ORT NO. UMTA-MA-06-0025-77-17

GENERAL VEHICLE TEST INSTRUMENTATION MANUAL

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Transportation Systems Center
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SEPTEMBER 1977
OPERATIONAL HANDBOOK

DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Office of Rail Technology
Washington DC 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0025-77-		

4. Title and Subtitle	5. Report Date
GENERAL VEHICLE TEST INSTRUMENTATION MANUAL	July 1977
	6. Performing Organization Code
7. Author(s): Lowell V. Babb	8. Performing Organization Report No.: DOT-TSC-UMTA-77-40
9. Performing Organization Name and Address: U.S. Department of Transportation, Transportation Systems Center, Kendall Square, Cambridge MA 02142	10. Work Unit No. (TRAIS): UM-704/R7706
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, Urban Mass Transportation Administration, Office of Technology Development and Deployment, Office of Rail Technology, Washington DC 20590	13. Type of Report and Period Covered: on cover: Operational Handbook
	14. Sponsoring Agency Code: UTD-30

15. Supplementary Notes

16. Abstract

A General Vehicle Test System (GVTS) has been developed by the Transportation Systems Center, Cambridge, Massachusetts to facilitate rail transit vehicle testing at the Transportation Test Center, Pueblo, Colorado. This system was designed to be responsive to requirements specified in the publication GENERAL VEHICLE TEST PLAN (GVTP) for URBAN RAIL TRANSIT CARS, report number UMTA-MA-06-0025-75-14. This manual describes the GVTS instrumentation equipment and techniques to be used for vehicle tests. The GVTS includes measurement systems for vehicle voltage, current, acceleration/vibration, pressure, temperature, displacement, strain and test reference data.

17. Key Words	18. Distribution Statement
Instrumentation Dynamic Vehicle Performance Measuring Devices Urban Rail Transit Cars	DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	245	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

Under the sponsorship of the Office of Rail Technology Division of the Urban Mass Transportation Administration, Office of Technology, Development and Deployment, the Transportation Systems Center (TSC) provides technical support for improving urban rail transportation systems. To facilitate rail vehicle testing at the Transportation Test Center in Pueblo, Colorado, the Urban Rail Supporting Technology Program of TSC has developed a General Vehicle Test System (GVTS). This system includes instrumentation, digital data acquisition and processing equipment and certain special purpose measurement systems. The GVTS was designed to be responsive to requirements specified in the General Vehicle Test Plan (GVTP) for Urban Rail Transit Cars, document number UMTA-MA-06-0025-75-14, September 1975.

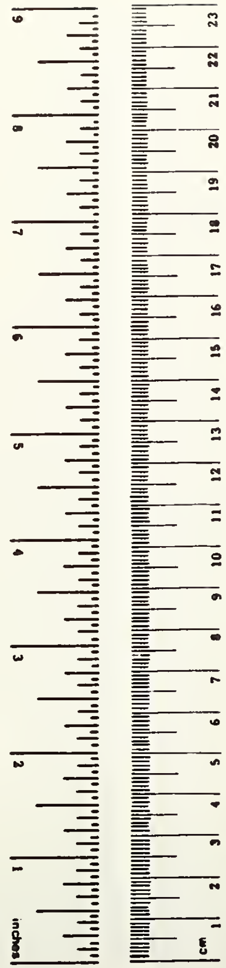
This manual describes the instrumentation equipment and the detailed techniques for ensuring the acquisition of valid test data. The GVTS includes measurement systems for vehicle electrical current and voltage, acceleration/vibration, air pressure, equipment temperature, mechanical strain, displacement and test reference data such as vehicle speed and location.

This work was performed under the direction of George Neat, Assistant Program Manager for Test and Evaluation for the TSC Urban Rail Supporting Technology Program. The equipment was designed by TSC staff member Phillip Silvia and the author.

METRIC CONVERSION FACTORS

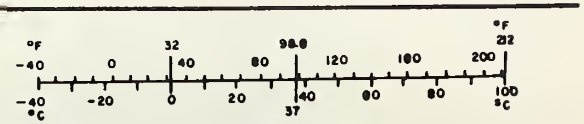
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 BACKGROUND

The Office of Rail Technology Division of the Urban Mass Transportation Administration (UMTA) Office of Technology Development and Deployment is conducting programs directed towards the improvement of urban rail transportation systems. These research and development programs will result in improved prototype vehicle and component designs, improved ways and structures, and improved structural components.

The Transportation Systems Center (TSC) has been designated by UMTA as System Manager for the necessary technical support in these developmental areas. The UMTA-sponsored Urban Rail Supporting Technology (URST) Program at TSC has implemented a test program which has included tests on the New York City Transit Authority and the Massachusetts Bay Transportation Authority as well as on the Rail Transit Test Track at the Transportation Test Center (TTC) in Pueblo, Colorado.

A General Vehicle Test System (GVTS) has been developed by the TSC to facilitate vehicle testing at the TTC. This sytem was designed to be responsive to requirements specified in the publication General Vehicle Test Plan (GVTP) for Urban Rail Transit Cars, report number UMTA-MA-06-0025-75-14 (formerly TSC GSP-064). The purpose of this referenced document is to provide a standardized framework for the planning, execution, data analysis, and reporting of urban rail vehicle tests. To accomplish the required standardization, Standard Output specifications are listed and defined in the GVTP. These output lists describe the required operating characteristics of the instrumentation to be utilized to make the measurements and the required signal processing characteristics for derived outputs. Parameters to be measured include electrical current, voltage, acceleration/vibration, pressure, temperature, strain, and displacement.

The GVTS is an integrated instrumentation system consisting of transducers, signal conditioners, signal filters, interface and control electronics, a data acquisition system, signal monitoring and output devices, and all related hardware and software. For purposes of design and development, the GVTS is divided into three parts,

Part 1: The instrumentation system up to and including the signal filters and associated hardware.

Part 2: The digital data acquisition system with associated software, and

Part 3: Special purpose measurement systems such as noise, radio frequency interference, spin/slide, adhesion, and dynamic shake.

1.2 PURPOSE

The purpose of this manual is to fully describe the instrumentation system (Part 1) of the GVTS. In addition, the standardized techniques to be employed to ensure the acquisition of valid test data using the system are documented in detail.

A companion document, General Vehicle Test Instrumentation Evaluation, Report Number UMTA-MA-06-0025-77-9, March 1977, reports the results of evaluative tests performed on the instrumentation systems. These tests took place at the Transportation Test Center, Pueblo, Colorado under actual rail transit operating conditions.

The equipment for General Vehicle Testing described in this manual is complemented by a second system developed under contract to Boeing Vertol Co. for use on the State-of-the-Art Car (SOAC) test program. The SOAC instrumentation system includes analog magnetic tape recorders and is described in Volume VI of the SOAC test report.*

*State-of-the-Art Car Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Report, Volume VI: SOAC Instrumentation System, Report number UMTA-MA-06-0025-76-6, National Technical Information Service, Springfield, Virginia 22161, Document Number PB-244 752

1.3 Approach

Section 2 of this document presents a system overview of the entire GVTS. A summary of the instrumentation systems referenced to the applicable Standard Outputs of the GVTP comprises Section 3. Signal monitor and calibration equipment is described in Section 4 while the instrumentation electrical shielding and grounding techniques are given in Section 5. Descriptions of the supporting documentation file, the inventory control system, and miscellaneous system notes are included in Sections 6 through 8 respectively. References are listed in Section 9.

Each individual measurement system is described in detail in a related appendix to this document. Each appendix contains the following information as required:

a. Description - The intended use of the measurement system, list of required equipment, additional items, supporting documentation, and applicable photographs.

b. Special Handling - Precautions necessary to ensure operator safety and to prevent damage to the equipment.

c. Theory of Operation - A brief description of the principles employed in the sensor configurations.

d. Shield and Ground Technique - The required connections discussed and shown on a wiring block diagram.

e. Measurement System Functional Wire List Summary - A pin-to-pin listing of the total subsystem, useful when isolating system defects and malfunctions.

f. Mode Card Setup - The required modifications to existing signal conditioner mode cards. These include the addition of excitation voltage programming resistors, calibration resistors, filter capacitors, and the selection of proper jumpers.

g. Vehicle Mounting - The recommended mounting technique with any constraints necessary to ensure valid data and instrument survival. A listing of special tools and any required vehicle modifications.

h. Calibration, Primary - Methods to be used for system calibration with traceability to the National Bureau of Standards.

i. Calibration, Secondary - Methods to be used to verify the calibration or operation, or both, of each system after installation on a test vehicle.

j. Additional Information - Any significant information not previously discussed. It may include operational details, disassembly procedures, etc.

2. SYSTEM DESCRIPTION

2.1 SYSTEM OVERVIEW

The General Vehicle Test System (GVTS) is composed of a number of measurement systems that measure and condition analog/digital electrical equivalents of physical parameters. (See Figure 2-1.) The analog/digital signals are channeled through various electronics to the Data Acquisition System (DAS) where the analog signals are converted to digital. The DAS has the necessary features to allow limited real-time data processing and output and complete post-test data processing and output.

The types of physical parameters measured are listed to the left in Figure 2-1, followed by a measurement instrumentation listing of specific types of sensors, transducers, or other source devices. The general sequence, type, and location of components of the measurement systems (or reference data systems) are designated at the bottom of the figure. Specific components of each measurement system are identified by model or type designation and manufacturer or supplier.

In the following paragraphs, the categories of equipment are briefly described while more detailed information on each individual component is provided in subsequent sections of this manual and in each appendix. The Signal Conditioning, Signal Filtering and Data Acquisition Systems, however, are only treated in this section. More detailed data on these systems is available in the manufacturer's instruction manuals.

Components of the GVTS that are located in the interior of the test vehicle are normally installed in a three-bay electronics rack. Figures 2-2 and 2-3 illustrate one configuration of this rack used during the instrumentation evaluation tests.

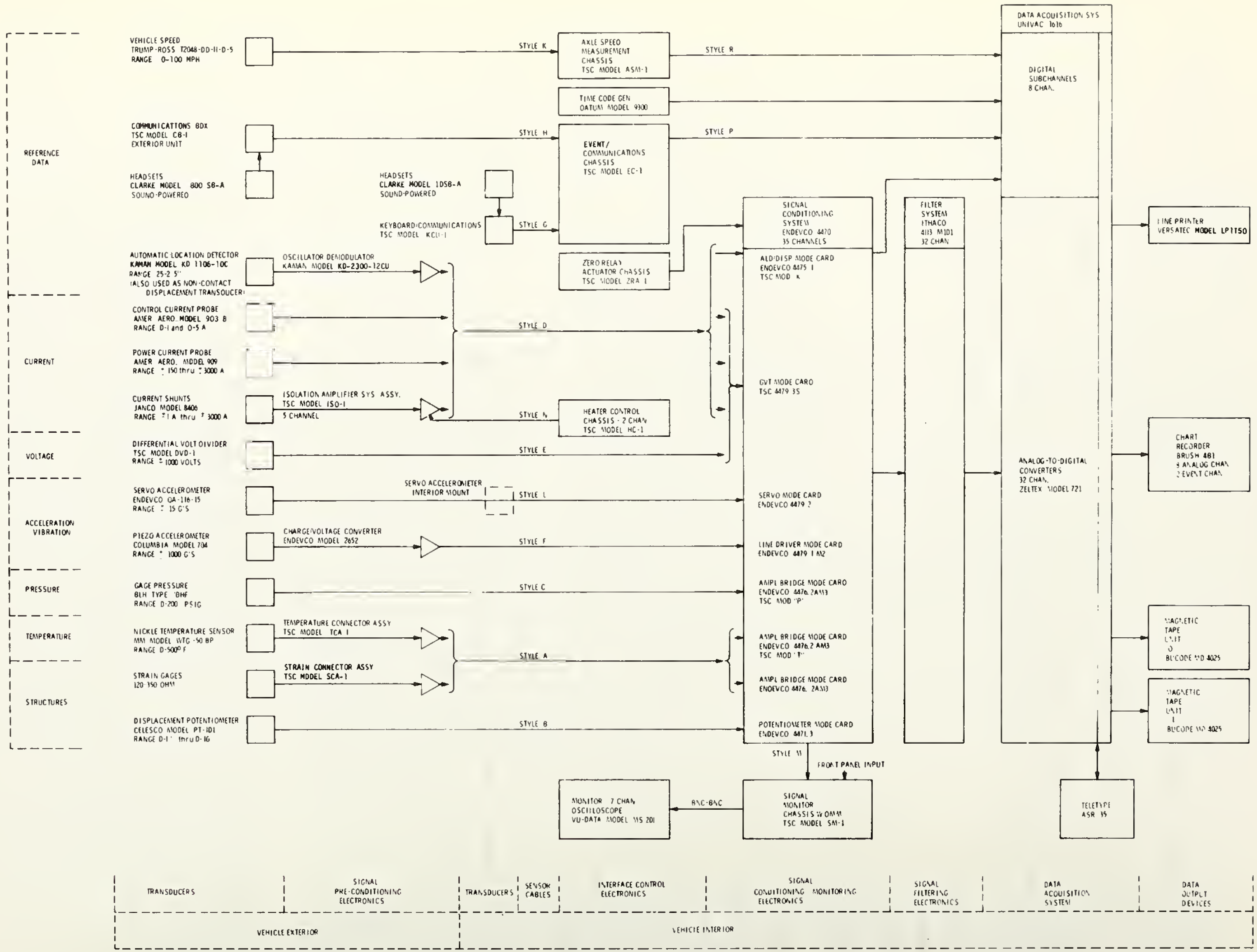


FIGURE 2-1. GENERAL VEHICLE TEST SYSTEM BLOCK DIAGRAM

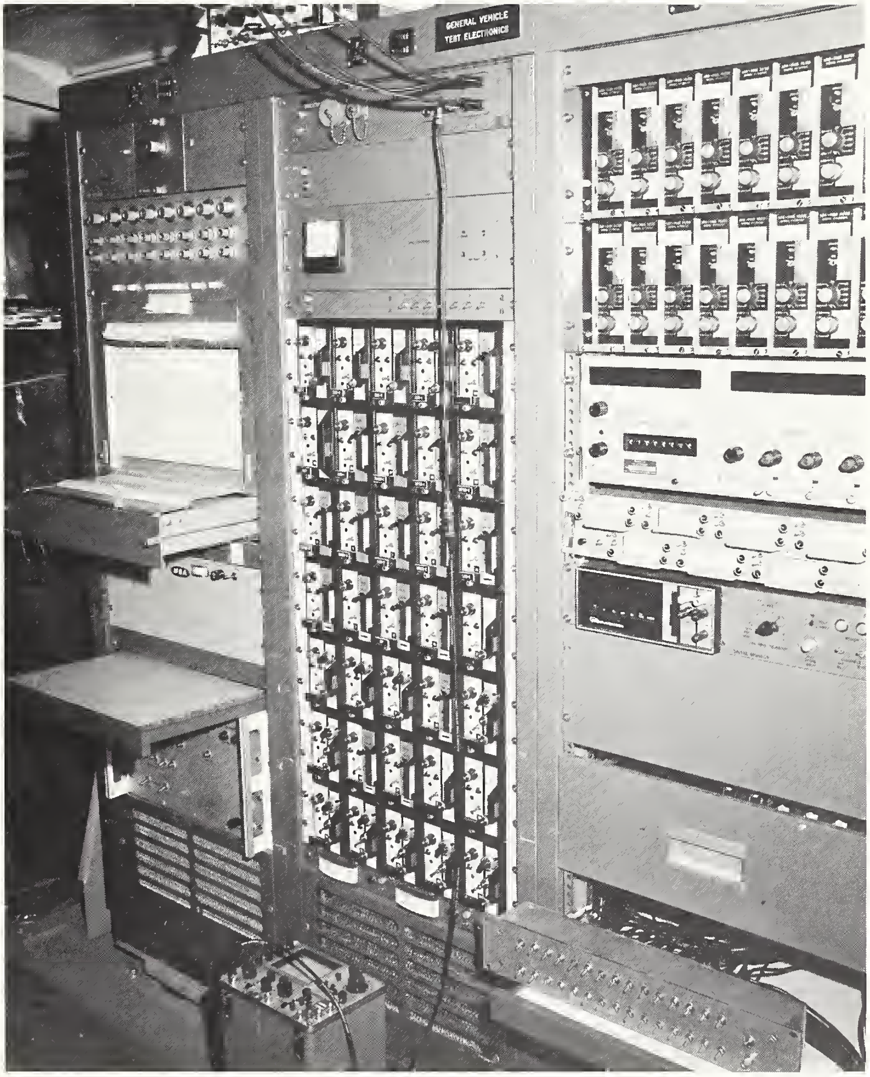


FIGURE 2-2. THREE BAY EQUIPMENT RACK

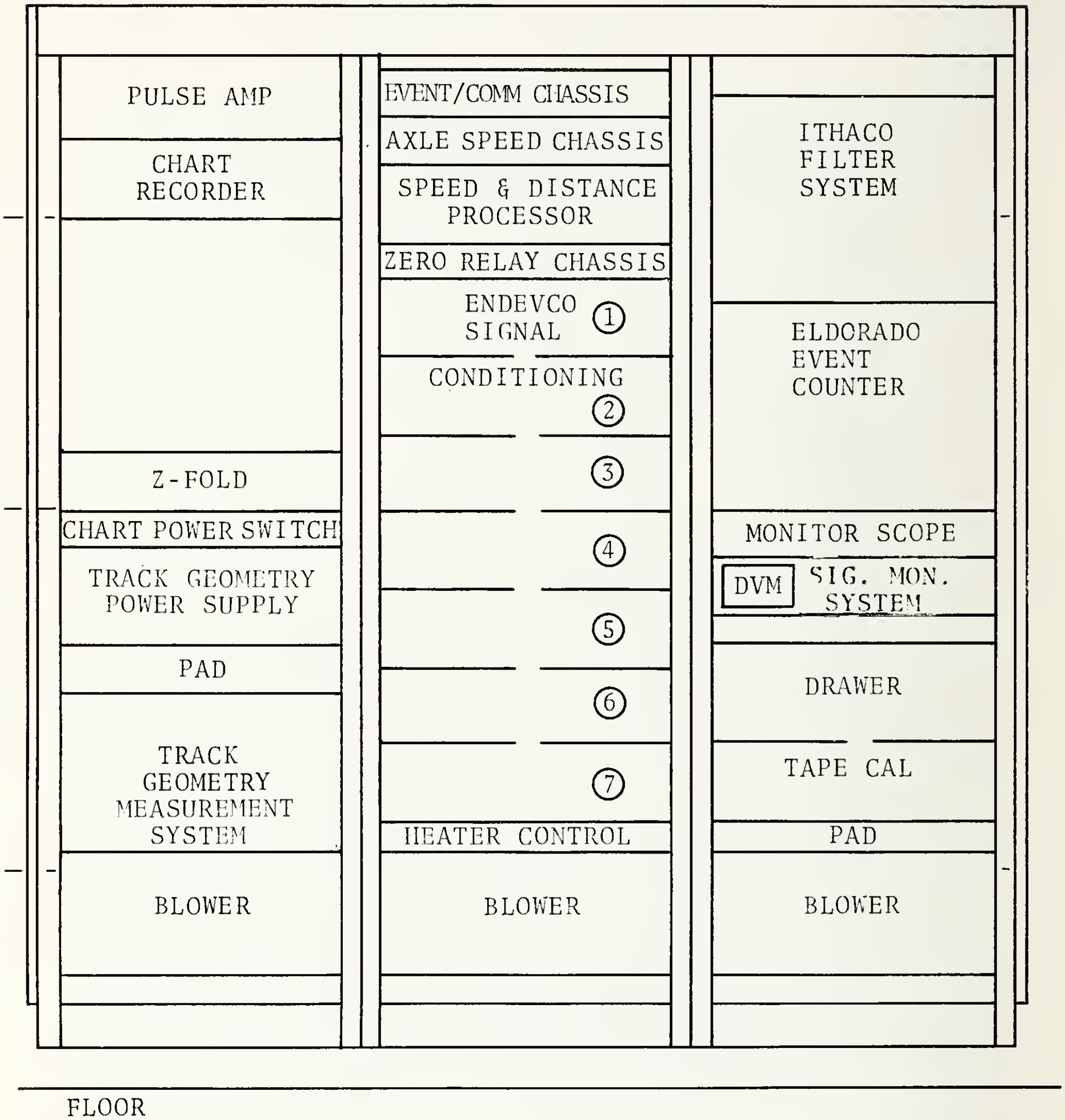


FIGURE 2-3. LAYOUT OF EQUIPMENT RACK

2.2 INSTRUMENTATION SYSTEMS

Each measurement system has unique outputs; therefore, the various outputs must be conditioned to match the input requirements of the Data Acquisition System. The following paragraphs are a general description of the electronic devices necessary to accomplish this interface.

<u>Transducer or Sensor</u> - The transducer or sensor produces electrical equivalents of the specified parameter variable. They are chosen to meet unique requirements for the specified measurement and are identified and described in the appendices that discuss the particular measurement system.

<u>Signal Preconditioning Electronics</u> - Signal preconditioning electronics, located on the exterior of the vehicle, condition the output of some sensors to provide proximity amplification, isolation, detection, excitation, compensation, conversion, etc. For example the Oscillator/Demodulator circuit excites the target detection probe of the Automatic Location Detector measurement system, and forms a bridge circuit that detects the output of the probe.

<u>Sensor Cables</u> - Standardized cables for each measurement system are designated by a style letter designation. Each cable is 60 feet long. The characteristics of each cable style are given in the supporting documentation file.

<u>Interface and Control Electronics</u> - The power, interconnections, temperature control, and display functions for some equipment, are provided by the interface and control electronics. For example, the Axle Speed Measurement Chassis (ASM-1) supplies power to the Rotary Pulse Generator and provides interconnection with the data acquisition system.

<u>Signal Conditioning and Monitoring Electronics</u> - The Signal Conditioning System ENDEVCO 4470 provides excitation voltages for some transducers or sensors and for some pre-conditioning circuits.

The 4470 also provides amplification as required to normalize all analog signals to a plus or minus 5-volt level. The Signal Monitor SM-1 provides real-time static monitoring (digital multimeter) and dynamic monitoring (oscilloscope) of any of the analog data signals. The Signal Conditioning System is described below while the Signal Monitoring System is described in detail in Section 4.

ENDEVCO 4470 consists of 35 separate channels, each channel of which is composed of a modular unit and a plug-in "mode" card. Seven rack adapters provide for mounting of the modules, five modules per adapter, in a standard 19-inch rack, and provide interconnections for power, signal input, signal output, and monitor and calibration functions.

The master module is a basic unit package containing circuit components generally common to most conditioning circuits. It contains a highly regulated instrument power supply, calibration circuits, and the interconnections for the plug-in mode card.

The mode card contains circuit components designed for a specific type of signal conditioning. Conditioning functions of the measurement system are all routed through the mode card and the function of a particular module is "specialized" by the card installed. Any module can be used to perform any conditioning function by installing the appropriate card. Cards may be of a standard circuit configuration or a custom circuit. The block diagram and interconnection of each card is shown in the related measurement system appendix of this manual.

Signal Filtering Electronics - The Signal Filtering Electronics Ithaco 4113 is used to enhance the signal-to-noise ratio of the measurement systems and to prevent signal aliasing during digitization. The system is made up of thirty-two separate channels of low pass filter networks. Each channel is switch selectable between a four-pole Bessel (linear phase delay characteristic) or a four-pole Butterworth (maximum flat amplitude response). The cut-off frequency of each channel can be varied from one Hertz to one Megahertz. Each of the separate filters, Ithaco

4113M101, is an integral modular unit. Eight of these modules are installed into a rack mounted adapter which provides a common AC power input, switch, indicator lamp and fuse. Four of these adapters are used in the GVTS while only two are shown in Figures 2-2 and 2-3.

2.3 DATA ACQUISITION SYSTEM AND OUTPUT DEVICES

The GVT Data Acquisition System includes the necessary components for processing, recording, and displaying vehicle test data. The DAS receives analog GVT inputs from the various systems, also discrete inputs from the GVT vehicle speed system, the time code generator, the event switches, etc., and performs real-time analog-to-digital data conversion. Real-time processing may be performed or the data may be recorded for later post-test processing. Output provisions include a digital-to-analog converter output for a chart recorder.

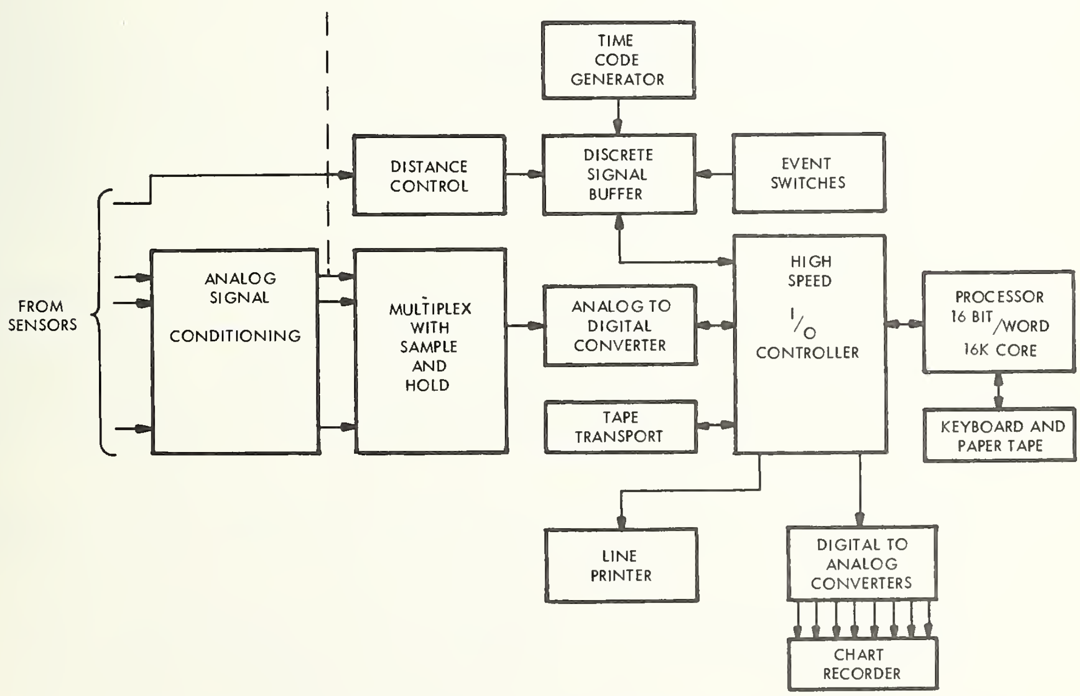


FIGURE 2-4. DATA ACQUISITION SYSTEM BLOCK DIAGRAM

The block diagram (Figure 2-4) outlines the DAS main components. The block on the extreme left represents the sensors and analog signal conditioners, totalling up to 32 instruments, the inputs of which become filtered, amplified and referenced to the Multiplex Unit. In addition to analog signals, the Conditioning Unit can enter digital signals, or discrete pulses, into the computer via the Discrete Signal Buffer.

The functional computing and processing equipment with accessories consists of the following units:

a. Univac 1616 Digital Computer consisting of a central processor, a memory containing 24K of 16-bit words, and an Input/Output Controller channel. Memory capacity can be expanded in 8K increments to total 16K and in 16K increments to a total of 64K. All memory modules are directly addressable.

b. The Digital-to-Analog Converters (DAC) accept computer information as control words and data words from the Univac I/O Controller. The control words are used to address the nine DAC's and to channel 8-bit data bytes to the addressed DAC.

c. The Analog-to-Digital Converter (ADC) is a Zeltex 721 Multiplexer containing two 16-channel multiplexer modules with two sample and holds controlled by a sequencer module. The unit uses the successive approximation technique for comparing analog data with a stable voltage reference.

d. The Univac Discrete Signal Buffer (Input/Output Interface) connects the I/O Controller with up to eight discrete devices, each device providing 16 data bits to the I/O Controller. The unit is used to input data from the Time Code Generator, the Distance Control and the Event Switches to the Data Acquisition System.

The Data Output Devices provide digital magnetic tape records of raw and processed data, real-time stripcharts, and printouts.

a. The Line Printer is a VERSATEC MATRIX LP1150 unit that prints computer-provided data, accepting synchronous coded data in series from the Input/Output Controller (IOC). It converts codes to characters by using a Read Only Memory.

b. The Magnetic Tape System (Bucode 4025) uses its data storage and retrieval facilities to provide the DAS bulk storage capability. The unit is an industry-standard NRZI 9-track transport with a reading and writing speed of 100 ips. The unit also contains a Datum formatter.

c. The Gould Brush 481 Chart Recorder is an incremental drive unit with eight signal channels and one timing channel fed by the DAS. The recorder uses the pressurized ink writing technique over a 40-mm wide graph for each signal channel. The timing channel utilizes an event marker between channels 1 and 2.

d. Automatic Send/Receive (ASR) 35 Teletypewriter serves to record information received from a signal line as a coded combination of characters and functions. The unit translates code combinations into mechanical motions imprinting a message or initiating a function.

3. INSTRUMENTATION SUMMARY

Summary sheets for each of the General Vehicle Test measurement systems are included in this section. The format for these summary sheets is shown in Figure 3-1. The format includes the applicable Standard Outputs from the GVTP, a brief description of the measurement method/concept, system performance (accuracy and frequency response), the specific areas where GVTP requirements are not met, system equipment, and calibration (primary and secondary). When writing test reports, these summary sheets (Figures 3-3 through 3-17) may be excerpted from this document and used to describe the instrumentation system.

The accuracy of each component is determined by a root-sum-square (RSS) error analysis of the entire measurement system. The error contributions for each component are listed on a system error analysis sheet shown in Figure 3-2. The completed system error analysis sheets are filed in the supporting documentation file. The frequency response of the measurement system is determined by the lowest response of any of the system components. A reduction in the frequency response limit can be achieved by selective addition of mode card components and by the signal filtering electronics.

MEASUREMENT SYSTEM: ______________

APPLICABLE STANDARD OUTPUTS (GVTP)

MEASUREMENT METHOD/CONCEPT

SYSTEM PERFORMANCE

ACCURACY....................

FREQUENCY RESPONSE..........

GVTP SPECIFICATION EXCEPTIONS

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM				
TYPE				
RANGE				
QUANTITY				

CALIBRATION

PRIMARY

SECONDARY

NOTES

FIGURE 3-1. SAMPLE SUMMARY SHEET

SYSTEM ERROR ANALYSIS

____

PARAMETER	SENSOR		PRE-CONDITIONER		MODE CARD	
Accuracy, %FS						
Linearity, %FS						
Hysteresis, %FS						
Resolution, %FS						
Repeatability, %FS						
Zero Temp Drift, %FS						
Gain Temp Drift, %FS						
Noise, %FS						
Dial Setting Error, %FS						
Freq Response, $\pm$ 5 % *						
Common-Mode Rejection Ratio*						
Computed RSS Error						

SYSTEM RSS ERROR____________%FS

NOTES:

1. The letter following each entry refers to its source.
   M-Manufacturer's Spec
   T-TSC Lab Test
   C-Computed
   E-Estimated
2. An asterisk indicates that this entry is not used in the RSS calculation.
3. Temperature drift entries assume $\Delta t=40^{o}F$ for vehicle exterior mounted items and $\Delta t=20^{o}F$ for interior items.
4. Dial setting errors are minimized by using calibration resistors when applicable.

FIGURE 3-2. SAMPLE SYSTEM ERROR ANALYSIS SHEET

MEASUREMENT SYSTEM: SPEED/DISTANCE

APPLICABLE STANDARD OUTPUTS (GVTP)

Vehicle Speed ....VS/A

MEASUREMENT METHOD/CONCEPT

An axle-mounted rotary pulse generator (RPG) (calibrated to wheel circumference) measures wheel rotation.

SYSTEM PERFORMANCE

ACCURACY.....................2% FS

FREQUENCY RESPONSE..........DC to 12 Hz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Trump-Ross RPG	—	TSC	TSC Axle Speed Chassis
TYPE	2048-DD-11-D-5LED-5	—	Speed & Distance Chassis	ASM-1
RANGE	2048 Pulses /Rev.	—	0-100 MPH	—
QUANTITY	2	—	1	1

CALIBRATION

PRIMARY Precision dividing head rotation of RPG.

SECONDARY Simulate RPG output with function generator; measure wheel circumference by rolling vehicle.

NOTES

The occurrence of wheel slippage creates errors in the actual vehicle speed and distance measurement.

FIGURE 3-3. SPEED/DISTANCE TEST SUMMARY SHEET

MEASUREMENT SYSTEM: EVENT

APPLICABLE STANDARD OUTPUTS (GVTP)

Event Trace..............ET/A

MEASUREMENT METHOD/CONCEPT

Digital computer word entered via keyboard. Eight separate event capabilities.

SYSTEM PERFORMANCE

ACCURACY...................NA

FREQUENCY RESPONSE.........NA

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	TSC Keyboard Unit	—	—	TSC Event/ Comm. Chassis
TYPE	KCU-1	—	—	EC-1
RANGE	8 Events	—	—	Up to 3 Input Channels
QUANTITY	2	—	—	1

CALIBRATION

PRIMARY NA

SECONDARY Operational Check.

NOTES

FIGURE 3-4. EVENT TEST SUMMARY SHEET

MEASUREMENT SYSTEM: COMMUNICATIONS

APPLICABLE STANDARD OUTPUTS (GVTP)

None

MEASUREMENT METHOD/CONCEPT

Sound-powered headsets with outlet locations as required.

SYSTEM PERFORMANCE

ACCURACY....................NA

FREQUENCY RESPONSE..........Voice

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Clarke Headsets	TSC Comm. Box	—	TSC Event/ Comm Chassis
TYPE	800 SB-A	CB-1	—	EC-1
RANGE	—	—	—	—
QUANTITY	8	10	—	1

CALIBRATION

PRIMARY NA

SECONDARY Operational Check.

NOTES

FIGURE 3-5. COMMUNICATIONS TEST SUMMARY SHEET

MEASUREMENT SYSTEM: AUTOMATIC LOCATION DETECTOR (ALD)

APPLICABLE STANDARD OUTPUTS (GVTP)

None

MEASUREMENT METHOD/CONCEPT

A proximity detector actuated by metallic objects (rail, impedance boxes, or targets) located in the rail head plane along track centerline.

SYSTEM PERFORMANCE

ACCURACY....................3 inches

FREQUENCY RESPONSE.........Operational up to 80 MPH

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	KAMAN Probe	KAMAN Oscil-lator/Demod	ENDEVCO/TSC	—
TYPE	KD1106-10C	KD 2300-12CU	4470/4475.1 W/TSC Mod K	—
RANGE	Probe/Target Spacing 2 in. Max	—	—	—
QUANTITY	2	2	2	—

CALIBRATION

PRIMARY A rotating disk with simulated targets.

SECONDARY A static hand-held calibration target.

NOTES

FIGURE 3-6. AUTOMATIC LOCATION DETECTOR TEST SUMMARY SHEET

MEASUREMENT SYSTEM: CONTROL CURRENT

APPLICABLE STANDARD OUTPUTS (GVTP)

Master Controller Signal..................CS/A
Dynamic Brake Feedback Signal............DBFB/A
Friction Brake Control Signal............FBCS/A

MEASUREMENT METHOD/CONCEPT

The DC current carrying conductor is inserted in thru-hole of sensor. Magnetic field generated by current flow is detected.

SYSTEM PERFORMANCE

ACCURACY....................1.2% FS

FREQUENCY RESPONSE.........DC to 20 Hz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	American Aero-space Probe	—	ENDEVCO/TSC	—
TYPE	Series 903B	—	'4470/4479.3S	—
RANGE	0-1/0-5 Amps	—	—	—
QUANTITY	2/3	—	20	—

CALIBRATION

PRIMARY NBS traceable DC current.

SECONDARY Voltage substitution.

NOTES

FIGURE 3-7. CONTROL CURRENT TEST SUMMARY SHEET

MEASUREMENT SYSTEM: POWER CURRENT

APPLICABLE STANDARD OUTPUTS (GVTP)

DC Line Current ....LCD/A
DC Motor Armature Current................MACD/A
DC Motor Field Current...................MFCD/A

MEASUREMENT METHOD/CONCEPT

The probe is clamped on to the current carrying conductor. A magneto-resistor bridge circuit detects the generated magnetic field.

SYSTEM PERFORMANCE

ACCURACY....................2.3% FS (See Note 1).

FREQUENCY RESPONSE..........DC to 4 kHz

GVTP SPECIFICATION EXCEPTIONS

Accuracy is specified to be ±2.0% FS (See Note 1).

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	American Aerospace Probe	—	ENDEVCO/TSC	—
TYPE	Series 909	—	4470/4479.3S	—
RANGE	See Note 2	—	—	—
QUANTITY	See Note 2	—	20	—

CALIBRATION

PRIMARY — NBS traceable DC current.

SECONDARY — Voltage substitution.

NOTES

1. To obtain the system performance accuracy stated, extreme care must be exercised to follow the vehicle mounting constraints.
2.

Range	Quantity	Range	Quantity
±150 Amp	4	±2000	2
±500 Amp	4	±3000	2
±1000 Amp	4		

FIGURE 3-8. POWER CURRENT TEST SUMMARY SHEET

MEASUREMENT SYSTEM: CURRENT SHUNT

APPLICABLE STANDARD OUTPUTS (GVTP)

Master Controller Signal	CS/A	DC Line Current	LCD/A
Dynamic Brake Feedback Signal	DBFB/A	DC Motor Armature Current	MACD/A
Friction Brake Control Signal	FBCS/A	DC Motor Field Current	MFCD/A

MEASUREMENT METHOD/CONCEPT

Calibrated low value resistors (current shunts) inserted in circuit. Voltage drop across shunt indicates current flow.

SYSTEM PERFORMANCE

ACCURACY.................... 0.8% FS (See Note 1).

FREQUENCY RESPONSE.......... DC to 1 kHz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	JANCO Current Shunt	TSC Isolation Amplifier	ENDEVCO/TSC	TSC Heater Control Chassis
TYPE	Series 8406	ISO-1	4470/4479.3S	HC-1
RANGE	See Note 2	-	-	-
QUANTITY	See Note 2	2 W/5 Chan. Ea.	20	1 W/2 Chan.

CALIBRATION

PRIMARY NBS traceable DC current.

SECONDARY Voltage substitution.

NOTES: 1. Additional errors can be induced by dynamic common-mode voltages.

2. Current Shunt Range/Quantities

Range	Quan	Range	Quan	Range	Quan	Range	Quan
1 amp	2	50 amp	6	300 amp	5	1000 amp	5
5 amp	4	100 amp	6	500 amp	5	1500 amp	2
25 amp	6	150 amp	5	750 amp	5	2000 amp	2
						3000 amp	2

FIGURE 3-9. CURRENT SHUNT TEST SUMMARY SHEET

MEASUREMENT SYSTEM: VOLTAGE

APPLICABLE STANDARD OUTPUTS (GVTP)

DC Line Voltage..........................LVD/A
DC Motor Armature Voltage................MAVD/A

MEASUREMENT METHOD/CONCEPT

Precision resistor divider networks (200:1 ratio) in differential circuit configuration.

SYSTEM PERFORMANCE

ACCURACY....................0.5% FS

FREQUENCY RESPONSE.........DC to 4 kHz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	TSC Differential Voltage Divider	—	ENDEVCO/TSC	—
TYPE	TSC Md DVD-1	—	4470/4479.3S	—
RANGE	± 1000 Volts	—	—	—
QUANTITY	10	—	20	—

CALIBRATION

PRIMARY NBS traceable precision high voltage power supply.

SECONDARY Voltage substitution.

NOTES

FIGURE 3-10. VOLTAGE TEST SUMMARY SHEET

MEASUREMENT SYSTEM: SERVO ACCELEROMETER

APPLICABLE STANDARD OUTPUTS (GVTP)

Acceleration, carbody....AC/A

MEASUREMENT METHOD/CONCEPT

A seismic element within the unit deflects when accelerated. The current required to magnetically force the element back to a neutral position is a measure of the impressed acceleration.

SYSTEM PERFORMANCE

ACCURACY.................... 1.0% FS

FREQUENCY RESPONSE.......... DC to 350 Hz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Kistler Servo Accelerometer	—	ENDEVCO/TSC	—
TYPE	Md QA-116-15	—	4470/4479.2	—
RANGE	Up To ± 15 g	—	—	—
QUANTITY	12	—	11	—

CALIBRATION

PRIMARY — NBS traceable reference accelerometer; dynamic comparison.

SECONDARY — Electronic current torque acceleration simulation.

NOTES

FIGURE 3-11. SERVO ACCELEROMETER TEST SUMMARY SHEET

MEASUREMENT SYSTEM: PIEZO ACCELEROMETER

APPLICABLE STANDARD OUTPUTS (GVTP)

Acceleration, Journal....AJ/A

MEASUREMENT METHOD/CONCEPT

Impressed accelerations deform a piezoelectric crystal generating a current flow.

SYSTEM PERFORMANCE

ACCURACY.................... 3.5% FS

FREQUENCY RESPONSE.......... 3 to 6000 Hz

GVTP SPECIFICATION EXCEPTIONS

Low frequency response is specified to be 0.1 Hz.

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Columbia Piezo Accelerometer	ENDEVCO Charge/Voltage Converter	ENDEVCO	—
TYPE	Md 704	Md 2652	4470/4479.1M2	—
RANGE	Up To ± 1000 g	—	—	—
QUANTITY	7	6	7	—

CALIBRATION

PRIMARY NBS traceable reference accelerometer; dynamic comparison.

SECONDARY Voltage substitution.

NOTES

FIGURE 3-12. PIEZO ACCELEROMETER TEST SUMMARY SHEET

MEASUREMENT SYSTEM: PRESSURE

APPLICABLE STANDARD OUTPUTS (GVTP)

Brake cylinder pressure..BCP/A

MEASUREMENT METHOD/CONCEPT

A beam deflected by pressure input is instrumented with strain gages. Change in gage resistance is related to magnitude of the pressure.

SYSTEM PERFORMANCE

ACCURACY.................... 0.8% FS

FREQUENCY RESPONSE.......... DC to 9 kHz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	BLH Pressure Cell	—	ENDEVCO/TSC	—
TYPE	Md DHF	—	4470/4476.2AM3 W/TSC MOD P	—
RANGE	0-200 psig	—	—	—
QUANTITY	2	—	2	—

CALIBRATION

PRIMARY NBS traceable dead weight tester.

SECONDARY Shunt resistor and pressure simulation.

NOTES

FIGURE 3-13. PRESSURE TEST SUMMARY SHEET

MEASUREMENT SYSTEM: TEMPERATURE

APPLICABLE STANDARD OUTPUTS (GVTP)

Brake Temperature........BT/A and BT/B
Equipment Temperature....EQT/A

MEASUREMENT METHOD/CONCEPT

The electrical resistance of a bondable gage varies as a function of temperature. The signal is linearized in the signal conditioning circuitry.

SYSTEM PERFORMANCE

ACCURACY....................0.8% FS @ 500°F. Full Range

FREQUENCY RESPONSE..........NA

GVTP SPECIFICATION EXCEPTIONS

Full range is specified to be up to 1200°F.

