONEX CORPORATION

ESCORT

Escort is a distributed and centralized system since it can operate with or without field master controller units. (See Figure IV-10.) Current applications of the Escort system, however, include centralized operation because it maintains power at central while placing all the functionality at each intersection. This means that every intersection can perform all the necessary traffic functions without any supervision. So, if communications between central and any intersection should be lost, or the central computer itself should go down, the actual traffic control portion of the system will continue to operate as if nothing has happened. This operation is facilitated through the use of the Sonex Zero Drift Coordinator/System Interface Unit (ZDC). System integration with already existing controller units is also not a problem since the ZDC can interface with any standard controller unit. In the event that Model 170 controller units are used, the external ZDC unit is replaced with the compatible ZDC Prom Module. The ZDC Prom Module is an Intel Microprocessor driven, single printed circuit board device that inserts directly into the Model 170 controller unit via the standard prom module slot. The prom module has all the functionality found in the ZDC unit.

The ZDC acts as the controller unit's supervisor by issuing timing plans, preventing offset drift, monitoring and recording all important events. All commands issued to the controller unit come directly from the ZDC's internal database, and all recorded events are stored in its internal "historical log." This not only frees the central computer from having to perform these duties itself, but also makes the system more reliable by allowing each intersection to operate completely independent from the rest of the system, including the central computer; because of this design, the ZDC can even be used to coordinate intersections not included in a central based system.

The "historical log" containing the recorded events, including detector input information, is uploaded to the central computer for analysis and report output, etc. The database used for actual traffic control can be generated at central and then downloaded to any or all intersection ZDC's at any time.

Escort uses a minicomputer at central to supply power, and a network of microcomputers for users interface and convenience. With this architecture, Escort can control an unlimited number of intersections, i.e. 1000s, while all operator interfacing with the system is done via the PC environment. By utilizing the networking capabilities of the minicomputer, virtually any number of microcomputer terminals can be linked to the system. All interactions with the traffic system are done through these linked microcomputers. This not only permits the traffic engineer to work in the familiar PC environment, but also allows the sharing of information among users. In addition to being a low cost workstation, the PC is capable of Super VGA, 1024 by 768, high resolution graphics. Another benefit of this architecture is that any available software from both the mini and micro environments can be utilized by anyone in the network.

The power of the Escort minicomputer and the convenience of the microcomputer provide the following features at central:

- Support for thousands of intersections.
- Networking of system PC's using standard protocols.
- Permits the system to meet the application requirements of the entire transportation department.
- Ensures the integrity of system data and timing plans.
- Supplies real time and historical reports.
- User friendly environment.
- Easy to use database structure.
  - All data is in decimal or English notation.
  - All timing plans are in seconds instead of percentages.
- Supports route-preemption timing-plans.
- Multiple password security levels.

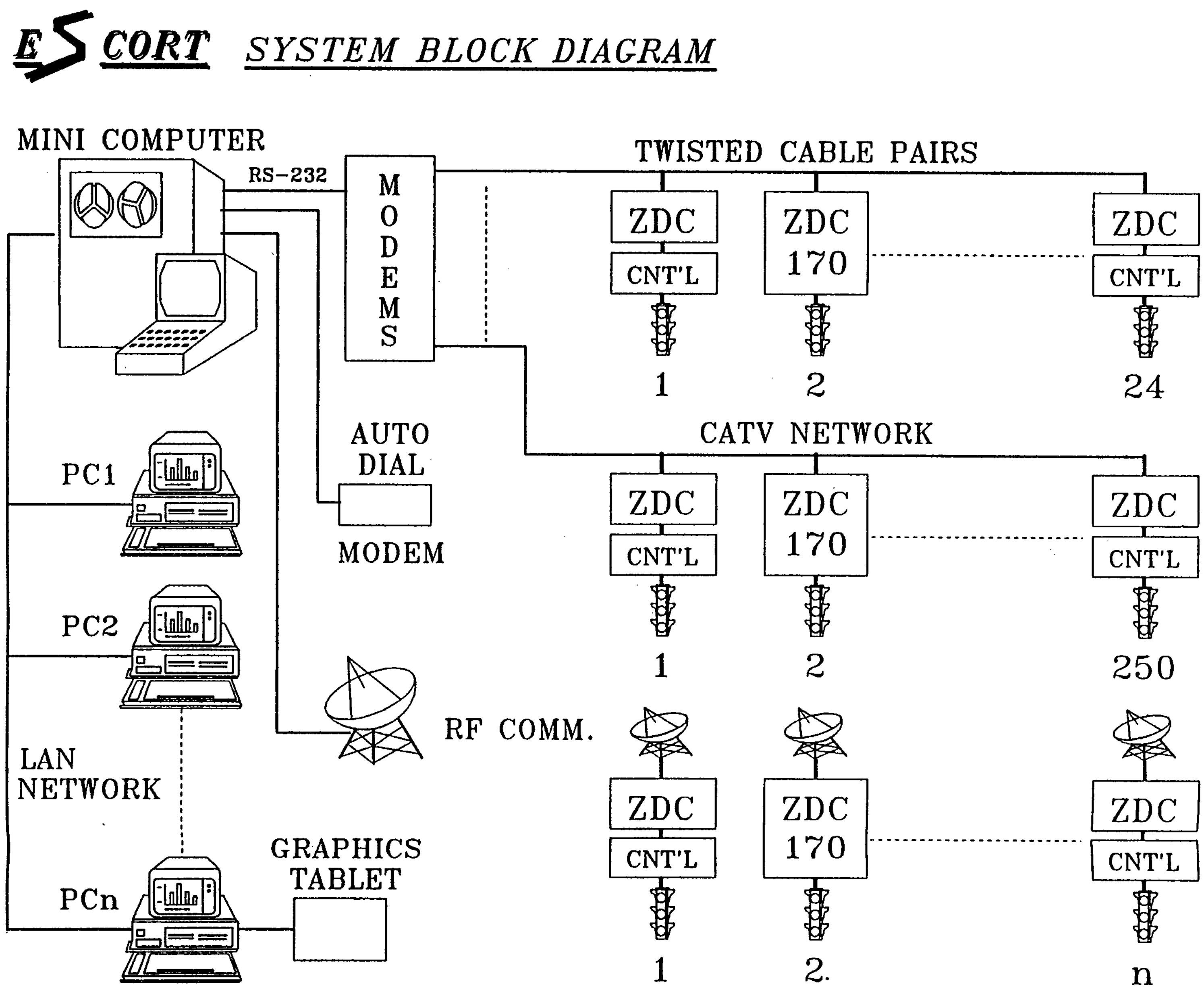


Figure IV-10. Sonex Escort Hybrid System Architecture

- Database downloading and uploading on a system, section or intersection basis.
- High resolution graphics.
    - Mouse and digitizer interface allows detailed custom drawings of intersections, sections and area maps to be drawn and saved on disk.
    - Custom intersection, section and map drawings are used for real-time report display.
- Traffic responsive operation using pattern matching algorithms for plan selection.
- Real-time communications to all intersections.
- Supports 1.5 timing plan generation. (Passer II & Transyt 7F).

Escort supports 34 timing plans, two of which are reserved for "Free" and "Flash" operation. The other 32 timing plans (cycle, offset and split) are user-defined. Also, the system supports up to 10 different weekly schedules in a year, 10 different daily schedules, and each day schedule can be divided into 24 separate time periods; each time period can be assigned to any of the 34 timing plans.

Escort supports up to 16 system detectors, 24 intersections per serial port (with twisted pair wire) and 250 intersection per serial port (with coaxial cable). Each controlled intersection can be polled once every second, for real-time reporting of the entire system. Escort supports wire and dedicated telephone (1200 bps) lines, CATV, dedicated coaxial cable, radio, and fiber optic communication links (19,200 bps). Multiple media also can be supported in a single system. Typically, Sonex uses its own ZDC internal modem with wire and dedicated telephone lines, and a Sonex S90-05 RD modem with CATV communications.

AUTOMATIC SIGNAL/EAGLE SIGNAL

MONARC™

The MONARC™ is a Master Office Network Area Responsive Control System. It provides centralized transportation management and control while providing distributed area wide on-street control.

The MONARC™ operates with a minimum configuration of 386 or 486 MB, 8 MB RAM, 100 MB disk, VGA or XGA color monitor, and OS/2 operating system. It can control up to 500 intersections per personal computers. Similarly, there is no practical limit on the number of workstations that can be interfaced with the central computer. A 386/486 file server PC can be used as optional. (See Figure IV-11.)

MONARC™ functions with several control modes including Time-of-Day/Day-of-Month; Manual; Flash; Pre-empt; Traffic Responsive; Local Time Base; Traffic Incident & Demand Management (Quick Response).

MONARC™ interfaces with any NEMA or Model 170/179 controller units, lane control, VMS, ramp metering, surveillance camera control/monitor, and automatic vehicle identification and monitoring equipment. The field communication interface between the Monarc and local equipment is accomplished through a 1200 Baud, TDM/FSK, twisted pair cable or via fiberoptic, CATV, Radio, Coaxial Cable and telephone lines.

Other unique features of the MONARC™ system include the following:

- Window-based user interface allowing simultaneous execution of multiple tasks.
- Multiple full function workstations (remote or networked). Conflict checking to ensure only single user data access. Security provided via user ID's with password and associated privilege levels.
- Upload and download of data from and to EPAC controller units, masters, and remote interface units.
- Support of all NEMA controller units through remote interface units and Model 170 controller units directly.
- Unlimited number of intersections per group, sync pulses for all groups referenced to a common time, intersections switchable between groups.
- Locking of compatible group cycle lengths under traffic responsive operation.
- Area graphics displays with current intersection, detector and group status, including dynamic zoom.
- Intersection graphics displaying real time signal and detector status. Multiple window displays allowed. Great flexibility in defining intersection diagrams, features and text.
- Systems events, Operator Commands, Time Based Commands and Quick Response Commands, all logged to disk and optionally to windows on workstations.
- Maintenance of historical detector data.
- Traffic Incident and Demand Management software. Operator definable triggering criteria and command execution to handle special traffic conditions.
- Traffic Analysis package providing time/space plots and timing plan generation based on historical/current detector data.
- Traffic responsive mode supports up to 48 traffic patterns per group.
- Time Base Control allowing schedule.

MONARC System Architecture

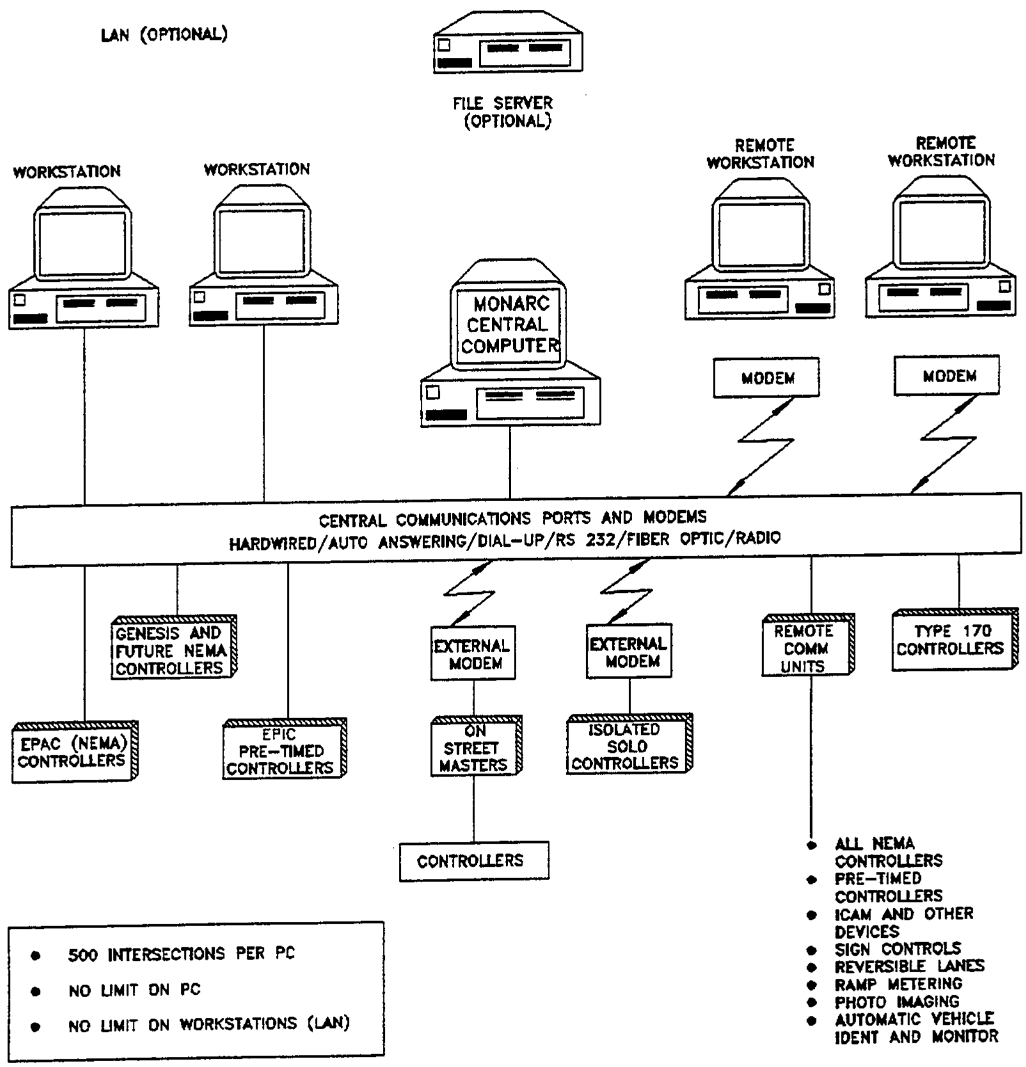


Figure IV-11. MONARC™ System Architecture assignment up to a year in advance. Automatic Daylight Savings Time and leap year adjustment.

- Extensive context-sensitive help windows and additional user aids, i.e. undo, copy, compare, etc. On-line Tutorial to guide new users through MONARC™ capabilities.
- Cable layouts and cabinet wiring diagrams using CAD or graphic programs.
- Maintenance and Inventory Management using spreadsheet format.
- Intersection descriptions provide graphics and/or text to further document intersection.

- Photo Imaging/Vehicle Identification capabilities.
- System Analysis: Traffic flow MOE's & extensive system detector logging and reporting.
- Utilize a variety of graphic formats allowing system incorporation of user generated graphic files, e.g. DXF based Area maps, etc.
- ICAM (Information and Control Monitoring) Systems

FARRADYNE SYSTEMS, INC.

MIST

MIST (Management Information System for Traffic) is a new concept in traffic control system management. The use of IMB's OS/2 operating system provides a windowed environment with pull-down menus. This provides a user-friendly system which avoids extensive training requirements and the need to learn a system command language. System maps, intersection maps, and cabinet/wiring drawings can be translated from Autocad or DXF compatible files into the MIST system. A graphics editor is provided with the system that is capable of creating, enhancing, or editing these drawings.

The MIST system is compatible with various field and system equipment, such as TCT LMD 8000 controller units, Model 170 controller units (Bi Tran and Wapiti software), remote coordinating units, on-street masters (NEMA and Model 170), as well as functioning as a front-end for existing UTCS systems. The MIST system is also able to control and monitor variable message signs, highway advisory radio stations, ramp metering equipment, and closed circuit cameras (CCTV). Incident detection algorithms and signal timing optimization programs can also be incorporated into the MIST system.

The MIST system uses IBM-compatible 386/486 PC computers with a minimum configuration of 6 MB RAM, 500 MB hard disk and a VGA color monitor. These PC(s) can be configured in a stand-alone mode, within a Local Area Network (LAN), or within a distributed system. The maximum number of user workstations is 20. This flexibility allows the MIST system to meet the wide variety of needs placed on today's municipalities. The MIST system can be used for applications ranging from a small city system to a state-wide distributed control system. Remote communications from a laptop with a standard dial-up line is also available. The communications media supported by the MIST system include twisted pair, coaxial cable, fiber optic, radio, microwave, and dial-up telephone lines. Communications capabilities include 1,200 to 96,000 bps, with 30 intersections per channel at 1,200 bps. A typical MIST configuration layout is shown in Figure IV-12.

MIST can control up to 240 intersections per single processor and up to 2000 intersections per a network. A single processor can control up to 24 sections; 200 sections can be controlled by a single network. A total of 24 detectors can be supported for each intersection. MIST control modes for timing plans include TOD, central manual, local manual, TRSP, local, flash, and preempt. MIST supports 16 special functions including 8 with timing plans and 8 with special function schedule.

The polling technique used by the MIST system allows up to 30 intersections per communications channel and can provide a system wide, real-time display of green returns. During normal polling periods, every intersection is communicated with twice per minute to get status and detector information. In addition, one intersection per communications channel can be communicated with once per second to display real-time graphic information. Detector data is used to provide detector and link Measures of Effectiveness (MOEs) including volumes, occupancies, and speeds. The summary period for detector MOEs is user-defined.

The traffic control functions provided with the MIST system were designed from the best characteristics of UTCS and closed-loop systems. The traffic responsive algorithm uses the UTCS-type, pattern matching algorithm for plan selection. The MIST system is capable of automatically generating the necessary inputs to the algorithm from the historical volume and occupancy data stored in the system database. The system maintains a permanent record of all significant system activities, including user access, intersection operation, detector and link MOEs, trouble calls, and equipment repairs.

The MIST system also provides editing of controller unit parameters and is able to compare the field database with the central database to find any discrepancies. All the system commands such as traffic responsive, time of day, manual, free, and flash can be performed on an intersection, section, or system-wide level. During traffic responsive operation, multiple sections can be made to operate as one system by using the master/slave, section locking feature.

Reports can be generated from 30 standard formats that are provided with the system. These reports contain valuable information such as the system status, traffic flows, equipment repair histories, and database configuration. Additional user-defined reports can also be generated by identifying the information desired by the user. The MIST system is capable of storing permanent or temporary schedules of system operation. System control functions and report generation can be scheduled by time of day through the use of the MIST event scheduler.

The MIST system can provide user-defined alarm reports. The MIST system can monitor communications equipment, detectors, controller units, and other hardware devices to detect and report malfunctions. When equipment failures are detected, the system is capable of generating an audible/visual alarm, dialing a pager, and/or automatically entering the failure in the system log.

Another important feature provided in the MIST system is the tracking of inventory and maintenance activities. These functions can be enhanced by the use of a bar code reader for the data entry of repair activities, thus reducing paperwork and errors. The use of bar code labels on controller units, conflict monitors, cabinets, detectors, etc. can provide information on every system component, even when the components are moved from intersection to intersection.

The maintenance section can store information about trouble calls, equipment repairs, and repair activities in order to generate statistics related to equipment failure rates. Repair logs of all repair activities are maintained in the system database. These logs include location, trouble call ID, problem reported, as well as the technician's name, problem found, data, and time of repair. Bar chart displays and reports can be generated that indicate the Mean Time To Repair (MTTR) and the Mean Time Between Failures (MTBF) of the equipment on an intersection, section, or system-wide basis.

These comparison reports assist the traffic engineer in making future purchases by determining the performance of the existing equipment. The inventory features provide the capability to identity specific equipment at assigned locations. The identification of equipment provides information on the system component including the type of equipment, manufacturer, model, purchase date, warranty period, etc. You can retrieve a complete inventory of all equipment installed at a specific intersection or all of the spare equipment inventory recorded in the system.

MIST has been installed and is operational in the following locations: Lancaster, CA; Huntington, WV; Noshua, NH; UCLA, CA; La Mesa, CA; Hillsborough County, FL; State of Delaware; Puerto Rico; Atlantic City, NJ; and Montgomery, AL.