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Micro Measurement Temp Gage	TSC Temp Connector Assy.	ENDEVOC/TSC Amplified Bridge	—
TYPE	Md WTG-50 BP	Md TCA-1	4470/4476-2AM3 W/TSC MOD T	—
RANGE	0-500°F	—	—	—
QUANTITY	15	10	10	—

CALIBRATION

PRIMARY — NBS traceable thermal chamber.

SECONDARY — Resistor substitution.

NOTES

FIGURE 3-14. TEMPERATURE TEST SUMMARY SHEET

MEASUREMENT SYSTEM: STRAIN

APPLICABLE STANDARD OUTPUTS (GVTP)

Structural Test Parameter, Strain........STPS/A

MEASUREMENT METHOD/CONCEPT

Resistance of a bondable gage varies as a function of applied mechanical strain.

SYSTEM PERFORMANCE

ACCURACY.....................3.0% FS

FREQUENCY RESPONSE..........DC to 10 kHz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	Commercial Strain Gage	TSC-Strain Connector Assy.	ENDEVCO	—
TYPE	—	Md SCA-I	4470/4476.2AM3	—
RANGE	—	—	—	—
QUANTITY	—	2	12	—

CALIBRATION

PRIMARY — NBS traceable load applied to gaged component.

SECONDARY — Shunt resistor strain simulation.

NOTES

FIGURE 3-15. STRAIN TEST SUMMARY SHEET

MEASUREMENT SYSTEM: POTENTIOMETER DISPLACEMENT

APPLICABLE STANDARD OUTPUTS (GVTP)

Structural Test Parameter, Displacement...STPD/A

MEASUREMENT METHOD/CONCEPT

A potentiometer wiper is positioned by the extension (retraction) of a spring-restrained cable.

SYSTEM PERFORMANCE

ACCURACY.................... 1.0% FS

FREQUENCY RESPONSE.......... 50 Hz at ± 0.1 inch sinusoidal displacement

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	CELESCO Disp. Pot.	—	ENDEVCO	—
TYPE	Md. PT101	—	4470/4471.3	—
RANGE	See Note	—	—	—
QUANTITY	See Note	—	12	—

CALIBRATION

PRIMARY NBS Traceable length standards.

SECONDARY Voltage substitution

NOTES

Range	Quantity
0-1 inch	4
0-3 inch	10

Range	Quantity
0-5 inch	4
0-10 inch	2

FIGURE 3-16. POTENTIOMETER DISPLACEMENT TEST SUMMARY SHEET

MEASUREMENT SYSTEM: NON-CONTACT DISPLACEMENT

APPLICABLE STANDARD OUTPUTS (GVTP)

Structural Test Parameter, Displacement..STPD/A

MEASUREMENT METHOD/CONCEPT

The distance between a probe and conductive target is indicated by the signal unbalance between two coils. Losses occur due to eddy currents in the targets.

SYSTEM PERFORMANCE

ACCURACY....................1.6% FS

FREQUENCY RESPONSE..........DC to 10 kHz

GVTP SPECIFICATION EXCEPTIONS

None

EQUIPMENT

	SENSOR	PRE-CONDITIONER	SIGNAL COND.	INTERFACE/CONT.
MFR./ITEM	KAMAN Non-Contact Probe	KAMAN OSC./Demod	ENDEVCO/TSC	—
TYPE	Md KD 1106	Md KD 2300	4470/4475.1 W/TSC Mod K	—
RANGE	See Note	—	—	—
QUANTITY	See Note	6	2	—

CALIBRATION

PRIMARY — NBS traceable length standard.

SECONDARY — Voltage substitution.

NOTES

Range	Quantity
0.25-2.25 inch	2
0.1-1.1 inch	3
0.05-.55 inch	1

FIGURE 3-17. NON-CONTACT DISPLACEMENT TEST SUMMARY SHEET

4. SIGNAL MONITOR AND CALIBRATION EQUIPMENT

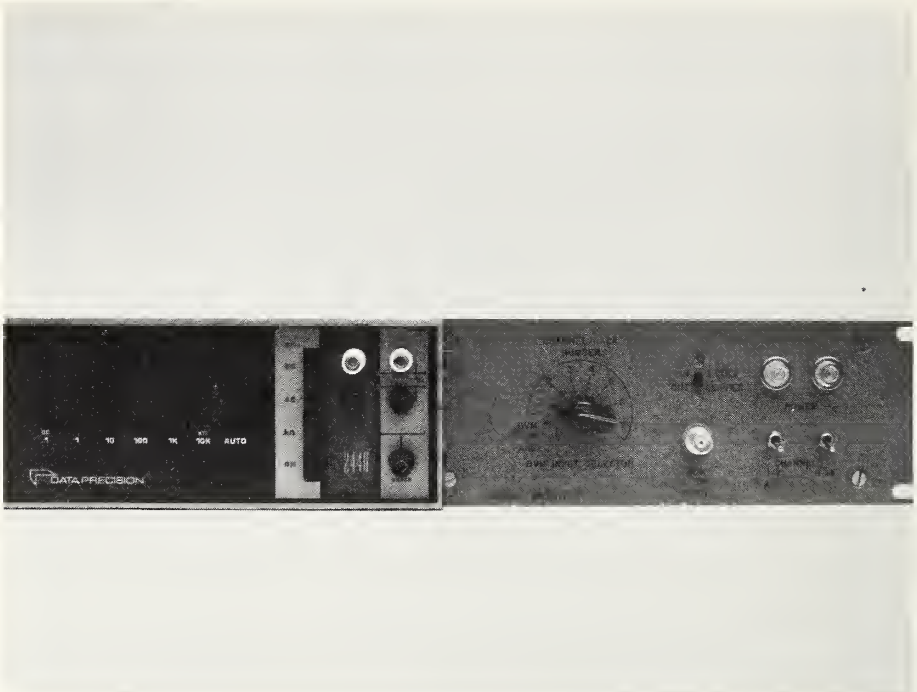
4.1 OPERATIONAL CONCEPT

Each of the 35 master modules of the signal conditioning system has a two-position toggle switch. When the master module is inserted into the 5-channel rack adapter, depressing the monitor toggle switch on the module causes the channel output signal or the channel excitation voltage to be connected to a three contact terminal strip located on the rear of the rack mount adapter. The three contacts are the A signal, B signal, and shield.

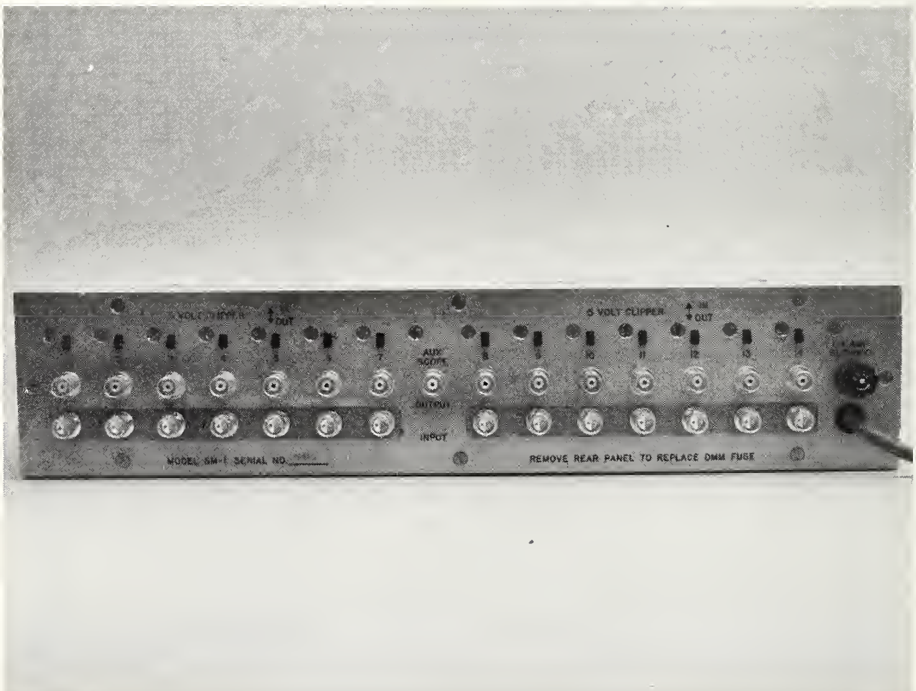
Certain mode cards that can be inserted into the master module have the capability of providing a four step bipolar calibration signal. The desired calibration signal can be chosen by means of an eight-position rotary switch located on the master module front panel. Placing the cal switch in the desired position and depressing the calibrate pushbutton generates the cal signal on the mode card. A zero-signal pushbutton is also provided on the master module front panel. Both the calibration and zero-signal functions can also be activated by using internal relays. These relays are energized by applying a 24 volt potential to the appropriate contacts on a terminal strip also located on the rear of the rack adapter. All five channels within a specific rack adapter have relays connected in parallel.

4.2 SIGNAL MONITOR CHASSIS

The signal from the monitor terminal strip on each rack adapter is routed to separate channels on the signal monitor chassis. The front and rear panels of this chassis are shown in Figure 4-1. The chassis contains 15 channels of differential-input with single-ended output amplifiers. The floating, differential inputs are required so that signals from individual signal conditioning channels are not connected to any ground reference while they are being monitored. As discussed in Section 5, the shield and ground connections for each signal are



(Control Panel View)



(Connector Panel View)

FIGURE 4-1. SIGNAL MONITOR SYSTEM

optimized and any additional ground connection would create an undesired ground loop. The single-ended outputs are chassis-ground referenced and may be displayed or recorded on any conventional ground referenced equipment. The signal monitor chassis also contains a differential input digital multimeter. The first seven channels of the chassis, which correspond to the seven signal conditioning rack adapters, can be routed in parallel to the multimeter depending on the position of the front panel input selector rotary switch. For example, the switch is shown in position 1 with the signal applied to the chassis channel No. 1 input also routed in parallel to the digital multimeter. By placing the input selector switch on the front-panel position the multimeter may be normally operated using the front panel jacks. The 15th channel in this chassis is the auxiliary scope input channel. This channel contains a differential input to a single ended amplifier with the input connector located on the front panel. To facilitate the observation of signals experiencing "soft" saturation, a slide switch may be positioned to connect a diode-clipping circuit to any of the 15 channels. When in the "in" position, the clipping circuit causes a "hard" appearing saturation of any signal exceeding the plus or minus 5 volt level. The connections for the signal monitor system are shown on a wiring diagram in Figure 4-2. The schematic of the style M interconnecting cable is shown in Figure 4-3. The internal construction of the signal monitor system is shown in Figure 4-4. The amplifier assemblies are compartmentalized with all wiring shielded. In addition, all of the 115 VAC wiring is compartmentalized or shielded. Channel isolation within this chassis exceeds 80 dB. It is emphasized that the signal displayed by this system has not been low pass filtered by the Ithaco filter system.

An alternate use of this signal monitor chassis is to buffer up to 14 channels of signal conditioning prior to recording on a ground-referenced magnetic tape recorder. This provides the General Vehicle Test System (GVTS) with a backup recording scheme utilizing analog equipment. In normal GVT operation the output of the signal monitor chassis would be connected to a seven channel oscilloscope to provide

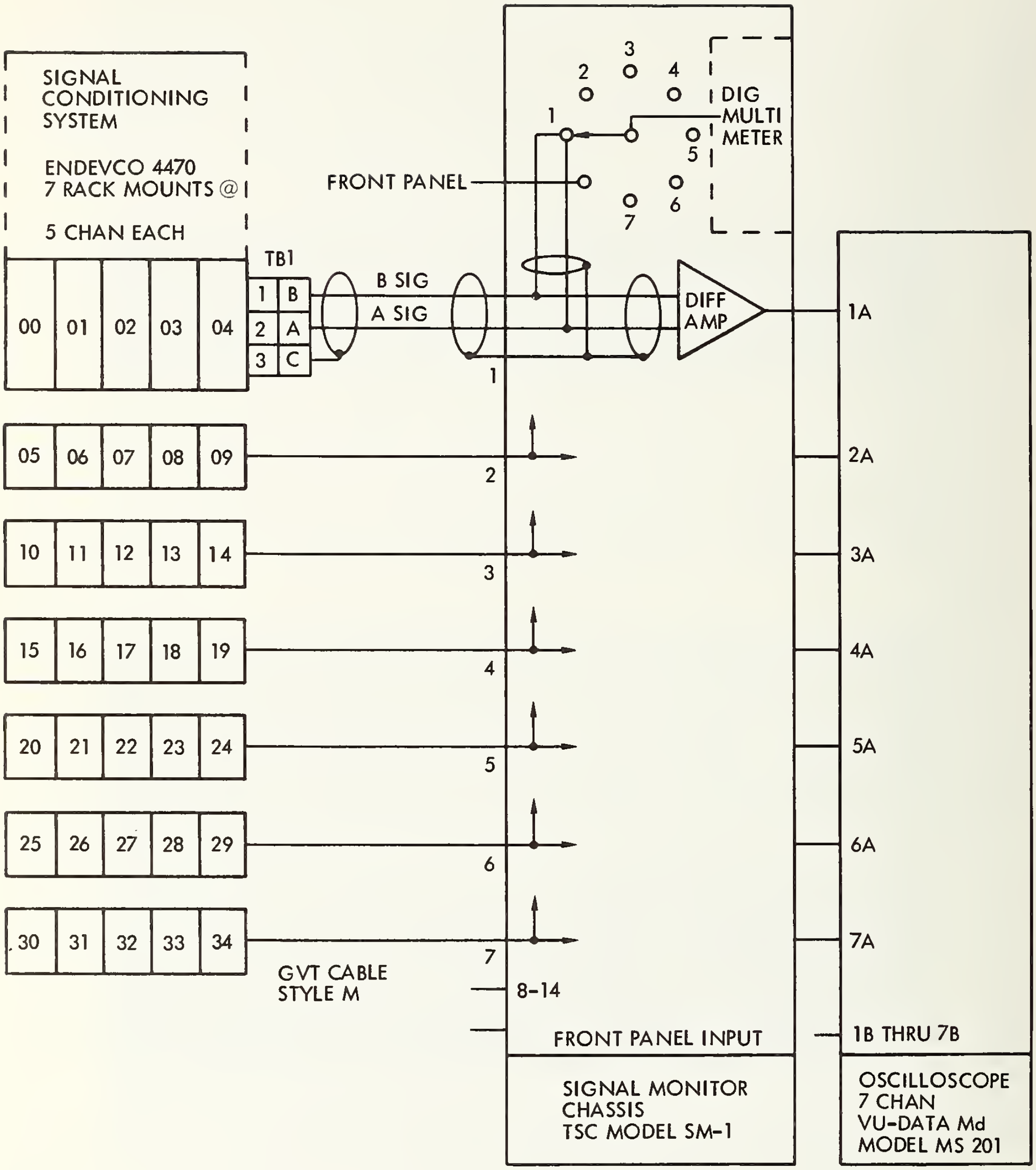
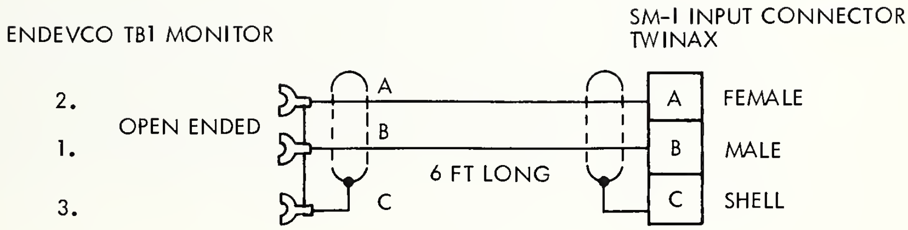


FIGURE 4-2. SIGNAL MONITOR SYSTEM WIRING DIAGRAM

GENERAL VEHICLE TEST CABLE

STYLE M



CABLE

2 COND (TWISTED) W/SHIELD 22 AWG
SHIELD

NOTES:

MONITOR TERMINAL BOARD ON ENDEVCO 4470 RACK TO SIGNAL
MONITOR CHASSIS

FIGURE 4-3. GENERAL VEHICLE TEST CABLE STYLE M dynamic signal monitoring during a test. The digital multimeter is especially useful during pretest calibration of each signal conditioning channel.

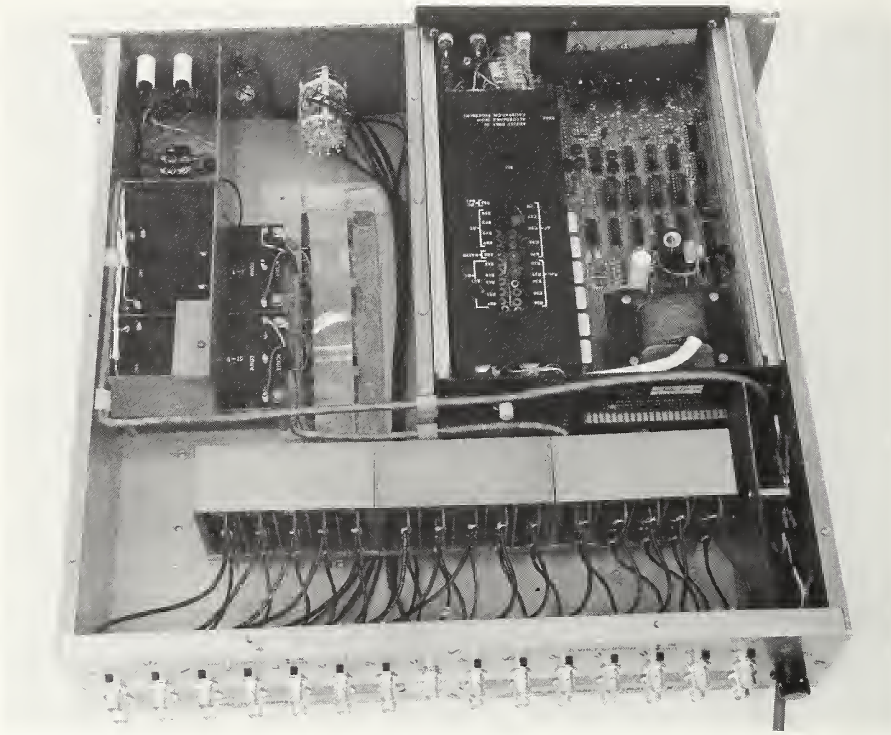


FIGURE 4-4. SIGNAL MONITOR SYSTEM - CHASSIS VIEW

The supporting documentation file described in Section 6 contains the following items (Bins 3 and 4):

a. Fabrication Dwg.........Signal Monitor Interface Assy
   TSC No. 60005

b. Mfg Operators Manual....Data Precision Digital Multimeter
   (DMM) Md 2400-B1

c. DMM Modification Procedure

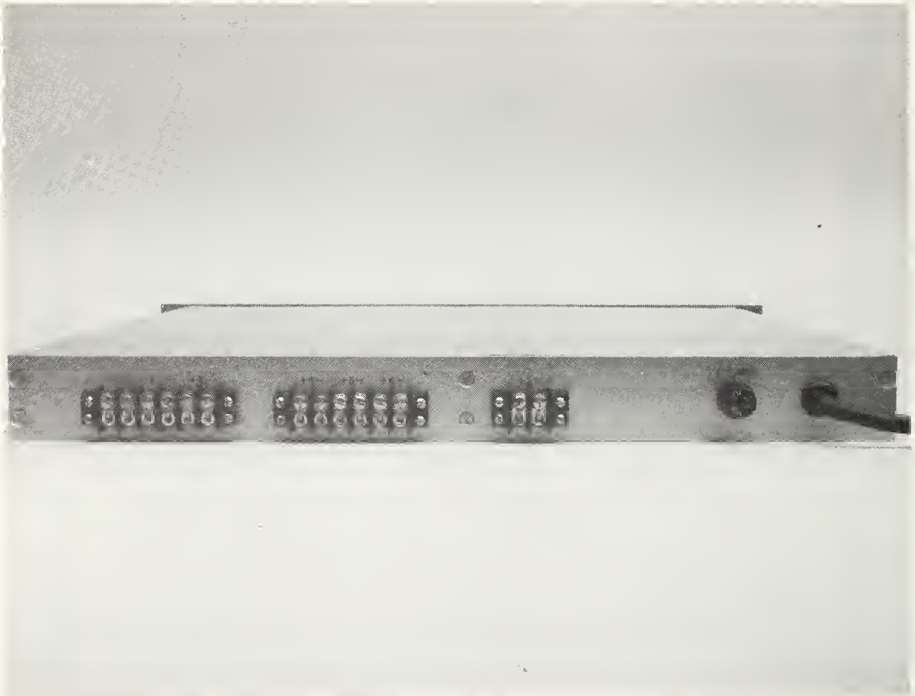
4.3 ZERO-RELAY ACTUATOR CHASSIS

To actuate the relays described in paragraph 4.1 a chassis was constructed with a switch selectable 24 VDC power supply. This chassis is intended to provide actuation of the zero relay when using certain mode cards during the calibration procedure. It may be wired so that any of the six relays can be actuated. A photograph of the front panel and rear panel of this chassis is shown in Figure 4-5. Relays within the master module chassis require 8 mA for the calibration function and 15 mA for the zero function. The chassis contains a 200 mA, 24 volt supply. Using the seven front-panel toggle switches and appropriate wiring between the terminal strips on the rear panel, any suitable combination of relay actuations can be achieved within the limits of the power supply. It is noted that the relays on all five master modules located in a single rack adapter are connected in parallel. This will limit the number of parallel relay channels that can be simultaneously actuated.

The supporting documentation file contains the following items (Bin 5):

a. TSC Fabrication Dwg.........Zero-Relay Actuator Assy
Md ZRA-1
TSC Dwg No. 6-0006

b. Mfg. Spec Sheet.............Acopian Power Supply



(Connector Panel View)

(Control Panel View)

FIGURE 4-5. ZERO-RELAY ACTUATOR

5. SHIELD/GROUND TECHNIQUE

5.1 BASIC PRINCIPLES

The shield/ground technique used in the General Vehicle Test System (GVTS) generally adheres to the principles described by Morrison in his text "Grounding and Shielding Techniques in Instrumentation".[2] In specific instances, each measurement system shield is electrically connected to the B-signal (low) at one point only. In a similar manner, the system shield is earth (train) grounded at the same point. The location of this train ground point is a function of the system. Certain systems are grounded at the sensor, while others are grounded at the signal conditioner.

5.2 CONNECTION TECHNIQUE

To facilitate proper shield and ground connections, each measurement system description in this document is provided with a block diagram. A master sheet of this block diagram showing the permanent shield/ground wiring is included as Figure 5-1. To complete the shield/ground diagram, the signal low-to-shield connection, shield-to-ground connection, and a preamplifier (if required) must be added. Such a completed block diagram is shown in Figure 5-2. Bold lines show the particular connections required in the configuration.

A switch panel has been fabricated to provide the means for making connections at the signal conditioner. Figure 5-2 shows a layout of the two switches. A pigtail from the B signal of the signal conditioner output cable is connected to the "B SIG" switch. Closing the switch connects the B signal to the shield. Closing the "SHD" switch connects the shield to ground. The proper switch settings are shown on each measurement system block diagram.

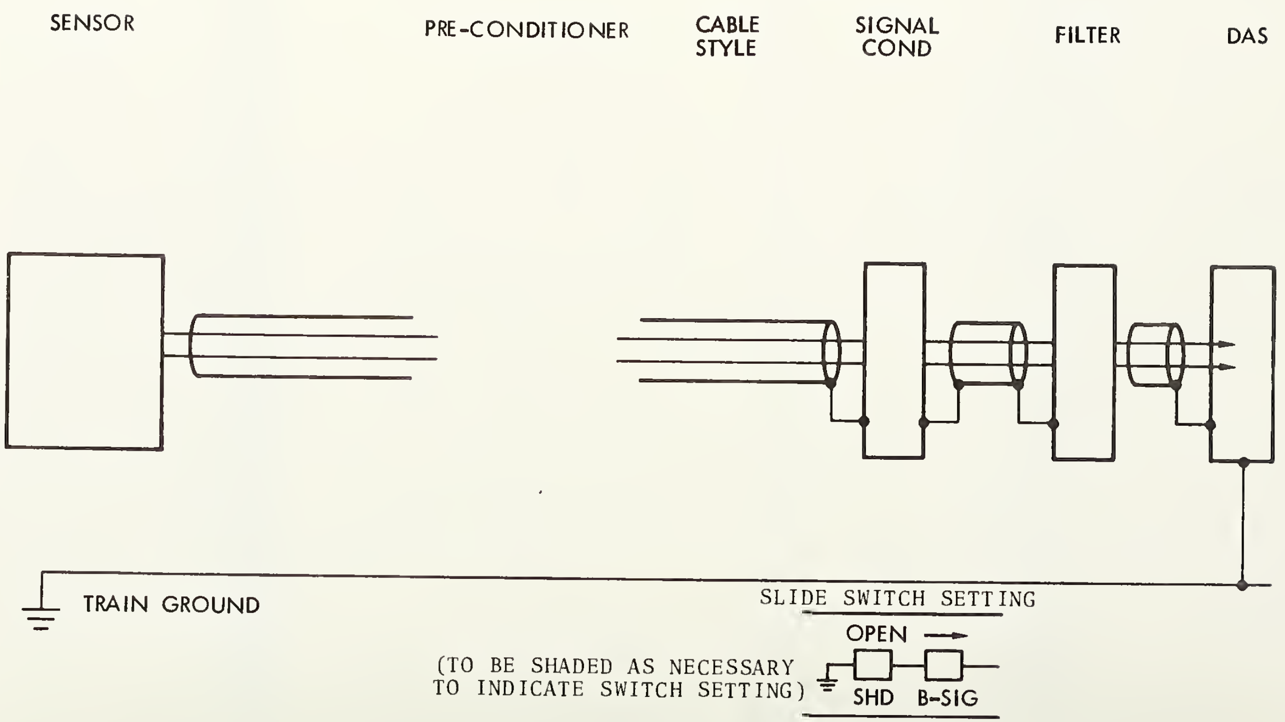


FIGURE 5-1. SHIELD/GROUND WIRING BLOCK DIAGRAM - MASTER SHEET

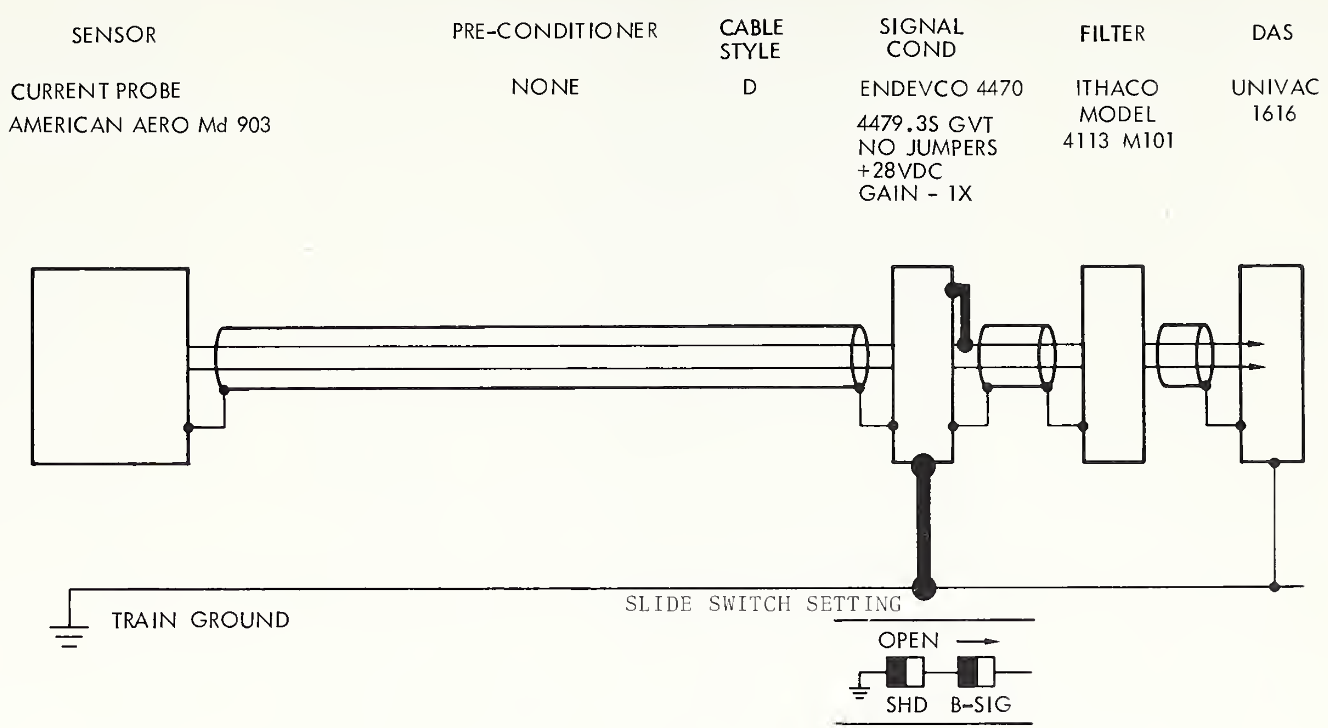


FIGURE 5-2. SYSTEM SHIELD/GROUND WIRING BLOCK PROGRAM (SAMPLE FROM CONTROL CURRENT PROBE)

The installed switch panel is presented in Figure 5-3. The TSC Drawing No. 6-0007 is included in the supporting documentation file (BIN2).

FIGURE 5-3. SHIELD/GROUND SWITCH PANEL

To prevent signal cross-talk or unwanted ground loops, each channel is electrically isolated. As a result, the shield/ground connections for each individual measurement system may be optimized independent of other channels. It should be noted that the signal conditioner chassis is not attached to the power cord third wire. To ensure a train ground connection, connect a ground braid between the chassis and ground.

6. SUPPORTING DOCUMENTATION

A complete set of documentation of the General Vehicle Test System (GVTS) has been compiled. This documentation includes:

a. Complete mechanical and electrical drawings of TSC designed equipment and manufacturers' data sheets and/or instruction manuals.

b. Calibration reports and the results of operational checkouts. This section will periodically be updated when new calibrations are performed or when a failure of any piece of equipment occurs. This section will form a history of each item that will be used to determine the frequency of required calibrations.

c. Copies of the applicable purchase requisitions (PR). This PR number is cross-referenced in Section 7 and will be useful if additional quantities of this instrumentation are to be purchased.

The supporting documentation will be available at the Transportation Test Center and Transportation Systems Center. Any additions or deletions will be reflected in both sets of documentation.

The items of equipment for which applicable documentation exists include:

Supporting Documentation File Index

Bin No.	
1	System Equipment List
2	4470 Shield/Ground Switch Bus
3	Signal Monitor Chassis
4	Signal Monitor - Digital Multimeter
5	Zero Relay Actuator Chassis
6	Rotary Pulse Generator
7	Axle Speed Measurement Chassis
8	Speed and Distance Chassis
9	Event/Communications Chassis

Supporting Documentation File Index (Cont)

Bin No.	
10	Headsets and Junction Boxes
11	Automatic Location Detector
12	Control Current Probe
13	Power Current Probe
14	Current Shunts
15	Isolation Amplifier System
16	Heater Control Chassis
17	Differential Voltage Divider
18	Servo Accelerometer
19	Piezo Accelerometer
20	Pressure
21	Temperature
22	Strain
23	Potentiometer Displacement
24	Non-Contact Displacement
25, 26	Purchase Requisitions
27	GVT Mode Card
28	GVT Cable Specifications
29	Equipment Photographs

7. INVENTORY CONTROL

7.1 APPROACH

The majority of components of the General Vehicle Test System are system oriented. That is, a single item such as a mode card, is not readily adaptable to another type of system. The transducers, however, are readily transferable to any general purpose instrumentation system. To maintain control of each of the sensors, and prevent loss, an inventory control system has been designed. Each of the more than 200 sensors is described on a 5 by 8 file card. The cards are housed in two five-drawer, flip-top card files. These files are located with the instrumentation system at the Transportation Test Center (TTC).

7.2 INVENTORY CONTROL CARD DESCRIPTION

The front and back of the inventory control card are shown in Figures 7-1 and 7-2, respectively. The card has been designated as TSC form, No. 4430.13. The front of the card contains a general description of the sensor and associated equipment. The lower edge of the card contains the noun (name), model no. (range), manufacturer, serial number, and TSC property tag no. This information is visible for all sensor cards stored in the file drawers. On the back of the card, location and sign-out data can be listed. The expected location of the borrowed sensor, along with the date and the borrower's initials, is listed when the sensor is loaned out. When the sensor is returned, the date <u>in</u> is listed, along with the initials of the TTC property custodian. When completed, this portion of the card will be a history of the use of each sensor.

The description of the sensor is repeated on the lower (blue) edge on the back of the card. Whenever the sensor is borrowed, this inventory card is placed in the file drawer so that the blue portion is visible. In this way, the availability of all sensors in the system can be quickly determined by opening a file drawer, and noting the blue or white card edges.

GVT SENSOR INVENTORY CONTROL

DESCRIPTION

USE: POWER CURRENT

RANGE: ± 500 Amps

SENSITIVITY: 500A/100mv NOM

LAST CALIBRATION DATE:

PRE-CONDITIONING ELEC.: ISO AMPLIFIER MD ISO-1

CABLE STYLE: D

MODE CARD: GVT 4479.3S

PROCUREMENT TYPE: 18-1

NO.: TER 6819

REMARKS:

NOUN	MODEL NO. (RANGE)	MANUFACTURER	SERIAL NO.	TSC NO.
CURRENT SHUNTS	8406-500 ±500	JANCO	3	

FIGURE 7-1. INVENTORY CONTROL CARD, FRONT

TSC F 4430.13

LOCATION AND SIGN-OUT DATA

LOCATION	DATE OUT	INITIALS	DATE IN	INITIALS	LOCATION	DATE OUT	INITIALS	DATE IN	INITIALS
NOUN	MODEL NO.(RANGE)				MANUFACTURER	SERIAL NO.		TSC NO.	

This Line Shaded Blue On This Side Of Card Only

FIGURE 7-2. INVENTORY CONTROL CARD, BACK

8. SYSTEM NOTES

8.1 DISCUSSION

The items discussed in this Section are not required to properly operate the General Vehicle Test system. They are included, however, to facilitate use of the system. Test experience at the Transportation Test Center (TTC) and laboratory tests have indicated that these items are useful. It is anticipated that as the test system is used and more experience is gained, this Section will be expanded.

8.2 MAGNETIC PARAMETER TAGS

The pretest calibration and real-time monitoring of up to 35 channels of data can be quite cumbersome. It was determined that referring to a parameter list each time a channel was to be monitored would greatly increase the complexity of the monitoring operation. Many parameter lists would have to be generated because of the various kinds of general vehicle tests. To simplify this operation, magnetic parameter labels were fabricated. Each label contains the Standard Output designation from GVTP. The magnetic tags are shown in Figure 8-1. The tags are installed on the master modules, as shown in Figure 8-2. The manufacturer's name plate has been removed from the master module and a magnetic material affixed to the aluminum housing in its place. During the pretest setup of the instrumentation system, the appropriate magnetic tag is affixed on the module. It is noted that the monitor toggle switch is located directly above the magnetic tag on the master module. The instant identification of each channel greatly facilitates the sensor system calibration and monitoring.

It has been suggested that this magnetic tag system be expanded to label the chart recorder channels as well.

8.3 MONITOR TOGGLE SWITCH HOLDER

When calibrating the data channels, the monitor toggle switch which is spring-restrained must be placed in the balance position for long periods of time.

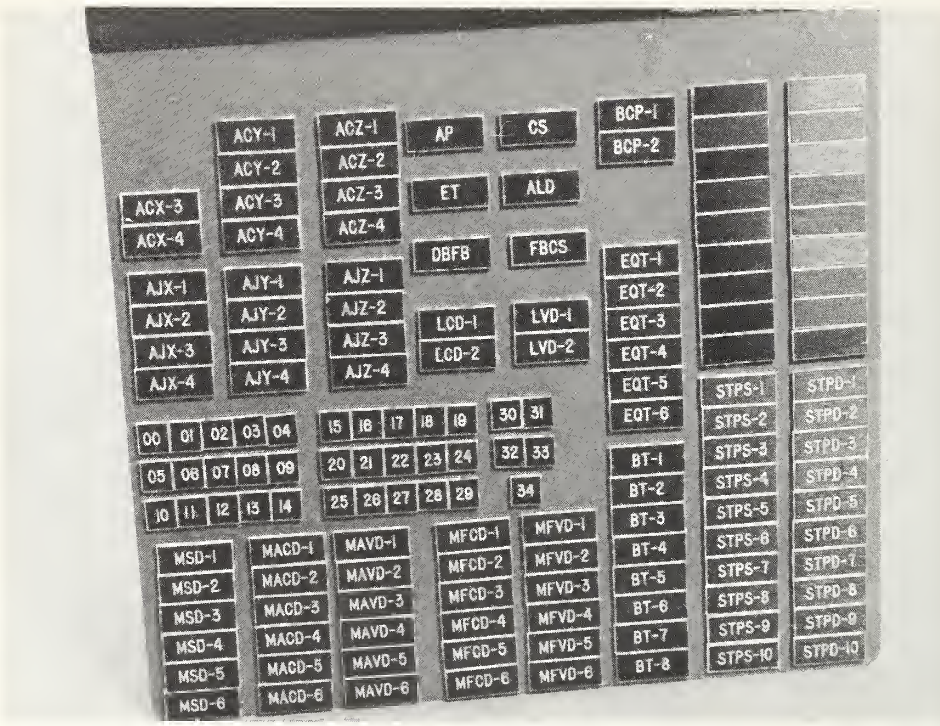


FIGURE 8-1. MAGNETIC PARAMETER TAGS

FIGURE 8-2. INSTALLED TAG ON MASTER MODULE

To eliminate the need for manually holding the switch in this position, a rubber holder was fabricated from an eraser. The size of the eraser was approximately 1 x 1 x 1/4 inch. The top edge was beveled at a 15° angle to conveniently fit beneath the toggle arm and the bottom corner was rounded to ease the installation of the holder without dislodging the magnetic parameter tag. This holder can also be used during dynamic vehicle tests if one of the data channels is to be continually monitored.

8.4 CABLE TIES

Two types of cable ties can be used when installing the sensor cables, both inside and outside of the test vehicle. A temporary type is the ball and eyelet tie that is blue in color. These ties are easily removed and are used to temporarily hold cables in place until all cables for a given test have been installed. They can also be used when securing individual cables for storage. A second type of cable wrap is much stronger and of a more permanent nature. These wraps are white in color and are used for permanent cable installations during a test series. They must be cut and are therefore destroyed when removed from the vehicle.

9. REFERENCES

1. "General Vehicle Test Plan (GVTP) for Urban Rail Transit Cars," Department of Transportation Final Report, Report No. UMTA-MA-06-0025-75-14, September 1975.

2. "Grounding and Shielding Techniques in Instrumentation," Ralph Morrison, Wiley Interscience, 1967.

3. "Digital Processing of Signals," Bernard Gold and Charles M. Rader, Lincoln Laboratory, Massachusetts Institute of Technology.

4. "General Vehicle Test Instrumentation Evaluation" UMTA-MA-06-0025-77-9. March 1977.

5. State-of-the-Art-Car Engineering Tests at Department of Transportation High Speed Ground Center, Final Test Report. Department of Transportation Final Report No. UMTA-MA-06-0025-75-1 thru 7, 7 Volumes, January 1975.

APPENDIX A REFERENCE DATA

A1 SPEED MEASUREMENT SYSTEM
A2 EVENT/COMMUNICATIONS MEASUREMENT SYSTEM
A3 AUTOMATIC LOCATION DETECTOR MEASUREMENT SYSTEM

A 1. SPEED MEASUREMENT SYSTEM

A1.1 DESCRIPTION

The Speed measurement system is used to determine the rotational velocity of one of the vehicle axles. The transducer furnishes a fixed number of pulses per revolution of the wheel. By calibrating the conditioning electronics to correspond with the wheel circumference, a measure of the velocity of the vehicle and the distance traveled can be obtained. The system does not account for wheel slippage, and speed and distance errors result when slippage occurs.

The Speed measurement system consists of the following items:

a. Rotary Pulse Generator (RPG)....Trump-Ross
Model T 2048-DD-11-D-5
Led-5 Figure A1-1

b. GVT Cable........................Style K

c. Axle Speed Measurement Chassis....................TSC Model ASM-1
Figure A1-2

The supporting documentation file contains the following applicable items (Bins 6 thru 8):

a. Mfg. Specification Sheet.......Trump-Ross RPG

b. Fabrication Dwg.................Axle Speed Measurement System
TSC ASM-1
Dwg No. 6-0003

c. Operator's Manual w/Dwg.........Speed and Distance Processor

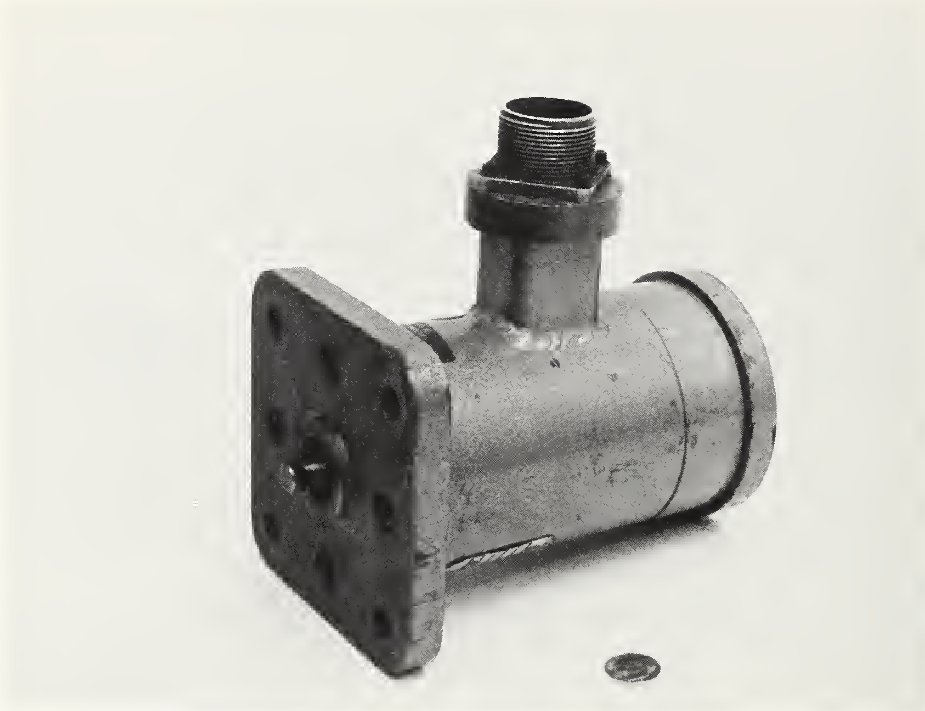


FIGURE A1-1. ROTARY PULSE GENERATOR

A1.2 SPECIAL HANDLING

No special handling of this device is required.