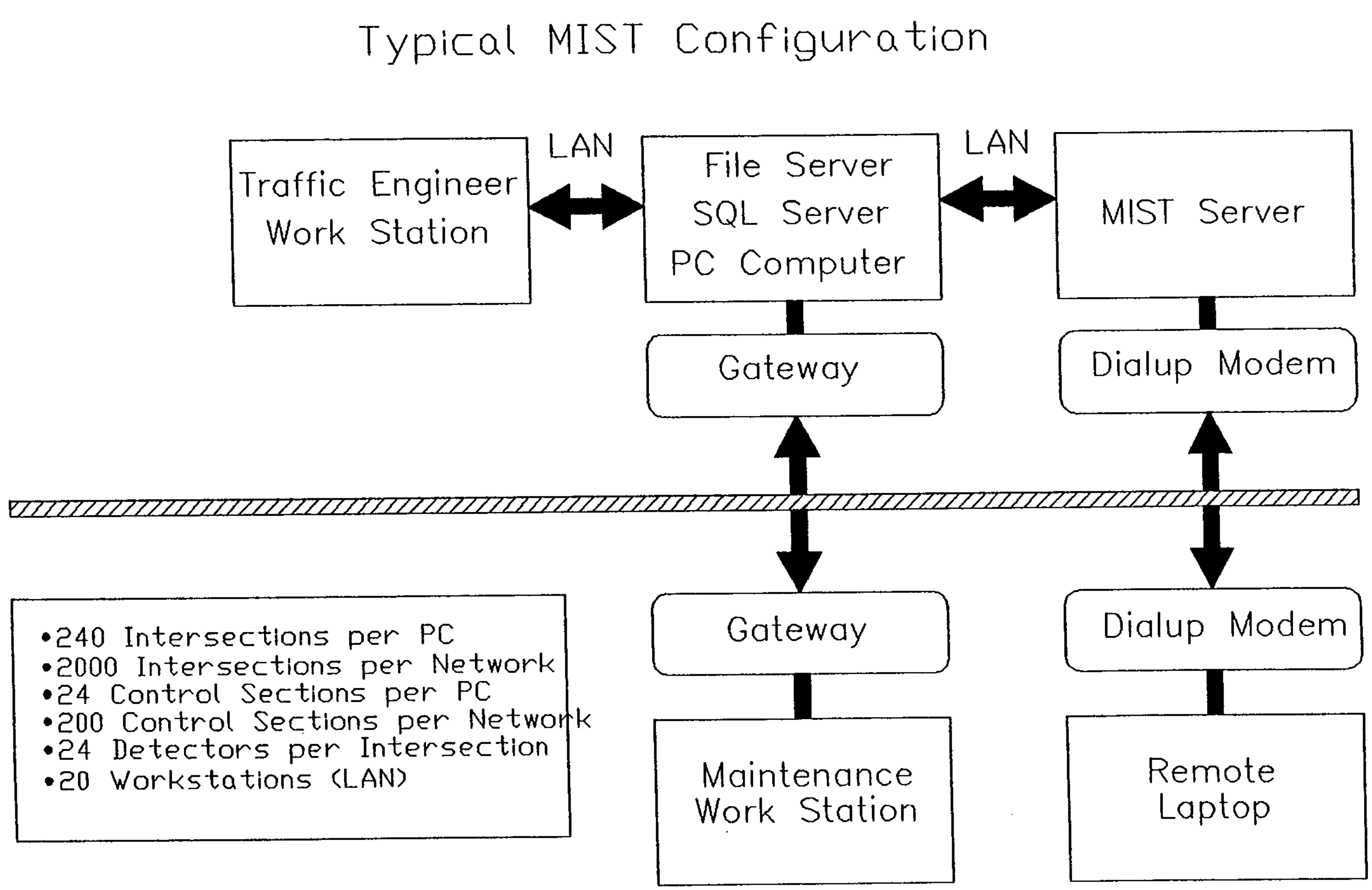


Figure IV-12. MIST Configuration

COMPUTERIZED SIGNAL TIMING TECHNIQUES

Signal timing is a very critical element of a successful traffic control system. It has been indicated that approximately less than five percent of the total cost for a traffic control system is usually spent on preparation of traffic signal timing plans.

Typically, the credibility of a traffic signal system is measured based on the user-developed traffic signal plans including cycle lengths, splits, offsets, progression bands and travel time/speed. As indicated earlier, all closed loop and hybrid signal systems use three common modes of operation: Time base, manual, and TRSP. In each one of these modes the timing plans are user-developed and, therefore, the quality of progression and efficient signal operation can be as good as the quality of the signal timing plans.

Generally, timing plans are developed using off-line computer techniques. Typical computerized programs for signal timing optimization and evaluation include Transyt 7F, Passer II-90, Soap, and Arterial Analysis Package (AAP). Each of these programs are described briefly below. Other programs are also used. (See Table IV-3.)

TRANSYT 7F

Transyt is an acronym for TRAffic Network StudY Tool. This program is perhaps the most widely used traffic signal timing software for arterial and network signal optimization. The program was initially developed in the United Kingdom in 1967. Transyt uses standard traffic data and timing parameters as inputs to evaluate existing and predetermined timing plans, and optimize new timing plans. The MOEs produced by Transyt include stops, delays, and fuel consumption. Additionally, Transyt produces time-space diagrams, platoon progression diagrams, interval lengths, splits, and offsets.

PASSER II-90

PASSER is an acronym for Progressive Analysis and Signal System Evaluation Routine. The original program was written by Dr. Carrol Messer of the Texas Transportation Institute in 1973. Passer is a microscopic, deterministic, optimization model designed specifically to determine optimal arterial signal progression. Passer considers actuated controls and multiphase operation.

Passer II-90, the newest version, can be used to optimize arterial progression, evaluate existing arterial signal timing, optimizes timing plans for best through progression band, determine highway capacity analysis and estimate fuel consumption. Passer II-90 also has a new dynamic graphic simulation capability to enable the user to examine operational effects and visualize signal coordination.

Passer II-90 uses a user-friendly menu driven, input/output processor.

SOAP 84

SOAP is an acronym for Signal Operations Analysis Package. Soap was originally developed by Mr. Dennis Robertson in 1979 as a mainframe model. This program was developed to determine signal timing plans for individual intersections. Since then, Soap has been converted to microcomputer applications and the program now includes a Data Input Manager (DIM) for easy assembly of input. Soap can develop timing plans for 6 design periods in a single run and can determine the best timing plan for each up to 48 continuous 15-minute periods. The MOEs of Soap are stops and delays.

ARTERIAL ANALYSIS PACKAGE (AAP)

The AAP package was developed as a timing tool to allow the user to use three of the most common timing programs (Transyt 7F, Passer II-90 and Soap) to perform comprehensive analyses and design of network and arterial timing plans. The AAP allows the user to enter the data only once in order to run all three programs. All three programs must be purchased separately to operate the AAP software.

Table IV-3. State-of-the-Art Signal Timing Programs: Optimization, Evaluation, and Simulation.

PROGRAM	GRID/NETWORK OPTIMIZATION	ISOLATED INTERSECTION OPTIMIZATION	ARTERIAL PROGRESSION	EVALUATE EXISTING TIMING	OPTIMIZE PHASE SEQUENCE	TIME-SPACE DIAGRAM	DATA INPUT MANAGER	CAPACITY ANALYSIS	SIMULATION OF OPERATION	ANIMATION	LEVEL OF SERVICE
TRANSYT 7F	X		X	X		X	X				
PASSER II-90			X	X	X	X				X	
SOAP 84		X		X							
MAXBAND (*)	X		X		X						
PASSER III		X		X	X						
AAPEX	X	X	X	X	X	X	X			X	
PASSER IV	X		X	X		X	X				
HCM 85		(MANUAL)						X			
TRAF-NETSIM				X			X	X	X	X	
HCM/CINEMA		X		X				X		X	X
EXPERT SIGNAL		X		X	X		X		X		

* — Denotes Main Frame Program

Other signal optimization and simulation programs are available from McTrans and/or PcTrans.

Transyt, and Passer are among the most popular programs used today. There are several other programs, however, that can be of a great value and help to traffic engineers, especially those involved in simulation, developing timing plans or even examining timing plans.

The following is a list and descriptions of traffic simulation models.

Traffic Simulation Models

Simulation models allow the traffic engineer to evaluate a variety of proposed operational improvements prior to implementing the changes in the field. The models vary in their level of detail and are classified as either microscopic (simulation of individual vehicles) or macroscopic (simulation of platoons of traffic). The models also apply to different type of facilities (e.g. signalized networks, freeways, or corridors).

TRAF-NETSIM: TRAF-NETSIM is a microscopic simulation model that provides a detailed evaluation of proposed operational improvements in a signalized network. For example, TRAF-NETSIM can evaluate the effects of converting a street to one-way, adding lanes or turn pockets, moving the location of a bus stop or installing a new signal.

The TRAF-NETSIM model is available from the McTrans Center and PC-Trans. A maintenance fee is included in the price of the software. A training course and a user friendly tutorial for TRAF-NETSIM are available. A Users Manual may be purchased from McTrans or PC-Trans.

A number of related microcomputer programs are distributed with TRAF-NETSIM to assist the user in inputting data and analyzing the results of the simulation. These include NEDIT, a menu-driven input preprocessor and GTRAF, a graphics package to provide color displays of both input and output data. The graphics include displays such as details of intersection geometrics, highlighting of potential problem areas or "hot spots," and an animation of the simulated traffic flow.

FRESIM: FRESIM is a detailed, microscopic simulation model for freeways. It can be used, for example, to evaluate the effects of ramp metering, adding new lanes to a freeway, or lengthening an acceleration lane. The FRESIM model is under development and testing. An input preprocessor and a tutorial in the use of FRESIM are also under development. No release data has been scheduled.

FREQ: FREQ is a macroscopic simulation model that can be used to design and evaluate alternative freeway entry control strategies such as ramp metering, and select the best strategy to optimize traffic flow on the freeway. The impacts of vehicles diverted from the freeway onto surface streets are also considered. FREQ provides estimates of changes in travel patterns due to ramp metering. For example, drivers who shift to car pools or busses to take advantage of priority treatment at the ramps may be one scenario.

The FREQ model is available from the University of California in Berkeley. Ordering information can be obtained from the Systems Unit, Institute of Transportation Studies, University of California, 114 McLaughlin Hall, Berkeley, California 94720.

CORFLO: The CORFLO model formerly called TRAFLO, provides a macroscopic simulation of a corridor containing both signalized intersections and freeways. It also contains a traffic assignment model that can redistribute traffic flows in response to control or geometric changes in the corridor. For example, the model provides a powerful tool for analyzing alternative construction traffic management strategies. CORFLO is currently being tested by FHWA, and graphics software to display the input data and the results of the simulation is under development.

Other Traffic Engineering Software

Highway Capacity Software: The Highway Capacity Software (HCS) replicates the procedures described in the 1985 Highway

Capacity Manual (HCM). It is a tool that greatly increases productivity and accuracy. Perhaps more than any other program, though, it can be misused as a black box. It should be used in conjunction with the 1985 HCM, not as a replacement for it. The 1985 HCM can be purchased from the Transportation Research Board or the Institute of Transportation Engineers.

The HCS and its user documentation are distributed by the McTrans Center. McTrans also offers a training course in its use. The price of the HCS includes a surcharge that goes towards the maintenance of the software. McTrans uses this money to correct any bugs reported by users and to enhance the operation of the software.

Over 2300 copies of the HCS have been distributed by McTrans. It has been generally accepted by the user community as faithfully replicating the 1985 HCM procedures. However, there are a number of other highway capacity software packages available, both in the public domain and proprietary. These packages generally contain features in addition to those available in the HCS. Both the McTrans Center and PC-TRANS can provide information on these packages.

There is no one who sanctions highway capacity software packages. The HCM itself is not a standard. Responsibility for capacity studies rests with the analyst, where it should. the software packages provide a means of eliminating tedious number crunching or extensive table analyses, thereby greatly increasing accuracy and productivity.

Other Software

Many other useful traffic engineering programs are available from McTrans and PC-TRANS. For a catalog and ordering information, call or write to the centers at the addresses below.

McTrans Center
University of Florida
512 Weil Hall
Gainesville, FL 32611
(904) 393-0378

PC-TRANS
University of Kansas
2011 Learned Hall
Lawrence, KS 66045
(913) 864-3787

CHAPTER V — HANDS-ON TRAFFIC SIGNAL SYSTEMS SOFTWARE

This session is designed to demonstrate state-of-the-art closed loop and hybrid traffic signal systems. The following systems will be demonstrated in the mobile trailer and each participant will have an opportunity to operate and examine the features fo these systems.

- MARC 360: Automatic Signal/Eagle Signal
- MONARC: Automatic Signal/Eagle Signal
- QuickNet II: BI Tran System Inc.
- Zone Monitor IV: Econolite
- ZDC Escort: Sonex
- Traconet: Traconex
- MIST: Farradyne
- Traffic View: Wapiti Micro Systems
- SMARTWAYS: Transyt
- LM100: Traffic Control Technologies
- TMS: Frederic R. Harris

Participants are encouraged to examine the systems' graphics, reporting, downloading, uploading, timing plan selection patterns, polling, intersection data entry, editing, etc.

CHAPTER VI — EMERGING TRAFFIC CONTROL TECHNOLOGIES

This session is devoted to short discussions of various technologies that are relatively recent developments or technologies currently under development by a major manufacturer or a public agency. This session discusses communications media, controller units, on-line signal timing advancements, and current IVHS projects.

COMMUNICATIONS

Spread-Spectrum Communications

Because of the relatively high cost of installing cable based communication systems and the increased need for traffic control systems in more rural areas, there has been an increased interest in radio technology for traffic control communications.

The principal limitation to radio technology is the availability of frequency channels. Data channels generally have a bandwidth of 25 Khz in order to support a data rate of 9600 bps, with two channels required for full-duplex operation.

Spread spectrum radio has been used for military applications. It spreads the transmitted power over a wide spectrum and encodes the signal such that detection by unauthorized users is difficult and security is high. Since 1985, the FCC has permitted the use of this technology without site license in a 900 Mhz band at powers up to 1.0 watt. This frequency imposes line-of-sight limitations and limits the distance for reliable operation to only two or three miles.

At least one manufacturer has begun the market units for use in traffic systems applications.

Fiberoptic Communications

The use of fiberoptic cable (in lieu of twisted-pair, copper-wire cables) is being considered by many users for the communications link in large freeway surveillance systems and for large centralized traffic signal systems.

Fiberoptic cable has the advantages of providing a very large bandwidth for greater capacity in transmitting data and, at the same time, providing immunity from line noise and interference. The National Electrical Code permits the fiberoptic cable to be installed in the same conduit with the traffic signal cables/conductors, thus effecting savings in the cost of installation.

Fiberoptic cable was used by the City of Los Angeles, California, for its UTCS-based centralized traffic signal system. Similarly, Daytona Beach, Florida and Montgomery County, Maryland use fiberoptic trunk line in their traffic signal control systems.

Traffic Fiber Systems, Inc. currently has a dual mode, double duplex communication, fiberoptic modem, Model FO212 DATA LINK, that is being used to interconnect traffic control equipment using the RS232 ports via fiberoptic cables. The Model FO212 DATA LINK modem has front-mount controls, master/local operation LEDs, battery backup (9V), and is compatible with NEMA/170 Environmental Specifications. It performs in daisy chain operation.

Recently, consideration has been given to multiplexing white color spectrum and shades to produce additional bandwith capacity.

CONTROLLER UNITS

Model 170-ATC Controller Units

The Model 170-ATC controller unit is still under development by the California Department of Transportation. This model of the 170 series will use a more advanced microprocessor (Motorola 68000 series) in lieu of the Motorola 6800 microprocessor that was used in the original Model 170. This controller unit uses a VME bus and utilizes either a 16 or 32 bit microprocessor.

In addition to controlling the timing of the signal at an intersection (either isolated or under the control of a master), this controller unit will allow the user to compute such traffic parameters as speed, volume, headway and occupancy.

Model 170 SBC 68 Controller Unit

Features of this controller unit are identical to the Model 170 ATC except it uses a standard bus instead of a VME bus. New York is developing this contoller unit.

ON-LINE SIGNAL TIMING

Real Time Traffic Adaptive Control (RTTAC) for IVHS

This project was contracted to Farradyne Systems by the FHWA in mid 1992 to develop and field evaluate a real-time, traffic adaptive signal control system that is similar tothe SCATS and SCOOT systems, suitable for use in IVHS environment by 1997. The project encompasses the first stage of a long-term effort. It is assumed by the FHWA that a single major contract will be awarded to the consortium composed of state and local DOT's, private industry, and academia.

Optimized Policies for Adaptive Control (OPAC)

This project was also awarded to Farradyne Systems to develop a non-line signal timing optimization software and hardware control for a single intersection control. The software and hardware developed it compatible with both NEMA and Model 170 controller units. This program develops real-time timing plans including cycle lengths, offsets, and splits. The OPAc is currently under testing on the New Jersey State Route 18 to examine its application in a closed loop environment.

CURRENT IVHS PROJECTS

The following are selected operational tests which are being conducted with Federal funding participation.

- TRANSCOM: TRANSCOM is a consortium of 14 transportation and public safety agencies in the New York and New Jersey area whose goal is to improve interagency response to traffic incidents. As part of this goal, a cooperative effort has been initiated to equip approximately 1,000 commercial vehicles with transponders. Readers will be placed at selected toll booths to provide automatic toll collection for equipped vehicles. Readers will also be installed at other locations, allowing vehicles equipped with transponders to serve as traffic probes. The test will evaluate the sue of this data to determine real-time traffic information such as speed, travel time, and the occurrence of incidents.

- SMART Corridor Project: The SMART Corridor is a joint demonstration project located along 12.3 miles of Santa Monica corridor in Los Angeles. The objectives of the SMART Corridor are to provide congestion relief, reduce accidents, reduce fuel consumption, and improve air quality. This will be accomplished using advanced technologies to advise travelers of current conditions and alternative routes using communications systems such as Highway Advisory Radio (HAR), Changeable Message Signs (CMS), kiosks, and teletext, improving emergency response, and providing coordinated interagency traffic management.

- **GuideStar Project**: GuideStar is a cooperative effort that will bring together a number of on-going operational traffic management and traveler information systems efforts with a wide range of new IVHS projects and technologies designed to reduce congestion and improve safety throughout Michigan. The project will emphasize the gathering and distribution of traffic information for the use of traffic managers and motorists. The effort will include the development of the Autoscope™ video imaging vehicle detection system. Michigan is currently establishing a major laboratory for GuideStar IVHS activities along a 3-mile corridor in the Twin Cities metropolitan area.

- **Pathfinder Project**: Pathfinder is a cooperative effort by Caltrans, FHWA, and General Motors (GM). It is an in-vehicle navigation system project aimed at improving traffic flow. Pathfinder will provide drivers of 25 specially equipped cars with up-to-date information about accidents, congestion, highway construction, and alternative routes as they operate in Los Angeles' SMART corridor. A control center will manage the communication, detecting traffic density and vehicle speeds via detector and by using Pathfinder vehicles as probes, and transmitting congestion information to equipped vehicles. The information is then presented to the driver in the form of an electronic map on a display screen or via digital voice.

- **TravTek**: TravTek (Travel Technology) represents a public/private partnership involving the city of Orlando, Florida, the Florida DOT, FHWA, GM and the American Automobile Association (AAA). The goal of TravTek is to provide traffic congestion information, motorist services ("yellow pages") information, tourist information, and route guidance to operators of 100 test vehicles equipped with an in-vehicle TravTek device. Route guidance will reflect real time traffic conditions in the TravTek traffic network. A Traffic Management Center will obtain traffic congestion information from various sources and provide this integrated information, via digital data broadcast, to the test vehicles and the sources.

- **ADVANCE**: ADVANCE (Advanced Driver and Vehicle Advisory Navigation Concept) is a cooperative effort to evaluate the performance of the first large-scale dynamic route guidance system in the United States. Participants include the Illinois DOT, Motorola, Inc., the Illinois Universities Transportation Research Consortium, and FHWA. Up to 5,000 private and commercial vehicles in the northwestern suburbs of Chicago will be equipped with in-vehicle navigation and route guidance systems. Vehicles will serve as probes, providing real-time traffic information. This information will then be transmitted to the equipped vehicles and used to develop a preferred route. The routing information will then be presented to the driver in the form of dynamic routing instructions.

- **DIRECT**: DIRECT (Driver Information Radio using Communication Technologies) will deploy and evaluate four alternative low cost methods of communicating advisory information to motorists. These include Radio Data Systems (RDS), Automatic Highway Advisory Radio (AHAR), HAR using AM radio, and cellular phone. A Metropolitan Transportation Center will collect traffic information from various sources and provide traffic updates to travelers on an exception basis. Initial experimental testing will involve 30 specially-equipped vehicles; subsequent testing will involve additional vehicles using conventional equipment (AM radio and cellular phone).

- HELP/Crescent: HELP (Heavy Vehicle Electronic License Plate Program) is a multi-state, multinational research effort to design and test an integrated heavy vehicle monitoring system using Automatic Vehicle Identification (AVI), Automatic Vehicle Classification (AVC),and Weigh-in-Motion (WIM) technology. Collected data will be processed by a central computer, and then be used by both government and the trucking industry for regulatory, weight enforcement, and fleet management purposes. The demonstration phase of HELP is known as the Crescent project which will include approximately 40 equipped sites ranging from British Columbia southward along I-5 to California and then eastward along I-10 to Texas, branching onto I-5. The goal is to have a system in which a truck, entering the system in British Columbia, can drive through the entire network without having to stop at over weight stations or ports-of-entry.

- Advantage I-75: Advantage I-75 represents a partnership of public and private sector interests along the I-75 corridor. The project will facilitate motor-carrier operations by allowing transponder-equipped and properly documented trucks to travel any segment along the entire length of I-75 at mainline speeds with minimal stopping at weight/inspection stations. Preclearance decisions at downstream stations will be based on truck size and weight measurements taken upstream and on computerized checking of operating credentials in each state. Advantage I-75 features application of off-the-shelf technology and decentralized and statutory authority relative to motor carriers and their operations.

IVHS issues that are expected to be investigated further include:

- System architecture; i.e. communications media, system data flows and protocols, data rates and message format, electrical interface, etc.
- Standards, i.e. performance and functional.
- Evaluation, i.e. development of criteria for evaluating and judging the results and findings of research and operational field experiments.
- Human factors, i.e. public acceptance.
- Liability, i.e. system design and performance.
- Private opportunities; i.e. private franchising.
- Access by private services, i.e. opportunities for private organizations to network with state and/or local governments.

GLOSSARY

ACTUATED — Identifies type of control which responds to calling signals generated by action of vehicle or pedestrian. (See Semi-Actuated and Full-Actuated.)