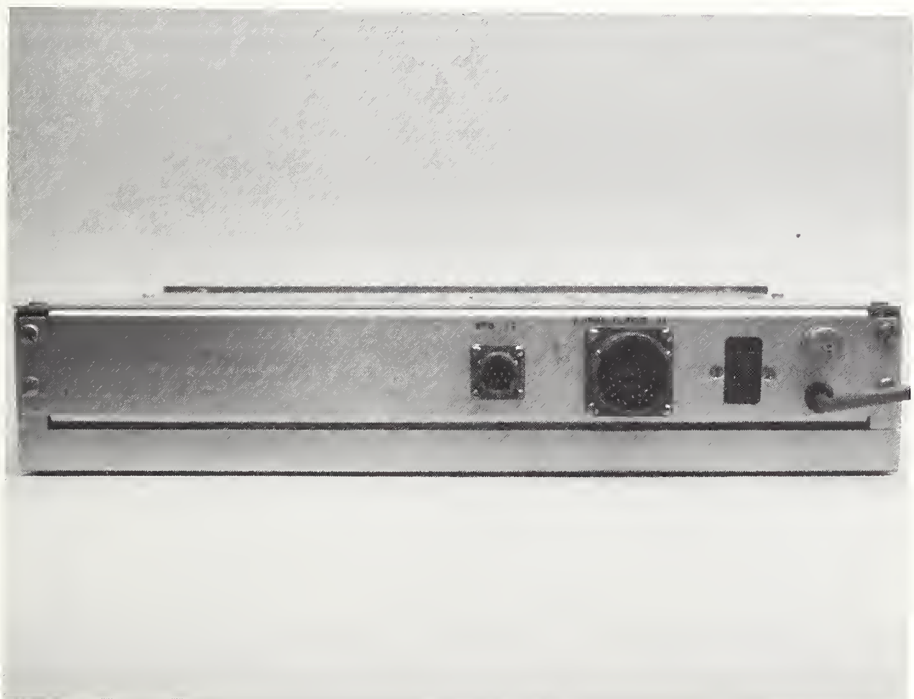
A1.3 THEORY OF OPERATION

The Rotary Pulse Generator (RPG) is an optical device. A rotating mask with alternate transparent and opaque areas interrupts a light beam directed on to a photosensitive element. The mask contains 2048 pulse-generating areas. The resulting digital signal is transmitted from a differential line driver over a twisted pair cable to maximize the noise immunity.

Power for the RPG electronics is furnished by one +5 Volt power supply housed within the axle speed measurement chassis. A connector is available on the rear of the chassis for the RPG output.

These pulses may be input directly into the digital data acquisition system or a TSC fabricated speed and distance chassis.

(Control Panel View)



(Connector Panel View)

FIGURE A1-2. AXLE SPEED MEASUREMENT CHASSIS

This chassis converts the pulses from the RPG into an analog speed signal. In addition, two pulse divider networks are included in this chassis. One network provides the proper digital divisor required to furnish eight pulses per foot of vehicle travel. This pulse train is used to drive an incremental chart recorder when distance-based charts are required. The second divider network provides one pulse per foot that can be directly recorded on magnetic tape or used to drive a digital-to-analog converter to output a distance trace.

A1.4 SHIELD/GROUND TECHNIQUE

The shield and ground connections required for this system are hard wired. No additional connections are required or permitted.

A1.5 FUNCTIONAL WIRE LIST

Because the current system is an interim solution, a complete pin-to-pin listing is not given. Schematic diagrams, however, of the sensor and DAS cables are illustrated in Figures A1-3 and A1-4.

A1.6 MODE CARD SETUP

Not applicable.

A1.7 VEHICLE MOUNTING

The mounting of the RPG to the vehicle axle must be determined for each type of test vehicle. Some vehicles have inboard journal bearings while others have outboard journal bearings. A direct connection to the vehicle axle is optimal but other methods have been devised.

Figure A1-5 shows the RPG mounting on the R42 vehicle. In this instance, a pipe plug is removed from the outboard journal, and a custom designed fixture inserted. The RPG is outfitted with a plunger-type coupling which fits against a centering hole on the axle. The axial play of the axle in the journal box

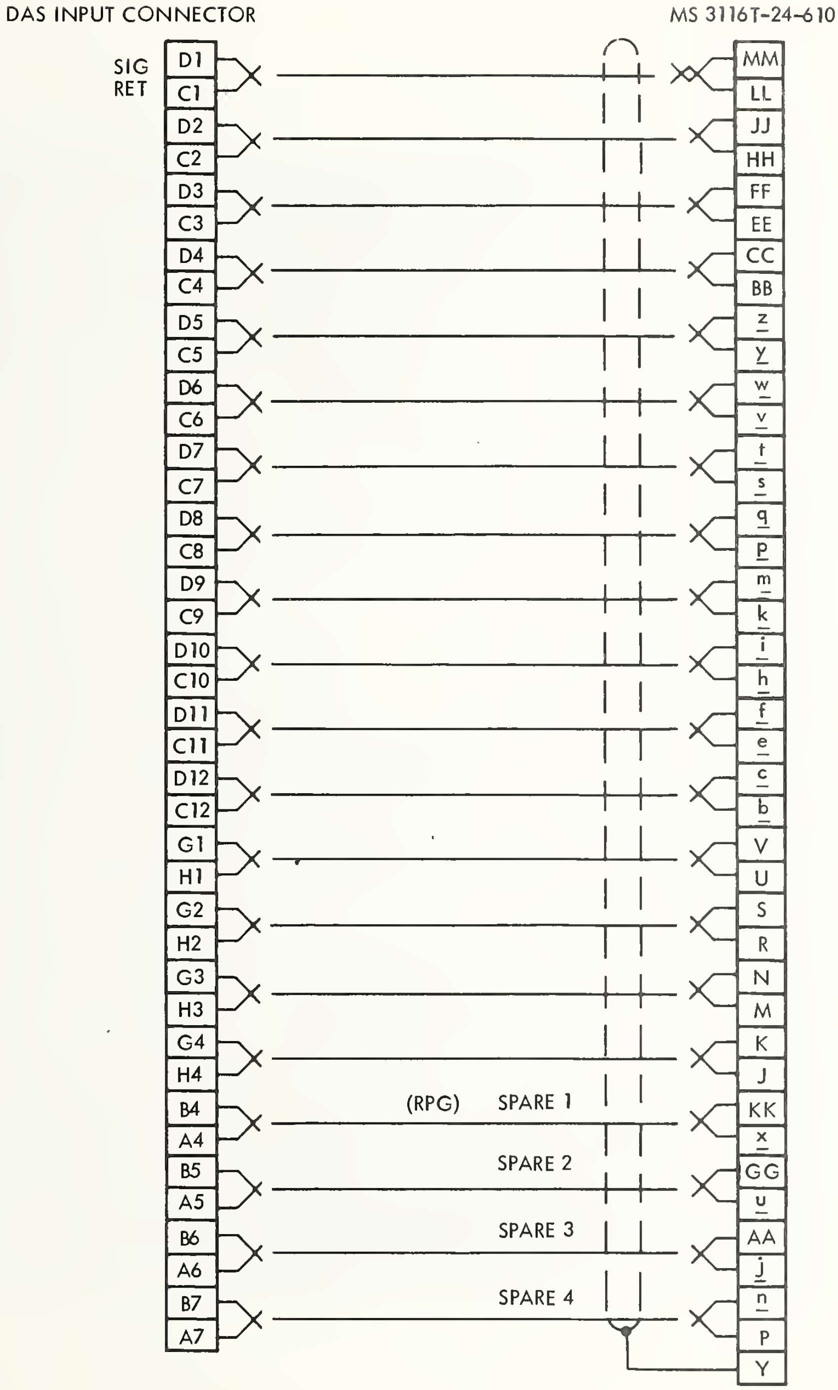


FIGURE A1-3. GVT CABLE STYLE R PHYSICAL/ FUNCTIONAL CHARACTERISTICS

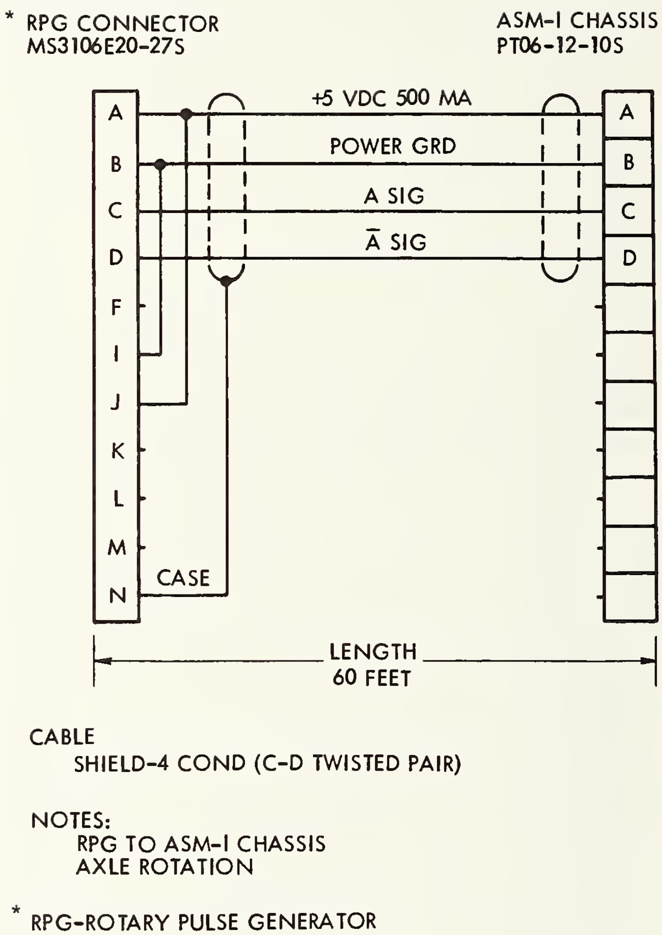


FIGURE A1-4. GVT CABLE STYLE K PHYSICAL/ FUNCTIONAL CHARACTERISTICS

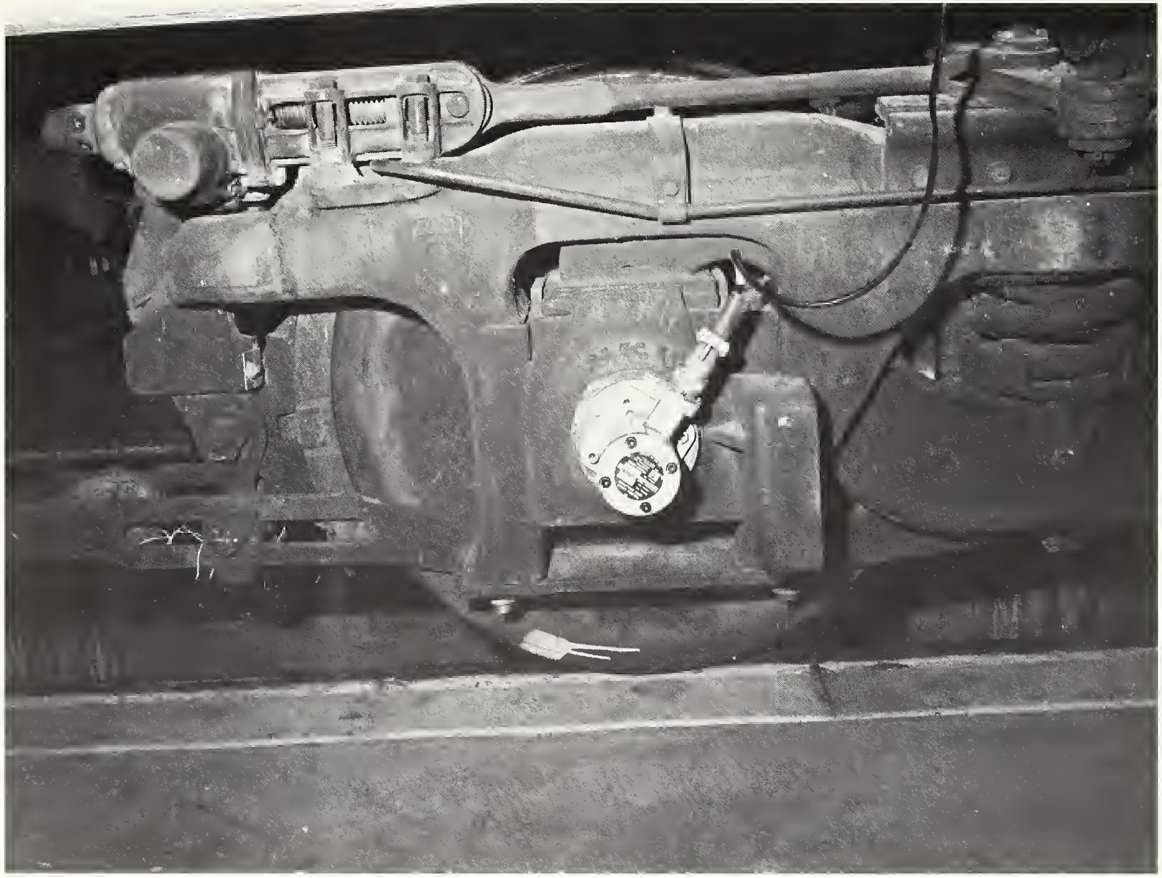


FIGURE A1-5. RPG MOUNTED ON THE R42 VEHICLE exceeds 1/4". Newer vehicles, such as the R44, feature a hard mount of the RPG to the axle with a modified journal box.

Tests on the MBTA Green Line on a PCC vehicle utilized the RPG. In this case, the journal bearings were inboard and the RPG connected to the axle as shown in Figure A1-6. A custom fabricated coupling was inserted into a threaded hole in the axle. Flexible metal bellows were used to couple the RPG to the axle. This approach provides the most accurate transfer to the wheel rotation to the RPG. Because of the torsional stiffness of the bellow couplings, limited "wind-up" occurs due to misalignment. The use of a pair of bellows permits greater shaft misalignment.

Due to mounting constraints on a Cleveland Transit System test vehicle, a third type of RPG mount was designed as shown in Figure A1-7. This system utilized a four foot long flexible shaft to transfer the axle rotation to the RPG. The wind-up of this coupling technique was severe with speed variations exceeding 5 percent. This approach is not recommended.

No special tools are required to attach the RPG but as is obvious from the previous paragraph custom designed mounting brackets are required. Modifications to the vehicle may be required to install the instrument. These are best determined on a case-by-case basis.

A1.8 CALIBRATION

A1.8.1 Primary. To calibrate the RPG, a precision dividing head must be used. As the dividing head is used to rotate the RPG shaft, the total number of pulses and their spacing accuracy can be determined.

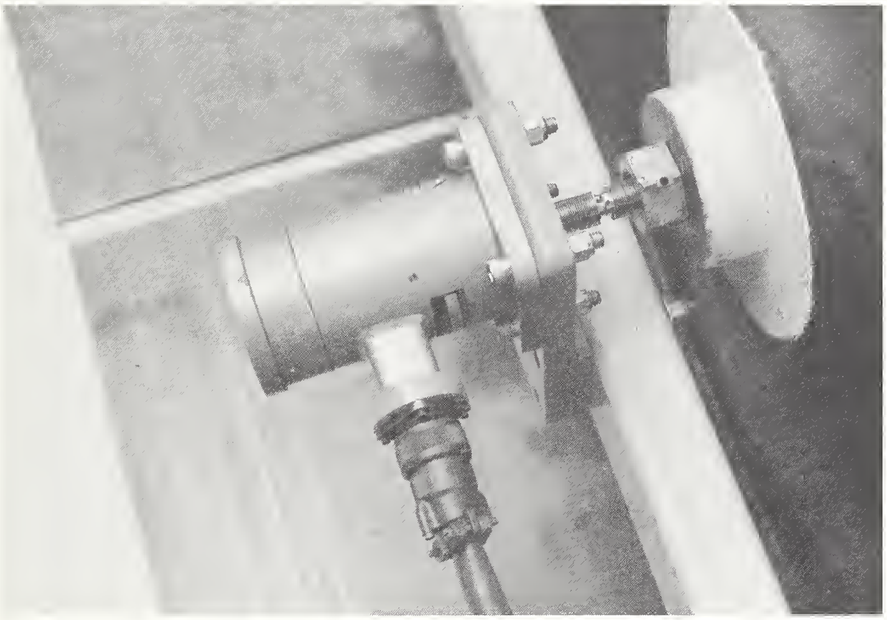


FIGURE A1-6. RPG MOUNTED ON THE PCC VEHICLE

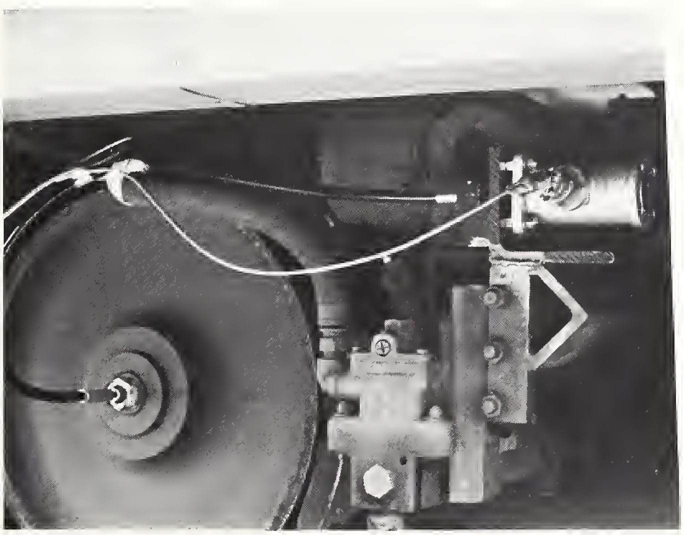


FIGURE A1-7. RPG MOUNTED ON THE CLEVELAND TRANSIT VEHICLE

A1.8.2 Secondary. To calibrate the speed and distance measurement onboard the vehicle, the wheel circumference must be known. It has been determined that taping a small gauge copper wire across the wheel surface causes minute copper traces to be deposited on the rail as the vehicle is moved. By measuring the distance between these traces, an accurate measure of wheel circumference can be obtained. While on the vehicle, the speed measurement can be calibrated by precision distance marks and a stop watch. An alternate approach is to use a TTC radar gun.

A2. EVENT/COMMUNICATIONS MEASUREMENT SYSTEM

A2.1 DESCRIPTION

The Event/Communications measurement system is used to provide reference information during a vehicle test and communications between the test crew. The Event system utilizes a keyboard which can input any of eight distinct codes into the data acquisition system. These codes can be defined in any suitable manner depending on the test being run. The Communications system is used to provide information transfer between members of the test crew. Headset outlets can be located at strategic points on the test vehicle. The headsets also serve the purpose of isolating the test crew from extraneous noise and interference.

The keyboard unit is shown in Figure A2-1. Figure A2-2 shows the Event/Communications chassis. A headset and an exterior unit are shown in Figure A2-3.

The Event/Communications system consists of the following items:

a. Keyboard........................TSC Model KCU-1

b. GVT Cable.......................Style G

c. Headset........................Clarke Model 800SB-A

d. Communication Units,
   Exterior........................TSC Model CB-1

e. GVT Cable.......................Style H

f. Event/Communications
   Chassis........................TSC Model EC-1

g. DAS Input Cable ....Style P

The supporting documentation file contains the following applicable items (Bins 9 and 10):

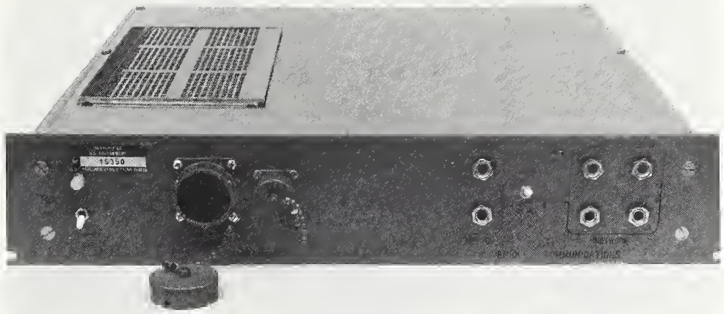
a. Fabrication Dwg................Event/Communications Systems Components Md EC-1 TSC Dwg. No. 6-0002 Communication Box Md CB-1 TSC Dwg. 6-0008

b. Fabrication Specification......Event/Communications System TSC-TS-330-EE

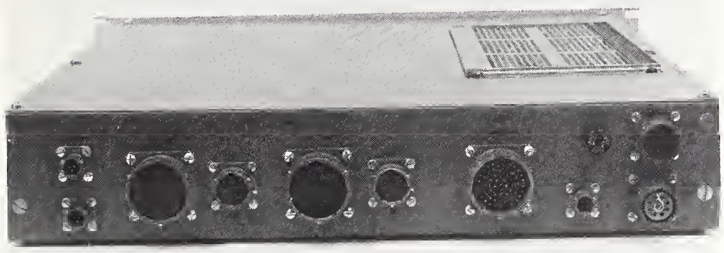
c. MFG Operators Manual...........Acopian Power Supply

d. MFG Data Sheets................Clarke Sound-Powered Headset

FIGURE A2-1. KEYBOARD UNIT



(Control Indicator Panel View)



(Connector Panel View)

FIGURE A2-2. EVENT/COMMUNICATIONS CHASSIS

FIGURE A2-3. HEADSET AND EXTERIOR UNIT

A2.2 SPECIAL HANDLING

No special handling of this system is required.

A2.3 THEORY OF OPERATION

A2.3.1 Event. The Keyboard Unit has eight pushbutton switches that correspond to the individual bits of an eight-bit computer word. Depressing one of these switches causes a light to be illuminated on the keyboard and a computer interrupt to be generated. The computer can decode the interrupt signal and determine which switch was depressed. The keyboard interfaces with the Event/Communications chassis. This chassis provides a +5 volt DC power supply for the keyboard display. The chassis contains three input/output connectors to handle up to three keyboard units.

A future improvement of the Event measurement system will provide the capability of entering a two-digit number along with the specific event word. This number will be displayed on the keyboard.

A2.3.2 Communications. The headsets used on the Communications system contain piezoelectric crystals that convert voice-induced mechanical vibrations into an electrical signal. No auxiliary power is required to activate the system. Each headset is plugged into a junction box that is interconnected with similar boxes throughout the vehicle. Up to six headsets may be used simultaneously. Junction connectors are located on the exterior units, the keyboard unit, and the Event/Comm EC-1 chassis.

The output signal of the voice system may be recorded on a voice recorder to assist in the documentation of the test. A switch on the chassis can be used to disconnect two of the communications jacks on the chassis from the system network.

A2.4 SHIELD/GROUND TECHNIQUE

The entire communication system is hard wired and all grounding is achieved within the system. The only requirement is that the chassis be electrically connected to train ground.

A2.5 FUNCTIONAL WIRE LIST SUMMARY

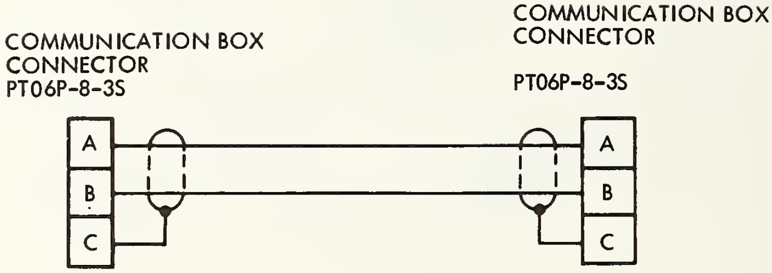
Because this system does not yet have a full digit input and display capability, a pin-to-pin listing is not given. Schematic diagrams of the three cables are shown in Figures A2-4 through A2-6.

A2.6 MODE CARD SETUP

Not Applicable.

A2.7 VEHICLE MOUNTING

Up to three keyboard units can be installed on the vehicle. Cable lengths of 110, 70, and 10 ft. are available and can be used to locate the keyboard units in the motorman's cabs on a pair of test vehicles and at the equipment console.



CABLE

2 CONDUCTOR
SHIELD

NOTES:

LENGTH	QUANTITY
12 FEET	3
60 FEET	3

USE ON VEHICLE EXTERIOR COMMUNICATIONS

FIGURE A2-4. GENERAL VEHICLE TEST CABLE STYLE H

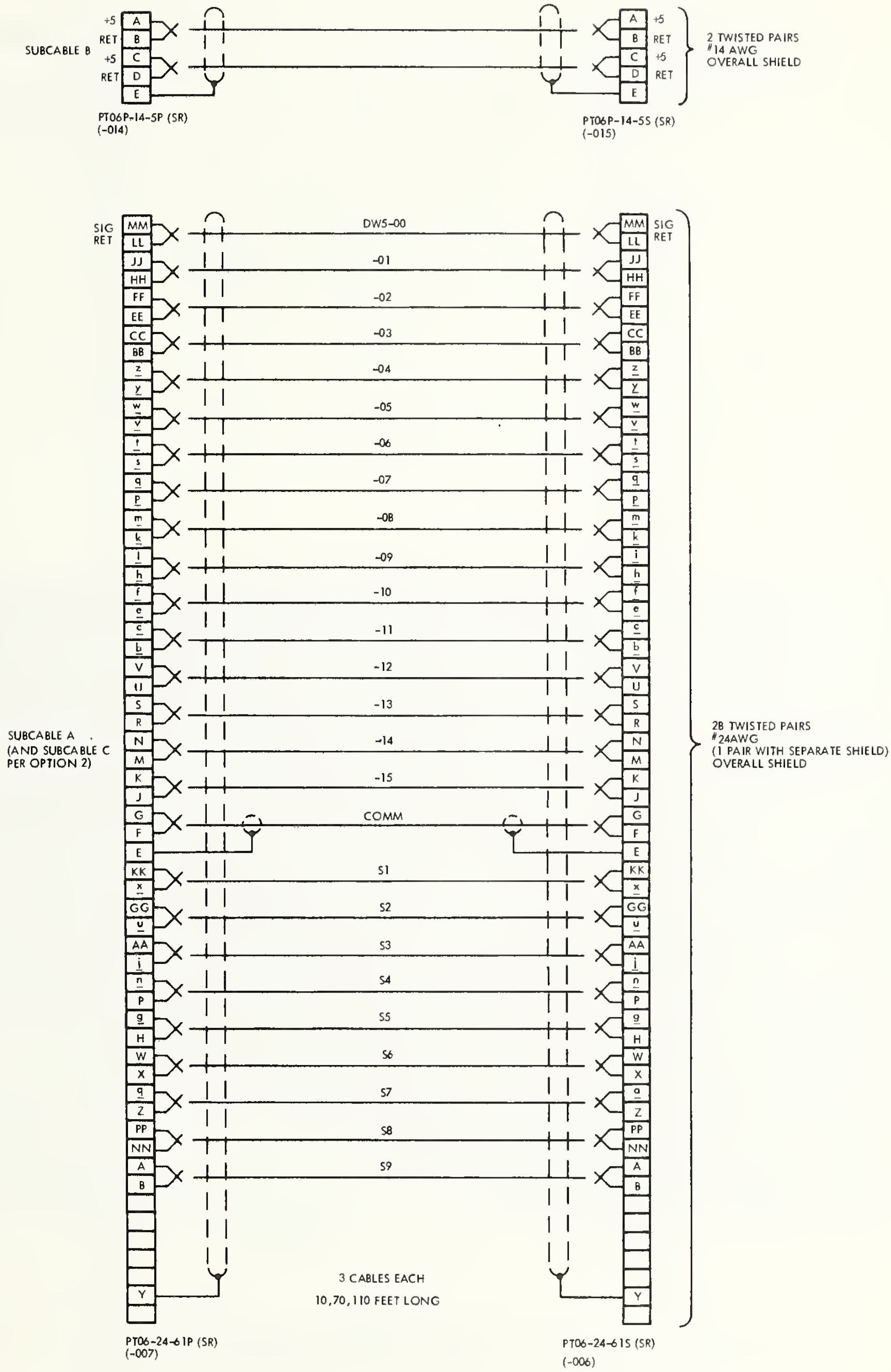
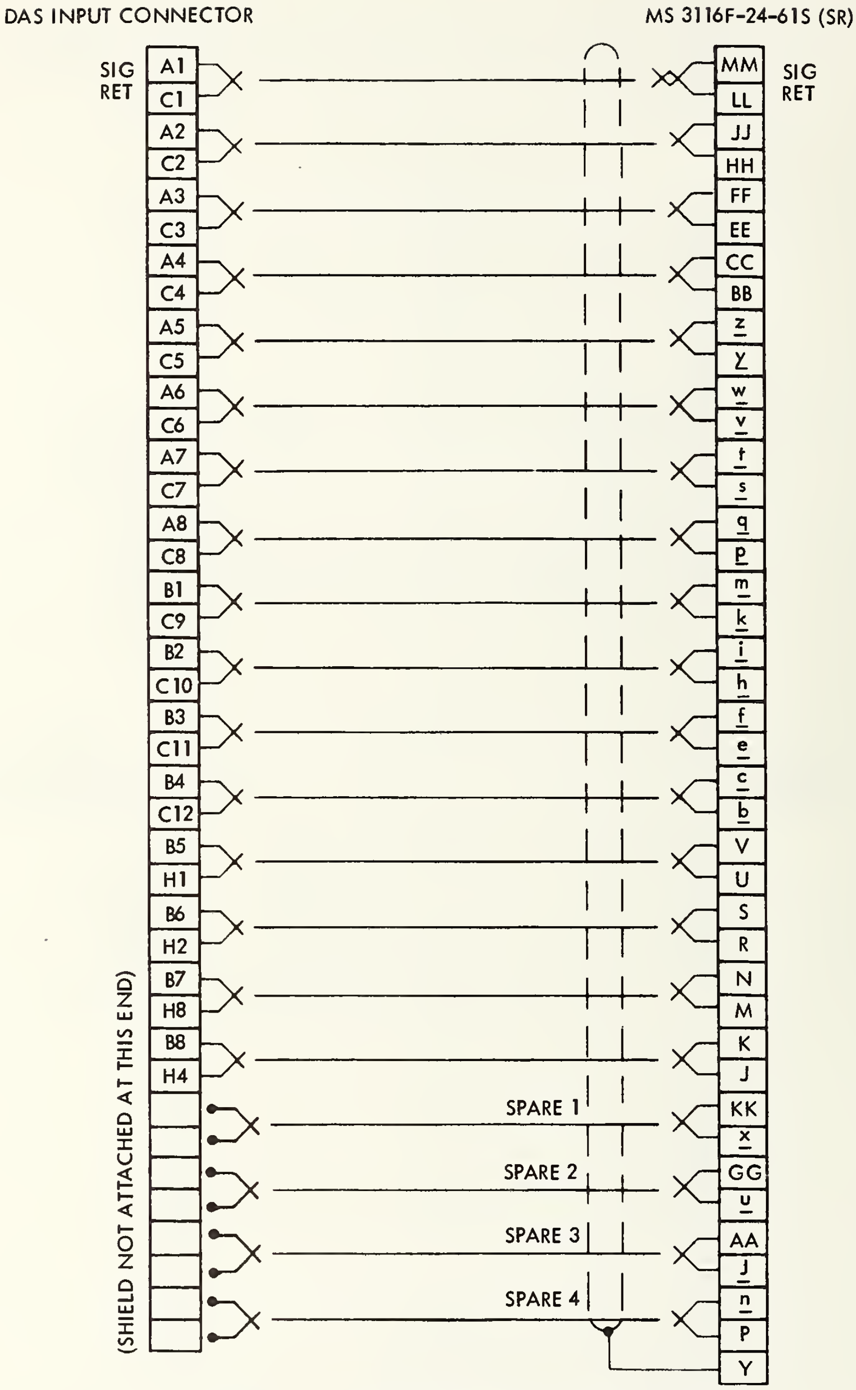


FIGURE A2-5. GENERAL VEHICLE TEST CABLE STYLE G



CABLE 20 TWISTED PAIRS WITH OVERALL SHIELD
USE FROM EVENT/COMM CHASSIS TO DAS
LENGTH 10 FEET

FIGURE A2-6. GENERAL VEHICLE TEST CABLE STYLE P

The exterior communications units can be located at strategic areas both inside and outside of the vehicle. A photograph of an installation beneath the R42 vehicle is shown in Figure A2-7. In this case, a special right angle bracket was fabricated to allow the use of existing mounting holes.

No special tools are required to install this system and no modifications to the vehicle are required.

A2.8 CALIBRATION

A calibration of this system is not required. However, an operational checkout should be periodically performed to ensure that the system is functioning properly.

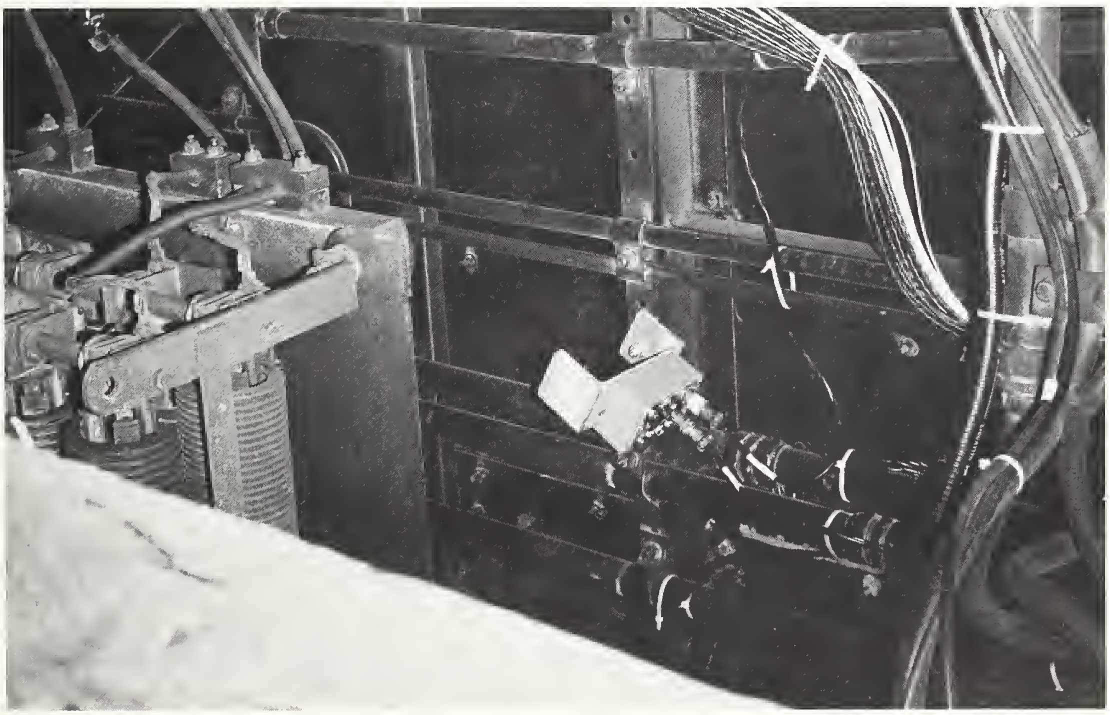


FIGURE A2-7. EXTERIOR COMMUNICATION UNIT, MOUNTED ON R42 VEHICLE AS SEEN FROM MAINTENANCE PIT

A3. AUTOMATIC LOCATION DETECTOR MEASUREMENT SYSTEM

A3-1 DESCRIPTION

The Automatic Location Detector (ALD) measurement system is a non-contact device used to detect metallic objects located along the centerline of a roadbed. The objects to be detected include turn-outs, impedance bonds, and specially designed aluminum targets. Placement of the targets can be optimized for given vehicle tests. A sensing probe is attached to the vehicle and a signal is generated as the vehicle passes over a target. The selected ALD will work reliably at target/probe spacings up to two inches, in all weather conditions, and at vehicle speeds up to 80 miles per hour.

The ALD measurement system consists of the following items:

a. Probe......................KAMAN Md KD1106-10C*

b. Probe Cable................KAMAN Md 850615-015*

c. Oscillator/Demodulator.....KAMAN Md KD2300-12CU*,**

d. GVT Cable..................Style D

e. Signal Conditioner.........Endevco 4470/4475.1
W/TSC Mod K

The ALD sensor system can also be used as an accurate non-contacting displacement sensor. This use is described in Appendix G3 of this report.

*Refer to Figure A3-1.

**A Circuit modification is required in the shield/ground system. This mod allows use of the Style D cable and is described in paragraph A4.

FIGURE A3-1. PROBE, PROBE CABLE, AND OSCILLATOR/DEMODULATOR

The supporting documentation file contains the following applicable items (B in 11):

a. MFG Data Sheet.............KAMAN System Md KD-2300-12 CU

b. MFG Operator's Manual......KAMAN System Md KD-2300-12 CU

c. MFG Application Note.......KAMAN System Targets Note No. 104

A3.2 SPECIAL HANDLING

No special handling of this system is required.

A3.3 THEORY OF OPERATION

The probe contains two coils which form the arms of an impedance bridge. The bridge is activated by a 1 MHz signal generated in the oscillator/demodulator. The impedance of the coils changes when a conductor is moved near the coils. This change in impedance is detected and a DC output signal is generated.

When using the probe as an ALD, a simple calibration is sufficient to provide the indication of a target. If used as a displacement measuring device, a more detailed calibration is required to provide a linear transfer function for displacement versus output.

A3.4 SHIELD/GROUND TECHNIQUE

As received, the shield of the probe cable is electrically connected to the probe housing, the oscillator/demodulator (O/D) case, and to signal low. To allow the continuation of this shield into the GVT cable and signal conditioning system, a circuit modification is required. Pin F of the O/D output connector (PT02-10-6P) is normally connected to the oscillator circuit to allow synchronization of two or more units located near each other. This is further described in the non-contact displacement sensor supporting documentation. For GVT applications, Pin F is attached to the O/D case by jumping to Pin E of the same connector. (The KAMAN wire from Pin F to the lower circuit board is removed.) As such, the signal low to shield connection is accomplished internal to the O/D unit. To ensure a train-ground connection, it is recommended that the O/D case be electrically attached to the train structure. A jumper lead may be required to effect the electrical connection. The required ground connection is shown in Figure A3-2. No other connections are permitted.

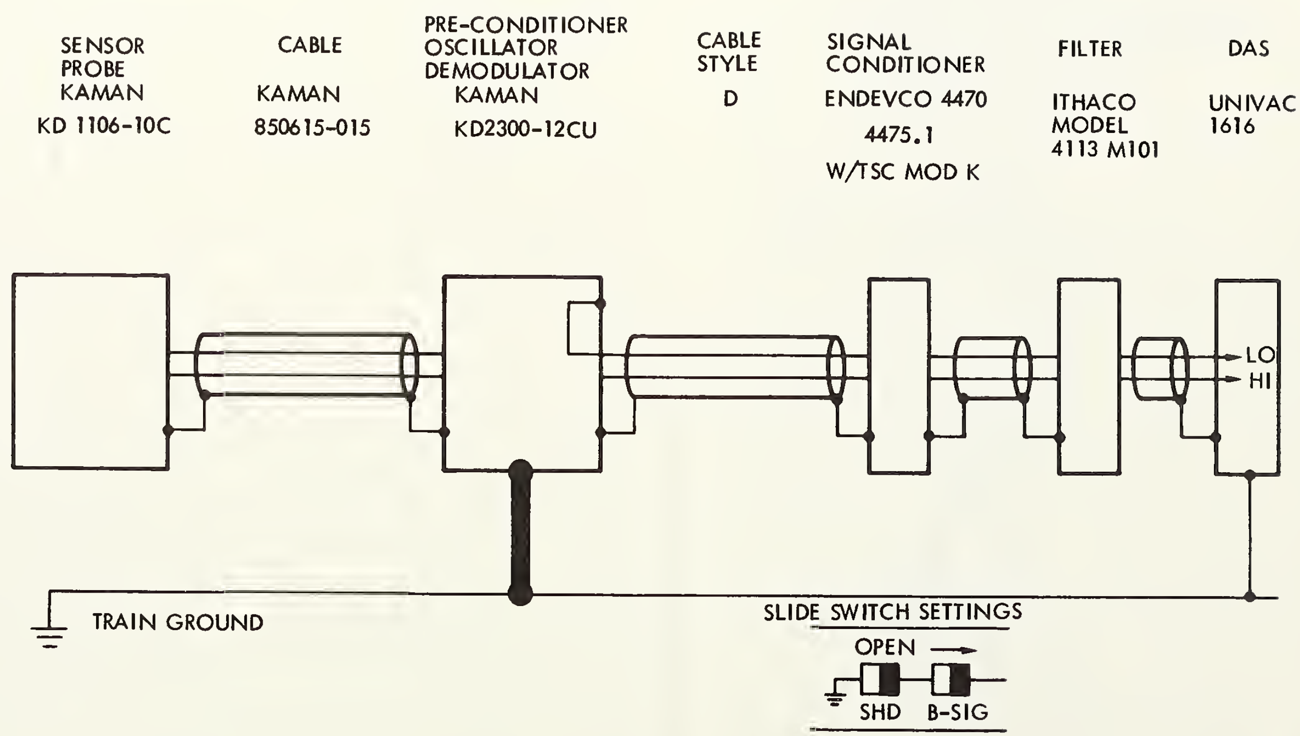


FIGURE A3-2. AUTOMATIC LOCATION DETECTOR SHIELD/GROUND CONNECTIONS

A3.5 FUNCTIONAL WIRE LIST SUMMARY

Figure A3-3 shows the pin-to-pin connections for the system. For detailed schematics of each component, the reader is referred to the supporting documentation.

A3.6 MODE CARD SETUP

A standard signal conditioner mode card is not available to provide the desired power and signal operations for the KAMAN displacement/ALD sensor systems. The requirements include:

a. Power....................$\pm$12 VDC with common.

b. ALD Signal..............TTL compatible signal indicating the presence of a metallic target.

c. Displacement Signal.....Analog signal proportional to target/probe spacing. Gain options with zero offset capability.

The required mode card was designed and uses a model 4475.1 Designers Card. A block diagram of the circuitry is shown in Figure A3-4. The circuit schematic is shown in Figure A3-5 and a photograph of the board is shown in Figure A3-6.

The power supply furnishes a regulated $\pm$12 volt dual potential with mid-point common. The digital section compares the input signal which is normally saturated at 6.8 volts to a regulated 4 volt input. When a target is sensed by the probe, the systems drops out of saturation to less than 0.5V. The comparator switches on at 4V and a TTL "1" is output.