ACTUATION — The action of a vehicle or pedestrian which causes a detector to create a call in that phase or movement to request right-of-way.

ADAPTIVE SPLIT CONTROL — A means of local intersection split selection based on vehicular activity.

ADDRESS — The identification of specific intersections for transmission of commands or the receipt of data.

ADVANCE CALL DETECTOR — A detector located a considerable distance ahead of an intersection which calls the green to that approach.

ADVANCE WARNING — A per movement output used to give advance notice of an upcoming yellow or red indication. Typically used at hidden intersections with "prepare to stop" indicators.

ALGORITHM — A procedure, process, or rule for the solution of a problem. An algorithm may be a set of computational rules for the solution of a mathematically expressed problem.

ALL-RED INTERVAL — The display of red indications for all entering vehicular traffic.

ALTERNATE — Coordination method whereby successive signal indications along an artery do not give the same indication at the same time. Single double and occasionally triple alternates are set up. Typically used in urban grid systems.

AMPLIFIER (DETECTOR) — An electrical device used to sense electrical load changes on associated sensing equipment (e.g. inductive loops) and provide an output to an intersection controller for vehicle detection.

APPROACH — The remaining traffic lanes minus any exclusive turns or parking lanes.

ARTERIAL — A main street generally considered to be a thoroughfare with preferential right-of-way.

ASCII — American Standard Code or Information. A standard code that assigns special bits patterns of data.

ASYNCHRONOUS — A non-synchronized condition. Free running without any specific relationship in operation to any other condition.

AUTO/MANUAL SWITCH — A cabinet switch, when operated, discontinues normal signal operation and permits manual operation.

AVERAGE — (1) In coordination, the offset and cycle lengths used during periods other than peak periods.

BACKGROUND CYCLE — Term used in coordination systems to identify the cycle length established by coordination unit and master control; takes precedence over intersection control cycle length.

BACK PANEL — A board within the controller cabinet upon which are mounted field terminals, fuse receptacles or circuit breakers, and other portions of the controller assembly not included in the controller unit or auxiliary devices.

BAND (GREEN BAND) — Through or green elapsed time between the first and last possible vehicle permitted through an intersection in a progressive coordination system.

BARRIER LINE — See Compatibility Line.

BAUD RATE — The input rate of data transmission to a communications channel, usually expressed in bits per second.

BIT — An abbreviation for binary digit. A single character in a binary number.

BUFFER — A device used to make two other devices or systems compatible, in particular, a device or routine that compensates for differences in times of occupance or rates of flow when data is transmitted between devices.

BYTE — A term used to indicate a number of consecutive binary digits that are usually operated as a unit. Eight bits usually constitute a byte.

CALL — Vehicle or pedestrian. The result of a detector actuation. A signal in the control indicating the presence of a vehicle or pedestrian requesting right-of-way.

COMMUNICATIONS — Broad term used to denote the transmission of intelligence between two or more points separated by some distance. May be electrical impulses with specific identities or actual audible signals.

CABINET — An outdoor enclosure for housing the controller unit and associated equipment.

CALL — A demand for service registered in a controller assembly.

CALLING DETECTOR — A detector installed in a selected location to detect vehicles that may not otherwise be detected, and whose output may be modified by the controller unit.

CAPACITY — The maximum number of vehicles that can pass over a given section of a lane or roadway, during a given time period, under prevailing traffic conditions.

CARRIER FREQUENCY — A single frequency that is modulated by the lower frequency signals being communicated or carried, each carrier frequency provides an independent communications channel.

CENTRAL BUSINESS DISTRICT (CBD) — The portion of a municipality in which the dominant land use is for intense business activity.

CENTRAL PROCESSING UNIT — The hardware component of a computer system that contains the circuits that control and perform the execution of instructions (also called MPU).

CENTRALIZED SYSTEM — A computer control system in which the master computer, communication facilities, console, keyboard, and display equipment are all situated at a single, central location. From this center, the operating staff coordinates and controls traffic signals and related traffic control functions throughout the area.

CHECK — An outgoing circuit that indicates the existence of an unanswered call.

CHECKSUM — A mathematical value determined by programmed memory. A checksum error in an indication that one or more bits of programmed memory have changed incorrectly.

CLEARANCE INTERVAL(S) — The interval(s) from the end of the right-of-way of one phase to the beginning of a conflicting phase.

CLOSED-LOOP SYSTEM — A system in which the computer controls an external process using information received from the process; e.g., the closed loop in a traffic control system is from the computer to the controllers and from the detectors to the computer.

CNA (CALL TO NON-ACTUATED) — An actuated controller feature whereby the associated phase will always serve the walk plus ped clear time regardless of detector inputs. For more see: CNA in Applications Section.

COMPATIBILITY LINE — The dividing line crossing both rings, in dual ring operation, that separates compatible phase combinations. Usually it divides phases associated with North/South versus East/West.

CONDITIONAL SERVICE — A dual-ring feature which allows re-service to an odd phase (left turn) once the opposing through phase has gapped out. The service is conditioned by the time remaining in the adjacent through phase's MAX time.

CONFLICT MONITOR — A device used to continually check for the presence of conflicting signal indications and to provide an output in response to the conflict.

CONFLICTING PHASES — Two or more traffic phases which cause interfering traffic movements if operated concurrently.

CONTINUOUS-PRESENCE MODE — A mode in which the detector output continues if any vehicle (first or last remaining) remains in the field of influence.

CONTROLLER — A device which controls the sequence and duration of indications displayed by traffic signals.

CONTROLLER VOLTAGE MONITOR (CVM) — An open collector output maintained low by the controller as long as the internally generated operating voltages are within tolerances. Used by the conflict monitor to place the intersection in flash should voltages fail.

COORDINATION — The broad term applied to the interconnection controls in a manner which allows vehicles to traverse the roadway without encountering delay due to signalization.

CRITICAL INTERSECTION — A selected, heavily traveled intersection within a coordinated arterial. This intersection would be employed to dynamically control the split at selected signalized intersections within the arterial, based on vehicle detector input.

CROSSTALK — The adverse interaction of any channel of a detector unit with any other detector channel in that unit or another unit. It is the mutual coupling of magnetic fields that produces an interaction between two or more detector units in the same cabinet when the units are operating at similar frequencies. Crosstalk results in a detector outputting an actuation in the absence of a vehicle.

CROSSWALK — Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.

CYCLE — The total time required to complete one sequence of signalization around an intersection. In basic pretimed control the cycle length is fixed; in actuation the cycle length varies (up to predetermined maximums) according to the number of vehicles involved.

CYCLE ZERO POINT — See Time Reference Point.

DATA BASE — The assemblage of data constants and parameters used by a computer algorithm in the execution of the traffic control function. Normally included are timing parameters, adjustment coefficients, algorithm coefficients, and limit parameters.

DEMAND — The need for service; e.g., the number of vehicles desiring to use a given segment of roadway for a specific unit of time.

DENSITY — A measure of the concentration of vehicles, stated as the number of vehicles per mile (space density). Density = Volume/Speed (point density).

DETECTOR — A device for indicating vehicles or pedestrians desiring the right-of-way.

DETECTION ZONE — The area of the roadway within which a vehicle will be detected by a vehicle detector.

DETECTOR — The process of identifying the presence or passage of a vehicle at a specific point or the presence of one or more vehicles in a specific area.

DETECTOR AMPLIFIER — See Amplifier.

DETECTOR — A device for indicating the presence or passage of vehicles. This general term is usually supplemented with a modifier indicating type such as loop detector, magnetic detector, etc. operation (e.g., point detector, presence detector, etc.); or function (e.g., calling detector, extension detector, etc.).

DETECTOR AMPLIFIER — A device that is capable of intensifying the electrical energy produced by a sensor. An example is a magnetic detector amplifier. A loop detector unit is commonly called an amplifier, although its electronic function actually is different.

DETECTOR FAILURES — The occurrence of detector malfunctions, such as non-operation, chattering, or other erroneous signaling as well as occupancy errors and false alarms.

DETECTOR MEMORY (ON) — The retention of an actuation until the corresponding phase(s) is serviced.

DETECTOR UNIT — The portion of a detector system other than the sensor and lead-in cable, consisting of an electronic assembly.

DIAGNOSTICS — A program that facilitates computer maintenance by detection and isolation of malfunctions or mistakes.

DIAL — Generally referenced to a pretimed type of control. Consists of a dial with graduations in one percent increments 0 to 100. The scale graduations are matched with physical locations of switch actuations on initiate signals used in sequencing signalization.

DIMMING — This feature allows selected signal indication to be dimmed during night time operation.

DISTRIBUTED SYSTEM — A control system in which individual computers are installed in each of the major control areas of a total system and supervising master is used to provide interface between the individual areas and to make decisions on timing patterns effecting two or more areas.

DOS (DISK OPERATING SYSTEM — An organized collection of techniques and procedures for operating a disk-drive based computer system. This can be part of a software package designed to perform input/output procedures, sort, data conversion, or test, to name a few.

DOWNSTREAM — The roadway movement at an intersection which extends from the stop line, across the intersection and beyond in the through movement.

DUAL ENTRY — A mode of operation (dual-ring) in which one phase in each ring must be in service. If a call does not exist in a ring when it crosses the barrier, a phase is selected in that ring to be activated by the controller in a predetermined manner.

DUAL-RING CONTROLLER UNIT — A controller unit containing two interlocking rings which are arranged to time in a preferred sequence and to allow concurrent timing of both rings, subject to the restraint of the compatibility line (barrier).

DUPLEX — Two-way communication over a single communication link. See Half Duplex; Full Duplex.

DWELL — See Rest.

EEPROM (Electrically Erasable Programmable Read-only Memory) — A device which stores data that can be altered by computer instructions. EEPROMs can be erased and programmed without special physical processes.

ELECTRO/MECHANICAL — Refers to equipment which performs its functions on the basis that an electrical impulse causes a mechanical action to take place. No electron tubes or significant solid-state devices are used.

ELECTRONIC — Generally applied to equipment using electron tubes and/or solid-state devices. This catalog separates the two with electronic specifically assigned to electron tube equipment only.

ENHANCED PED — A CNA-1 (call to non-actuated) related feature whereby the walk time will be equal to the MAX I value.

EXCEPTION DAYS — A traffic pattern timing routine stored in controller memory which is activated to compensate for unusual traffic flow caused by a special event (such as a sporting event).

EXCLUSIVE PEDESTRIAN PHASE — A traffic phase allocated to pedestrian traffic only, provides a right-of-way pedestrian indication to the exclusion of all vehicular phases (all red).

EXTENDIBLE RECALL — A form of recall whereby the associated phase will always serve MIN green and further green time is subject to detector extension.