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	D	A SIGNAL IN
X	j	KK	N	E	B SIGNAL IN (COMMON)
Z	b	BB	J	B	COMMON
N	c	CC	K	-	COMMON
W	d	DD	A	C	-12 VDC EXCITATION
20	g	FF	B	A	+12 VDC EXCITATION
22	Y	Y	F	F	SHIELD
P	-	-	-	-	-12 VDC, POWER IN
R	-	-	-	-	+12 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-10-6S; Cable Style D

FIGURE A3-3. AUTOMATIC LOCATION DETECTOR SYSTEM FUNCTIONAL WIRE LIST SUMMARY

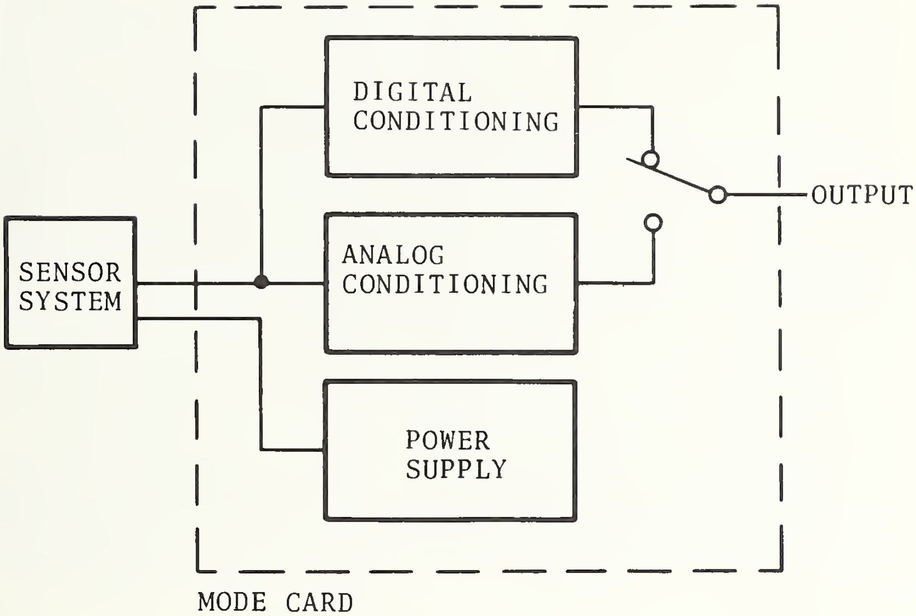


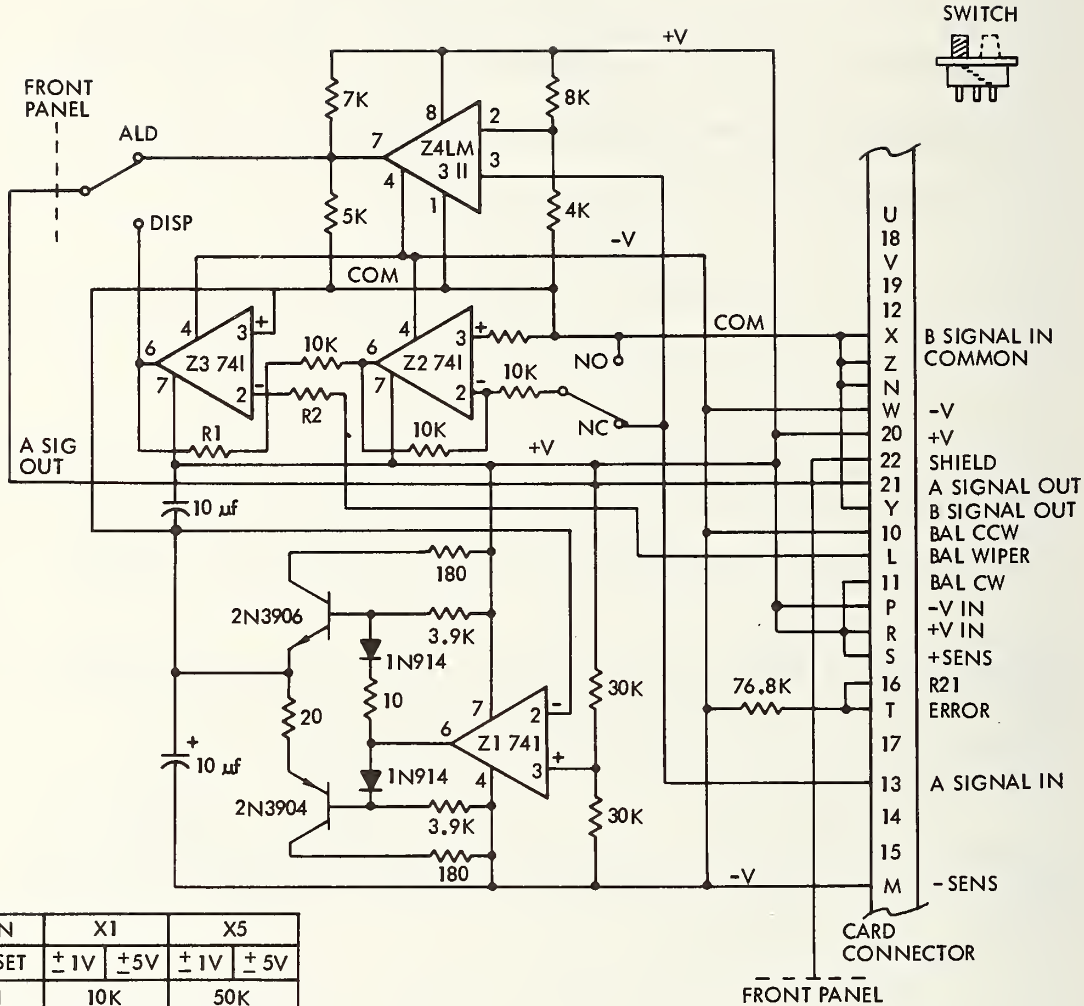
FIGURE A3-4. DISPLACEMENT/ALD MODE CARD BLOCK DIAGRAM

With no target, the output is a logic "0". The pulse width of the output is equivalent to the time of actual target detection. At high vehicle speeds, the pulse is shorter.

In the analog section, the input signal is buffered and applied to an amplifier with a fixed gain and zero offset range. These parameters may be changed by varying resistor values per the table on Figure A3-8.

By adjusting the 4470 master module pot, the zero offset is effected. The value of the offset voltage can be determined by depressing the zero pushbutton on the mode card. This shorts the input to the analog section and allows the offset voltage to be output.

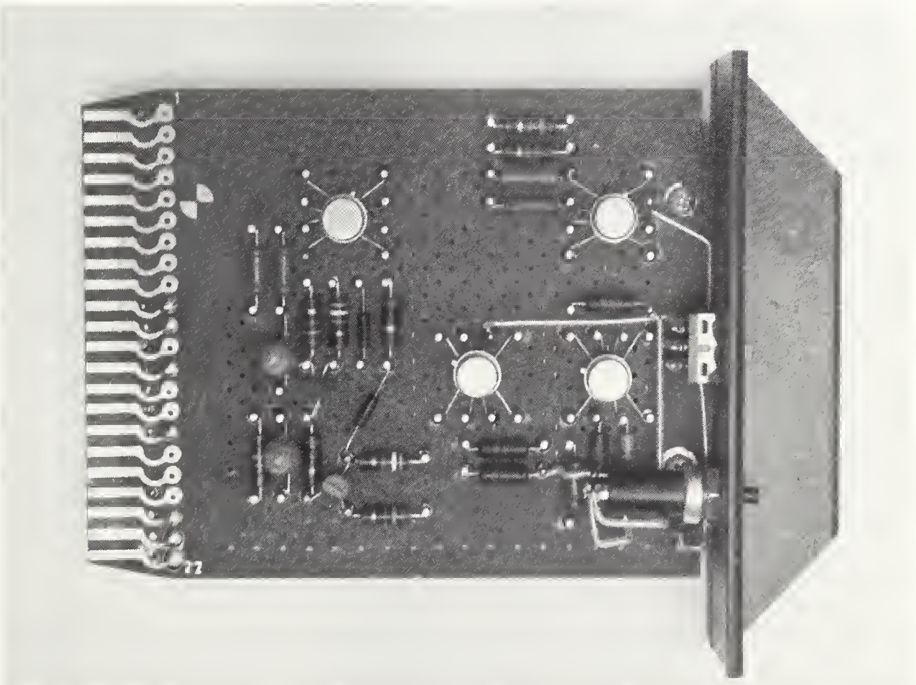
For ALD applications, no adjustments are required on the mode card after placing the front panel slide switch in the ALD position.



GAIN	X1		X5	
OFFSET	±1V	±5V	±1V	±5V
R1	10K		50K	
R2	120K	24K	600K	120K

FIGURE A3-5. ALD MODE CARD SCHEMATIC DEAGRAM

(Front Panel View)



(Circuit Board View)

FIGURE A3-6. MODEL 4475.1 DESIGNERS CARD
WITH DISPLACEMENT/ALD CIRCUIT

A3-7 VEHICLE MOUNTING

The targets to be detected should be located along the centerline between the running rails. In addition, the top surface of the targets should lie in the plane of the tops of the rails. The correct target placement is shown in Figure A3-7. On wooden ties, a hat section aluminum target may be affixed directly to the ties with wood screws, not nails. Alternately, an aluminum sheet could be affixed to a concrete tie with an epoxy.

The sensor should be attached to a lateral member of the vehicle truck midway between the rails. The vertical distance between the sensor face and the plane of the tops of the rails should be nominally set at 1.0 inch. The sensor may be attached to a suspended member of the truck if the 2 inch maximum target/probe spacing will not be exceeded by dynamic displacements.

The O/D unit should be attached to a suspended truck or carbody member such that electrical adjustments can be performed while holding a calibration target beneath the probe. The closer the O/D unit is to the probe, the easier the adjustment operation. Care must be taken to ensure a solid electrical connection between the O/D case and train ground.

Because the O/D is not sealed, it is recommended that it be housed in a waterproof case or plastic bag to prevent electrical failure. An alternate solution is to drip wax over exposed connectors.

No special tools are required but custom built mounting brackets are needed to interface with the vehicle. It is suggested that the probe and O/D be mounted on the same bracket to facilitate vehicle installation. A sample vehicle mounting bracket design is shown in Figure A3-8.

Since the probe and O/D may be clamped to the vehicle or mounted using existing bolts, no permanent modifications to the vehicle are required.

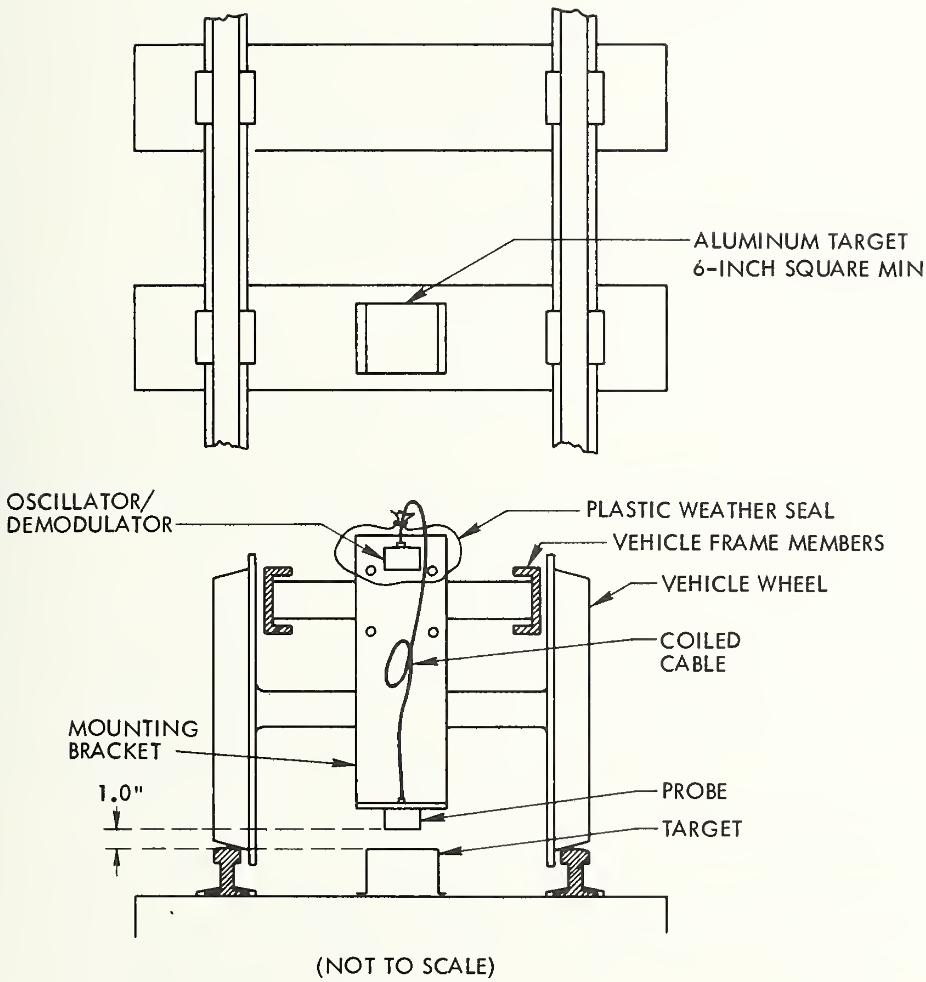


FIGURE A3-7. ALD TARGET/PROBE PLACEMENT

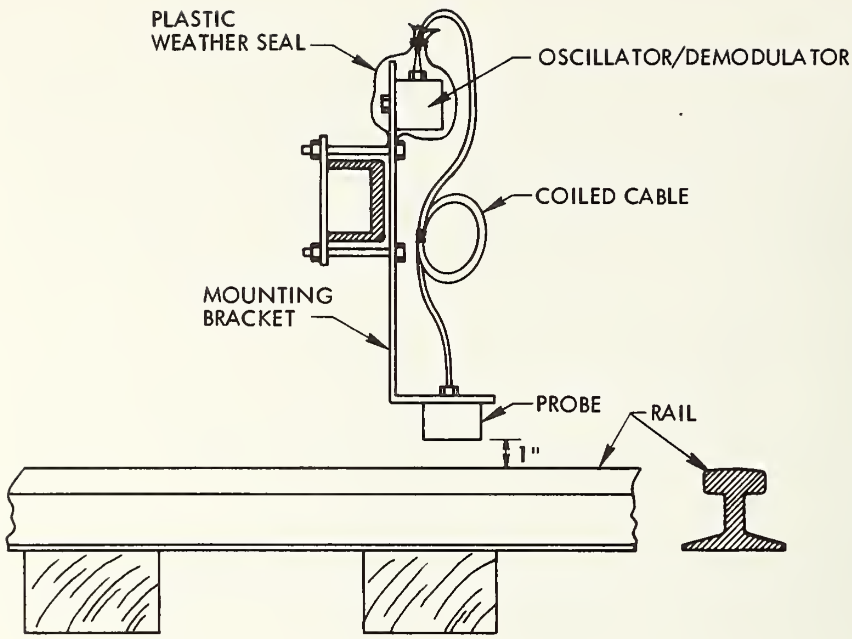


FIGURE A3-8. SAMPLE VEHICLE MOUNTING BRACKET

A3.8 CALIBRATION

A3.8.1 Primary. Because the ALD system is an on-off type of device, a primary calibration is limited to ensuring proper operation. By using a rotating disc simulation, all applicable parameters can be determined.

WARNING
EXTEME CARE IS REQUIRED WHEN PERFORMING A SIMULATION OF THIS TYPE DUE TO THE HIGH SPEEDS INVOLVED AND THE POTENTIAL FOR SERIOUS PERSONAL INJURY.

The simulation consists of affixing targets to a disc and spinning the disc in a drill press at various speeds. The actual position of the target can be determined using an optical sensor with known high-frequency response. By viewing the outputs of the optical sensor and ALD on an oscilloscope, the following parameters can be checked:

a. Distance trigger error versus target/probe spacing.

b. Distance trigger error versus simulated vehicle speed.

These errors appear as phase shifts on the scope trace.

A3.8.2 Secondary. After mounting the ALD probe and oscillator/demodulator unit as stated in paragraph A3-7, connect all electrical cables.

a. Place the slide switch on the mode card in the ALD position.

b. Insert the ALD "cal box" in the signal conditioning cable at the O/D unit. This cal box parallels the output signal so that a portable meter may be used outside the vehicle to determine the output voltage. The cal box and schematic are shown in Figure A3-9.

c. Rotate all four adjustment potentiometers on the O/D CCW until the output voltage stabilizes. Use care as the pots do not have mechanical stops and the end of range is determined by an unchanging output voltage.

d. Insure that no metallic targets such as turnout rails, etc., are within 12 inches of the probe.

e. Place the two inch square calibration target under the probe as shown in Figure A3-10. Grasp the handle away from the sensor as the proximity of the hand and arm may alter the calibration. Use the 2 inch spacer rod.

f. With the target still in place, adjust the coarse linearity control until the output signal saturates, approximately 6.8 volts. Now adjust CW slowly until the output voltage reduces to less than 0.5 volt.

g. Remove the target, the output should saturate. If it doesn't, the surrounding metal will not allow a 2 inch sensitivity.

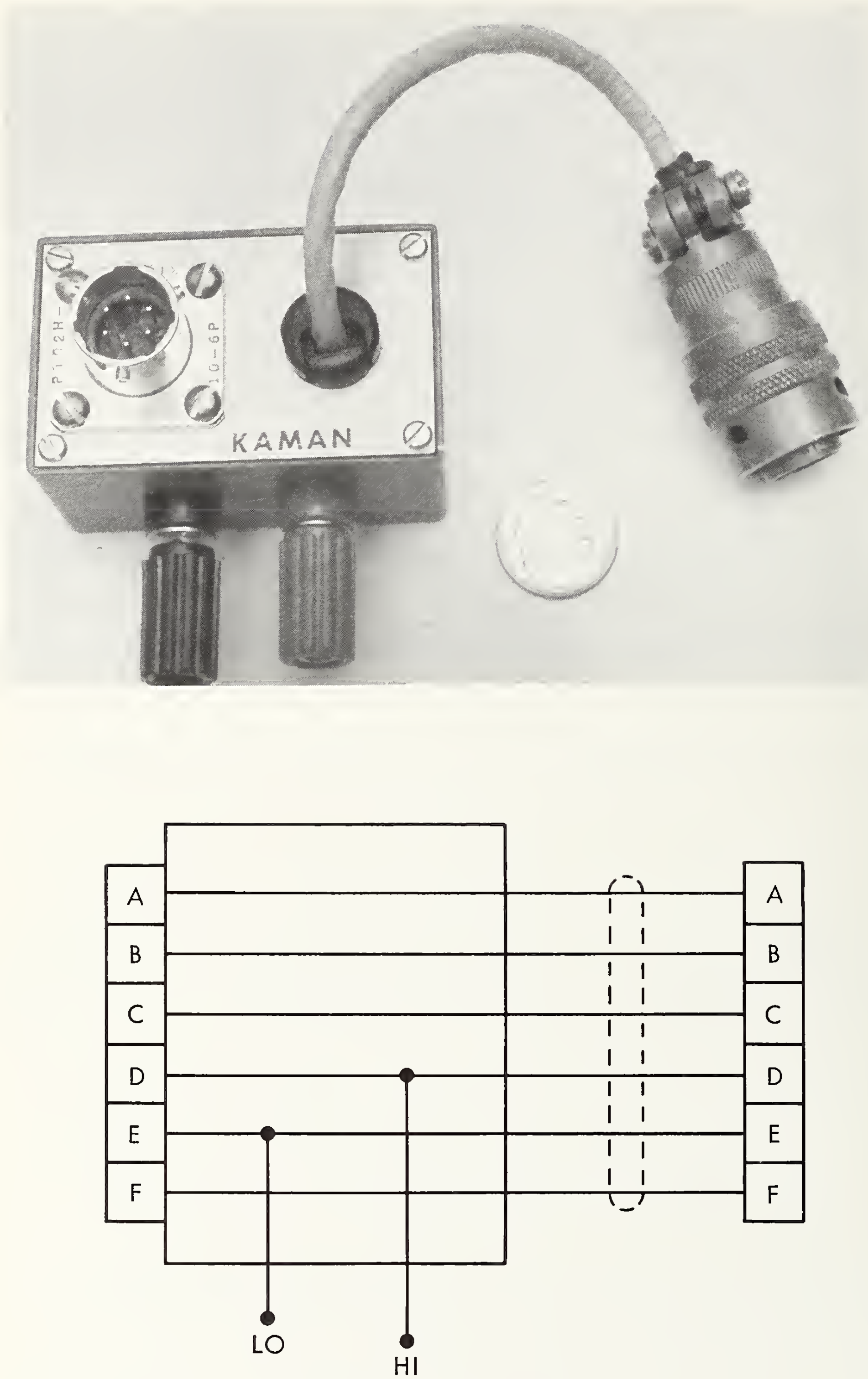


FIGURE A3-9. ALD CAL BOX

h. Reduce the nominal target/probe spacing from 1.0 to 0.75 inch. Repeat steps 5 through 7 using the 1.5 inch cal spacer.

An alternate approach eliminates the cal box but requires an observer at the instrumentation console. After step f, adjust the coarse linearity control CW until the output signal switches to 5 volts (nominal).

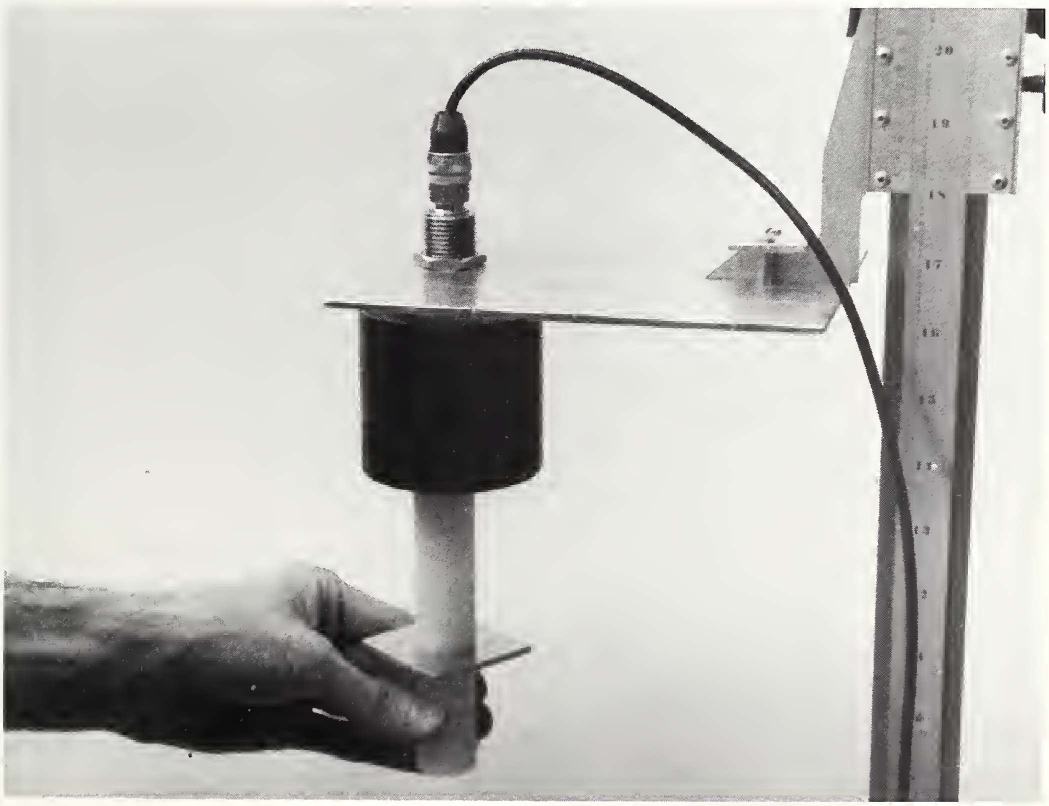


FIGURE A3-10. CALIBRATION TARGET UNDER PROBE

APPENDIX B CURRENT

B1 CONTROL CURRENT MEASUREMENT SYSTEM
B2 POWER CURRENT MEASUREMENT SYSTSM
B3 CURRENT SHUNT MEASUREMENT SYSTEM

B1. CONTROL CURRENT MEASUREMENT SYSTEM

B1.1 DESCRIPTION

Control currents are defined as unidirectional, slowly varying currents of up to 5 amperes. They are used to control various systems on a vehicle. On the State-of-the-Art-Car (SOAC), the P-signal and braking control signals were DC currents. Measurement of these currents is necessary when determining the response of the vehicle to operator initiated commands. The control current sensor is shown in Figure B1-1. The current carrying conductor being monitored must be inserted through the center-hole in the correct polarity.

The Control Current measurement system consists of the following items:

a. Control Current Sensor.....American Aerospace Series 903B (Modified Connector)

b. GVT Cable..................Style D

c. Signal Conditioner.........Endevco 4470/TSC 4479.3S

The supporting documentation file contains the following applicable items (Bin 12):

a. System Error Analysis

b. Mfg. Data Sheet............American Aerospace Series 903 Sensor

c. Mfg. Outline Dwg...........American Aerospace Dwg. No. 700-903

B1.2 SPECIAL HANDLING

No special handling of this system is required.

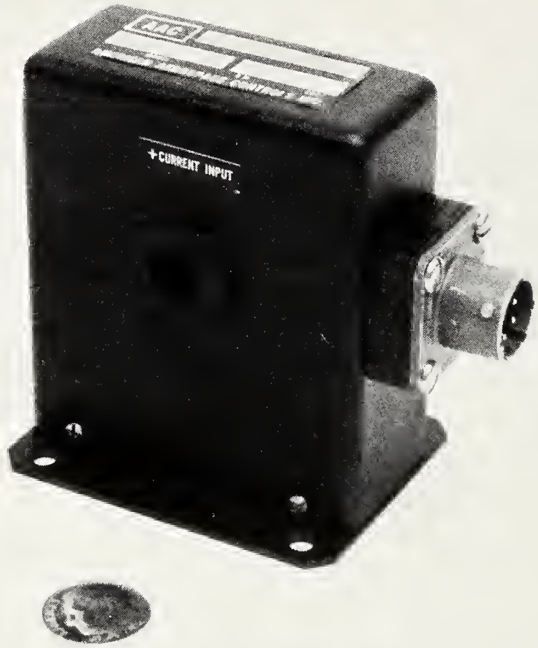


FIGURE B1-1. CONTROL CURRENT SENSOR

B1.3 THEORY OF OPERATION

The control current sensor utilizes a saturable toroidal core to sense the magnetic flux associated with a current flow. An American Aerospace (proprietary) detection and signal conditioning circuit produces a voltage analog of the input current.

B1.4 SHIELD/GROUND TECHNIQUES

Two options are available when connecting the signal and ground circuits on the current sensor. These are shown in Figure B1-2 and B1-3. If the case of the control current sensor is not grounded (mounted on an insulator) then Option I must be used. If the case is electrically grounded, then Option II must be used.

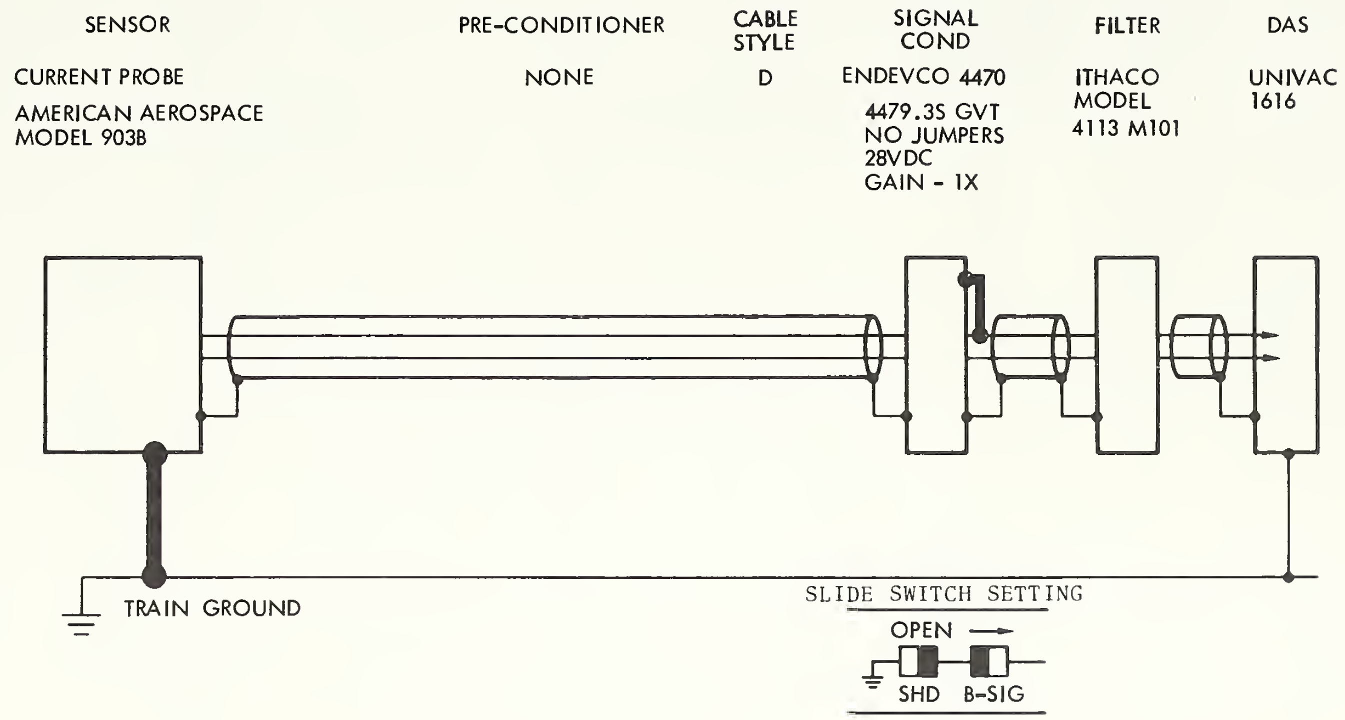


FIGURE B1-2. CONTROL CURRENT MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS - OPTION I

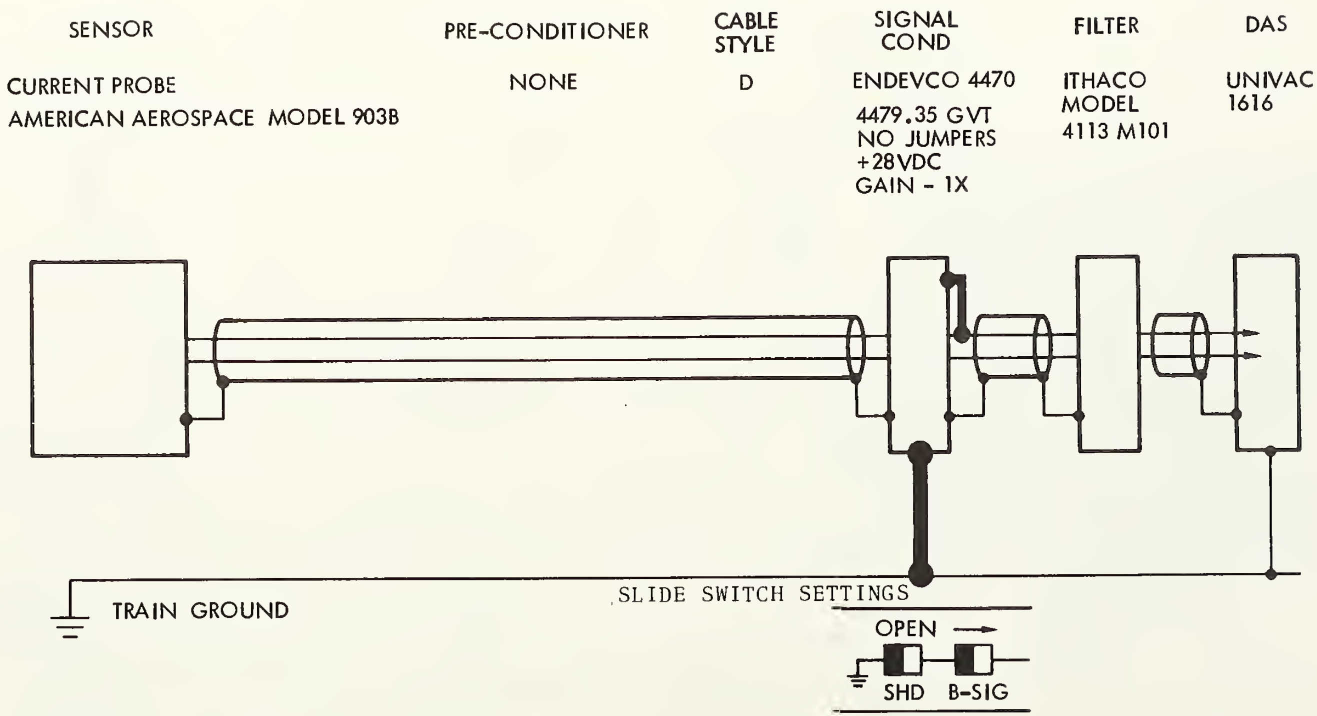


FIGURE B1-3. CONTROL CURRENT MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS - OPTION II

B1.5 FUNCTIONAL WIRE LIST SUMMARY

Figure B1-4 shows pin-to-pin connections for the Control Current Measurement system. Refer to supporting documentation for detailed schematics of each component.

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	D	A SIGNAL IN
X	j	KK	N	E	B SIGNAL IN (EXCIT RTN)
Z	b	BB	J	B	COMMON (NC IN SENSOR)
N	c	CC	K	-	
W	d	DD	A	C	EXCITATION, RETURN
20	g	FF	B	A	+28 VDC EXCITATION
22	Y	Y	F	F	SHIELD
P	-	-	-	-	-15 VDC, POWER IN
R	-	-	-	-	+15 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-10-6S; Cable Style D

FIGURE B1-4. CONTROL CURRENT MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

B1.6 MODE CARD SETUP

The mode card used to condition the control current signals is the TSC-Designed GVT card (See Figure B1-5). This card has the capability of four fixed gain settings, (X1, X10, X50, X100). To use the card with this sensor, remove jumpers between J1 and J2. Set the Supply Voltage switch (S3) on the front panel to the +28 position. As the sensor output is already 5 volts full scale, the Gain switch on the mode card should be set to the X1 gain setting.

B1.7 VEHICLE MOUNTING

The model 903B current sensor is minimally sensitive to external magnetic fields, magnetic material, and conductor configuration through the sense hole. As a result, mounting of the sensor is not critical. Any convenient location inside or outside of the vehicle can be used.

Locate a junction point of the conductor carrying the current to be measured. Disconnect the conductor at the junction point, insert the conductor through the sensor and connect the conductor. A decal on the sensor indicates the positive polarity input side and a current is assumed to flow from positive to negative polarity. The sensor will not operate if the conductor is not inserted in the properly polarized direction.

No special tools or permanent modifications to the vehicle are required but the control circuit cables to be monitored must be temporarily disconnected to allow insertion through the sensor.

B1.8 CALIBRATION

B1.8.1 <u>Primary</u>. To calibrate the control current sensor, use a precision current source that can be traced to NBS. Apply a range of currents to a conductor in the pass-through hole of the sensor. Adjust the gain and zero potentiometers for a proper output. The location of the adjustment pots is shown in Figure B1-6. The base plate of the sensor must be removed to adjust the gain pot. It is noted that the gain and zero adjustments are interactive.

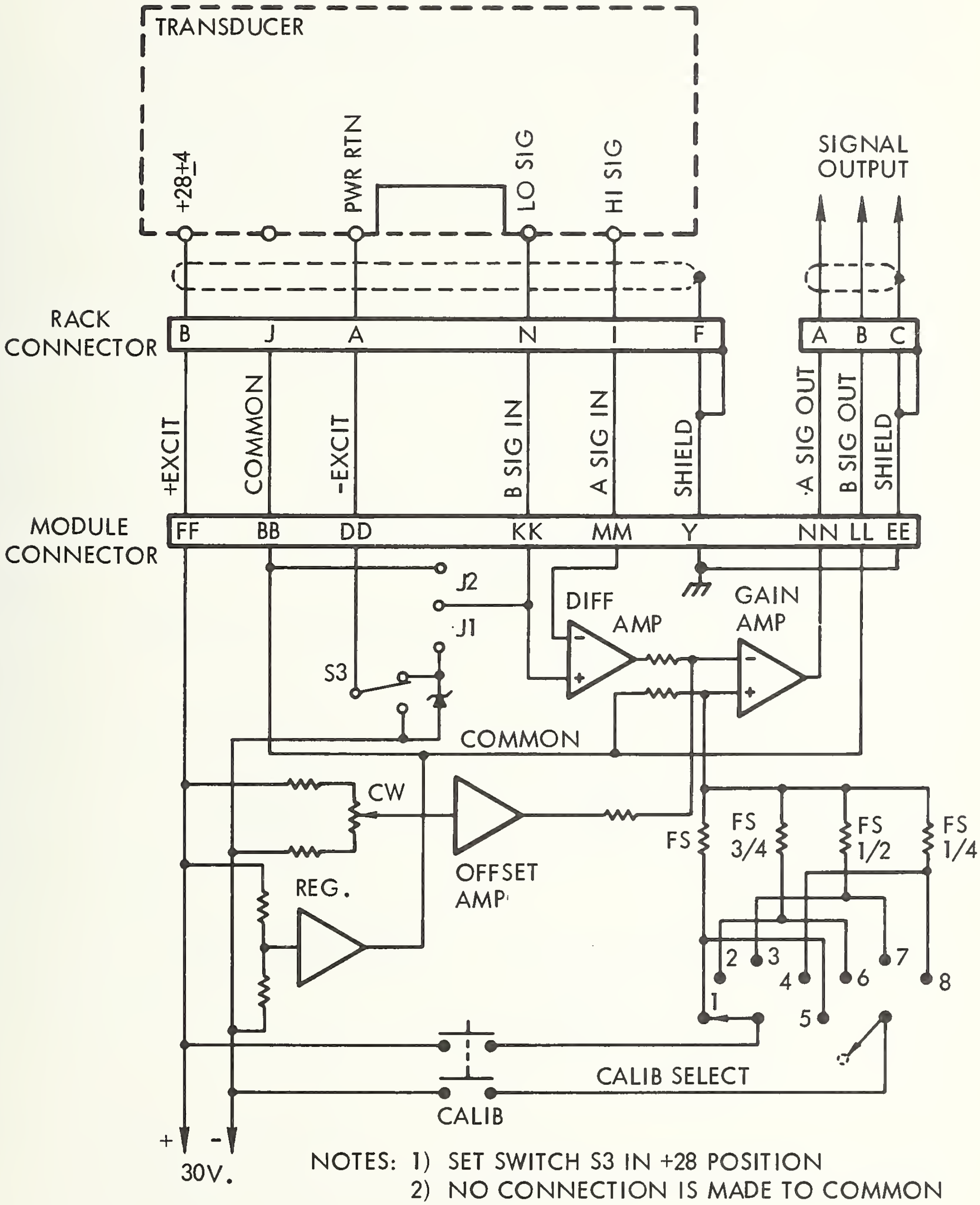


FIGURE B1-5. GVT MODE CARD SETUP FOR CONTROL CURRENT MEASUREMENT SYSTEM

B1.8.2 <u>Secondary</u>. No method currently exists for secondary calibration of the sensors after they have been installed on the test vehicle. It is possible to inject an auxiliary current through the sensor yoke, but a more appropriate technique would be to simulate the output of the probe using the ALD calibration box. This box contains the output connector necessary to mate with the GVT cable and provides a means for injecting a test voltage.

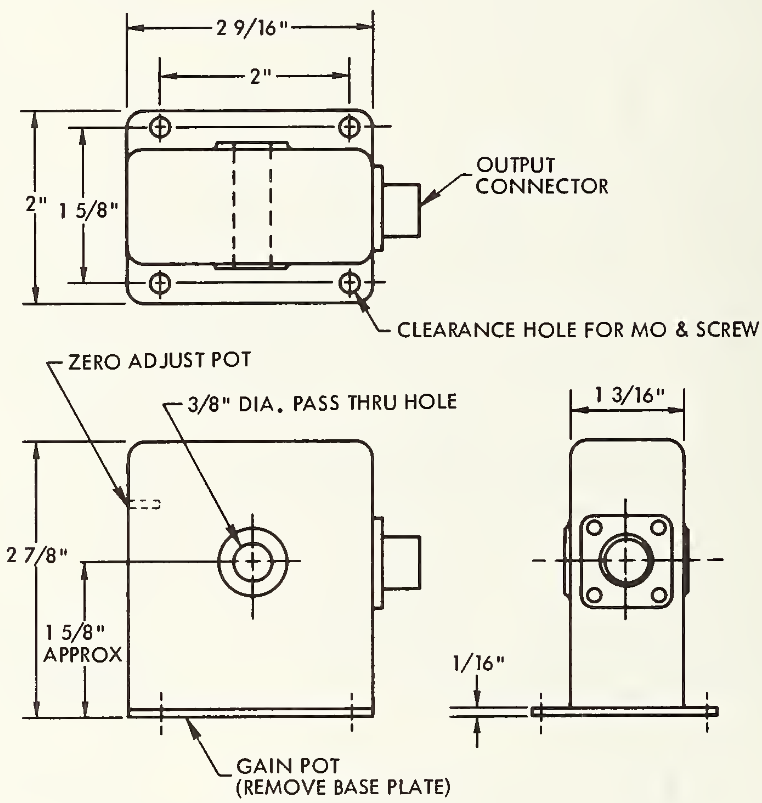


FIGURE B1-6. CURRENT SENSOR CALIBRATION POINTS

B2. POWER CURRENT MEASUREMENT SYSTEM

B2.1 DESCRIPTION

Power currents are defined as high level currents in a range of 50 to 3000 amperes. They include vehicle input line currents and motor field and armature currents. The measurement of these currents can be used to determine control systems response characteristics and vehicle energy consumption.

The power current sensor is shown in Figure B2-1. The Series 909 sensors are bi-directional current sensors and have a flexible yoke arrangement to facilitate clamping on conductors to be monitored.

The power current measurement system consists of the following items:

a. (Power) Current Sensor.....American Aerospace Series 909 (Modified Connector)

b. GVT Cable..................Style D

c. Signal Conditioner.........ENDEVCO 4470 TSC 4479.3S

The supporting documentation file contains the following items (Bin 13):

d. System Error Analysis

e. Mfg. Data Sheet............American Aerospace Series 909

f. Mfg. Outline Dwg...........American Aerospace Dwg. No. 700-909M5

B2.2 SPECIAL HANDLING

No special handling of the power current sensors is required. However, to obtain the rated accuracy, the vehicle installation technique is extremely critical, as described in paragraph B2.7.

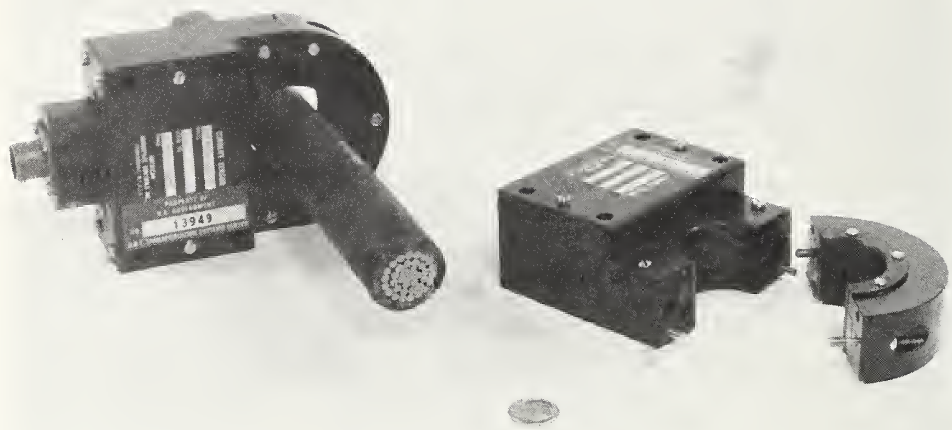


FIGURE B2-1. POWER CURRENT SENSOR - (LEFT) AS SEEN IN USE, (RIGHT) YOKE OPENED FOR INSTALLATION ON POWER CONDUCTOR

B2.3 THEORY OF OPERATION

Power current sensors incorporate a pair of magnetic flux sensitive resistors located in a magnetic core. These magneto-resistors, which form part of a bridge circuit, are biased with permanent magnets and react to the magnetic field produced by the current flow in the conductor. The sensed current thus produces a bridge unbalance which results in an output signal. The output signal is scaled by an internal amplifier to produce a ± 5 volt full scale signal when rated current is flowing in the conductor.

B2.4 SHIELD/GROUND TECHNIQUE

The proper shield and ground connections are shown in block diagram form in Figure B2-2. Note that the case of the instrument is isolated from the electronics of the sensor and it is therefore optional if the case is grounded. No other ground connections are permitted.