EXTENSION (GREEN) — The part of the green interval following the initial portion. Extensions are based on vehicle actuations.

EXTENSION DETECTOR — A detector arranged to register actuations at the controller only during the green interval for that approach so as to extend the green time of the actuating vehicles.

FAIL-SAFE — A primary safety consideration in equipment and system design. Precludes dangerous signalization when power or equipment malfunctions occur.

FEEDBACK — A system or circuit path which is provided to verify or limit the response to a command. Provides an indication that a command has been executed properly.

FIELD TERMINALS — Devices for connecting wires entering the controller assembly.

FIRMWARE — Logic circuits in read-only memory (ROM) that may be altered by the software under certain circumstances.

FIXED-TIME CONTROLLER — See Pre-timed Controller.

FLASH SWITCH — A cabinet switch, when operated, discontinues normal operation and causes the flashing of any predetermined combination of signal lights.

FORCE OFF — Action taken by external source which generates a signal to the intersection control(s) causing termination to begin in the phase exhibiting the right-of-way. Used in preemption and coordination.

FSK (Frequency Shift Keying) — A form of digital frequency modulation employing discrete frequencies for specific signals; e.g., marking signals. The transmitter is changed from one frequency to another; i.e. keyed to represent a different information character.

FULL ACTUATED — Identifies a type of intersection control with vehicle detector input capability in all phases.

GAP (PASSAGE) — The maximum time on volume density timed controllers allotted for vehicles to proceed through the intersection.

GAP, MINIMUM — The lower limit to which the extendable portion or terminating gap may be decreased on volume density time controllers.

GAP REDUCTION — A feature whereby the "unit extension" or allowed time spacing between successive vehicle actuations, on the phase displaying the green in the extendable portion of the interval, is reduced. See TBR (Time Before Reduction), TTR (Time To Reduce), and MIN GAP.

GREEN BAND — The time in seconds elapsed between the passing of the first and last possible vehicle in a group of vehicles moving in accordance with the designed speed of a progressive traffic control system.

GRID — A group of coordination thoroughfares covering a large area with movements in several directions. The entire area is controlled and synchronizes movements to minimized delay. Master control usually is centralized.

HARD COPY — Data permanently recorded on paper, film, or other tangible media for later reference.

HERTZ — The modern term used as the unit of measure when expressing alternating current potentials, formerly called cycles per second.

HOLD SIGNAL — A signal to an intersection controller commanding it to retain the specified phase (usually the coordinated phase) even in the presence of conflicting demands.

IMSA — International Municipal Signal Association.

INBOUND — The traffic condition wherein an imbalance exists with a heavier flow towards central points. Also described as the A.M. peak period.

INFRARED DETECTOR — With infrared detectors the detection zone is illuminated with low power infrared light. As vehicles pass in the detection zone, the infrared light is reflected from vehicles and is focused by an optical system onto a sensor matrix. A real time signal processing technique analyzes the received signal and determines the presence of a vehicle.

Infrared detectors are two types: Active and Passive. Active infrared detectors are most applicable to stop line presence and approach presence detection. Passive infrared detectors detect moving vehicles only, normally up to 300 feet from the detector unit.

INFRARED DETECTOR — A detector that senses radiation in the infrared spectrum.

INHIBIT — An action or signal which prevents a normal change in the operating sequence of a control. Is used to obtain coordination or other special condition upon command from an external source

INITIAL GREEN — See MIN GREEN.

INPUT/OUTPUT (I/O) — A general term for equipment used to communicate with a computer.

INTERCONNECTION — Refers to method of communication between distant points to obtain coordinated control or other master control. May be direct wire or telephone line.

INTERFACE — A relay or electronic device(s) which isolates and matches one portion of a system to another. Assures that each major unit receives impulses which exhibit the proper characteristics and prevents undesirable interaction between units.

INTERSECTION — The term applied to roadways that meet or cross.

INTERVAL — The time period allotted to a specific control function. Does not necessarily result in a signal change but does indicate a transfer to control within the unit to another circuit. Initial interval, extension interval, etc.

INTERVAL ADVANCE — Activation of this input will cause immediate termination of the interval in process of timing.

IVHS — Intelligent Vehicle Highway System.

LEAD-IN WIRE — (Loop Lead-In) That portion of the loop wire between the physical edge of the loop and the pull box; for a magnetic detector and magnetometer it is the wire which runs from the sensor (probe) to the pull box.

LEAD-IN CABLE — (Feeder Cable, Home-Run Cable, Transmission Line) The electrical cable which served to connect the lead-in wire to the input of the loop detector unit.

LANE — A standard width of roadway of significant proportion to permit a single vehicle safe passage.

LARGE AREA DETECTOR — (Area Detector) A detector or series of detectors wired together in series or series/parallel covering an area in the approach to an intersection. Detection area varies from 6 x 40 ft. to 6 x 100 ft. or larger. One of the more common configurations is four 6 x 6 ft. loops spaced 9 or 10 ft. apart for a length of 51 or 54 ft.

LEAD/LAG OPERATION — A feature which makes it possible to reverse the phase sequence on a phase pair basis. The phase pairs, 1-2, 3-4, 5-6, 7-8 when reversed, the odd phase will lag the even phase instead of leading as is normal.

LIMIT, EXTENSION — See MAX I.LIMIT, MAXIMUM - The maximum green time after an opposing actuation, which may start in the initial portion.

LIMITED-PRESENCE MODE — Operation of a detector whereby output continues for a limited period of time if vehicles remain in field of influence.

LINK — The length of roadway between two signalized intersections.

LOAD SWITCH — A device used to switch power to the signal lamps.

LOCAL CONTROLLER — See Controller.

LOCAL OFFSET UNIT (Local coordination unit; Local Supervisory Mechanism) — An auxiliary synchronous device applied to a non-synchronous controller to cause the controller to keep in step with a control frequency, which may be the AC power frequency. May have multiple-offset capabilities.

LOCKING, Section or Group — A method of system control whereby one section (or sub-system) selects the coordination pattern for one or more other sections.

LOOP DETECTOR — A detector that senses change in inductance of its inductive loop sensor caused by the passage or presence of a vehicle near the sensor.

LOOP DETECTOR UNIT — An electronic device which is capable of energizing the sensor loop(s), of monitoring the sensor loop(s) inductance, and of responding to a predetermined decrease in inductance with an output which indicates the passage or presence of vehicles in the zone of detection. It is the electronics package, exclusive of the loop(s) and lead-in cable.

MAIN STREET GREEN (MSG) — An electrical signal transmitted from the local controller to the central computer during the period when the local controller is displaying green for the coordinated phase.

MAGNETIC DETECTOR — A detector that senses changes in the Earth's magnetic field that are caused by the movement of a vehicle near its sensor. It is a vehicle detector placed under the roadway which makes use of both the Earth's magnetic field and the energy change created by the passage of a vehicle over the detector to produce an output.

MAGNETOMETER DETECTOR — A detector that measures the difference in the level of the earth's magnetic forces caused by the passage or presence of a vehicle near its sensor. It is a device capable of being activated by the magnetic disturbance caused by the passage or presence of a vehicle. A magnetic flux generator/sensor is installed in the roadway and connected to sensor amplifier electronics.

MANUAL OPERATION — The operation of a controller by means of a hand operated device; i.e., police push button.

MANUAL PUSH BUTTON — An auxiliary device for hand operation of a controller.

MANUAL RESET — A reset by which it is possible to manually establish the offset. Refer to Offset Seeking Modes.

MAP DISPLAY — A device which graphically portrays the system of streets under control. Indicator lights are placed at the signalized intersections to display various information provided by the computer system.

MASTER — A control device for supervising and monitoring a system of secondary (local) controllers, maintaining definite time interrelationships, and/or accomplishing other supervisory functions. In the case of traffic responsive operation, the master generally includes computation equipment and recording equipment.

MAXIMUM 1 (MAX I) — Usually refers to a time limit applied to traffic actuated controls to terminate the right-of-way and prevent massive delays to opposing vehicles during heavy traffic. Termination by maximum usually results in a recall placement to prevent trapping of vehicles.

MAXIMUM 2 (MAX II) — An optional feature usually associated with coordination methods. Provides two possible maximum time settings for cycle or right-of-way interval total time before termination begins.

MAXIMUM VARIABLE INITIAL — An actuated controller setting, associated with Variable Initial, its longest possible extension given to MIN green operating in Variable Initial. See Seconds Per Actuation (S/A).

MAX RECALL — A feature whereby the associated phase(s) will always serve the MAX time, regardless of detector inputs.

MEASURES OF EFFECTIVENESS (MOE) — Measures the effectiveness of the system in improving traffic flow. Common bases of comparison include: volume, occupancy, delays, and speed.

MICROWAVE DETECTOR — With microwave detectors microwave energy is beamed toward an area of roadway from an antenna mounted overhead or in a sidefire position on a pole. The antenna is angled toward traffic to create a dopplar effect on the reflected signal. When a vehicle passes through the beam, the energy is reflected back to the sensing unit (antenna) at a different frequency. The detector, electronic unit, senses the change in frequency which is an indication of the passage of a vehicle. The operating frequency is usually either K-band (24gHz) or X-band (10gHz).

MIN GAP — During the process of GAP REDUCTION, it is the lowest level to which the passage timer (gap) will reduce.

MIN GREEN — The guaranteed green time of a phase. If a time setting control is designated as minimum green, the green time shall not be less than that setting.

MIN RECALL — A feature whereby the associated phases(s) will always serve the MIN green time, regardless of detector inputs.

MIST — Management Information System for Traffic.

MOVEMENT — The term used to identify the direction of travel and the approach of a vehicle at an intersection. See Phase.

MUTCD FLASH — See Remote Flash.

NEMA — National Electrical Manufacturers Association.

NODE — Each signalized intersection in a traffic signal system. Also, each one-way traffic stream between nodes is a link. See Link.

NON-ACTUATED — Refers to a control type generally in the pretimed category, but can be one phase in any control which does not employ a vehicle call. Right-of-way timing for the not-actuated phase is fixed regardless of traffic volume except for possible dwell.

NON-LOCKING (MEMORY OFF) — A mode of actuated controller operation which does not require detector memory.

OCCUPANCY — The percentage of roadway occupied by a vehicle at an instant in time. In general use, it is a measurement based upon the ratio of vehicle presence time (indicated by a presence detector) over a fixed period of total time.

OFFSET — The relationship between two or more intersection controls along an artery such that vehicles starting at a reference point may proceed along the artery at a predetermined speed without stoppage. Is accomplished by resetting each intersection control from a master control to select the artery green point capable of true progression.

OFFSET INTERRUPTER — A method of offset seeking which distributes over two or more cycle lengths, any time required for large offset changes.

OFFSET SEEKING — A process performed by the local controller to get in step (in sync) with the master controller. When in sync, the local cycle zero point is offset from the master's sync pulse by a programmable value determined by the active offset period.

OMIT, PHASE — A command that causes omission of a phase.

OUTBOUND — The traffic condition wherein an imbalance exists with a heavier flow away from central points. Also described as the P.M. peak period.

OVERLAP — A right-of-way indication that allows traffic movement when the right-of-way is being assigned to two or more traffic phases.

PARITY CHECK — A summation check in which the binary digits in a character or word are added, and then sum checked against a single, previously computed parity digit; i.e., a check of whether the number of ones in a word is odd or even.

PASSAGE DETECTION — The ability of a vehicle detector to detect the passage of a vehicle moving through the detection zone and to ignore the presence of a vehicle stopped within the detection zone.

PASSAGE DETECTOR — (Motion Detector, Dynamic Detector, Movement Detector) vehicle detector that has the ability to detect the passage of a vehicle moving through the detection zone and to ignore the presence of a vehicle stopped within the detection zone.

PASSAGE TIME — The time allowed for a vehicle to travel at a given speed from the detector to the nearest point of conflicting traffic.

PATTERN — A unique set of traffic parameters (cycle, split, and offset) associated with each signalized intersection within a predefined group of intersection (a section or sub-zone).

PATTERN MATCHING — A technique used to select a pattern based on comparing measured traffic data with stored data associated with stored patterns.

PATTERN SELECTION — Choosing one of several patterns from a library of patterns, either manually or automatically, as a function of time-of-day or traffic responsive.

PEDESTRIAN — Any person on foot.

PEDESTRIAN CLEARANCE — The interval during which the "DON'T WALK" indication is flashed, starting after a "WALK" indication and ending before conflicting vehicles receive a green indication.

PEDESTRIAN DETECTOR — A detector capable of sensing manual operation by a pedestrian.

PEDESTRIAN PERMISSIVE PERIOD — Provides an independent permissive period for ped timing, which usually requires more guaranteed time than the vehicle. See Permissives.

PEDESTRIAN PHASE — A traffic phase allocated to pedestrian traffic which may provide a right-of-way pedestrian indication either concurrently with one or more vehicular phases, or to the exclusion of all vehicular phases.

PEDESTRIAN RECALL — With the control activation, pedestrian walk and clearance intervals for the phase are timed once during each cycle without the necessity of a push-button actuation.

PEDESTRIAN RECYCLE — Any pedestrian service that begins after the associated green phase.

PEDESTRIAN SIGNAL — A traffic control signal which is erected for the exclusive purpose of directing pedestrian traffic at signalized intersections.

PERCENTAGE — Used in lieu of expressing time in seconds since many intervals (which see) are a portion of the total cycle. The total cycle length can be changed due to coordination, 100 percent is used to indicate the total cycle length and the splits and intervals as a percentage of that total.

PERCENTILE SPEED — Information obtained from intersection warrants relating to vehicle speeds in an approach. Example: 80th percentile speed: that speed above which 80% and below which 20% of the speeds occurred in the approach.

PERMISSIVE PERIOD — Relates to selected periods during coordinated operation in which a call from the opposing phase can be acknowledged.

PHASE — A movement or movements controlled by one module or section of a control which is times by one timing device only. Symbol used:

PHASE DIAGRAM — A diagram illustrating the sequence of phases at an intersection, with movement arrows indicated for each phase and showing overlaps, concurrent timing, etc.

PHASE NEXT (TN) — A controller output, when active, the associated phase is committed to be next in sequence. The output will remain active until the phase becomes active. The TN decision is made at the end of the green interval of the terminating phase.

PHASE OMIT — See Omit.

PHASE OVERLAP — See Overlap.

PHASE SEQUENCE — See Sequence.

PLATOON — A group of vehicles in motion. Similar to a Queue but differs in that the group of vehicles are in motion. Has become the desired method of establishing coordination — allows a group of vehicles of a certain smooth right-of-way along an artery.

PRE-EMPTION — The transfer of the normal control of signals to a special signal control mode which may be required by railroad trains at crossings, emergency vehicles, mass transit vehicles, or for other special needs.

PRESENCE DETECTOR — A traffic detector which is able to detect the presence of a vehicle and hold the call for a specified minimum period of time that the vehicle is within its field of detection.

PRESENCE DETECTION — The ability of a vehicle detector to sense that a vehicle, whether moving or stopped, has appeared in its field.

PRESSURE SENSITIVE DETECTOR — A detector capable of sensing the pressure exerted by a vehicle passing over the surface of its sensor.

PRETIMED CONTROL — Refers to a type of intersection control where interval times are not related to vehicles detector actuations but remain a fixed percentage of the total cycle length.

PROGRAM — A preset signalization sequence(s) from a master in the systems concept. May be electro/mechanically produced or Traffic Adjusted by appropriate equipment and/or computer.

PROM (Programmable Read-only Memory) — A device which stores data that cannot be altered by computer instructions. Data is stored "burned" into this device externally by an electronic process. Some PROMs can be erased and programmed through special physical processes.

PROGRESSION — Refers to coordination method based upon offsets between intersections along an artery. Determined by time required to travel from one controlled intersection to the next and adjusted to give artery right-of-way without delay.

PULL BOX — (Hand Hole, Junction Box, Junction Well, Splice Box) A container usually at least 1 cubic ft. in size that is placed underground with a removable cover flush with the ground surface. Splices between lead-in cable and loop lead-in wire are located here.

PULSE MODE — Operation of a detector wherein a short output pulse is produced when detection occurs.

QUEUE — A platoon or group of vehicles waiting at an intersection.

RADAR DETECTION — A detector capable of sensing the passage of a vehicle through its field of emitted microwave energy.

RANDOM ACCESS MEMORY (RAM) — A storage device with both red and write capabilities which allows random access to stored data.

READ-ONLY MEMORY (ROM) — A storage device not alterable by computer instructions; e.g., magnetic core storage with a lock-out feature.

REAL-TIME CLOCK — A clock which indicates the passage of actual time of day rather than a clock set by the computer to measure an arbitrary interval of time (same as time-of-day clock).

RECALL — An operational mode for an actuated controller whereby a phase, either vehicle or pedestrian, is displayed each cycle whether demand exists or not. Usually in a temporary or emergency situation. See MIN Recall, MAX Recall, PED Recall, Soft Recall, Extendable Recall, and CNA.

RED CLEARANCE INTERVAL — A clearance interval, which may follow the yellow change interval, during which both the terminating phase and the next right-of-way phase display red.

RED REST — A feature whereby, in the absence of demand, the controller will return to all red instead of resting i green of the last serviced phase.

REMOTE FLASH — An input, when energized, causes normal signal operation to be discontinued and specified signal light to be operated in a flashing manner.

RESET — The action in an intersection control which causes the control to begin its cycle at a new position in time in relation to a reference. Resetting a control assures a desired offset between intersections in a progression system at all times.

REST — The state in which the controller unit remains until called out of that phase.

RIGHT-OF-WAY — A movement has the right-of-way on a green signal with some legitimacy during the yellow clearance interval.

RING — An ordered sequencing of mutually exclusive phases.

RS-232 INTERFACE — Standard interface between data terminal equipment and data communication equipment employing serial binary data interchange.

SAMPLING DETECTOR — Any type of vehicle detector used to obtain representative traffic flow information.

SAMPLING PERIOD — The length of time between each sample of a sensor.

SAMPLE RATE — The rate at which measurements of physical quantities are made; e.g., the number of times each second that a computer senses the status of a data sensor such as a loop detector.

SECONDARY CONTROLLER OPERATION (slave) — A method of operating the traffic signals under the supervision of a master controller.

SECONDARY OR LOCAL CONTROLLER — See Controller.

SECONDS PER ACTUATION (S/A) — An actuated controller setting, associated with variable initial. When a vehicle passes over a detector, a tabulation begins (S/A amount for each actuation), each successive actuation adding to the previous. The S/A amount is compounded until it overrides the MIN green period, and at that point becomes the new MIN green. See Maximum Variable Initial.

SEMI-ACTUATED — Identifies type of intersection control with one or more phases lacking vehicle detector input capability.

SENSOR — The sensing element of a detector.

SEQUENCE — The order in which signal intervals are displayed around an intersection on a pretimed control or with calls all around on an actuated control.

SERVICEABLE CONFLICTING CALL — A call which: a) occurs on a conflicting phase not having the right-of-way at the time the call is placed; b) occurs on a conflicting phase which is capable of responding to a call; or c) when occurring on a conflicting phase operating in an occupancy mode, remains present until given its right-of-way.

SIGNAL — An optical device which is electrically operated by a controller and visually communicates a prescribed action or actions to traffic.

SIMULTANEOUS — Coordination method whereby all signals along an artery give the same indications to given street at the same time.

SIMULTANEOUS GAP-OUT INHIBIT — A feature that disallows a phase's passage timer from starting up again once it has timed out.

SINGLE RING CONTROLLER OPERATION — A controller unit that operates two or more sequentially timed and individually selected conflicting phase so that they occur in an established order.

SMALL AREA DETECTOR (Point Detector) — A detector that measures the passage of vehicles past a point (i.e., a small area usually not exceeding 6 x 6 ft.

SOFT RECALL — A form of "extendable recall" except the phase in only served if no other "real calls" exist. Real calls are those for which there is a detector input actuation.

SOFTWARE — Programs that facilitate the efficient operation of a system, such as data bases, operating systems, and application programs.

SONIC DETECTOR — A detector that is capable of sensing the presence of a vehicle through its field of emitted ultrasonic energy.

SPECIAL EVENT PROGRAMMING — See Exception Days.

SPEED TRAP — Two or more detectors strategically positioned and spaced, to permit the computation of vehicle speed by measuring the time between actuations as a vehicle passes from one sensor to the next.

SPLASHOVER — An unwanted actuation caused by a vehicle in a lane adjacent to that in which the detector is located.

SPLIT — The division of time within the signal cycle between adjacent phases in the sequence.

SPLIT SELECTION, ADAPTIVE — See Adaptive Split Selection.

STOP LINE — A line which indicates where vehicles should stop when directed by a traffic control device.

STOP TIMING — Provision within a controller to suspend timing operations upon assertion of an external command.

STORAGE AREA — The area, usually expressed in terms of the number of vehicles, between the stop line and the detector located upstream. In pretimed control it may be the number of vehicles arbitrarily used to determine green time.

SUPERVISORY — Refers to master control equipment which generates programs to several intersection controls based upon clock, computer or other traffic adjusted equipment.

SURVEILLANCE — The process of observing traffic performance through the use of detectors.

SYNCHRONIZATION — (1) Refers to motors or cam switches which are designed to remain in step or in the correct rotational relationship at all times. (2) Internal circuitry used to be sure several circuits begin actions from the same reference point.