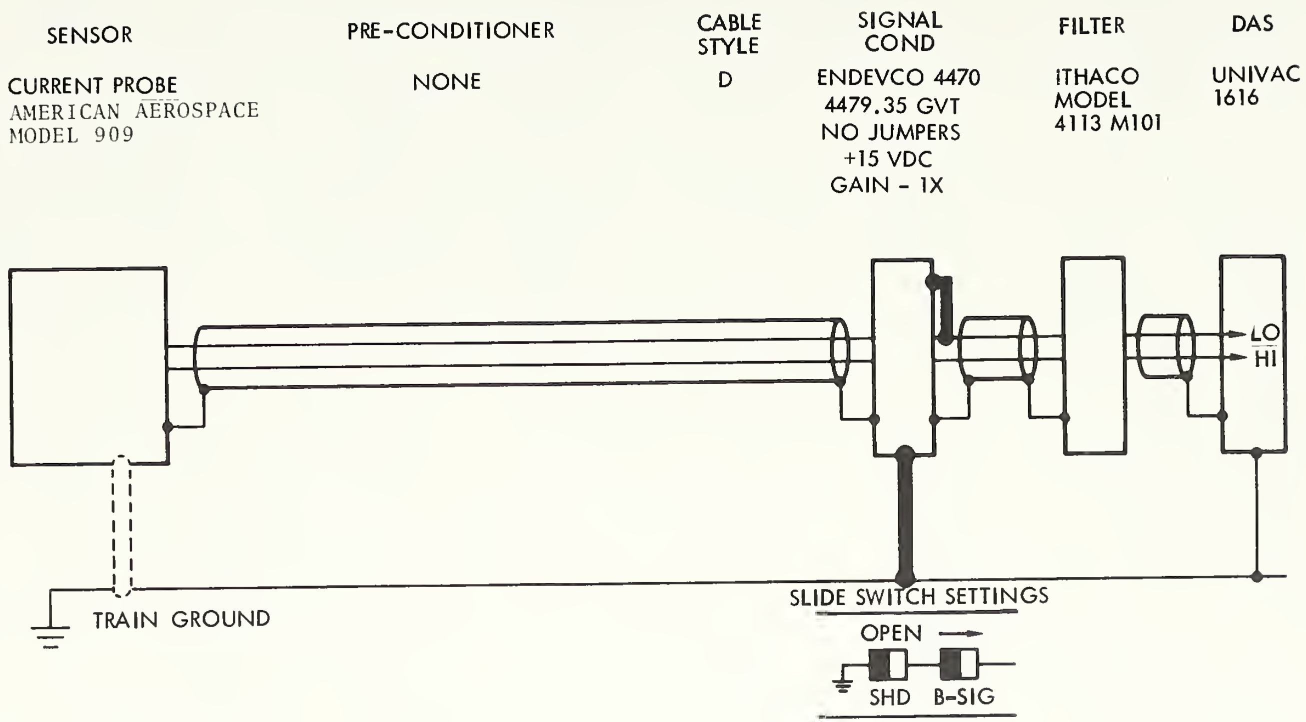


FIGURE B2-2. POWER CURRENT MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

B2.5 FUNCTIONAL WIRE LIST SUMMARY

Figure B2-3 shows pin-to-pin connection for the power current measurement system. Refer to supporting documentation for detailed schematics of each component.

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	D	A SIGNAL IN
X	j	KK	N	E	B SIGNAL IN (COMMON)
Z	b	BB	J	B	COMMON
N	c	CC	K	-	
W	d	DD	A	C	-15 VDC EXCITATION
20	g	FF	B	A	+15 VDC EXCITATION
22	Y	Y	F	F	SHIELD
P	-	-	-	-	-15 VDC, POWER IN
R	-	-	-	-	+15 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-10-6S; Cable Style D

FIGURE B2-3. POWER CURRENT MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

B2.6 MODE CARD SETUP

The mode card used to condition the power current sensor signals is the TSC-designed GVT card. This card (See Figure B2-4) has the capability of four fixed gain settings (X1, X10, X50, X100). To use the card with the power current sensor, remove the jumpers (J1 and J2) on the card. The front panel SUPPLY VOLTAGE switch, (S3), should be set to the +15 volt position. As the full scale output voltage of the sensor is 5 volts, the Gain setting should be X1.

B2.7 VEHICLE MOUNTING

The mounting of the power current sensor is extremely critical. The four main sources for error signals are listed below with the minimization of these error inputs discussed in the following paragraphs.

a. Position of the current carrying conductor in the sensor yoke.

b. Length of straight conductor extending from both sides of the sensor.

c. Nearby magnetic materials.

d. Nearby magnetic fields.

B2.7.1 The sensor is quite sensitive to the placement of the conductor in the sensor yoke. The diameter of a yoke hole is 1.5 inches. If the conductor is not centered along the center line of the yoke hole, the output signal variation may exceed ± 10 percent. For this reason, the actual test conductor and a calibration conductor must be shimmed by a buildup of tape or similar non-conductive material and secured in the sensor such that the conductor centerline coincides with the yoke centerline.

B2.7.2 Because the device senses the magnetic field of the current along the wire, a straight length of conductor must extend beyond the yoke at least 12 inches on each side as shown in Figure B2-5. This configuration will limit associated errors to less than 0.3 percent.

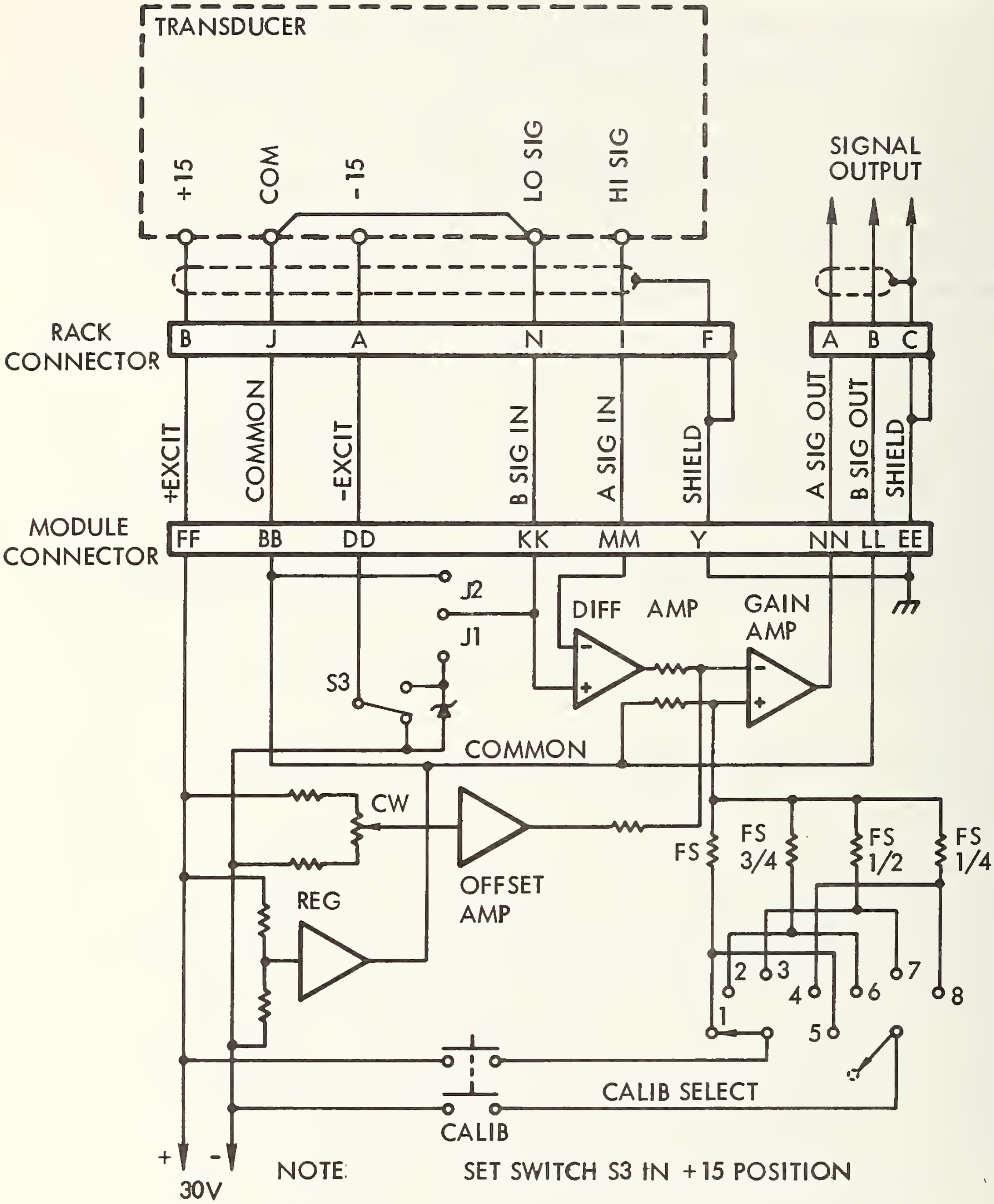


FIGURE B2-4. GUT MODE CARD SETUP FOR POWER CURRENT MEASUREMENTS

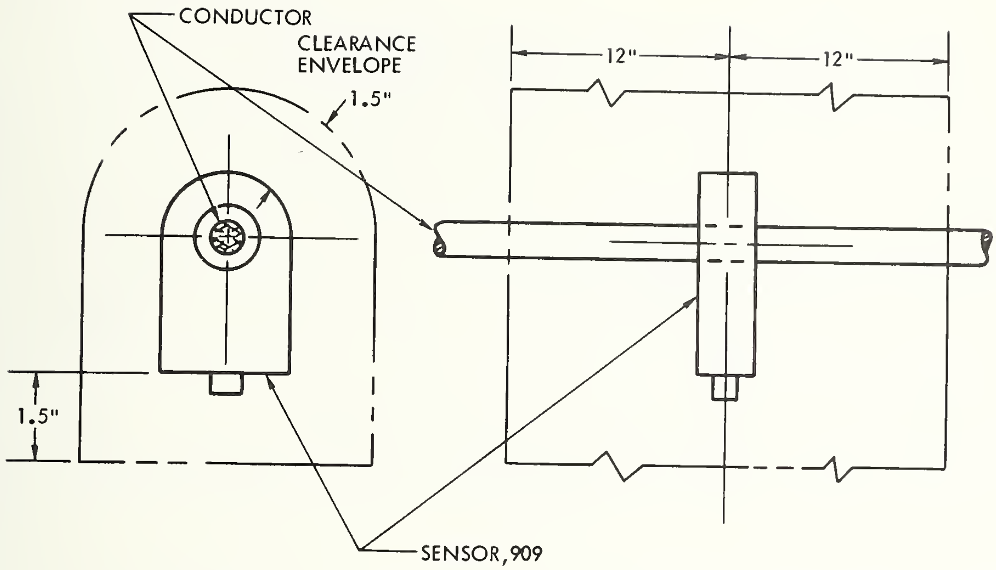
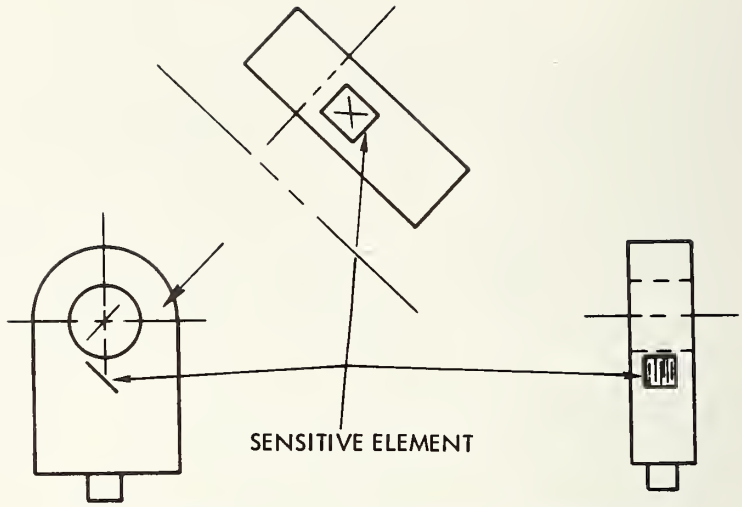


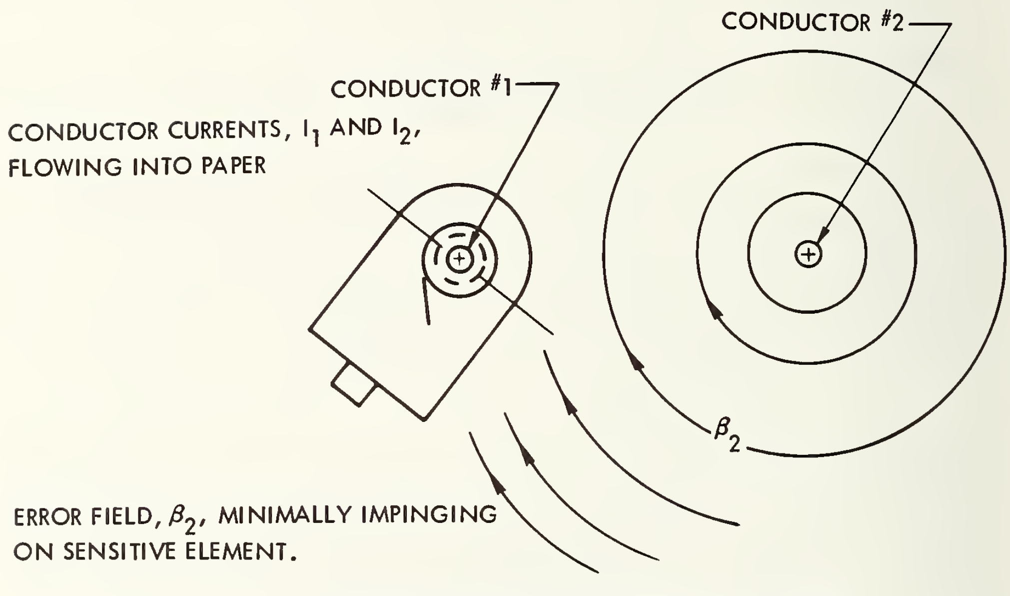
FIGURE B2-5. CONDUCTOR POSITIONING IN SENSOR AND CLEARANCE ENVELOPE REQUIREMENTS

B2.7.3 The proximity of magnetic materials to the sensor also induces significant errors. To limit the errors to less than 0.5 percent, the clearance envelope, also shown in Figure B2-5 should be observed. It is recommended that all mounting fixtures be made of aluminum or non-magnetic stainless steel.

B2.7.4 The largest source of error is from external magnetic fields generated by nearby current carrying conductors and/or traction motors. Although the device is shielded, errors exceeding 10 percent can occur. To minimize the errors from these nearby fields, the sensitive element of the sensor should be oriented parallel to the magnetic fields as shown in Figure B2-6. If a misalignment of 3° occurs, an error of 1.4% can result from typical currents on a transit vehicle. Increasing



a. ORIENTATION OF SENSITIVE AXIS, SERIES 909
(NOT TO SCALE)



b. PROPER ALIGNMENT OF SENSOR WITH NEARBY
CONDUCTORS

FIGURE B2-6. MINIMIZING ERRORS FROM NEARBY CONDUCTORS the distance between the conductor in which the current is sensed and other magnetic fields can greatly reduce this error. Sensors should never be mounted on or near the vehicle traction motors or the shoe current leads.

It may be desirable to install a jumper wire in the vehicle load circuit and route this wire to a suitable area for sensor installation. This technique will facilitate satisfying all of the above mounting constraints.

An alternate mounting technique employs an in-situ calibration after the sensor has been mounted. By temporarily modifying the vehicle control circuit, it is sometimes possible to allow current to flow in the conductor with the vehicle stationary. It is noted that this technique does not account for the magnetic field generated by nearby conductors or motors which can contribute significant errors.

No special tools are required to mount the power current probes and no permanent modifications to the vehicle are necessary. The use of temporary jumper wires may be required, however, to achieve a satisfactory installation.

B2.8 CALIBRATION

B2.8.1 Primary. To calibrate the power current sensor, current from an NBS precision current source is impressed through a conductor installed in the sensor yoke. It is imperative to adhere to the mounting clearance envelope constraints stated in paragraph B2-7. Gain and zero adjustment potentiometers are accessible from the outside of the sensor case. While inserting a known current, adjust the pots to provide the appropriate output signal. It is noted that these pots are interactive, therefore, care must be exercised when making the adjustments.

If a high level current is not available, a coil of wire may be used. The coil must be large enough to adhere to the mounting constraints stated above. It is noted that the product of the amp-turns is used to calculate the equivalent current flowing through the sensor yoke.

B2.8.2 Secondary No method currently exists for secondary calibration of the sensors after they have been installed on the test vehicle. It is possible to inject an auxiliary current through the sensor yoke, but a more appropriate technique, would be to simulate the output of the probe using the ALD calibration box. This box contains the output connector necessary to mate with the GVT cable and provides a means for injecting a test voltage.

B3. CURRENT SHUNT MEASUREMENT SYSTEM

B3.1 DESCRIPTION

The Current Shunt measurement system can be used to measure vehicle control and power currents ranging from 1 to 3000 amps. Frequency response of the system is from DC to 1000 Hz. Use of the Isolation Amplifier allows the shunts to be mounted in vehicle conductors that are referenced to line voltage (600 VDC). This high common mode voltage exists when measuring line currents, motor currents and some control currents. The isolation amplifier contains a thermal system to minimize the effects of system temperature variations.

The Current Shunt measurement system consists of the following items:

a. Current Shunts .... Janco Models 8406 A through D

b. Isolation Amplifier
w/Signal Cable .... TSC Model ISO-1

c. GVT Cable .... Style D

d. Signal Conditioner ..... Endevco 4470/TSC 4479.3S

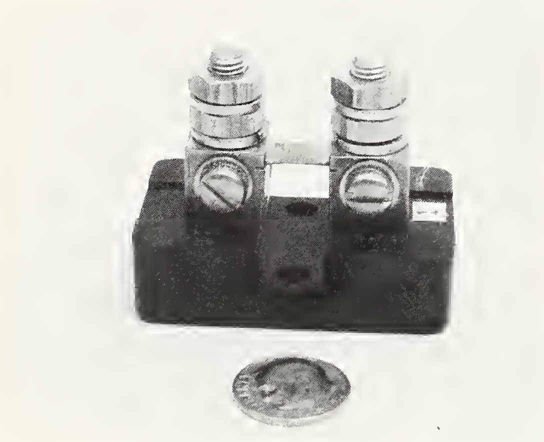
e. Heater Control Chassis . TSC Model HC-1

f. GVT Cable .... Style N (Heater)

Four representative current shunts are shown in Figure B3-1. The five-channel Isolation Amplifier is shown in Figure B3-2 and the Heater Control Chassis is shown in Figure B3-3.

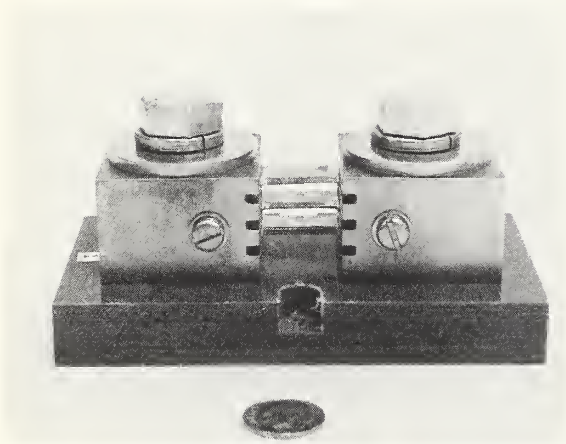
The thermal system setup and Isolation Amplifier disassembly procedures are presented in paragraph B3.9 of this section. A discussion of the effects of dynamic common mode voltages on accuracy of measurements is also presented in paragraph B3-9.

The supporting documentation file contains the following applicable items (Bins 14 thru 16):

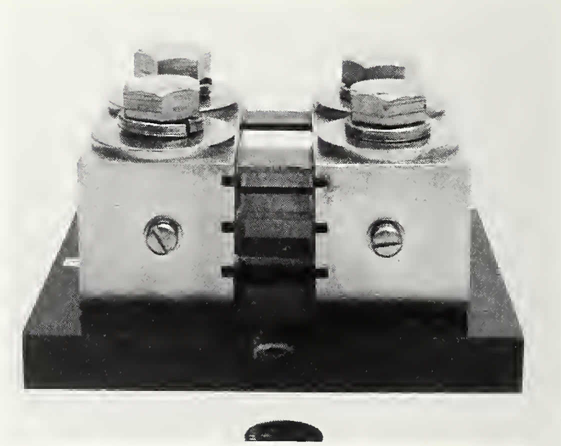


Model 8406A

Model 8406B



Model 8406C



Model 8406D

FIGURE B3-1. FOUR REPRESENTATIVE CURRENT SHUNTS

FIGURE B3-2. ISOLATION AMPLIFIER

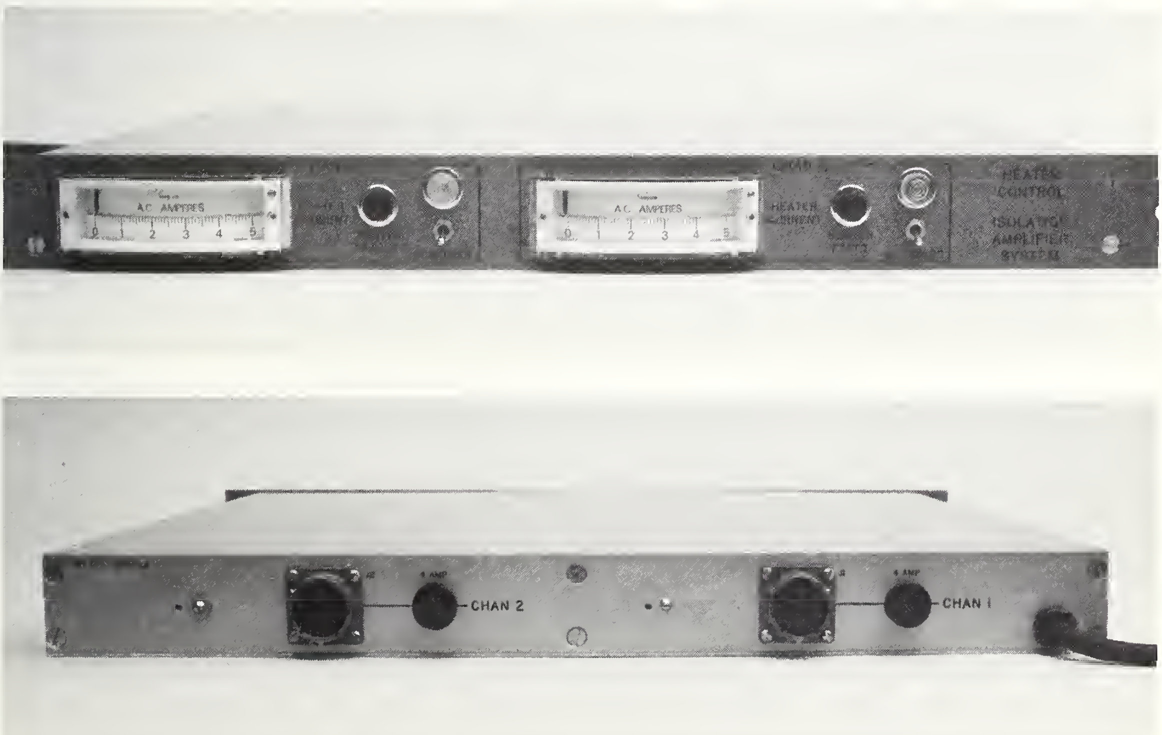


FIGURE B3-3. HEATER CONTROL CHASSIS

a.	System Error Analysis	
b.	Mfg. Outline Dwgs.	Janco Current Shunts Dwg. No. 8406A 8406B 8406C 8406D 8406-3000
c.	Mfg. Data Sheet	Stahlin Enclosures, Shunt, Molded Fiberglass
d.	Mfg. Data Sheet	Burndy Crimp Connectors #6, 4/0, 500 MCM Wire
e.	Mfg. Data/Inst. Sheet ...	Heat Shrinkable Seals, Aperseals Sigmaform Corp.
f.	Fabrication Dwg.	Isolation Amplifier System TSC ISO-1 Dwg. No. 6-0001
g.	Mfg. Data Sheet	Analog Devices ISO. Amp, 273K
h.	Mfg. Data/Inst. Sheet	Oven Industries Temp. Controller Mod. 5C1-207
i.	Fabrication Specification.	ISO Amp Contract TS-323-EE
j.	Mfg. Data Sheet	Bussman High Voltage Fuse, HVJ Melting Time Curve
k.	Mfg. Outline Dwg.	Stahlin Enclosure Mod. J1210W ISO Amp
l.	Fabrication Photograph ...	High-Voltage Cable Termination
m.	Fabrication Specification	High Voltage Cable

n. Mfg. Data Sheet .... Electro-flex Heater Elements

o. Fabrication Dwg. .... Heater Control Chassis Mod. HC-1 TSC Dwg. No. 6-0004

B3.2 SPECIAL HANDLING

When using the Isolation Amplifier, a direct connection to 600 volt lines is implied. To ensure operator's safety, observe the shock hazard warning noted on the instrument case.

WARNING SHOCK HAZARD PRIOR TO INSTALLING ANY LEADS, ELECTRICALLY CONNECT GROUND BRAID TO TRAIN GROUND.

B3.3 THEORY OF OPERATION

A current shunt is a precision calibrated low value resistor. It is electrically connected in series with a load when measuring the current through that load. By measuring the voltage drop across this resistor, the current can be determined by Ohm's Law. Shunts are normally rated such that a specified current produces a 100 millivolt signal. By proper amplification, an analog voltage proportional to the current is provided.

When shunts are installed in 600 volt lines, direct connection of the shunt signal to conventional ground referenced equipment would be catastrophic. For this reason, the signal is pre-conditioned in the Isolation Amplifier. Each amplifier (gain factor x 0.5) channel contains a modulator which converts the shunt voltage level into an equivalent frequency. This frequency is transformer coupled to a demodulator which reconverts the frequency into the signal voltage. The use of the transformer coupling provides adequate insulation for common mode voltages up to 5000 volts. The output signal of the Isolation Amplifier, now ground referenced, may be connected with the conventional system equipment.

The thermal system which controls the temperature within the Isolation Amplifier chassis is required to minimize the zero signal and gain drift. A proportional controller in conjunction with a resistance temperature detector provides the control. The heaters operate on 115 VAC that is throughput by the controller. The difference between the set point and the actual temperature determines the number of voltage cycles that are directed to the heaters during any one second period. To minimize the generation of RFI, a zero-crossing detector ensures that all AC switching occurs near zero volts. Operation of the thermal system can be monitored inside the vehicle on the Heater Control chassis. This chassis supplies the 115 VAC for the heaters and includes a current meter and fault lights. The fault light is illuminated when the over temperature thermostat located in the amplifier assembly trips or when the GVT heater cable (Style N) is not properly connected.

The circuit schematic for a single channel of the Isolation Amplifier is shown in Figure B3-4. The signal is input on a twisted pair cable with a double shield. The outer shield, designated the low voltage shield, is connected to ground for safety reasons. The inner shield is a high voltage shield and is connected to the common mode voltage at the shunt. The basic element of the circuit is an isolation amplifier module Model 273K manufactured by Analog Devices Corp. The resistors and inductors form a two pole low-pass filter to minimize the effects of the chopping circuitry in the module. R2 is a twenty-turn pot used as a gain adjust. Diodes are 10 volt zener diodes to limit the output voltage of the card. If a short exists in the circuit, the diodes can sustain sufficient current to blow the 60 mA fuse.

Figure B3-5 is a circuit schematic of the thermal system. The temperature controller, Oven Industries Model 5C1-207, proportions the correct amount of 115 VAC to the heater cover and heater base. The sensor is a resistance temperature device specifically matched to the controller. The AC power input is first directed to the thermoswitch which has an over temperature cutoff of 175°F. If the thermoswitch contacts open, the sense line causes a fault light to be illuminated in the heater control chassis.

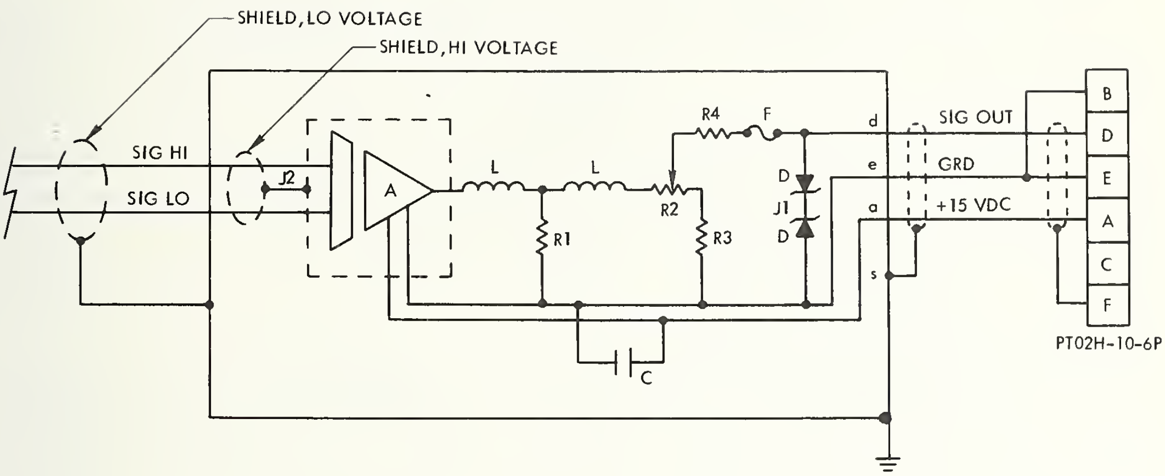


FIGURE B3-4. ISOLATION AMPLIFIER CIRCUIT SCHEMATIC

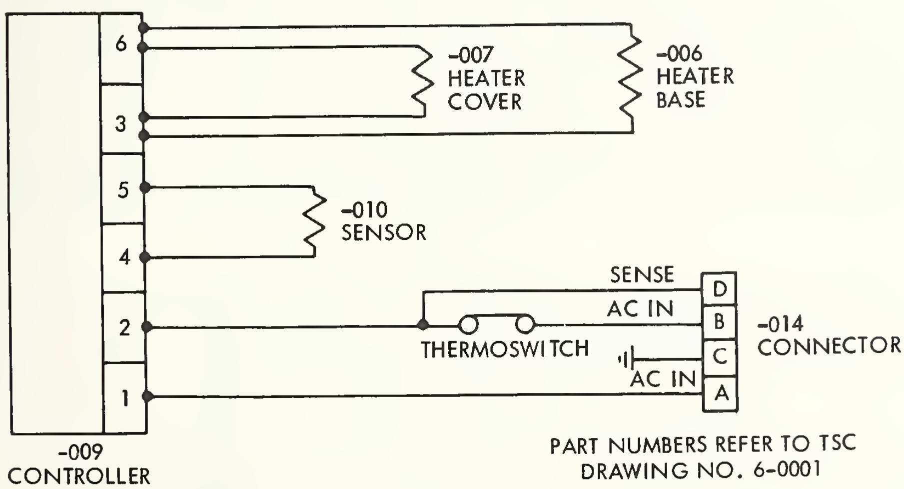


FIGURE B3-5. THERMAL SYSTEM CIRCUIT SCHEMATIC

B3.4 SHIELD/GROUND TECHNIQUE

For safety reasons, the Isolation Amplifier low voltage shield and signal low are connected to train ground at the amplifier. This is done by connecting a ground braid. No other ground connections are permitted. The proper connections are shown in Figure B3-6.

When the current shunts are mounted in ground referenced lines the Isolation Amplifier need not be used. In this case, the shield and ground connections are as shown in Figure B3-7.

B3.5 FUNCTIONAL WIRE LIST SUMMARY

Figure B3-8 shows the pin-to-pin connections for the current shunt measurement system. Refer to supporting documentation for detailed schematics of components. Figure B3-9 shows the physical/functional characteristics of the GVT Style N cable.

B3.6 MODE CARD SETUP

The mode card used to condition the shunt signals is the TSC designed GVT card. This card has the capability of four fixed gain settings (x1, x10, x50, x100). To use the card with the shunt system, remove both jumpers (J1 and J2), from the solder terminals on the card. On the front panel of the mode card, the supply voltage switch should be set to the +15 (volt) position. This provides the correct voltage required by the Isolation Amplifier.

If the shunt is used with an Isolation Amplifier (gain-x0.5) the Gain switch on the mode card should be set to x100 to provide a full-scale signal of 5 volts corresponding to a full-scale current through the shunt. If the shunt is installed in a ground-referenced conductor, and no Isolation Amplifier is used, the gain of the mode card should be set at x50 to provide the full-scale signal.

Figure B3-10 illustrates the correct mode card setup.

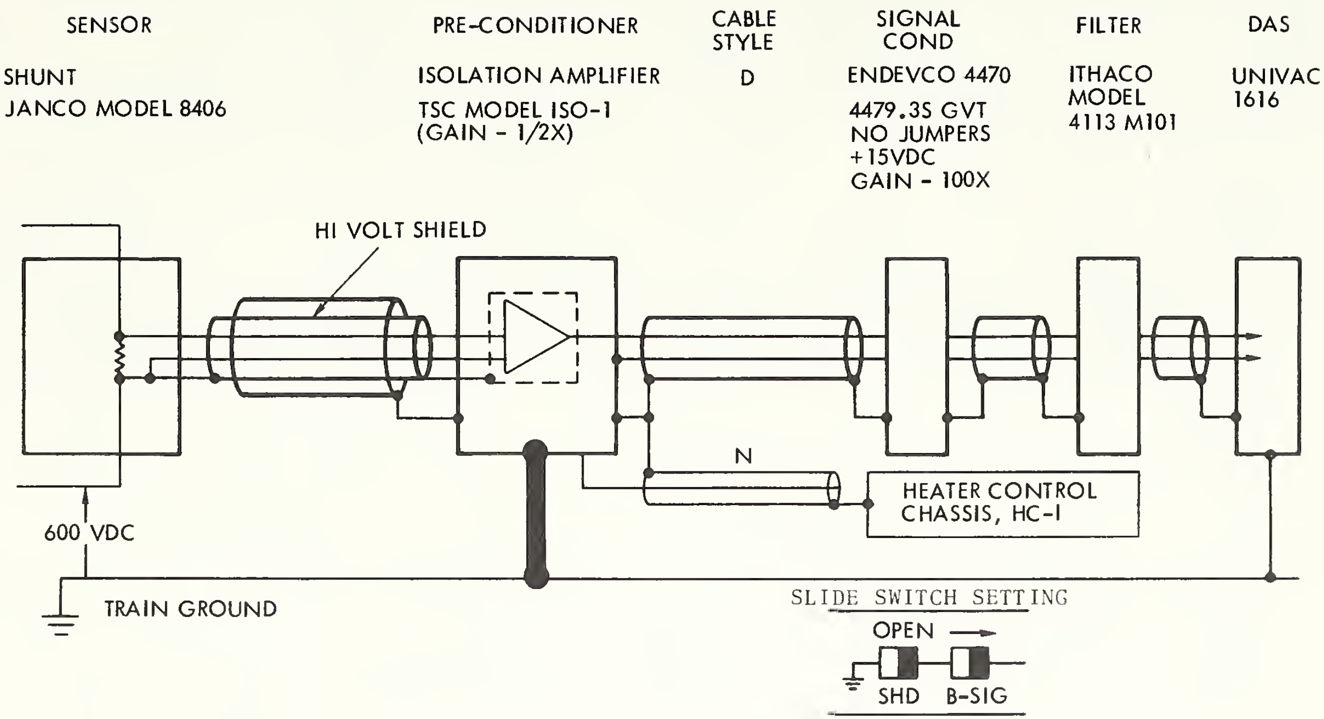


FIGURE B3-6. CURRENT SHUNT WITH ISOLATION AMPLIFIER SHIELD/GROUND CONNECTIONS

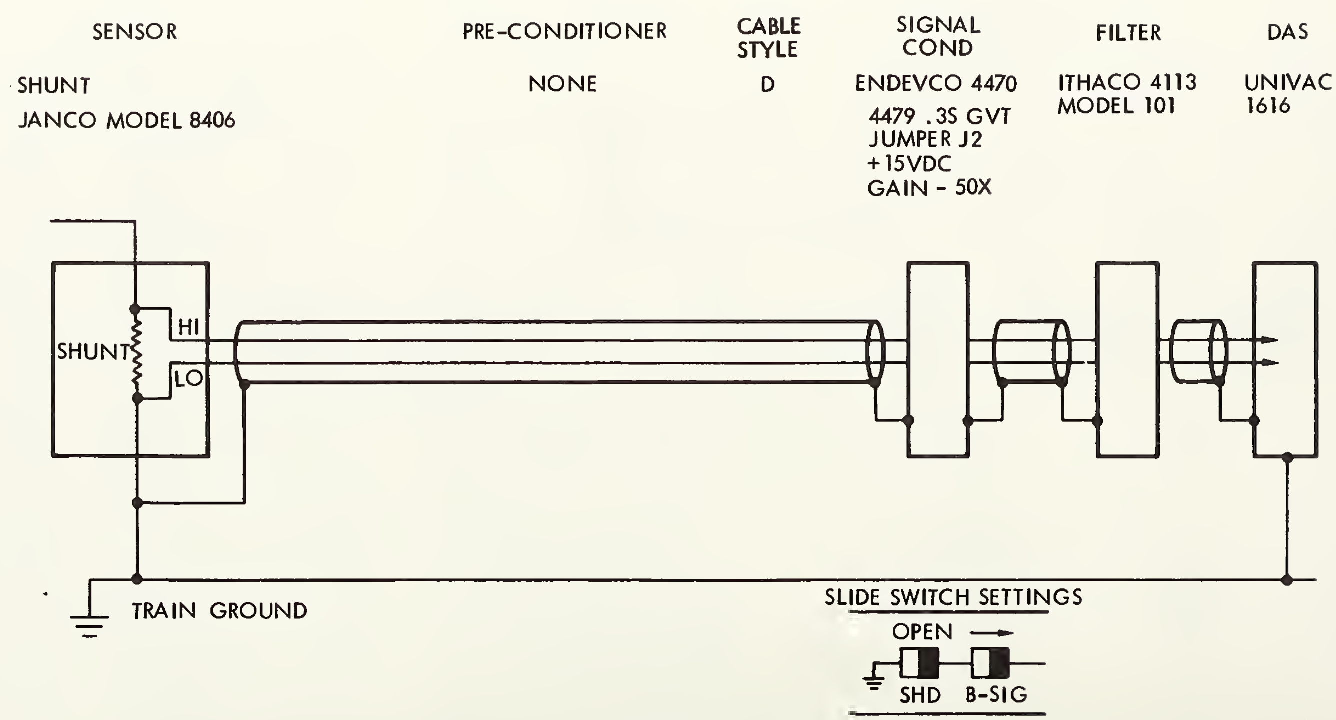


FIGURE B3-7. CURRENT SHUNT WITHOUT ISOLATION AMPLIFIER SHIELD/GROUND CONNECTIONS

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	D	A SIGNAL IN
X	j	KK	N	E	B SIGNAL IN (COMMON)
Z	b	BB	J	B	COMMON
N	c	CC	K	-	
W	d	DD	A	C	-15 VDC EXCITATION (NC IN ISO AMP)
20	g	FF	B	A	+15 VDC EXCITATION
22	Y ·	Y	F	F	SHIELD
P	-	-	-	-	-15 VDC, POWER IN
R	-	-	-	-	+15 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-10-6S; Cable Style D

FIGURE B3-8. CURRENT SHUNT MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

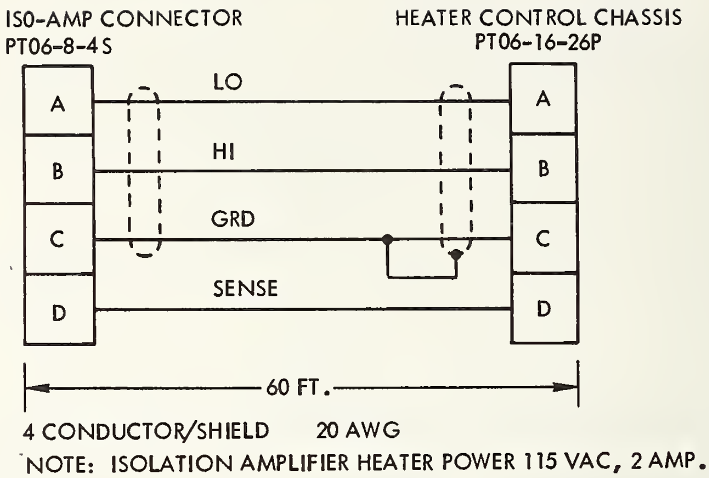


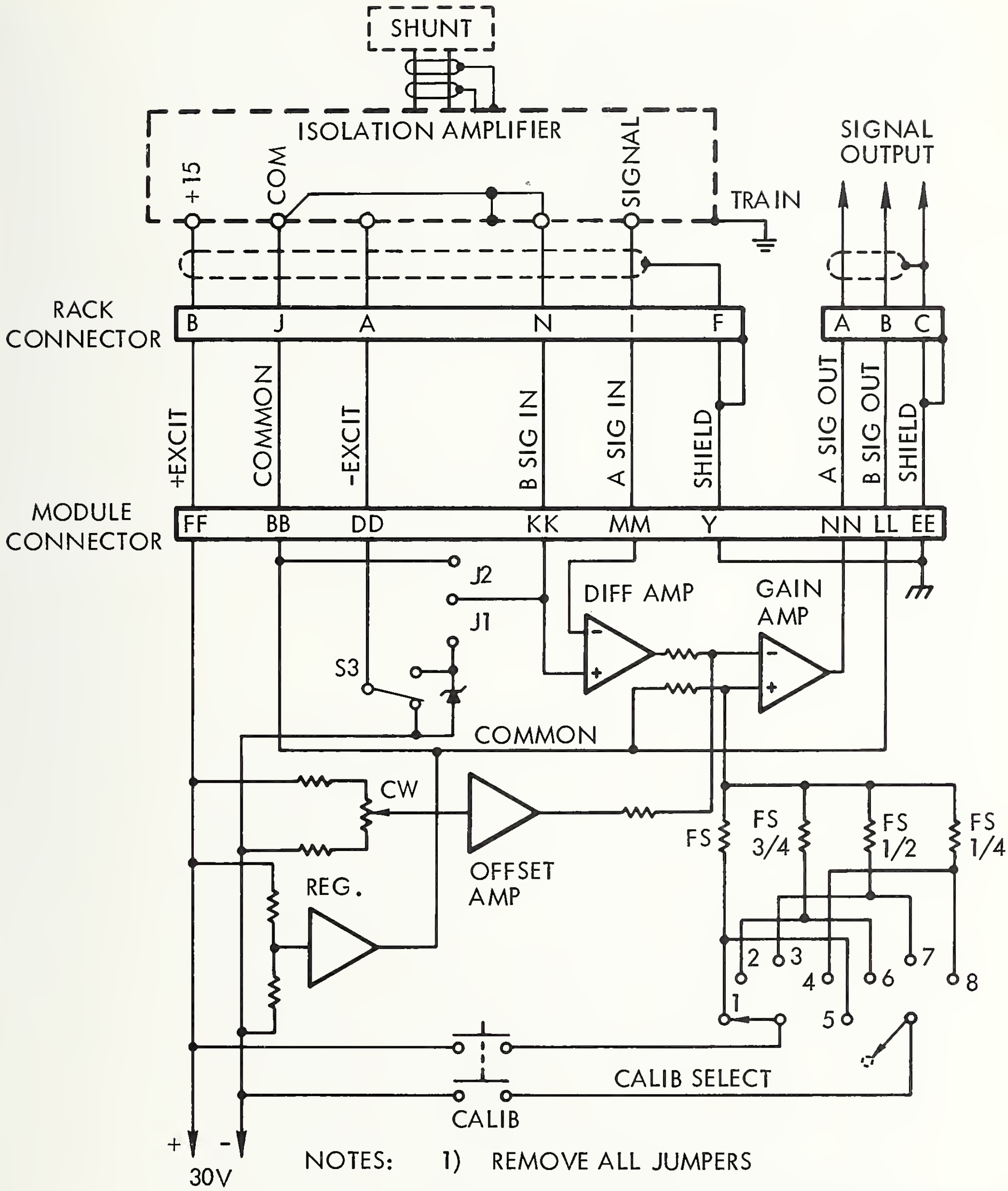
FIGURE B3-9. GVT CABLE STYLE N PHYSICAL/FUNCTIONAL CHARACTERISTICS

B3.7 VEHICLE MOUNTING

In most cases, the current shunts will be mounted in insulating boxes, as shown in Figure B3-11. These boxes are made from a fiberglass-type material and are rated at 600 volts DC. Three different sizes of the boxes are available, as shown in Figure B3-12. The boxes are watertight per NEMA 4 specifications. Holes can be drilled or punched in the boxes and they are readily cut with a coarse-tooth hacksaw.

Shrink-fit boots are provided to seal jumper wires used to connect the shunt to the vehicle circuits. Three sizes are available, as shown in Figure B3-13. To seal the signal wire leading from the shunt to the Isolation Amplifier, a reusable grip fitting is provided.

The electrical connections between the shunt and the vehicle circuit are made using custom-fabricated jumper cables. Crimp-type lugs are attached to the cables. An assortment of these lugs



NOTES: 1) REMOVE ALL JUMPERS

2) SET SWITCH S3 IN $\pm$15 POSITION

FIGURE B3-10. GVT MODE CARD SETUP FOR CURRENT SHUNT MEASUREMENTS

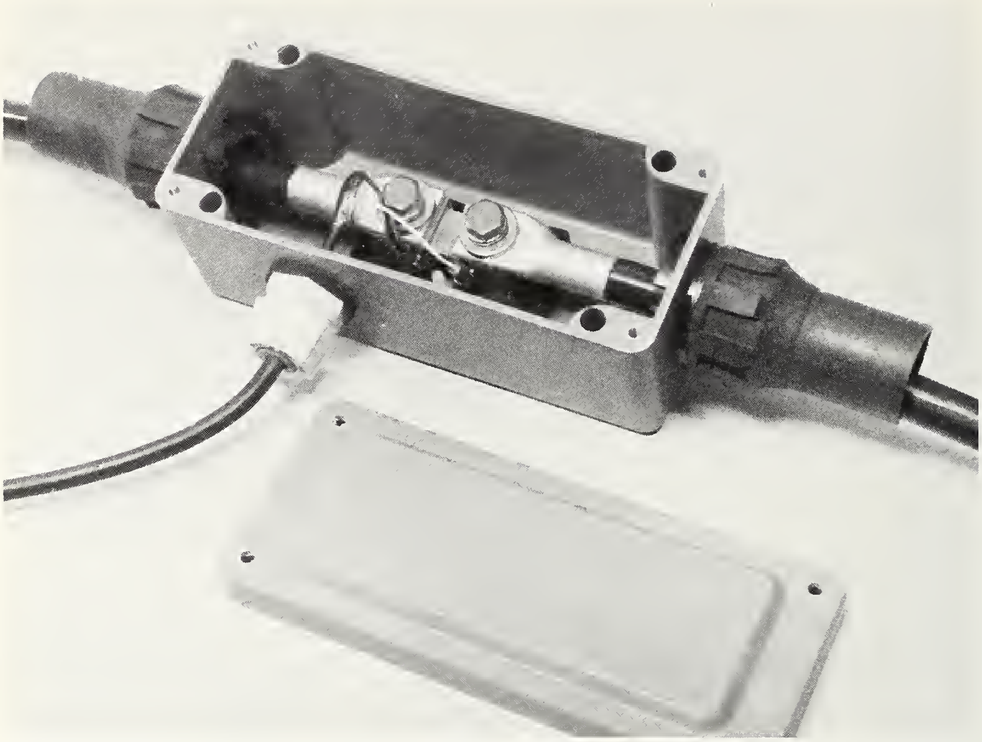


FIGURE B3-11. TYPICAL CURRENT SHUNT INSTALLATION INSIDE WEATHERPROOF, INSULATING JUNCTION BOX

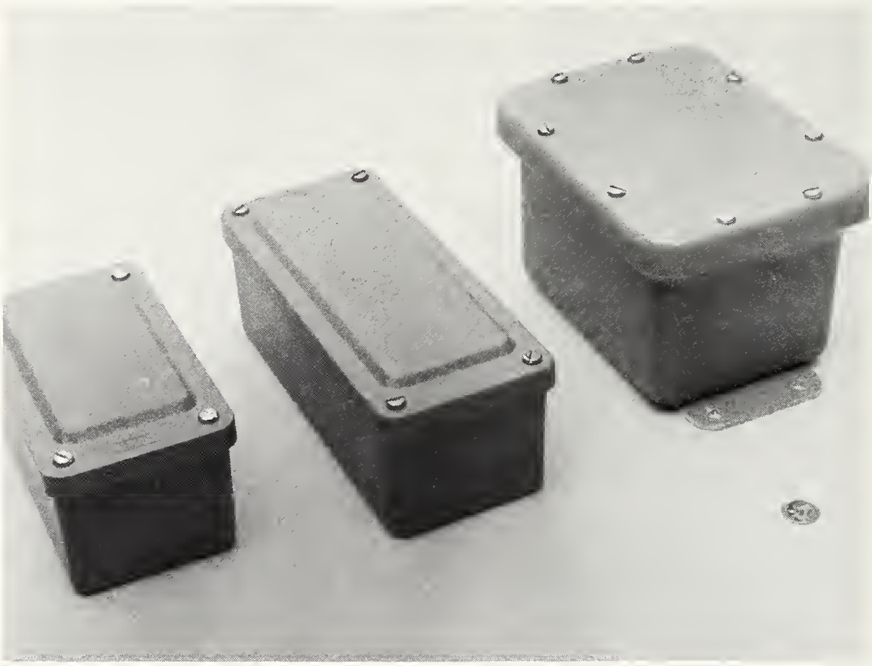


FIGURE B3-12. WEATHERPROOF, INSULATING JUNCTION BOXES SIZE RANGE AVAILABLE

FIGURE B3-13. TYPICAL SHRINK-FIT WEATHER SEALS AND REUSABLE GRIP SEAL

is shown in Figure B3-14. They may be drilled and bent, as required, to provide proper mounting. Lugs are available to fit No. 6, 4/0, and 500 MCM wire sizes. The different configurations for attaching the jumper wires to the shunts are shown in Figures B3-15 and B3-16. Determination of the proper jumper wire size used in a given installation should be based on the wire size used on the vehicle and on applicable electrical codes.

Figure B3-17 shows an actual current shunt installation on the R42 vehicle. This shunt is located just forward of the vehicle control unit. Note the shrink-fit boots and the insulation of all connections. On most vehicles, quick-disconnect terminals are located on the conductors leading from the control unit to the propulsion system. Use of quick disconnects allows for removal of the control unit for maintenance. Secondarily, it is also a convenient location to insert the current-measuring shunts.

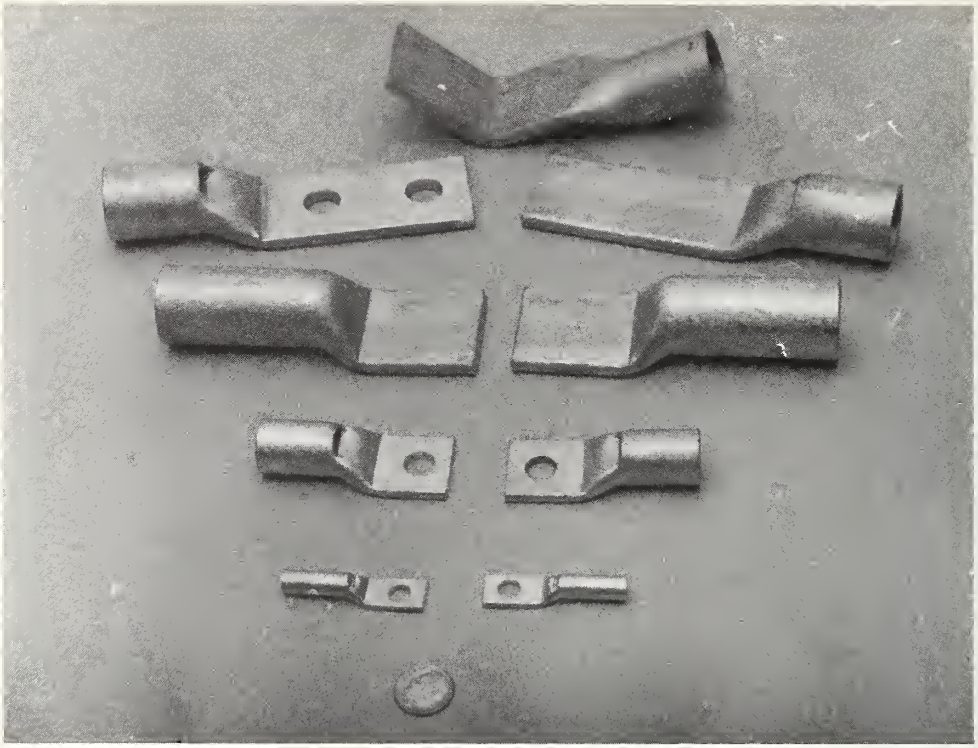


FIGURE B3-14. ASSORTMENT OF CABLE TERMINATION LUGS

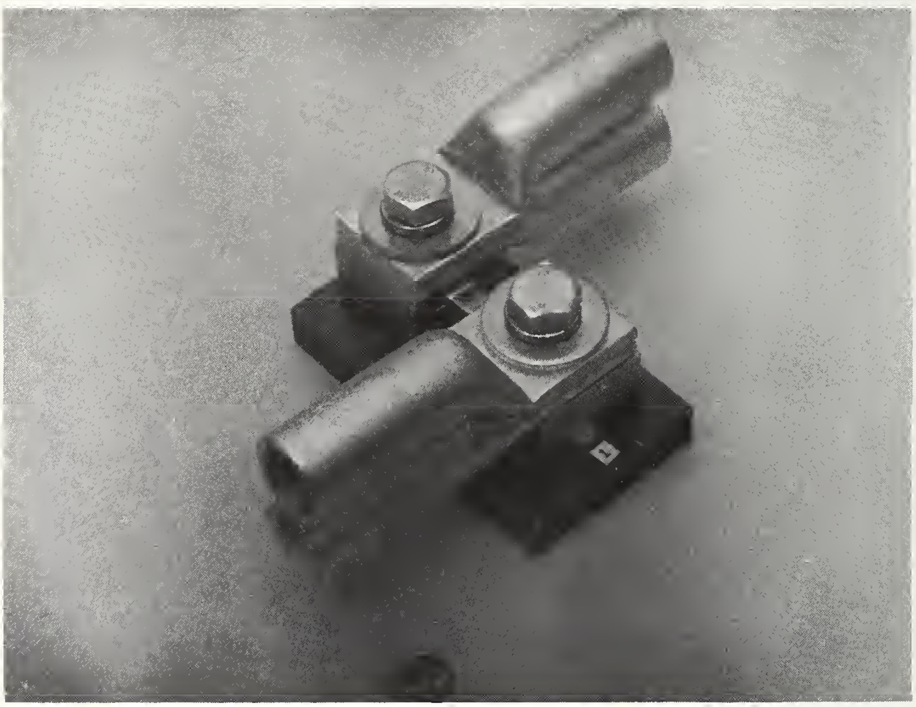


FIGURE B3-15. TYPICAL CABLE ATTACHMENT TECHNIQUE FOR TYPE 8406C CURRENT SHUNT

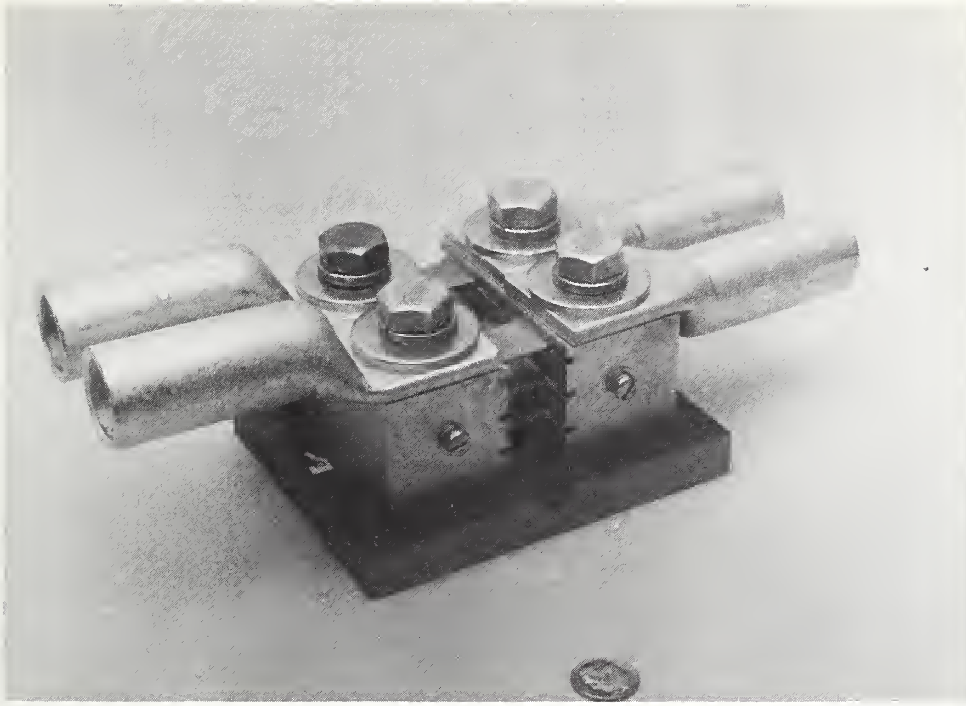


FIGURE B3-16. TYPICAL CABLE ATTACHMENT TECHNIQUE FOR TYPE 8406D CURRENT SHUNT

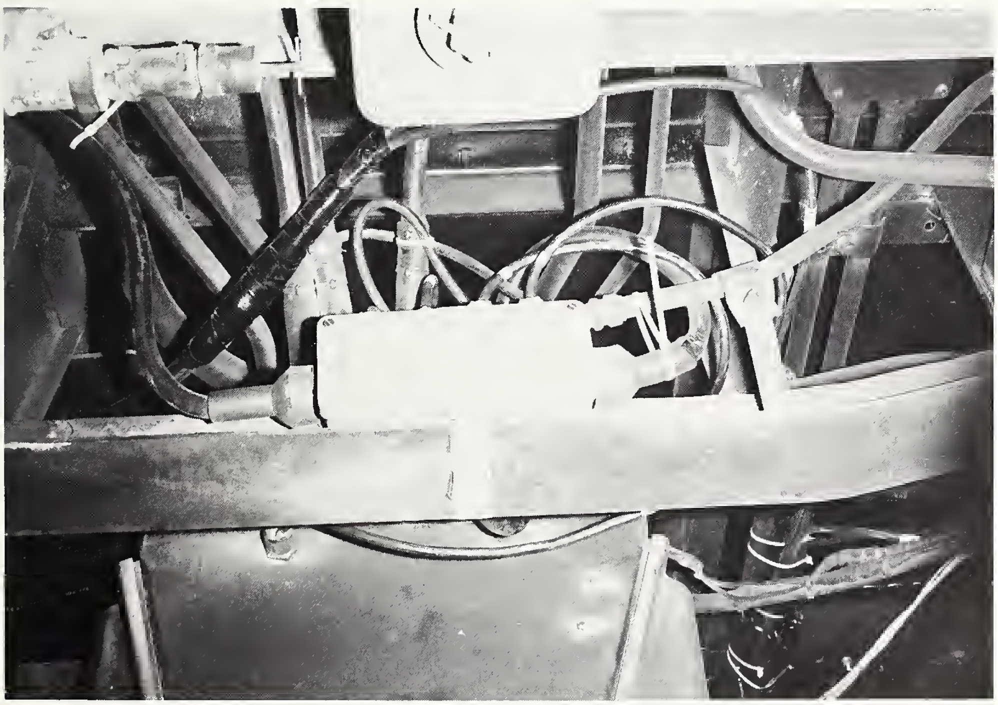


FIGURE B3-17. A CURRENT SHUNT INSTALLATION ON THE R42 VEHICLE

To measure the line current being drawn by the vehicle, alternate shunt mounting methods may be used as shown in Figure B3-18. In this case, the shunt is mounted directly in the knife switch box. The knife bar is removed and the shunt is used to complete the circuit. In the installation shown, the blades used to connect the shunt to the knife switch contacts were fabricated from terminal lugs of the type shown in Figure B3-14. A jumper (seen bent around the bottom edge of the Knife Switchbox in Figure B3-18) was also required in this installation to energize the vehicle auxiliary circuits.

A typical mounting for the Isolation Amplifier is shown in Figure B3-19. In this installation, a custom-fabricated frame was used to mount the Isolation Amplifier using existing bolt holes beneath the vehicle. The Isolation Amplifier contains five channels and includes the signal input cabling. Channels 1 and 2 of the Isolation Amplifier have 20-foot-long signal cables while signal cables for channels 3 through 5 are 10-feet long. The amplifier was mounted near the knife switch box so that the latter three cables could be connected to the knife switch shunt and the motor circuits (armature and field) at the near end of the control unit. The 20-foot cables should be used to connect the shunts attached to the far end of the control unit. It is again noted that the ground braid from the Isolation Amplifier MUST be attached to train ground. Previous tests have also indicated that excess signal-input cables should not be coiled beneath the unit. It is recommended that these cables be strung-out to minimize noise pick-up.

The special equipment required to install the shunts and Isolation Amplifier is listed below:

a. A hydraulic crimp tool to be used in fabricating the jumper wire cables.

b. A heat gun to shrink the rubber boots.

c. An isolation amplifier mounting frame.

d. Required jumper wire to connect the shunt (properly sized).

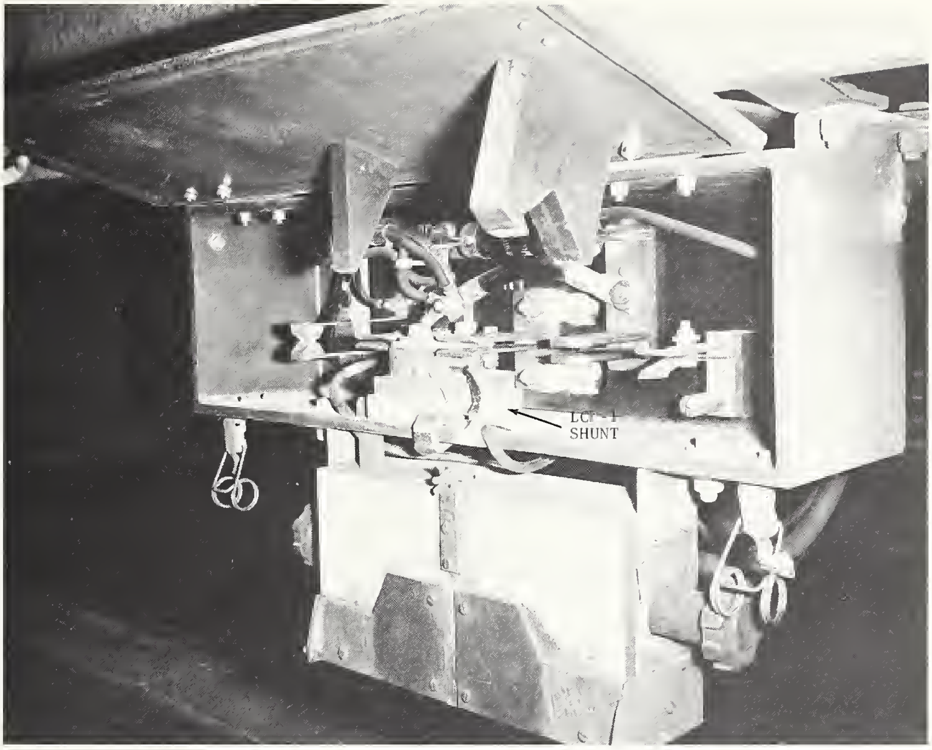


FIGURE B3-18. ALTERNATE CURRENT-SHUNT MOUNTING METHOD


FIGURE B3-19. TYPICAL ISOLATION AMPLIFIER MOUNTING METHOD

It is noted that quick-disconnect terminals on most vehicle control units provide an excellent location for the installation of shunts into the vehicle circuits.

B3.8 CALIBRATION

B3.8.1 Primary. The current shunts can best be calibrated by inserting the rated current through the device using precision current-generating equipment. This method accounts for any thermal effects induced in the shunt resistor. An alternate method for calibrating the shunts is to measure the actual resistance of the shunt element. This ranges from 33 micro-ohms to 100 milliohms.

The Isolation Amplifier can be calibrated by inserting a known AC sinusoidal signal at approximately 100 Hz into the signal cable. The output of the Isolation Amplifier can be measured with the gain of the amplifier adjusted as required. It is imperative that an adequate warmup of the thermal system be allowed. In general, warmup requires at least 2 hours, assuming a 70°F ambient temperature. The Isolation Amplifier does not have an internal zero signal offset adjustment (this is achieved in the mode card), and therefore an AC calibration signal is preferred. The amplifier gain is adjusted by potentiometers accessible through the cover.

B3.8.2 Secondary. After the shunt system with the Isolation Amplifier has been installed on the vehicle, a precision voltage may be inserted into various components of the system. By connecting a 0-100 mV signal to the shunt (with one lead disconnected), the throughput of the whole system can be determined. To check out the mode card and Style D cable, a 0-50 mV signal can be inserted, using the ALD calibration box. (See Appendix A3 of this report).

B3.9 ADDITIONAL INFORMATION

Information included in this section describes:

a. The thermal system setup procedure

b. The Isolation Amplifier disassembly procedure

c. Common-Mode Rejection Performance.

B3.9.1 Thermal Compensation System Setup. The procedure to setup the thermal compensation system is as follows:

a. Install a resistance temperature detector, described in the Temperature Measurement System, Appendix F of this manual, on the inside wall of the inner metal container.

b. Connect the Heater Control Chassis to the Isolation Amplifier using a GVT Style N Cable.

c. Replace the outer fiberglass cover with the calibration cover with labeled access holes.

d. Set the temperature adjust pot to the approximate center of its range (100-160°F).

e. Turn the bandwidth pot fully counterclockwise, then 1/8th turn clockwise.

f. Apply power by switching the Heater Control chassis to "ON". If a fault light illuminates, check the system hookup. If no visible errors are found, an open circuit in the overtemp thermostat is indicated. This thermostat is mounted in the Isolation Amplifier next to the temperature controller. It is a snap acting type with open-close temperatures of 175°F and 75°F, respectively. If the thermostat switch is open, check heater wiring for loose connections, etc., and repair. Reset (close) the thermal switch by applying "circuit freeze" spray to its case. If no fault light occurs, a current flow of approximately 3 amperes should occur. This current will be uninterrupted until the load temperature approaches the set point temperature (130°F).

g. Proportional control is indicated by a current flow of one second intervals after a sufficient warmup is indicated by the RTD on the oven wall. Longer on or off periods indicate the need for a wider bandwidth capability. Adjust the bandwidth control clockwise in 1/8th turn increments until current pulses occur once each second. The optimum setting of the bandwidth control is that point which reduces the temperature excursions of the load to a minimum.

h. During cold weather, a reduced warmup time can be achieved by lowering the set-point temperature. It is imperative, however, that a 30°F differential exist between the set point and highest expected ambient temperature.

i. At a 70° ambient with a 130°F set point, lab tests indicate a 2-hour warmup is required for the Isolation Amplifier modules to stabilize. This is due to the insulating properties of the module potting compound. At a 30°F ambient, a 4 hour warmup is required.

During actual testing, it may be desirable to energize the heaters throughout night periods to eliminate warmup delays. If a degraded accuracy of the current signals can be tolerated, the heater system need not be used.

B3.9.2 Isolation Amplifier Disassembly Procedure

a. Remove outer cover screws and cover. Detach ball chain from case and set cover aside as shown in Figure B3-20.

b. Remove inner case hold-down screws from the base flanges of the outer case and set the inner case on the right-front edge of the outer case. Use care to prevent straining of cables. Before proceeding further note that the signal cables are routed beneath the inner case to preheat them prior to entry into the oven. Insert an outer cover screw through the inner case flange to secure. This is shown in Figure B3-21.

c. Remove inner case cover screws and carefully place the inner cover upside down in the bottom of the outer case. Use care to prevent straining the heater leads.

d. To remove a circuit card, (as shown in Figure B3-22) remove the screw from the cable clamp. Insert a blunt rod into the cable grommet with the right hand and gently lift card with both hands as shown.

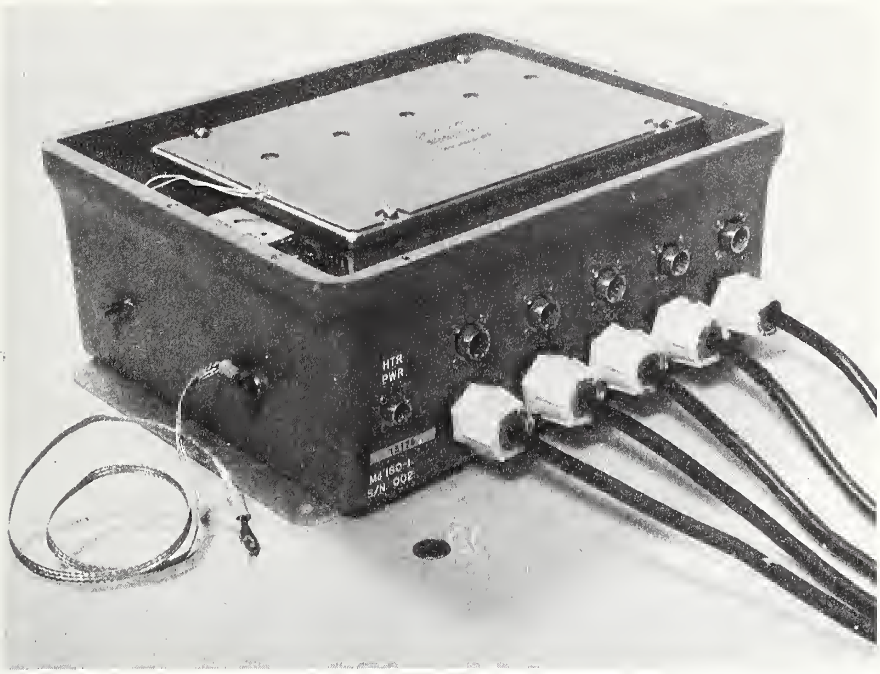


FIGURE B3-20. ISOLATION AMPLIFIER WITH COVER REMOVED

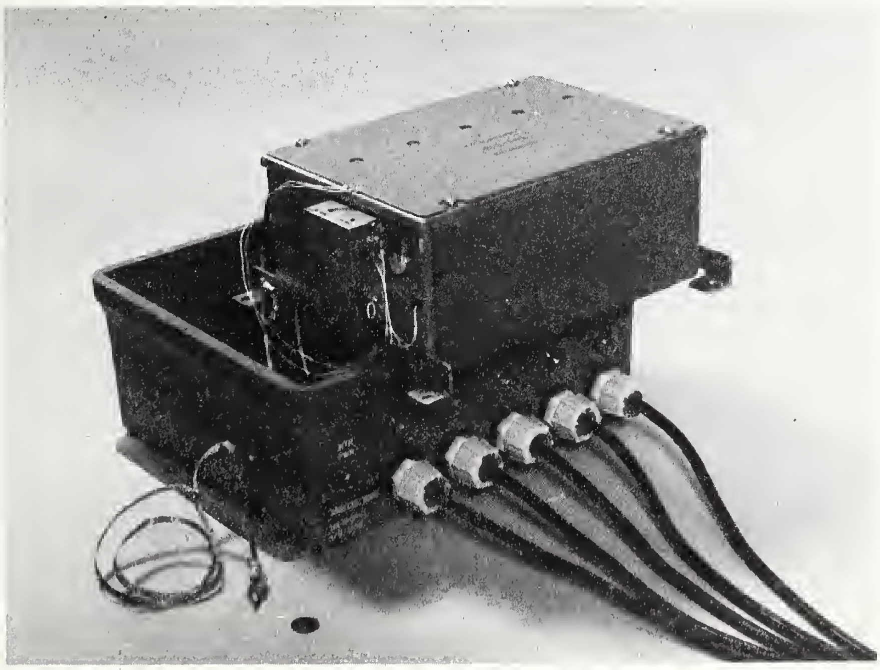


FIGURE B3-21. POSITIONING OF THE INNER CASE ON THE COVER OF THE CONNECTOR PANEL AND SIDEWALL OF THE MAIN CASE

B3.9.3 Common-Mode Rejection Performance. Figure B3-23 is a graphical representation of the Common-Mode Rejection Ratio (CMRR) of the Isolation Amplifier with signal conditioning system. The ratio is referenced to the system output signal. These values were experimentally determined in TSC lab tests. While the CMRR exceeds 140 dB at DC, it degrades with increasing frequency.

For example, assume a 100 volt peak-to-peak common-mode voltage (CMV) at 100 Hz. As shown on the graph, the CMRR is 60 dB at this frequency. Therefore, the output signal from this CMV is 60 dB down from 100 Vp-p or 100 mV p-p. This represents a signal error of $\pm 1\%$ FS (± 5 volts).

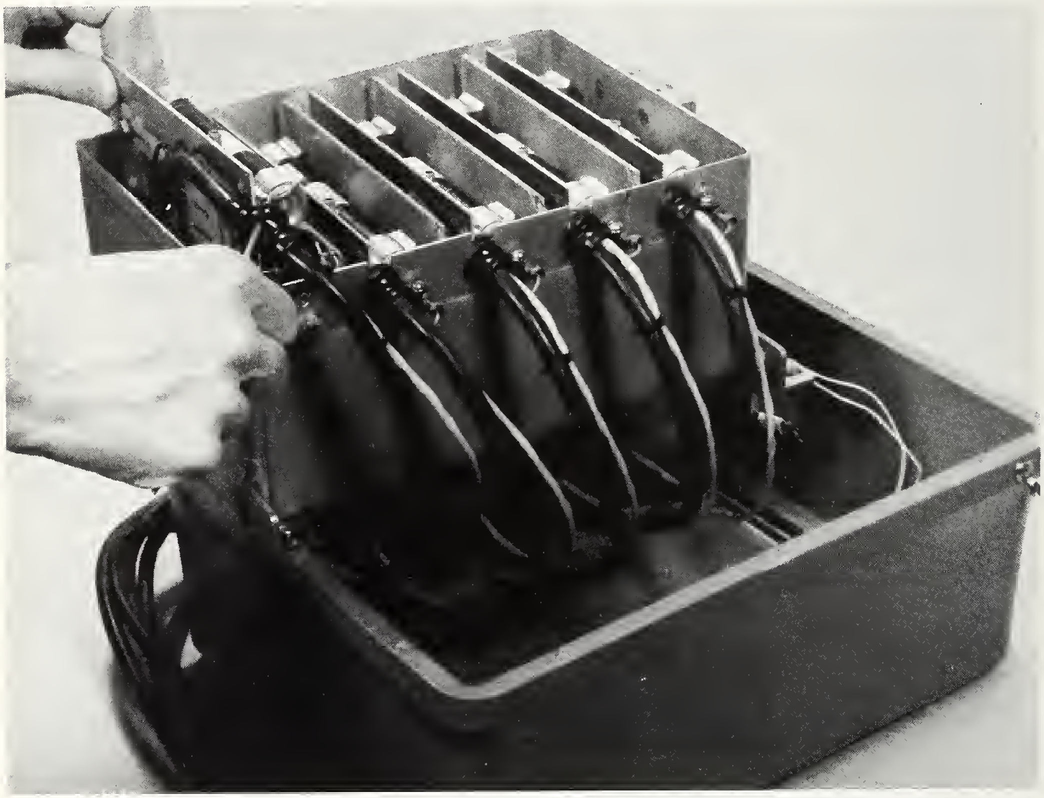


FIGURE B3-22. CIRCUIT CARD REMOVAL

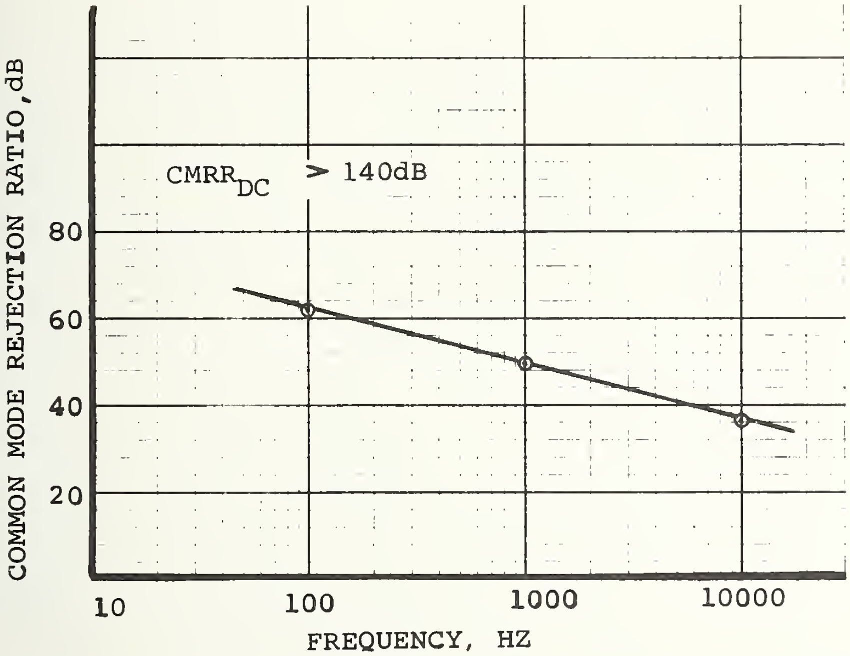


FIGURE B3-23. CURRENT SHUNT MEASUREMENT SYSTEM COMMON MODE REJECTION RATIO

When selecting the current shunt system for a particular measurement, use care to ensure an acceptable level of CMV errors. The current shunts should always be inserted in relatively constant potential conductors. In addition, the voltage with respect to train ground at the shunt should be monitored. If severe CMV's are observed, an alternate shunt location is dictated, or the use of other current sensor measurement systems should be considered.

C. VOLTAGE MEASUREMENT SYSTEM

C.1 DESCRIPTION

Voltages on board the vehicle are measured with a differential voltage divider (see Figure C-1). This device is totally passive and can be used to measure motor voltages and line voltages. The unit is housed in a stainless steel box that is watertight to NEMA4 specifications and contains 5-foot long integral leads.

The Voltage measurement system consists of the following items:

a. Voltage Divider........TSC Model DVD-1

b. GVT Cable..............Style E

c. Signal Conditioner.....TSC 4479.3S

Paragraph C.9 of this section describes the disassembly procedure for the voltage divider.

The supporting documentation file contains the following applicable items (Bin 17):

a. System Error Analysis

b. Fabrication Dwg.......Voltage Divider TSC Mod. DVD-1
Dwg. No. 5-0012

c. Fabrication Specification..................Voltage Divider Contract TS-317-JM

d. Mfg. Data Sheet.......Precision Resistors Caddock
Type MG

C.2 SPECIAL HANDLING

When using the differential voltage divider, a direct connection to 600 volt lines is implied. To ensure operator safety, observe the shock hazard warning noted on the instrument case.

WARNING

SHOCK HAZARD

PRIOR TO INSTALLING ANY LEADS, ELECTRICALLY CONNECT GROUND BRAID TO TRAIN GROUND.

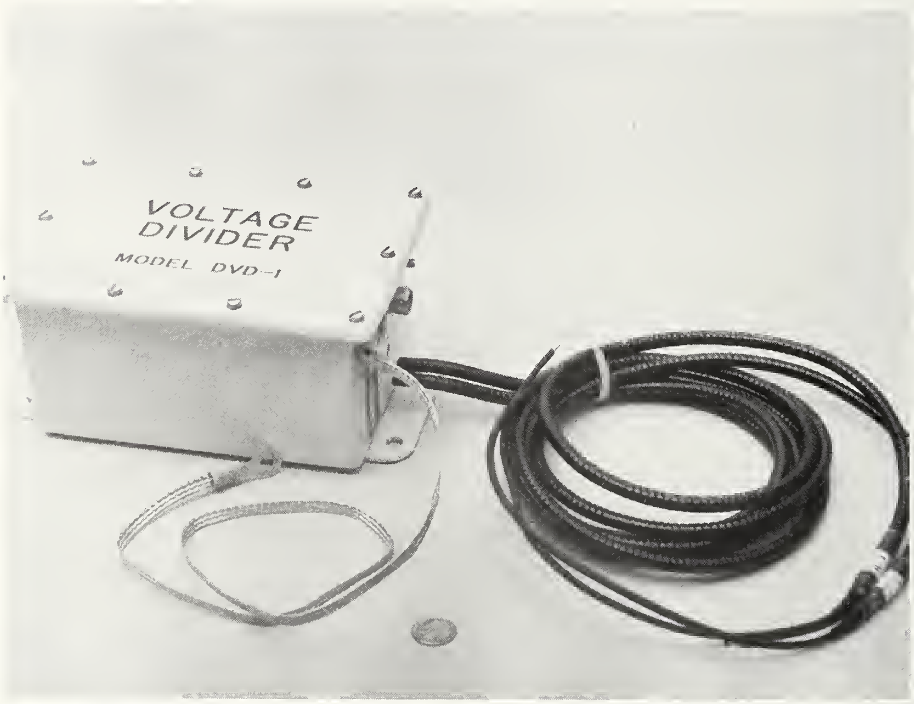
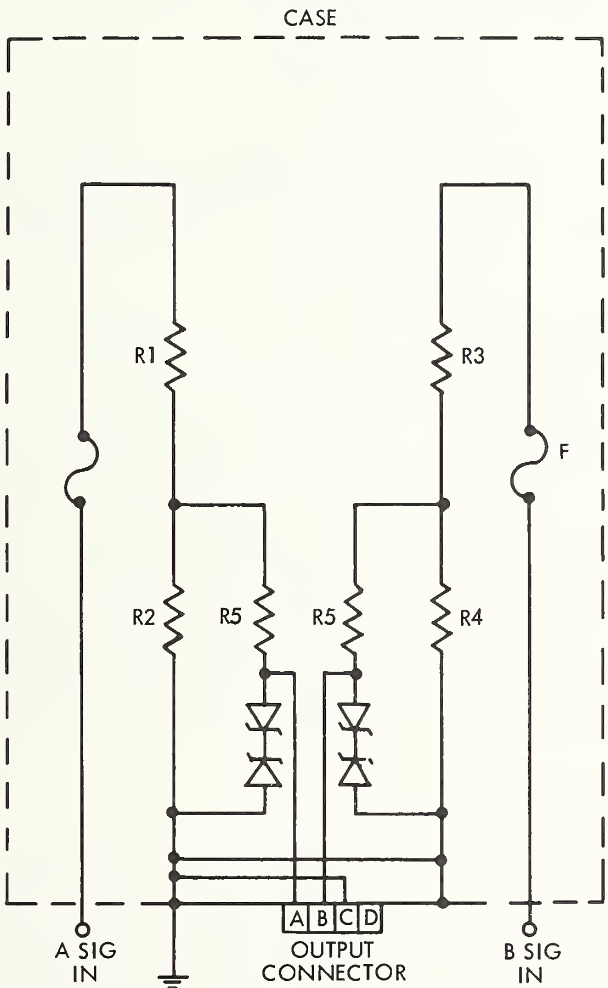


FIGURE C-1. TSC VOLTAGE DIVIDER MODEL DVD-1

C.3 THEORY OF OPERATION

The differential voltage divider contains two resistance divider networks. Each chain has a 200 to 1 ratio such that a 1000 volt input produces a 5 volt output. The resistors are precision high-voltage types with matched thermal coefficients.

A circuit schematic of the voltage divider is given in Figure C-2. The input signal for each chain is first directed through a 60 mA fuse. The divider network on the A signal side is made up of R1 and R2. R5 is a current limiting resistor prior to the 10 volt zener diodes. These diodes limit the output signal to 10 volts maximum, and will sustain sufficient current to blow the fuse if necessary.



R1/R2	995 KOHM/5 KOHM PAIR
R3/R4	995 KOHM/5 KOHM PAIR
R5	1.1 KOHM
DIODE	1N2974A
FUSE	HVJ-1/16

FIGURE C-2. TSC VOLTAGE DIVIDER SCHEMATIC DIAGRAM

C.4 SHIELD/GROUND TECHNIQUE

For safety reasons, the case and the signal shields of the voltage divider are attached to train ground with the integral ground braid on the device. No other ground connections are permitted. A block diagram of the total ground system is given in Figure C-3.

C.5 FUNCTIONAL WIRE LIST SUMMARY

Figure C-4 shows the pin-to-pin connections for the Voltage measurement system. Refer to supporting documentation for detailed schematics of each component.

C.6 MODE CARD SETUP

The mode card used to condition the voltage divider signal is the TSC-designed GVT mode card (see Figure C-5). This card has the capability of four fixed gain settings X1, X10, X50, X100. To use the card with the voltage divider, install jumper J2. Because the output signal from the voltage divider is 5 volts, the gain switch of the card should be set to X1. The front panel Supply voltage switch (S3), has no effect with the voltage divider as it is a totally passive device.

C.7 VEHICLE MOUNTING

The voltage divider generally will be mounted near conductors where the voltage attachment will be made. The use of jumpers, however, and crimp terminals may be required. To provide safe operation, the ground braid must be electrically connected to train ground.

If no convenient locations can be found for mounting the device, if may be advantageous to fabricate a custom frame to hold a series of dividers. Such a frame is shown in Figure C-6 with the voltage dividers mounted on the R42 vehicle.