SYSTEM STATUS — The operational condition of each monitored remote control unit or data sensing station in the system as indicated by a display or a print-out.

TBR (TIME BEFORE REDUCTION) — During the process of GAP REDUCTION, it is the time period before the Gap reduction process takes place.

TDM — See Time Division Multiplexing.

TELEMETRY — The automatic transmission of data over long distances.

TERMINATE — Applies most frequently in traffic control to the end of a timing interval. Termination of right-of-way begins in an active phase when a call is received from an inactive phase in a full actuated control; right-of-way termination must always include adequate intervals.

THIS PHASE NEXT (TN) — See Phase Next.

THRESHOLD — A specific level or value of a parameter above or below which a change of activity will occur.

THROUGH BAND — See Green Band.

THROUGH MOVEMENT — A movement at an intersection which continues in a straight line and across the intersection; does not turn in any direction.

TIME BASE COORDINATION — Coordinated operation in response to internally generated time clock commands selecting cycle, split, and offset.

TIME CLOCK — A device for the automatic selection of modes of operation of traffic signals in a manner prescribed by a predetermined time schedule.

TIME DIVISION MULTIPLEXING (TDM) — A technique for transmitting several different messages over one communication channel by dividing a fixed interval of time into several time slots and sending a discrete message within each time slot.

TIME-OF-DAY PATTERNS — Signal timing plans selected according to the time of day.

TIME REFERENCE POINT — A point in time which serves as the time reference signal; i.e., in the signal system for any one street, the time-space diagram is normally expressed in terms of the offset between each signal in the system and one particular signal which serves as the time reference signal. The start of the green time reference signal on this street is defined at the time reference point.

TIME/SPACE DIAGRAM — A semi-pictorial presentation of two or more intersections being coordinated that shows the offset, cycle, distance relationships.

TIME ZERO — The reference point used in coordinated systems to identify offsets along an artery.

TIMER — The timing unit in a controller cabinet. Most often referred to as the controller.

TRAFFIC ACTUATED — A type of traffic control signal in which the intervals are varied in accordance with the demands of traffic as registered by the actuation of detectors.

TRAFFIC ADJUSTED — Term used in master supervisory systems where vehicle actuations and other data are fed to the master for effecting signalization changes at several intersections rather than at each intersection independently.

TRAFFIC RESPONSIVE SYSTEM — A system in which a master controller specifies cycle/split/offset on the real-time demands of traffic as sensed by vehicle detectors.

TRANSITION — The process whereby the computer and the local intersections controllers change from one program to another.

TTR (TIME TO REDUCE) — During the process of Gap Reduction, it is the total time period for the reduction process to take place.

ULTRASONIC DETECTOR — Ultrasonic detectors use the same principle as the microwave detectors — a transducer transmits a beam of energy into an area and receives a reflected beam from a vehicle. The sonic detector transmits pulses of ultrasonic energy (20 to 50 kHz at 20 to 25 times/sec) through a transducer. The passage of a vehicle causes a beam to be reflected to the transducer at a different frequency. The transducer senses the change in frequency and converts it to electrical energy. This energy is relayed to a transceiver, which then sends an impulse to the controller unit to denote passage of a vehicle.

UPSTREAM — The roadway portion of an intersection which precedes the stop line.

VARIABLE INITIAL — A feature which allows the minimum green period to be extended depending on the size of the waiting vehicle queue. See Seconds per Actuation (S/A), Maximum Variable Initial, and Volume Density.

VOICE GRADE LINES — A channel suitable for transmission of speech, digital, analog, or facsimile data, generally in the frequency range of 300 to 3000 Hz.

VOLUME DENSITY — A process used with detectors located at, or at sufficient distance in advance of, the intersection which makes use of vehicle actuation quantities and time-of-waiting of the vehicles to vary green interval portions for increased capacity and minimized delays.

WARNING, ADVANCED — See Advanced Warning.

WARRANTS — The results of actual surveys made at an intersection to determine if signalization is needed or requires change. Refer to Uniform Manual for suggested methods and determining factors.

WEEK PROGRAM — A program used to determine the time of operation according to a weekly schedule which may be preset to vary from day to day.

YELLOW CHANGE INTERVAL — The first interval following the green right-of-way interval in which the signal indication for that phase is yellow.

YIELD POINT — Related to permissive period but more specifically a point in the cycle of a coordination system where the opposing phases are permitted to give right-of-way to one or more of the opposing phases.

ZONE DETECTION — See Detection zone.

ZONE OF DETECTION — (Area of Detection, Effective Loop Area, Field of Influence, Sensing Zone) That area of the roadway within which a vehicle is to be detected by a vehicle detector system.

APPENDIX A — FHWA AND NHI COURSES AND REFERENCES

This appendix includes a list of training courses, handbooks, guidelines, and manuals that are readily available to traffic engineers and technicians. For specific information about the description of the training courses, status, fee, and availability, contact the agencies listed below.

	Type	Days	Agency	Contact
NEMA Microprocessor Controller	W	3	NHI	202-366-2200 703-285-2776
Traffic Detector Video	V		FHWA/ITE	202-366-2200 202-554-8050
Traffic Detector Handbook	H	-	ITE FHWA	202-554-8050 202-306-2200
Traffic Signal Systems: Go for the Green	V	-	ITE	202-554-8050
Computer-Controlled Traffic Signal Systems	W	4	FHWA NHI	202-366-2200 703-285-2776
Traffic Control Systems & IVHS Handbook	H	-	FHWA	202-366-2182 202-366-2219
Traffic Control Communications	H	-	FHWA	202-366-2200
Traffic Signal Design Training Course	W	2	NHI	202-366-2200
Traffic Signal Workshops	W	5	GIT	404-894-2400
Traffic Signal Workshop	W	-	Northwestern University	800-323-4011
Micro-Computers in Transportation Engineering	W	5	Northwestern University	800-323-4011
Transyt — 7F Signal Timing Optimization	H	-	McTrans	904-392-0378
Arterial Analysis Package	W	3	FHWA	202-366-2200
International Municipal Signal Association	W	-	IMSA	315-331-2182
Manual of Traffic Signal Design	H	-	ITE	202-554-8050
Traffic Control Devices Handbook	H	-	FHWA	202-366-2189 703-285-2374
Type 170 Traffic Signal Controller User Guide Series	H	-	FHWA	703-285-2370
TRAFNETSIM Course	W	4	FHWA	202-366-2207
Transient Protection for Electronic Traffic Control Equipment	W	2	FHWA	202-366-2200

W — (Workshop) V — (Video Cassette) ITE — (Institute of Transportation Engineers)
H — (Handbook) GIT — (Georgia Institute of Technology)

APPENDIX B — ABBREVIATIONS

AC — Alternating current
ACIA — Asynchronous communications interface adapter
ALM — Alarm
ALU — Arithmetic logic unit
ASCII — American Standard Code for Information Interchange
AVG — Average
BCD — Binary-coded decimal
BV — Battery voltage
CMOS — Complementary metal-oxide semiconductor
CPU — Central processor unit
CTR — Controller
DC — Direct current
DCDR — Decoder
DOW — Day of week
EIA — Electronic Industries Association
EPROM — Erasable PROM
EXT — External
FIFO — First in - first out
GND — Ground
HR — Hour
Hz — Hertz (cycles per second)
IC — Integrated circuit
IND — Indicator
INT — Internal
INTFC — Interface
I/O — Input/Output
IPL — Intersection plan
KMC — Keyboard-input MPU-based controller
KYBD/DSPL — Keyboard display
LD — Local detector
LED — Light-emitting diode
LIP — Local Intersection Plan
LSB — Least significant bit
MPU — Microporcessor
MV — Multivibrator
MZ — Master zero
NEMA — National Electrical Manufacturers Association
OCC — Occupancy
PCB — Printed circuit board
PCL, PCH — Program counter
PDT — Power down timer
PGM — Program
P-P — Peak to Peak
PROM — Programmable read-only memory
PS — Power Supply
PSIO — Random access memory
ROM — Read-only memory
RTC — Real time clock
SIG — Signal
SO — Scaled occupancy
SPC — Special
STD — Standard
SV — Scaled volume
SYS DET — System detector
TLM — Telemetry
TOD — Time of day
TS — Traffic control systems
TTL — Transistor - transistor logic
TVS — Transient voltage suppressor
UV — Ultraviolet
VEH — Vehicle
WOY — Week-of-year

APPENDIX C

FHWA DEMONSTRATION PROJECT NO. 93
LIST OF CONTACTS

MANUFACTURERS	CONTACT PERSON	TELEPHONE NUMBER
ATSI	Jim Gilbert	(614) 593-4145
AUTOMATIC SIGNAL	John Necker/Alen Otley	(512) 837-8325
BI TRAN	Mike Travers	(410) 626-7580
DETECTOR SYSTEMS	Carl Zebel	(800) 828-7775/(714) 895-6366
DVP, INC.	Mark Price	(301) 670-9282
EBERLE DESIGN	Scott Evans	(602) 968-6407
ECONOLITE	Mike McGehee*/Harold Weiss**	*(714) 630-3700/**(410)866-8050
FARRADYNE	Vaughn Callaway	(301) 468-5568
FREDERIC R. HARRIS	*David Hill/Doug Byrd	*(703) 641-5600/(305) 876-0606
LECTRO	Jack Thomas*/Tim Cutler	*(410) 666-1497/(800)-551-3790
MICROWAVE SENSORS	Bob Hunter/Don Johnson	(313) 426-0140/(800)-521-0418
RTC	Dale Thompson	(817)860-1217
SAFETRAN	Steve Brown/Bob Russo/John Satcher	(719) 599-5600
SARASOTA	Ian Cardoza	(813) 366-8770
SETCON	Jerry Sweringen	(206) 885-0205
SIGNAL CONTROL	Richard D'Alessandro	(916) 878-7410
SOLID STATE DEVICES	Ken Travis	(602) 967-4712
SONEX	Mike Dadrio/Joe Pastre	(215) 533-4900
SETCON	Jerry Sweringer	(206) 885-0205
TSC	Eric Metz	(714) 371-0285
TCT	Mike McNeill/D. J. A'Alfonso	(315) 452-0056
3M	Earl Hoekman/George Palm*	*(615) 733-4056/(612) 733-6116
TRACONEX	Gary Lieberman/Greg Freel*	(407) 295-8418/(904) 262-7371*
TRANSYT	Dave Strofilino/Jerome Buie	(904) 562-2253
WHELEN ENGINEERING	Tom Fredericks	(203) 526-9504
WILLIAMSON MANUFACTURING	Lance Prior	(801) 973-9400
TRAFFIC CONSULTANT	Ziad Sabra	(410) 381-0167/(410)290-7299
FHWA	Charles Stockfisch	(202) 366-8039

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