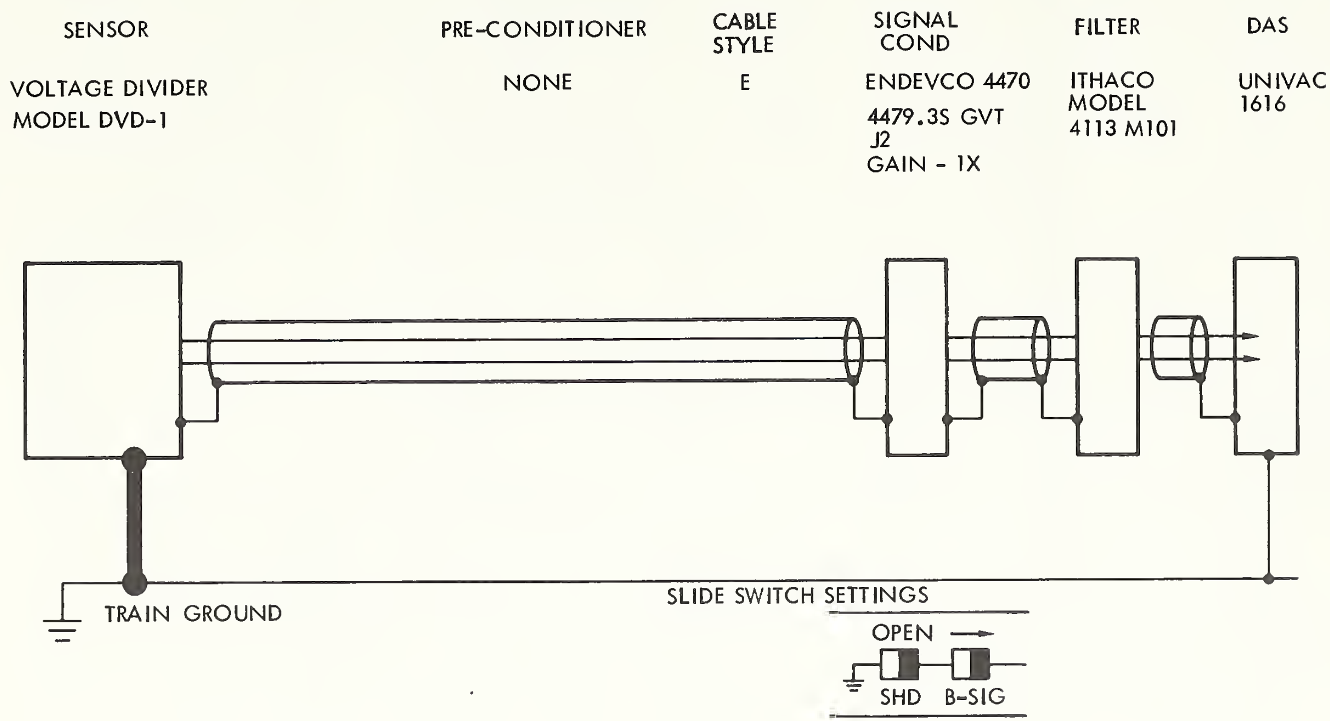


FIGURE C-3. VOLTAGE MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	A	A SIGNAL IN
X	j	KK	N	B	B SIGNAL IN
Z	b	BB	J	-	
N	c	CC	K	-	
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	C	SHIELD, GROUND
P	-	-	-	-	-15 VDC, POWER IN
R	-	-	-	-	+15 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-8-4S; Cable Style E

FIGURE C-4. VOLTAGE MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

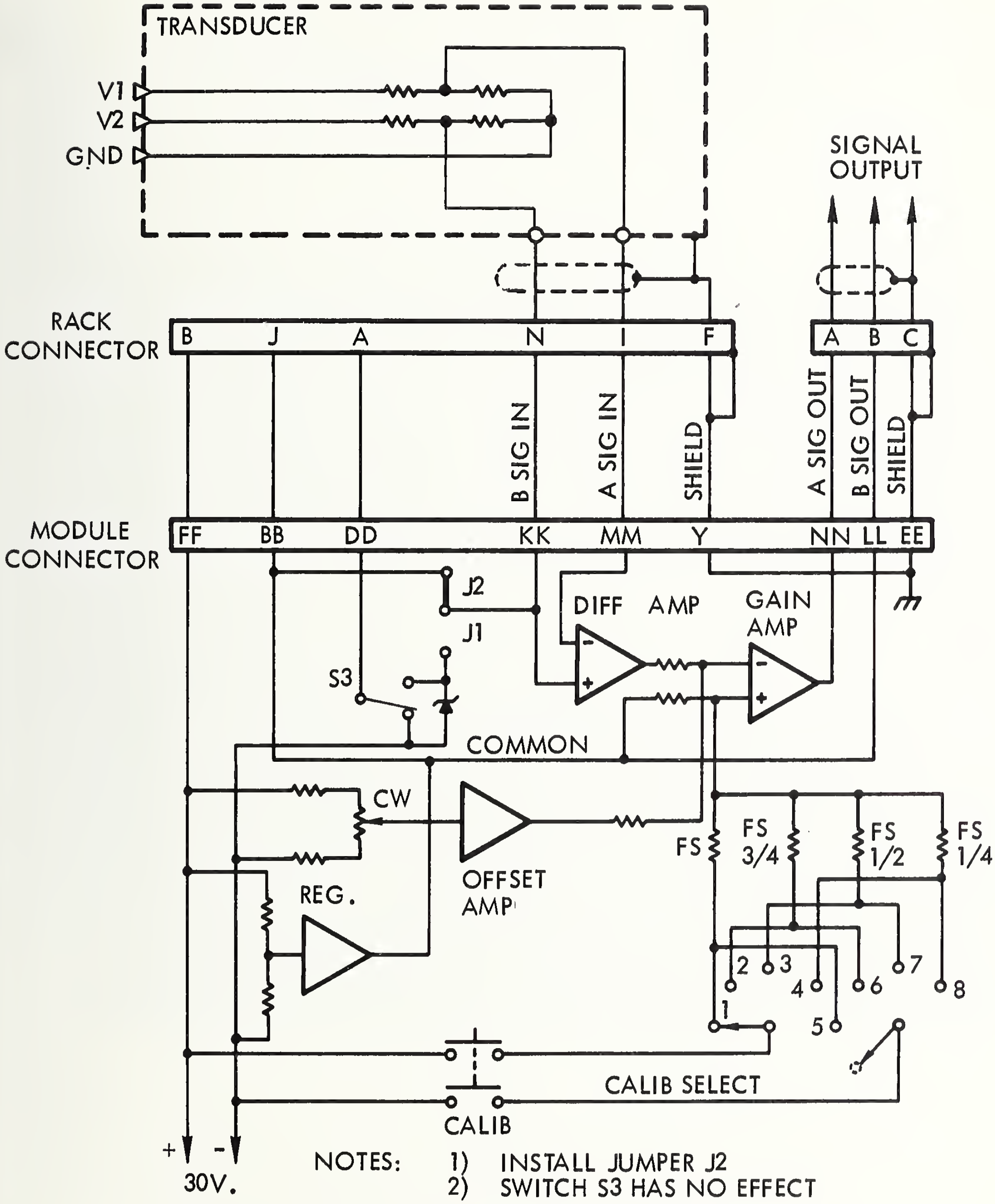


FIGURE C-5. GVT MODE CARD SETUP FOR VOLTAGE MEASUREMENT SYSTEM

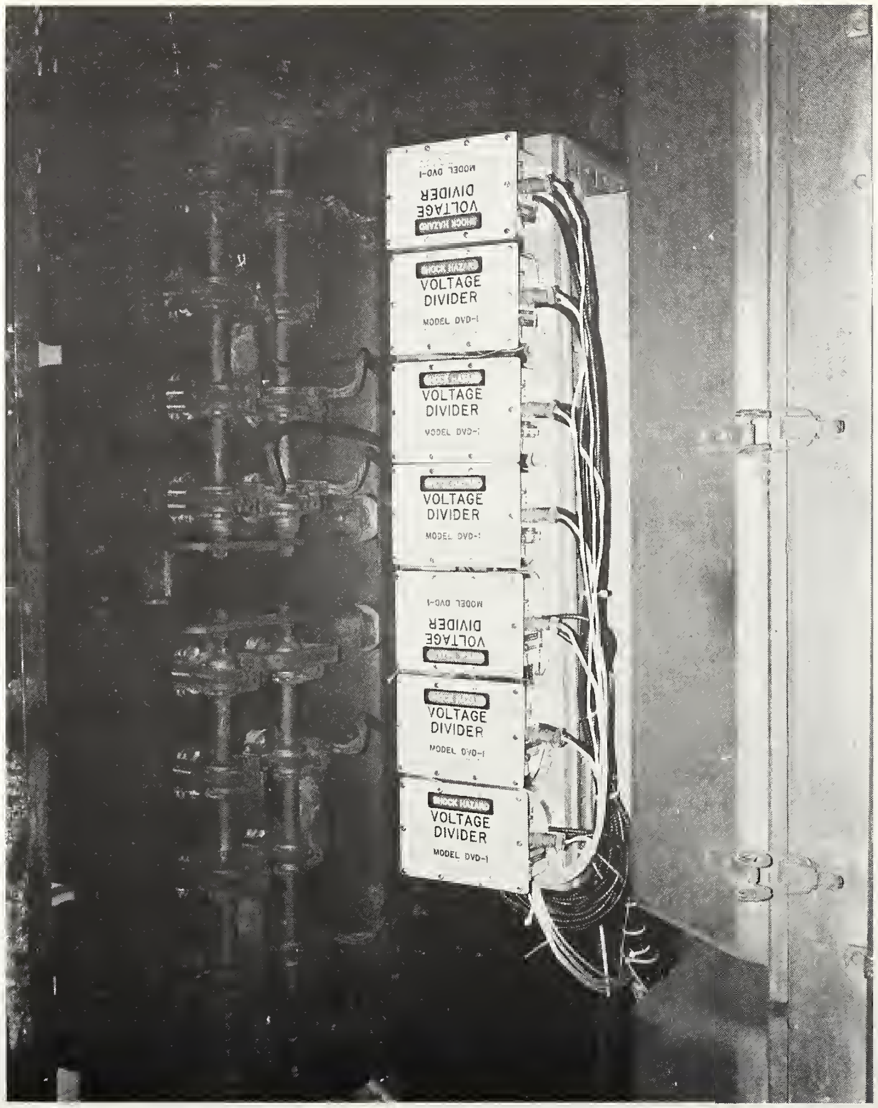


FIGURE C-6. TSC VOLTAGE DIVIDERS CUSTOM RACK MOUNTED ON R42 VEHICLES (VIEWED FROM MAINTENANCE PIT)

On certain vehicles, it may be possible to obtain the voltage connection directly inside the control unit. In this case, terminal lugs can be added to the voltage divider input cables and routed through existing access holes on the control unit.

C.8 CALIBRATION

C.8.1 Primary. The best way to calibrate the voltage divider is to insert a known signal into the divider input and observe that the output signal is 1/200 of the input. This should be done for each chain of the divider. There are no adjustments on the device and any malfunction will require a parts replacement.

C.8.2 Secondary. When installed on the vehicle, test signals can be inserted at various points in the system. No adjustment exists, therefore it is assumed that any failure in this system will have to be detected by a pre-and/or post-test calibration. Most failures would be easily detected.

C.9 ADDITIONAL INFORMATION

Disassembly Procedure

a. Remove the ten machine screws that hold the cover to the unit.

b. Unsolder the two leads that protrude through the circuit board on the right-hand side of the unit (see Figure C-7).

c. Unsolder the two jumper wires that are used to interconnect the diode pairs.

d. Remove the four machine screws that hold the circuit board.

e. Carefully pivot the circuit plate upward about the connector end of the unit (see Figure C-8).

f. Carefully remove the partition separating the fuses from the circuit board. This exposes the high voltage fuses.

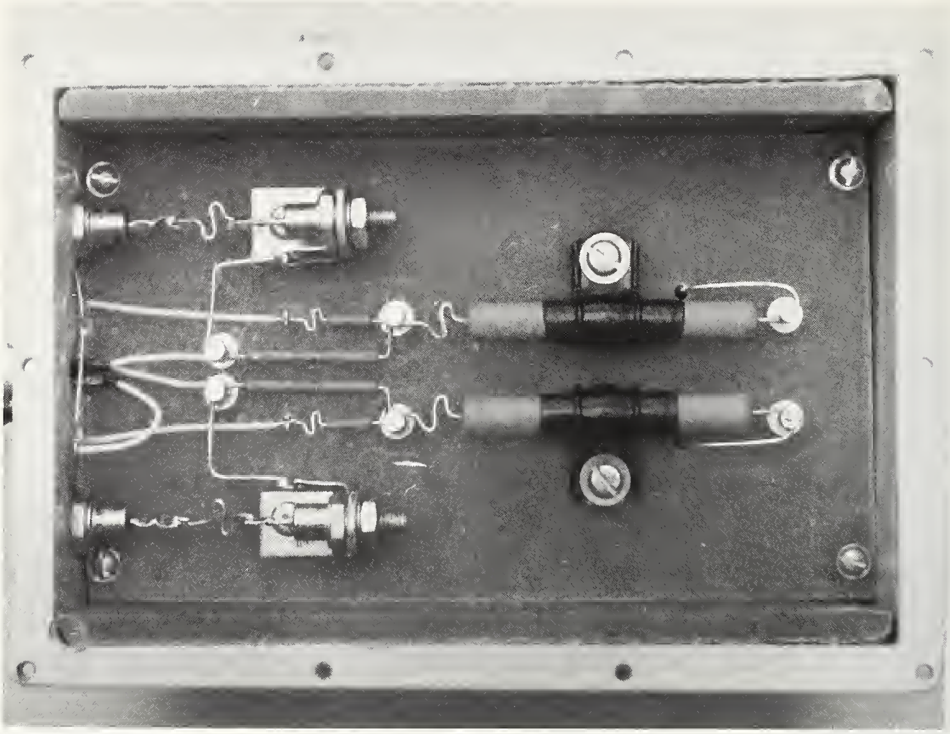


FIGURE C-7. TSC VOLTAGE DIVIDER COVER PLATE REMOVED, CIRCUIT EXPOSED

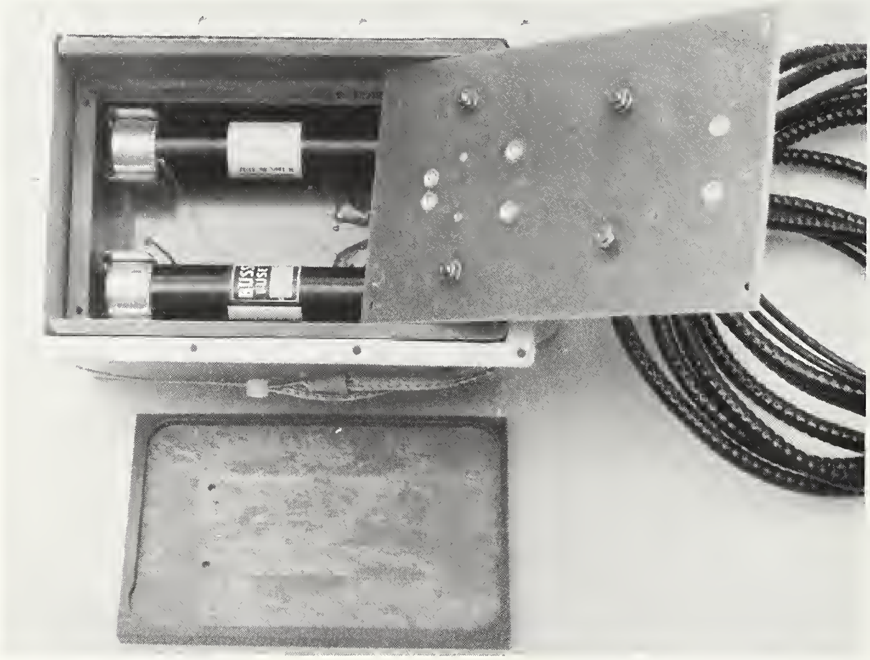


FIGURE C-8. CIRCUIT BOARD REMOVED TO EXPOSE FUSES

APPENDIX D ACCELERATION/VIBRATION

D1 SERVO ACCELEROMETER MEASUREMENT SYSTEM
D2 PIEZO ACCELEROMETER MEASUREMENT SYSTEM

D1. SERVO ACCELEROMETER MEASUREMENT SYSTEM

D1.1 DESCRIPTION

The Q-flex servo accelerometer in conjunction with the Endevco 4470 Signal Conditioner can be used to measure car body accelerations. This measurement is required to determine the vehicle bending mode shapes and the ride roughness. Figure D1-1 depicts a single servo accelerometer, while Figure D1-2 shows servo accelerometers installed in two types of mounting blocks.

The Servo Accelerometer measurement system consists of the following items:

a. Servo Accelerometer..........Endevco Model QA-116-15

b. GVT Cable....................Style L

c. Signal Conditioner...........Endevco 4470/4479.2

The supporting documentation file contains the following items (Bin 18):

a. System Error Analysis

b. Mfg. Data Sheet...............Q-flex Accelerometer Model QA-116-15

c. Mfg. Data Sheet...............Q-flex Mtg. Blocks

d. Mfg. Instruction Manual.......Q-flex Accelerometer

D1.2 SPECIAL HANDLING

CAUTION

USE CARE NOT TO IMPACT INSTALLATION TOOLS ON THE ACCELEROMETER. SHOCKS OF SEVERAL THOUSAND G'S CAN BE IMPARTED TO THE ACCELEROMETER FROM THE IMPACT OF A METAL WRENCH ON THE CASE.

FIGURE D1-1. A Q-FLEX ACCELEROMETER

FIGURE D1-2. Q-FLEX ACCELEROMETERS INSTALLED IN MOUNTING BLOCKS

When attaching the miniature cable to the accelerometer, use care to align the white dots on the male and female connector shells to ensure proper mating.

D1.3 THEORY OF OPERATION

The Q-flex servo accelerometer operates on a torque-balance principle. Small deflections of a flexural proof mass are sensed and used to control a torquer magnet which attempts to maintain that proof mass at its neutral position. By measuring the current applied to the torquer coil, a signal proportional to the impressed acceleration is achieved. For a detailed functional description, the reader is referred to the Q-flex instrumentation manual.

All power and signal conditioning is provided by the Endevco 4479.2 mode card.

D1.4 SHIELD/GROUND TECHNIQUES

Two separate connections are required to properly ground and shield the accelerometer sensor system. At one point in the system, the shield must be connected to the "B" signal (low). For the Q-flex accelerometer, this is accomplished by connecting the Endevco 4470 output cable pigtail (B Sig) of the appropriate switch bus terminal and closing the "B SIG" switch.

With a floating accelerometer case (tile floor or wooden mounting) use the Option I hookup to make ground connections at the Endevco 4470 chassis by closing the "SHD" switch as shown in Figure D1-3.

If the accelerometer case is mounted to train ground (Option II), no other ground connection is permissible, therefore, open the "SHD" switch as shown in Figure D1-4.

D1.5 FUNCTIONAL WIRE LIST SUMMARY

Figure D1-5 shows the pin-to-pin connections for the Servo Accelerometer measurement system. For detailed schematics of each component, the reader is referred to the supporting documentation.

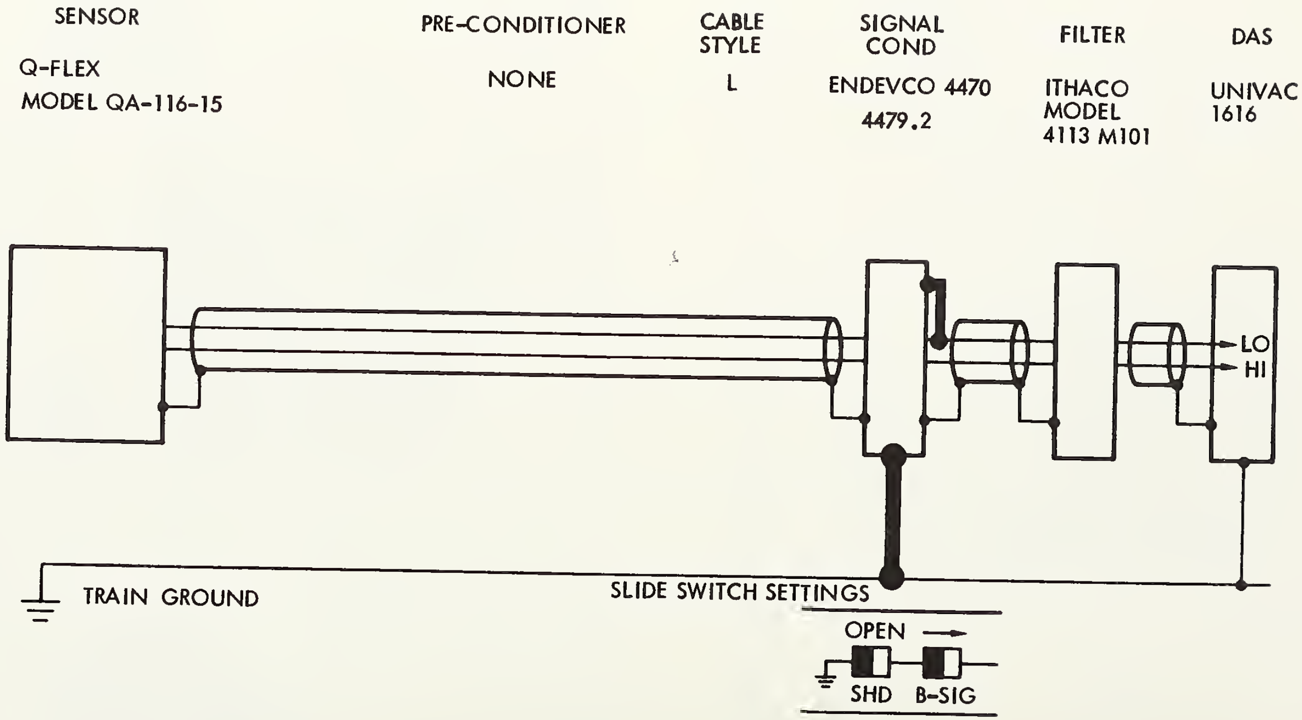


FIGURE D1-3. SERVO ACCELEROMETER MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS - OPTION 1

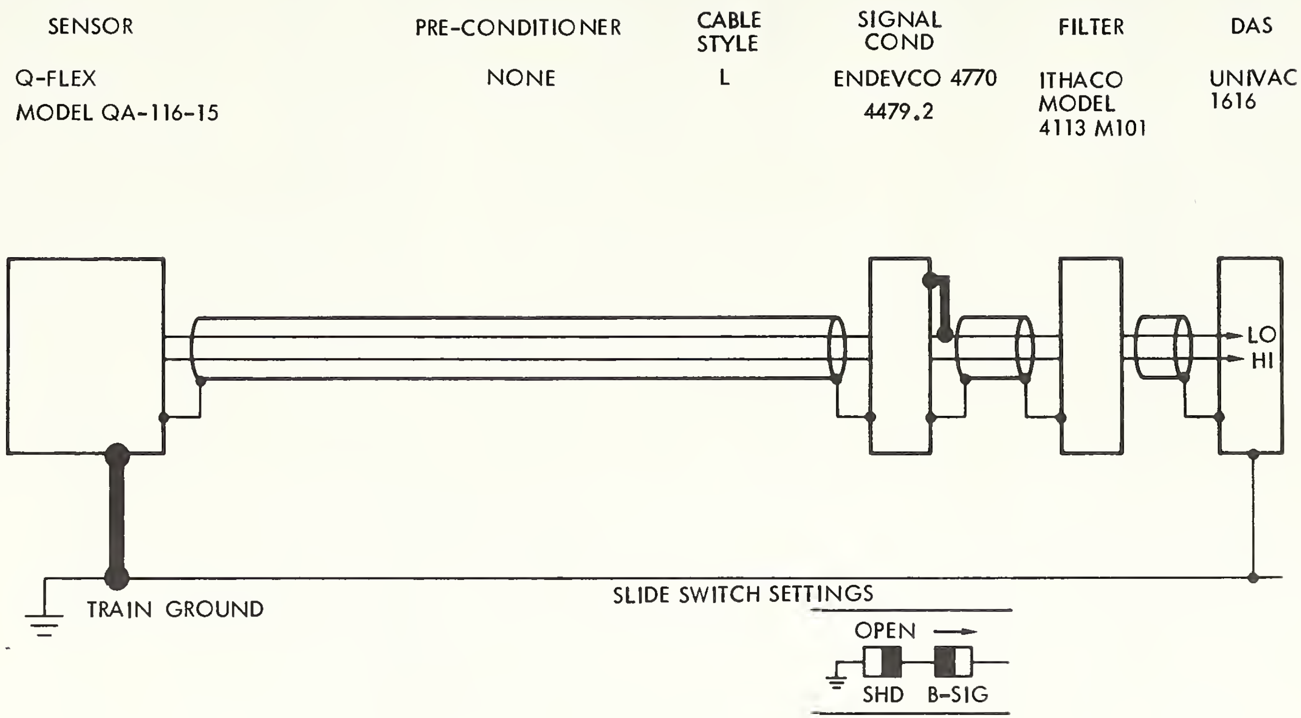


FIGURE D1-4. SERVO ACCELEROMETER MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS - OPTION 2

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	2	B SIGNAL IN
18	X	X	C	5	EXCITATION MIDPOINT
V	W	W	M	6	TEST
12(13)	m	MM	I	3	A SIGNAL IN
X	j	KK	N	-	
Z	b	BB	J	4	-15 VDC EXCITATION
N	c	CC	K	1	+15 VDC EXCITATION
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	SHELL	SHIELD
P	-	-	-	-	- VDC, POWER IN
R	-	-	-	-	+ VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector, Wavelab; Cable Style L

FIGURE D1-5. SERVO ACCELEROMETER MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

D1.6 MODE CARD SETUP

The 4479.2 mode card is specifically designed to interface with the Q-flex accelerometer. A mode switch, S1, on the printed circuit board must be in the Q-flex position (up) for proper operation.

To operate the self-test feature, a single modification is required. As shipped, the Q-flex calibration resistor, R44, (Cal Select Positions 4 and 8) is 47 kohms. To ensure operation with all available Q-flex accelerometers (Endevco and Kistler) R44 should be replaced with a 3 kohm resistor.

If the gains on the standard mode card (0.01, .1, 1, 10g/V) are not optimal for a specific test, the gain resistors on the mode card can be changed. To provide ranges of 0.1, 0.2, 0.4,1 g/V, resistors R8 and R9 should be changed to 1.111 kohm, R7 to 2.222 kohm, and 6.666 kohm resistor must be substituted for the jumper between positions 3 and 4 of S2A. Also, R17 should be removed and replaced with a jumper. All resistors should be wire wound and selected for +0.025 percent of indicated values with temperature coefficient of 20 ppm/°C.

D1.7 VEHICLE MOUNTING

The type of mounting of the accelerometers depends upon the parameter being measured. By utilizing the anodized aluminum single-axis and triaxial mounting blocks, accelerometer installation is facilitated. Accelerometers can be located inside or outside the passenger area. The mounting blocks can be affixed with available screws or cemented with a suitable adhesive.

No special tools are required but a standard Allen wrench must be used on the socket head cap screws to attach the accelerometer to the mounting block. To prevent galling of the thread in the aluminum mounting block, a lubricant should be used.

No modification to the vehicle is required except the surface preparation for adhesive mounting.

D1.8 CALIBRATION

D1.8.1 Primary. Each accelerometer should be compared to a known standard traceable to NBS. The following parameters should be checked:

a. Scale Factor

b. Zero Bias

c. Repeatability

d. Scale Factor Versus Temperature

e. Zero Bias Versus Temperature

f. Transverse Sensitivity

g. Frequency Response

h. Noise

Characteristics a, b, g, and h are extremely important and should be checked on a frequent basis. Instructions for performing the above tests are included in the manufacturer's instruction manual.

D1.8.2 Secondary. After each accelerometer is installed on the vehicle and connected to the 4470 system with the appropriate mode card, an operational check can be performed. Rotate the Endevco 4470 Cal Select rotary switch to position 4 and press Cal pushbutton.

The output should indicate a level between $\pm 15g$ and $+23g$.

NOTE

> This calibrate signal will saturate the electronics with the mode card gain control set in the low ranges.

To obtain a negative test signal of approximately the same magnitude, rotate the Cal Select switch to position 8 and depress the Cal pushbutton.

D2. PIEZO ACCELEROMETER MEASUREMENT SYSTEM

D2.1 DESCRIPTION

Piezo accelerometers are especially suited to high g, high frequency acceleration measurements. Journal box (AJ/A) accelerations can be measured but the low frequency cutoff of the piezoelectric crystal system ($\pm$0.5dB) occurs at 3 Hz instead of the desired 0.1 Hz. Use of the piezo for this measurement will depend upon the desired output.

The accelerometer and charge/voltage converter are shown in Figure D2-1 while Figure D2-2 displays the converter in its mounting fixture with the accelerometer and cable connected.

The Piezo Accelerometer measurement system consists of:

a. Accelerometer..........Columbia Model 704

b. Low Noise Coaxial
Cable..................Microdot

c. Charge Converter.......Endevco Model 2652

d. GVT Cable..............Style F

e. Signal Conditioner.....Endevco 4470/4479.1M2

The supporting documentation file contains the following applicable items (Bin 19):

a. System Error Analysis

b. Mfg. Data Sheet........Columbia Accelerometer Model 704

c. Mfg. Data Sheet........Endevco Accessories

d. Fabrication Dwg........Charge Converter Connector Block
TSC Model CC-1 Dwg No. 6-0010

e. Fabrication Procedure..Charge Converter Assembly

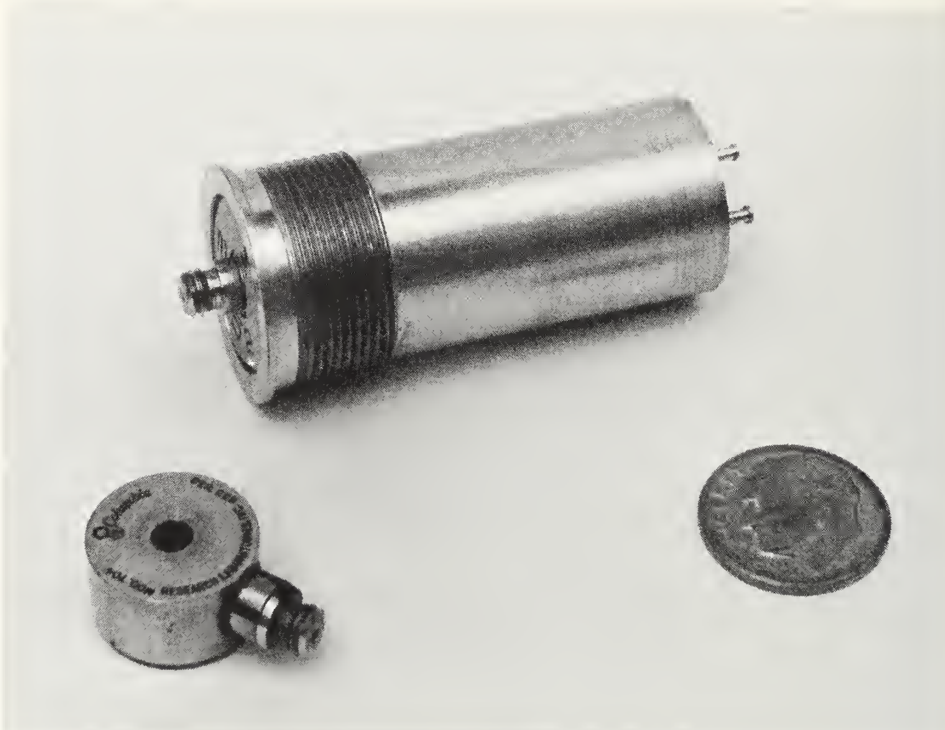


FIGURE D2-1. PIEZO ACCELEROMETER (LOWER LEFT) AND CHARGE/VOLTAGE CONVERTER

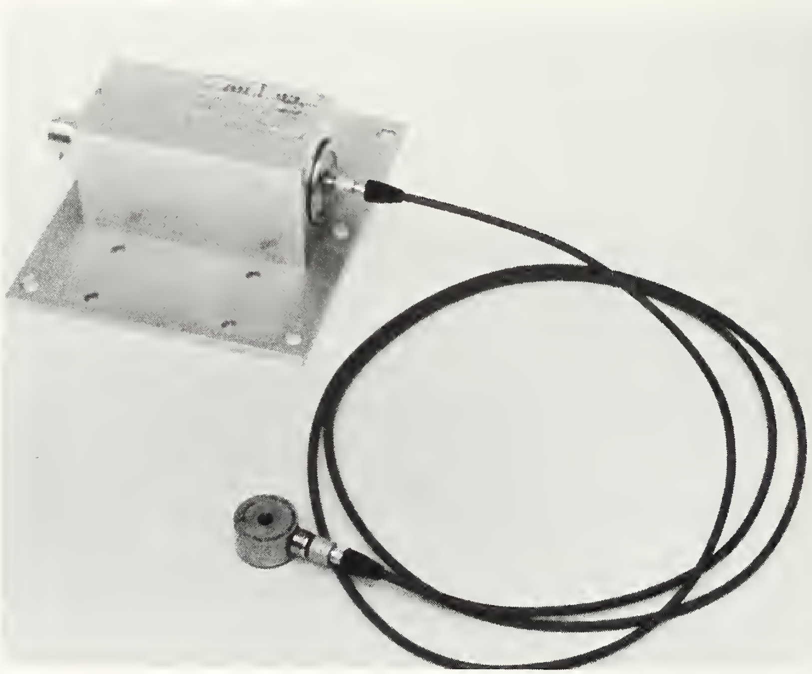


FIGURE D2-2. PIEZO ACCELEROMETER/CABLE/CHARGE CONVERTER/MOUNT ASSEMBLY, PRIOR TO INSTALLATION

D2.2 SPECIAL HANDLING

Use care not to impact installation tools on the accelerometer. Shocks of several thousand g's can be imparted to the accelerometer case.

The accelerometer should be stored in foam type packing material until ready for use.

If the accelerometer is inadvertently dropped or impacted, do not use the unit until a complete calibration check has been performed to ascertain the effects of this potentially damaging impact.

D2.3 THEORY OF OPERATION

A piezoelectric crystal is deformed by the force generated by movement of a proof mass within the accelerometer. A potential difference is created by the crystal deformation with a resultant induced charge. This charge is converted to a voltage in the charge converter (Model 2652). The signal voltage is scaled on the mode card and conditioned for output.

D2.4 SHIELD/GROUND TECHNIQUE

The accelerometer must be isolated from train ground using the attached insulating washer and an insulated screw. The charge converter case can be grounded or floating because of an internal shield. Signal low should be connected to the shield using the Endevco 4470 output cable pigtail connected to the appropriate switch bus terminal and closing the B-SIG switch. The train ground connection is made by closing the "SHD" switch. The required connections are shown in Figure D2-3.

D2.5 FUNCTIONAL WIRE LIST SUMMARY

Figure D2-4 shows the pin-to-pin connections for the system. For detailed schematics of each component, the reader is referred to the supporting documentation.

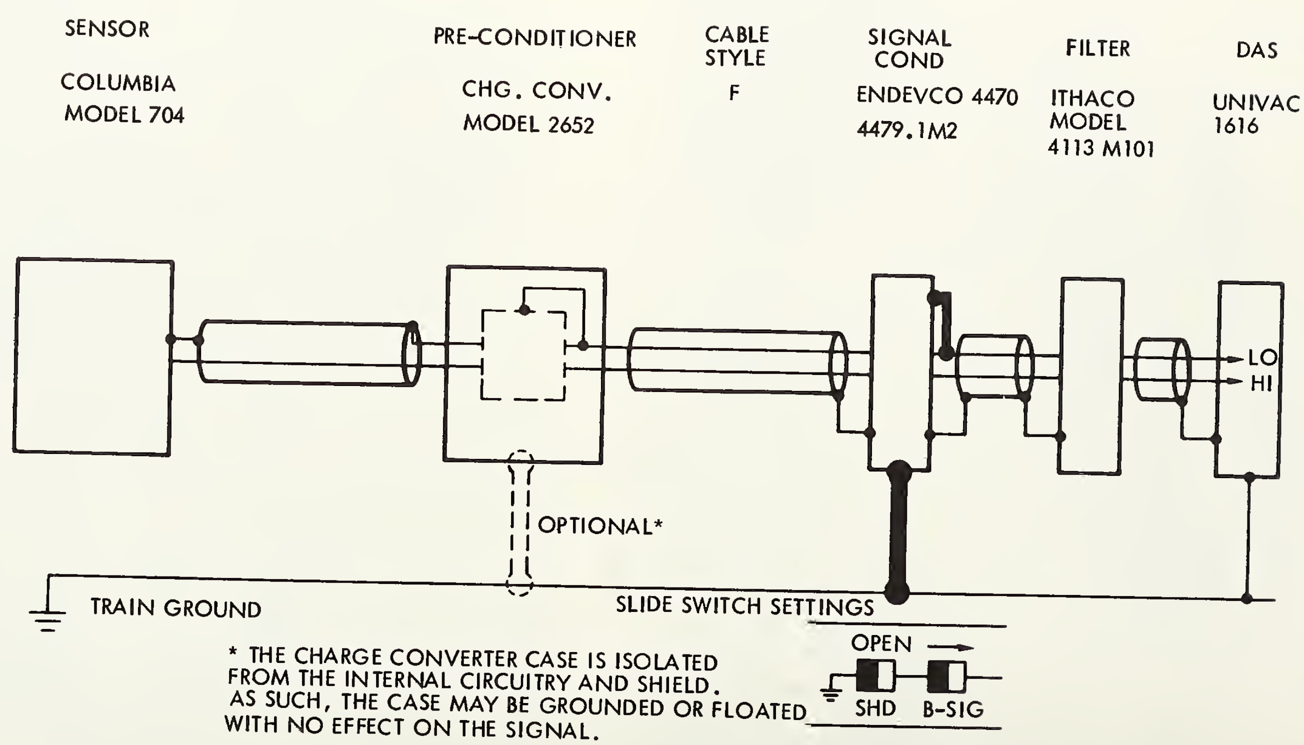


FIGURE D2-3. PIEZO ACCELEROMETER MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	A	A SIGNAL IN
X	j	KK	N	B	B SIGNAL IN
Z	b	BB	J	-	
N	c	CC	K	-	
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	-	SHIELD
P	-	-	-	-	GRD, POWER IN
R	-	-	-	-	+30 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (GRD)
22	f	EE	C	C	SHIELD

*Connector PT06-8-3S; Cable Style F

FIGURE D2-4. PIEZO ACCELEROMETER MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

D2.6 MODE CARD SETUP

The line driver conditioner mode card, Endevco 4479.1M2, is ready to use as received from the manufacturer. There are no provisions for internal calibration or other special features. The sensitivity of the accelerometer is set on the mode card dial pot in pc/g and the desired full scale g-range corresponding to ± 5 volts is selected.

If the selectable ranges are not adequate, intermediate ranges can be achieved by compensation on the dial pot. For example, assume an accelerometer sensitivity of 10 pc/g with a 60 g full scale desired range. Set the full scale switch to its 30g maximum. By setting the dial pot to 20 pc/g, a 60 g range results. In equation form:

$$\text{Range Desired} = \text{Range Setting}\left(\frac{\text{Sensitivity Setting}}{\text{Sensitivity Actual}}\right)$$

D2.7 VEHICLE MOUNTING

The accelerometers are affixed to the vehicle by means of single axis and triaxial mounting blocks. The mounting blocks can be attached to the vehicle using existing fasteners or cemented in place. In all cases, the accelerometer must be electrically isolated from train ground. Insulating screws and washers are used to attach the accelerometer to the mounting block. A light torque of approximately 10 inch pounds should be applied to No. 6-32 screws while No. 10-32 screws should be tightened to 18 inch-pounds.

In the aluminum mounting blocks, a anti-seizing compound should be applied to the threads.

CAUTION

DO NOT ALLOW COMPOUND TO CONTACT THE MOUNTING SURFACE

A dental cement is recommended for use on the mounting blocks. The surface must be clean and dry per cement manufacturer's instructions. Special tools required include:

a. Appropriate mounting block

b. Adhesive

c. Allen wrench - torque wrench.

No modification to the vehicle is required except the surface preparation prior to adhesive mounting.

D2.8 CALIBRATION

D2.8.1 Primary. The accelerometer should be periodically compared to a known standard accelerometer traceable to NBS. The following parameters should be checked.

a. Scale Factor

b. Scale Factor Versus Temperature

c. Transverse Sensitivity

d. Frequency Response

e. Noise.

The mode card and charge converter should be calibrated per the manufacturer's instruction manual.

D2.8.2 Secondary. No calibration provisions are included on the mode card but operation can be verified by gently tapping the accelerometer with a pencil eraser and noting the output.

The system may also be checked using a calibrator in place of the accelerometer to simulate an acceleration input.

E. PRESSURE MEASUREMENT SYSTEM

E.1 DESCRIPTION

The pressure transducers are used to measure vehicle air pressure from 0 to 200 psig. The location of the transducer determines the pressure source (brake cylinder, pipe, main or reserve reservoir, air spring, etc.). The pressure cell is shown in Figure E-1, and the pressure cell with its interface hardware is shown in Figure E-2.

The Pressure measurement system consists of the following items:

a. Pressure Cell ....BLH Type DHF

b. GVT Cable ....Style C

c. Signal Conditioner ....Endevco 4470/4476.2AM3 with TSC Mod P*

*The large letter "P" on the mode card front panel indicates that the card has been setup for the operation with a pressure cell.

The supporting documentation file contains the following applicable items (Bin 20):

a. System Error Analysis

b. Mfg. Operators Manual ......BLH Pressure Cell Type DHF

E.2 SPECIAL HANDLING

Do not use a wrench on the cover of the pressure cell when installing the units. Damage to the sensitive element may result.

E.3 THEORY OF OPERATION

The 0-200 psig type DHF pressure cells are equipped with a sensitive beam element attached to a diaphragm. As a pressure is applied against the diaphragm, the beam is deflected. Strain gages

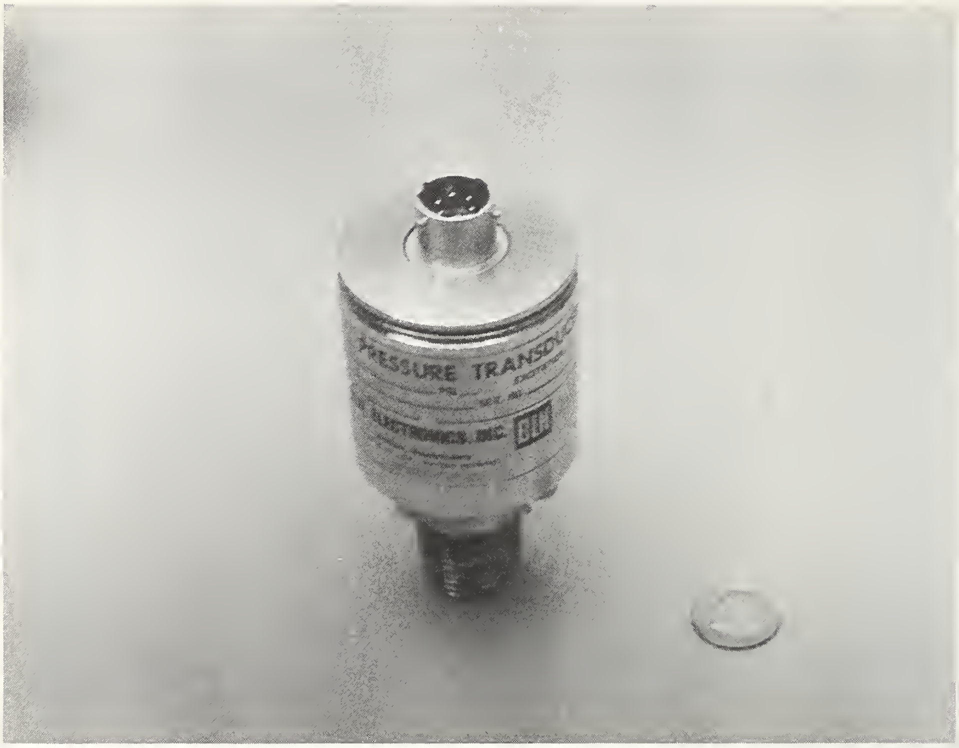


FIGURE E-1. PRESSURE CELL

FIGURE E2. PRESSURE CELL AND INTERFACE HARDWARE

are attached to the beam and provide an electrical signal proportional to the applied pressure. Resistors are included in the unit to compensate for temperature variations.

Strain gage bridge excitation and signal amplification are provided by the mode card.

E.4 SHIELD/GROUND TECHNIQUE

The case of the pressure cell is electrically isolated from the sensor circuitry and may be grounded or floated at the option of the user on most applications. The signal low to shield connection is made by closing the B SIG switch on the 4942 rack. The connection to train ground is accomplished by closing the SHD switch. These connections are shown in block diagram form in Figure E-3.

In areas of high electrical noise, a more sophisticated low noise shield/ground technique may be required. The case of the instrument must be floated from train ground (insulating hose pressure connection and insulating clamp to mechanically hold the cell). If noise is still being observed, electrically connect the cell case to the GVT cable shield.

E.5 FUNCTIONAL WIRE LIST SUMMARY

Figure E-4 shows the pin-to-pin connections for the system. For detailed schematics of each component, the reader is referred to the supporting documentation.

E.6 MODE CARD SETUP

The amplified bridge conditioner Endevco 4476.2AM3 is used in the system. A boldface "P" is added to the front panel as shown in Figure E-5. Electrical procedures are:

E.6.1 Modification Procedure

a. Remove R57 jumper.

b. Install an excitation voltage programming stable resistor.

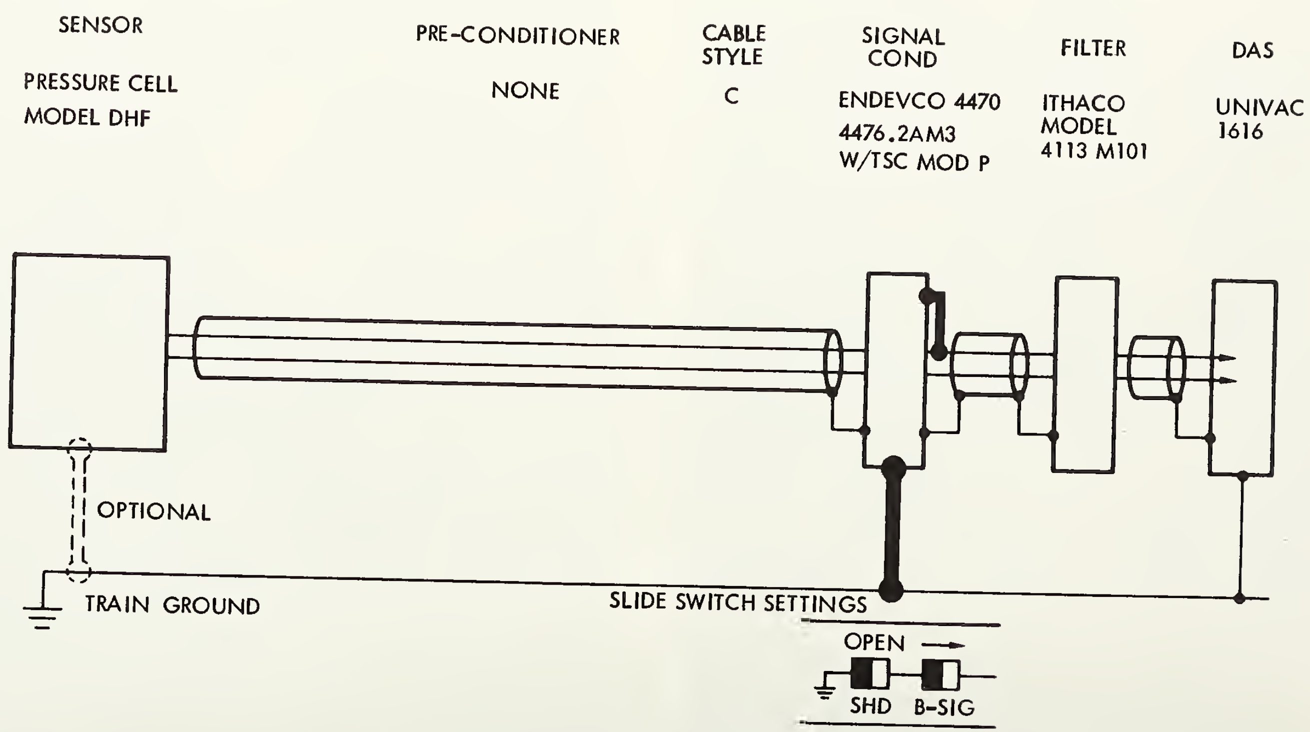


FIGURE E-3. PRESSURE MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	A	A SIGNAL IN
X	j	KK	N	B	B SIGNAL IN
Z	b	BB	J	C	EXCITATION RETURN
N	c	CC	K	D	+10 VDC, EXCITATION
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	-	SHIELD
P	-	-	-	-	-10 VDC, POWER IN
R	-	-	-	-	-10 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-10-6S; Cable Style C

FIGURE E-4. PRESSURE MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

FIGURE E-5. AMPLIFIED BRIDGE CONDITIONER (MOD P) FRONT PANEL

(R57 Approx. 6K for 10 VDC 50 ppm/°C)
Actual value is not critical.

c. Add Jumper F, A, B, C, D, E.

d. Remove R15, R16, R17 bridge completion resistors.

e. Change R58 to 1 megohm to increase balance pot resolution on Endevco 4470 Master Module.

f. Add R1 Cal Resistor.
Approx. 30 kohm for full scale.
Actual value is not critical.

g. Add C2, C3, C4 if desired to filter output (values per Endevco manual.

Using appropriate pressure sensor (mode card and sensor become a mated pair), actual test cable, and pressure cal box, the system may be calibrated. The calibration box contains a switch that electrically connects a calibration resistor that is internal to the transducer across one arm of the sensor bridge circuit.

A connector panel view and schematic of the Pressure measurement system "Cal Box" are shown in Figure E-6.

E.6.2 Post-Modification Calibration Procedure

a. Set up instruments as shown in Figure E-3 using proper grounding and shielding techniques. (See paragraph E-4.)

b. Let system warm-up 20 minutes minimum.

c. Set Gain to X100, system noise should be less than 10 mVp-p, record actual value.

d. Depress M/C Excit Zero and adjust Amp Zero pot for 0.000 volts output.

e. Release Excit Zero (wait 10 sec) and adjust Endevco 4470 Balance pot for zero output.

f. Switch Cal Box to "in". This shunts the transducer bridge with an NBS calibrated resistor internal to the sensor.

g. Adjust Endevco 4470 Gain Vernier to achieve X volts, where

$$X = \frac{\text{shunt value from cal sheet (mV/V)}}{\text{100\% capacity output (mV/V)}} \times 5 \text{ volts}$$

SAMPLE - BLH Type DHF S/N 76896

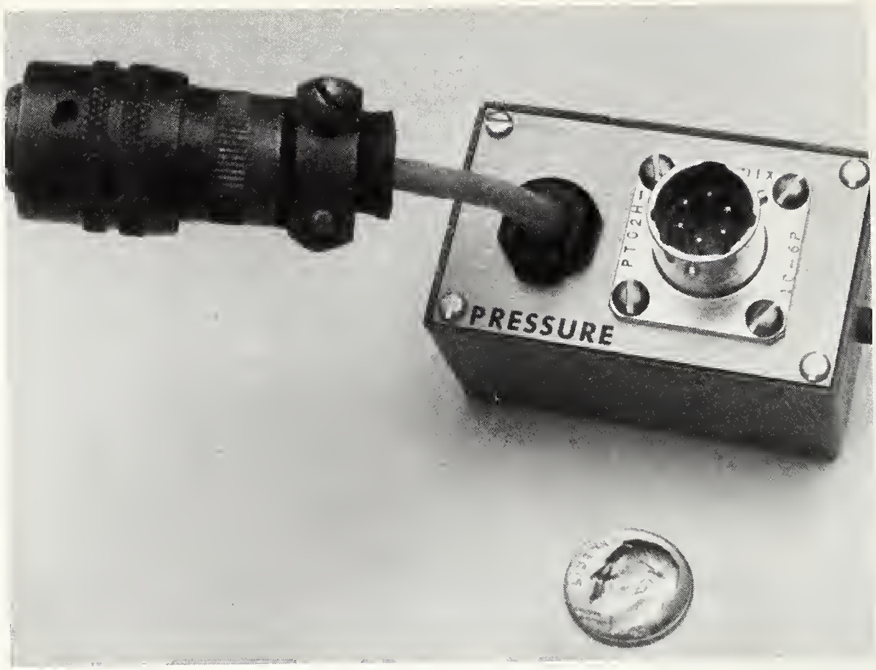
$$X = \frac{1.4740}{3.002} \times 5 = 2.455 \text{ VDC}$$

h. Switch Cal Box to "out". Verify zero output. Adjust as required.

i. Repeat g & h as required.

j. Type "X" value on mode card label.

Transducer BLH Type DHF
Ser. No. 76896
Sensitivity 40 psig/volt
Cal Box "In" 2.455, Cal 14.885



(Control/Indicator Panel View)

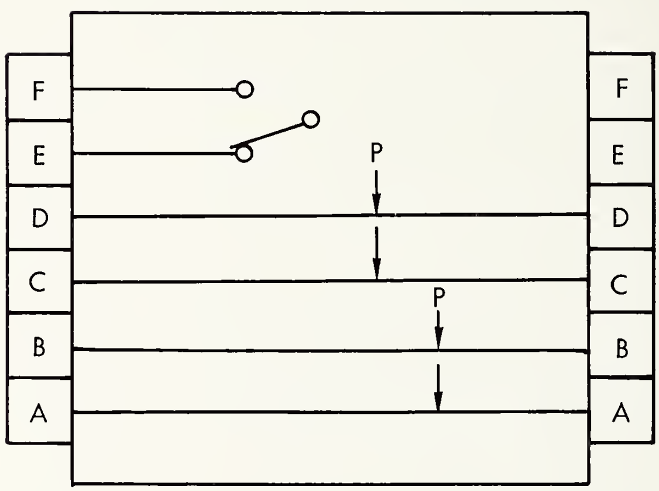


FIGURE E-6. PRESSURE SYSTEM "CAL BOX"

k. Switch Endevco 4470 Cal Select to Pos. 1 and depress Cal pushbutton. Record output on the mode card label as "Cal 1 - 4.885".

l. On-vehicle calibration can now be done in two ways.

1) Set zeros and adjust gain to output Cal 1 value while depressing Cal button.

2) Insert the Cal Box in circuit and adjust gain to output Cal Box "in" value.

By utilizing lab calibration values, the need for precision resistor values is eliminated. The resistor stability, however, is still important and RN60C resistors should be utilized.

The mode card setup data should be documented and filed with the pressure transducer calibration sheets.

The transducer label must be covered with a matte finish spray coating to facilitate reading and prevent scratches.

E-7. VEHICLE MOUNTING

The pressure transducer with street tee mounting fixture is designed to mount in-line with a brake cylinder air hose. Pipe thread adapters are available to allow connections to vehicle pipe fittings from 1/2" to 1-1/2" in 1/4" increments. Although the sensor exhibits minimal response to vibration and shock inputs (approximately 0.01%/g) it is advantageous to mount the sensor to minimize potentially damaging forces. The axis of highest vibration on a vehicle truck is vertical, therefore the axis of the sensor should also be vertical to minimize bending stresses on the pressure connection.

If the pressure cell cannot be mounted in line with the air hose, the pressure connection can be made with a flexible hose with appropriate fittings. The cell can be attached to the vehicle using a clamp on the case with a layer of rubber protective material between the clamp and the cell. This method is required if the optional low noise shield/ground technique is utilized.

No special tools are required to accomplish the pressure cell installation. Mounting fixtures include an assortment of pipe fitting adapters, clamps, and hoses. All pressure connections should be sealed with Teflon tape.

No permanent vehicle modifications are required but temporary access to pressure lines is necessary.

E.8. CALIBRATION

E.8.1 Primary. Utilizing a dead weight tester or a standard cell, the following values should be determined:

a. Capacity
b. Output in mV/V at 0
c. Output in mV/V at 50% of capacity
d. Output in MV/V at 100%
e. Output in MV/V at 50
f. Output in MV/V at 0
g. Output of shunt calibration using internal cal resistor* in mV/V
h. Input R
i. Output R
j. Zero Bal. mV/V

*Use "Cal Box" to activate shunt resistor.

E.8.2 Secondary

a. Method 1:

1) Set GAIN to X100.

2) With zero input pressure, adjust Amp Zero while depressing Excit Zero.

3) Release Excit Zero and zero output with balance pot.

4) With Cal Select in position 1, depress Cal button and adjust gain vernier until output corresponds to "Cal 1" value recorded on M/C handle.

b. Method 2:

1) Insert Cal Box ("out" position) in circuit at the transducer and perform 1-3 as above.

2) Switch Cal Box to "in" and adjust gain vernier until output corresponds to Cal Box "in" value recorded on M/C handle.

F. TEMPERATURE MEASUREMENT SYSTEM

F.1 DESCRIPTION

The Micro-Measurements bondable resistance temperature sensors are used to measure surface and free air temperatures from 0° to 500°F. Brake temperatures (BT/A, BT/B) and equipment temperatures (EQTA) per the GVTP may be measured up to the 500°F limit. Accuracy of the measurement system exceeds requirements. The measurement system consists of the following items:

a. Temperature Sensor ....Micro-Measurements Gage Type WTG-50 BP

b. Sensor Lead Wire ....#24 AWG Twisted pair

c. Temperature Connector Assy ....TSC Model TCA-1

d. GVT Cable ....Style A

e. Signal Conditioner ....Endevco 4470/4476.2AM3 with TSC Mod T

The sensor and connector assembly are shown in Figure F-1. The electrical connections on the connector assembly are shown in Figure F-2.

The sensor linearization technique is described in paragraph F.9 Additional Information.

The supporting documentation file contains the following applicable items (Bin 21):

a. System Error Analysis

b. Mfg. Data Sheet ....Micro-Measurements Temperature Gages

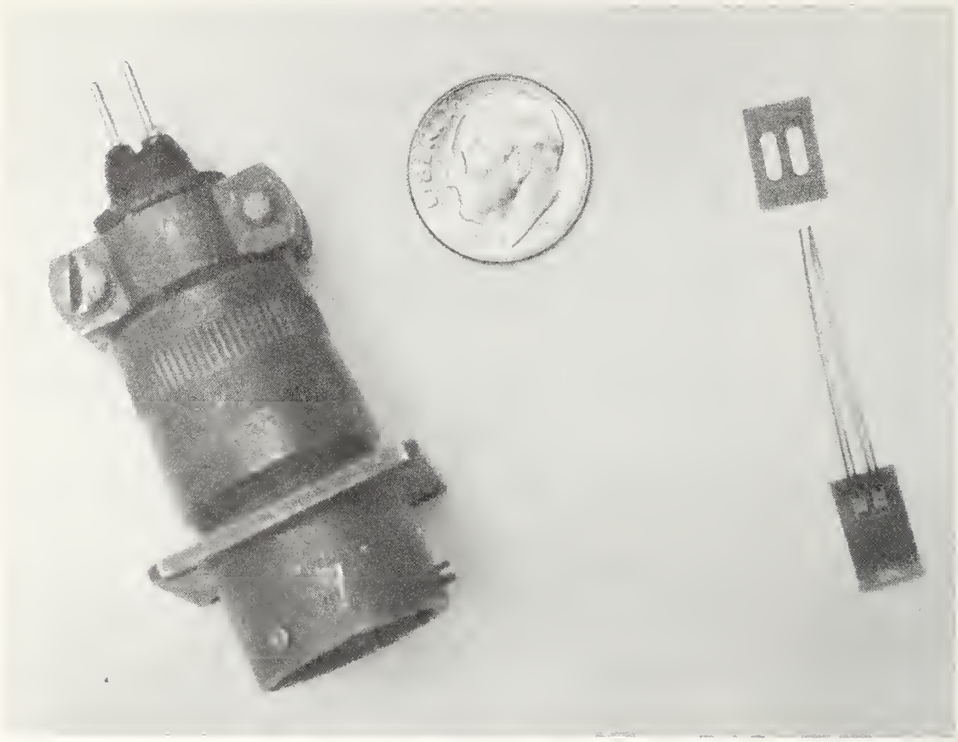


FIGURE F-1. TEMPERATURE SENSOR AND CONNECTOR ASSEMBLY

c. Mfg. Tech. Note ....Micro-Measurements
TN-140 Temp. Sensors
TT-128 Lead Attachment
TT-127 Bondable Terminals
B-137 Gage Adhesives

d. Mfg. Data Sheet ....Dow-Corning
Adhesive/Sealant

F.2 SPECIAL HANDLING

To prevent damage to the gages, extreme care must be exercised during installation. After testing, no attempt need be made to salvage the gage.

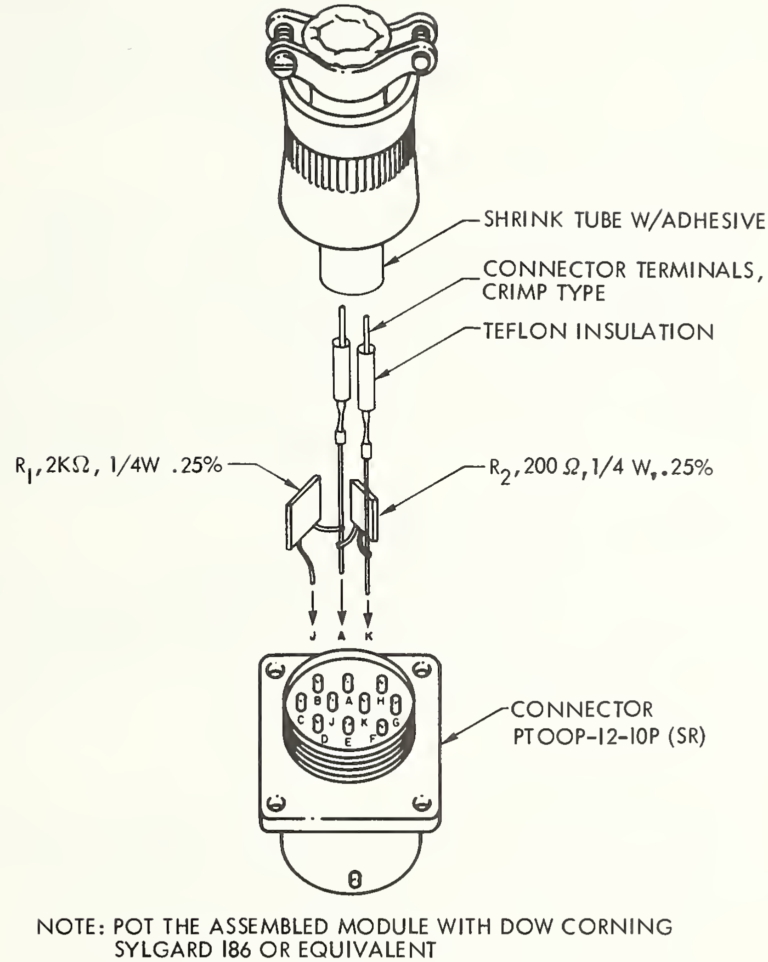


FIGURE F-2. TEMPERATURE CONNECTOR ASSEMBLY TSC MODEL TCA-1

F.3 THEORY OF OPERATION

The resistance of the temperature gages varies as a function of temperature. The variation is nonlinear and the resulting electrical signal is linearized by passive components located in the connector assembly. A modified amplified bridge mode card provides the necessary excitation and offset voltage and signal amplification. The system is set up such that 0.0 volt corresponds to 0°F with a nominal scale factor of 10 mV/°F.

F.4 SHIELD/GROUND TECHNIQUE

The sensors are installed with an insulating RTV adhesive. Similarly, no ground or shield connections are made within the connector assembly. The signal to shield connection is made with the 4942 switch bus by closing the B SIG switch. The connection to train ground is accomplished by closing the SHD switch. These connections are shown in block diagram form in Figure F-3.

F.5 FUNCTIONAL WIRE LIST SUMMARY

Figure F-4 shows pin-to-pin connections for the system. For detailed schematics of each component, the reader is referred to the supporting documentation.

F.6 MODE CARD SETUP

To condition the linearized sensor signal, a modified (T) Amplified Bridge Mode Card, Endevco Model 4476.2AM3 is used. The setup and modifications are listed below:

a. Remove jumpers C & D (Note: All jumpers except F were previously installed at factory).

b. Replace jumper at R57 with a 2.0 kΩ resistor.

c. Install jumper F.

d. Install four jumpers at R1 through R4.

e. Replace R58 with a 10 kΩ $\pm$1% resistor.

f. Install a 27Ω resistor at R15.

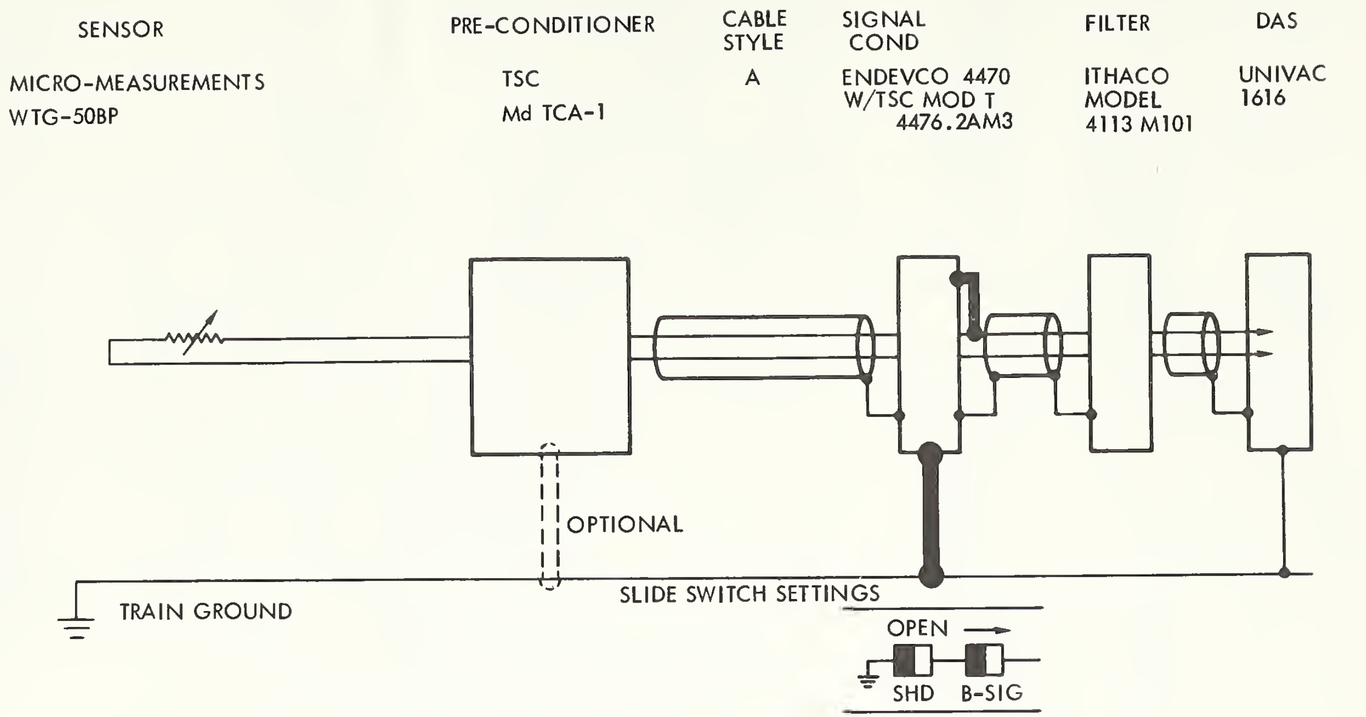


FIGURE F-3. TEMPERATURE MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT, RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	A	A SIGNAL IN
X	j	KK	N	-	
Z	b	BB	J	J	EXCITATION RETURN
N	c	CC	K	K	+5.6 VDC EXCITATION
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	F	SHIELD
P	-	-	-	-	-10 VDC, POWER IN
R	-	-	-	-	+10 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06P-12-10P; Cable Style A

FIGURE F-4. TEMPERATURE MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

g. Install a 2.0 kΩ resistor at R16.

h. Make modifications shown in Figure F-5 to printed circuit foil pattern.

i. Using "press-on" letters, add a bold face "T" to the mode card front panel.

The mode card and temperature connector assembly schematic are shown in Figure F-6. Photographs of the front panel and circuitry are shown in Figure F-7.

F.7 VEHICLE MOUNTING

Special equipment needed to mount the sensors and terminals include:

a. RTV 3145 adhesive sealant

b. Cellephone tape

c. Bondable terminals

d. Acetone w/swabs

e. Lead wire twisted pair

f. Tweezers

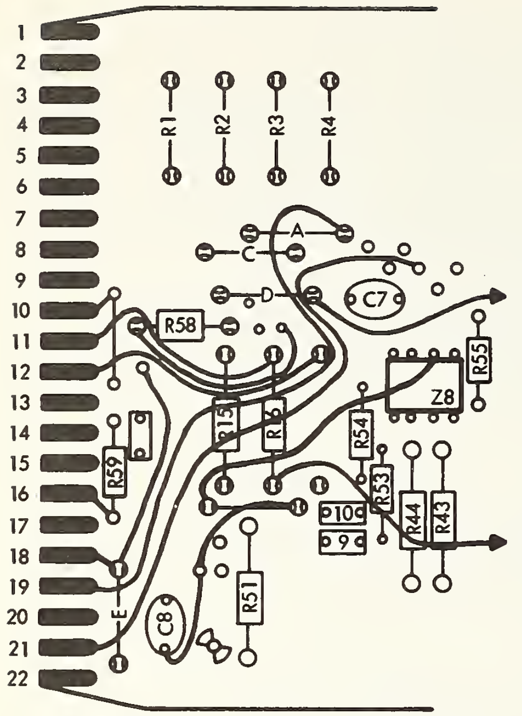
g. Teflon sheet w/spring clamp or weight.

The sensors are affixed to the structure with RTV 3145 adhesive/sealant. The smooth surface (except plastic) should be cleaned with acetone and a thin film of adhesive spread on the surface. Temporarily weight or spring clamp the gage in place using a small sheet of Teflon between the gage and weight. A 24 hour room temperature adhesive cure time is recommended.

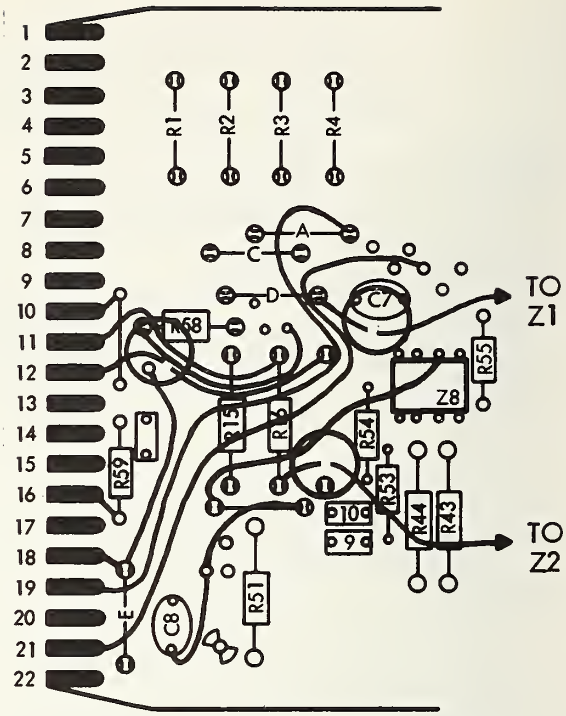
The gage lead wires should be strain relieved and soldered to a bonded solder terminal. The lead wire pair from the connector is also attached to the solder terminal. The length of the lead wires should be kept as short as possible.

NOTE

Excitation Voltage Sensing Is Not Utilized On The System, But It Is Recommended That Both Pairs of Gage Leads Be Attached To The Terminal Pads To Provide Circuit Redundancy.



COMPONENT SIDE (BEFORE)



COMPONENT SIDE
REMOVE 1/16" OF THE PATTERN
AS SHOWN IN THE 3 CIRCLES

COMPONENT
SIDE (AFTER)
INSTALL 3 JUMPERS
INSULATED WITH PTFE

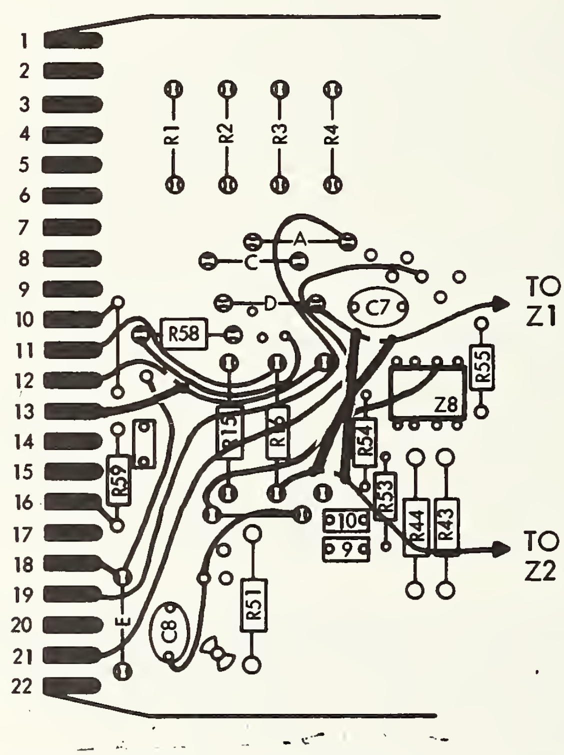


FIGURE F-5. MODE CARD SETUP- COMPONENT BOARD MODIFICATIONS

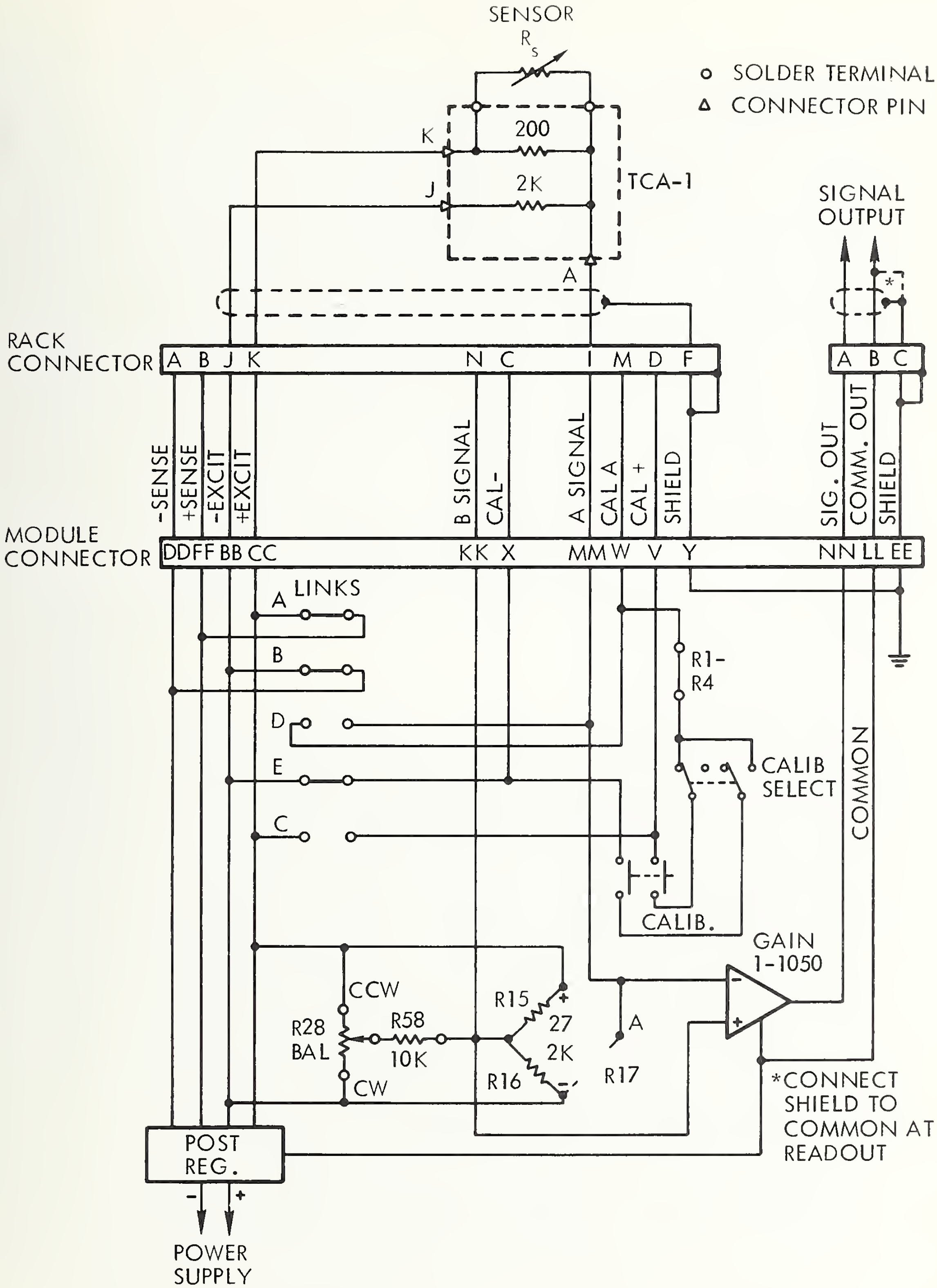
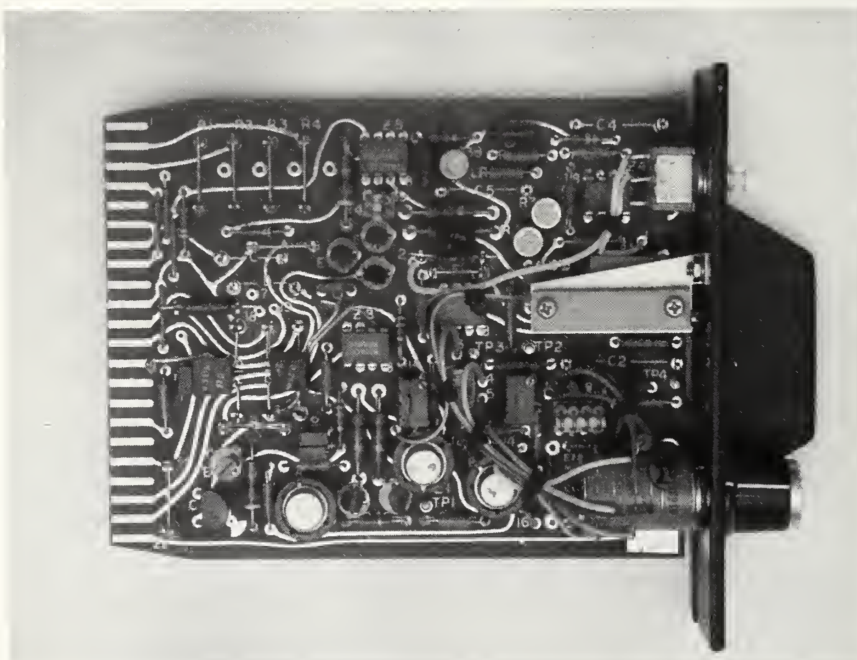


FIGURE F-6. MODE CARD SETUP FOR TEMPERATURE MEASUREMENTS

(Front Panel View)



(Circuit Board View)

FIGURE F-7. TSC MODIFIED (T) MODE CARD
AMPLIFIED BRIDGE CONDITIONER
MODEL 4476.2A

After attachment of the sensor, terminal and lead wires, the entire area should be coated with RTV sealant to minimize heat transfer to ambient air and to waterproof the installation. A 1/16-inch thick layer is recommended. No permanent modification to the vehicle is required. The connector assembly may be affixed with existing mechanical fasteners or glass tape.

The RTV adhesive was chosen for the following reasons:

a. It cures at room temperature.

b. Effective to 560°F.

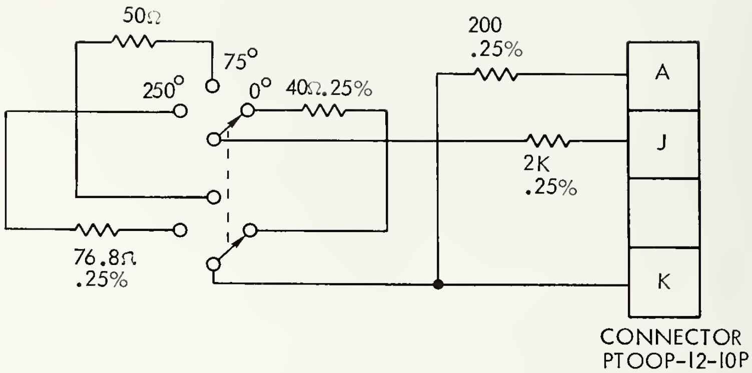
c. Minimal effect on heat transfer between mounting surface and gage.

d. Minimal transfer of surface strain errors to the device. (The gage configuration is very similar to a strain gage).

F.8 CALIBRATION

F.8.1 Primary. Each sensor has a resistance of 50.0 $\pm$0.05 ohms at 75°F. The tolerance error is less than 0.3°F. Tables of the resistance versus temperature are given in Tech Note TN-140. The values are for sensors mounted on aluminum and steel with good strain transmissability from the surface to the gage. With the RTV adhesive, the strains are not transmitted and slight errors will result. The resistance values used to determine the linearization circuit parameters were taken from the steel table. The coefficient of thermal expansion of the nickel sensor is within 8 percent of the steel coefficient, therefore use of the RTV adhesive is expected to introduce only small errors (on the order of 2°F at 500°F).

F.8.2 Secondary. Two "cal boxes" for the resistance temperature system were fabricated. Stable, precision resistors are substituted for the sensor and linearization network. The cal box mates directly with the Style A GVT cable. The cal box is shown with its schematic in Figure F-8.



THE 40, 50, AND 76.8 OHM RESISTORS SIMULATE THE TEMPERATURE GAGE AT 0°, 75°, AND 250° RESPECTIVELY

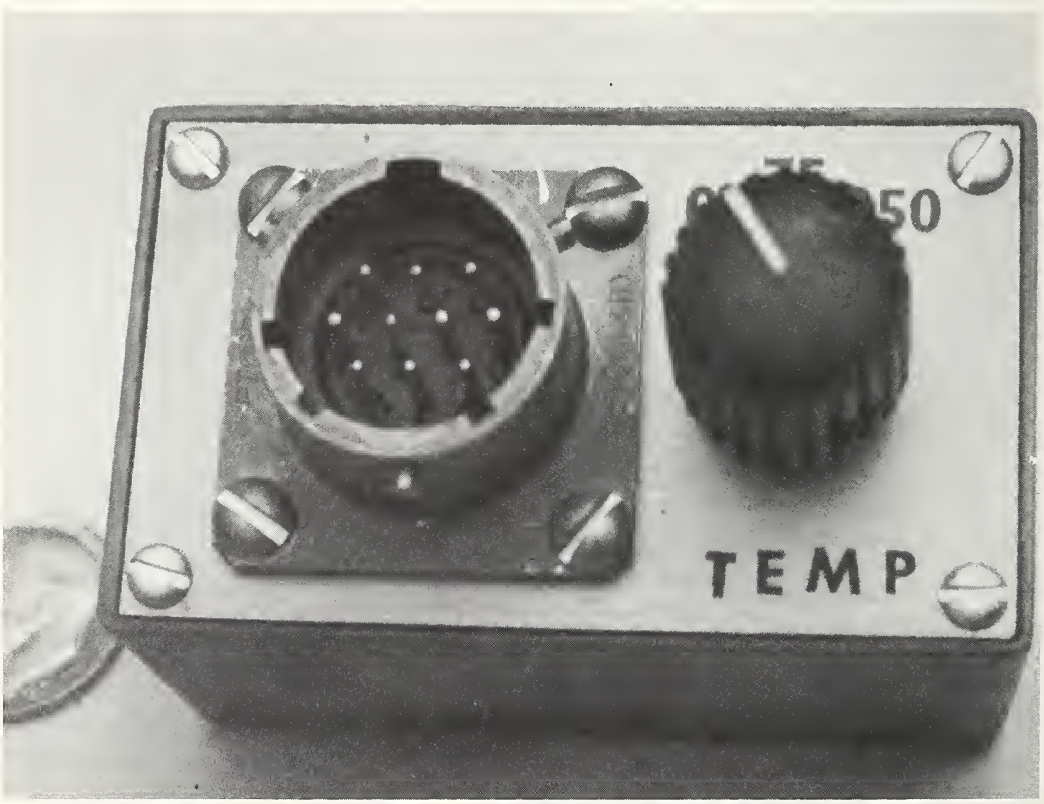


FIGURE F-8. TEMPERATURE SYSTEM "CAL BOX"

To calibrate the system:

a. Allow a 30 minute warmup of the Endevco 4470 system with applicable mode card.

b. Connect a temp cal box to the sensor cable.

c. Set cal box temp at 0.

d. Using monitor toggle switch on Endevco 4470 master module, verify the excitation voltage between 5.400 and 5.800 volts. If not, replace mode card.

e. With the monitor switch in the balance position, depress the mode card "Excit Zero" pushbutton and zero output using the mode card "Amp Zero" pot. Release "Excit Zero" button.

f. With the cal box still in the zero position, adjust the Endevco 4470 balance pot to zero output.

g. Rotate the cal box switch to the 75 or 250°F position and adjust the gain and gain vernier until the desired output is obtained.

It is suggested that a 10 mV/°F sensitivity be used. Set cal box to 250, gain at "X30" and adjust gain vernier until output is 2.500 volts.

F.9 ADDITIONAL INFORMATION

Sensor Linearization Technique

It was determined through computer analysis that the optimal system linearity is achieved by using the sensor, shunted by a 200-ohm resistor, in a voltage divider configuration. The sensor/200-ohm pair forms the lower leg of the voltage divider, and a 2 kΩ resistor is used for the upper leg. The 200-ohm resistor in parallel with the sensor partially linearizes the sensor resistance versus temperature curve. These values are given in Table F-1. The remaining nonlinearity is cancelled by the nonlinearity inherent in the voltage divider. The computer analysis also revealed that a constant 5 volt (nominal) voltage source, a system gain of approximately 47, and an offset voltage of approximately 82 mV would provide (with the voltage divider described above) a signal sensitivity of 10 mV/°F and zero volt output of 0°F.

The offset voltage is obtained at the junction of the bridge completion resistors R15 and R16 on the mode card. This signal plus the voltage divider output signal are applied to the variable gain, differential amplifier on the card. The calculated values of output voltage versus temperature are shown in Table F-2.

TABLE F-1 RESISTANCE VS. TEMPERATURE, 200 OHMS IN PARALLEL WITH SENSOR

499	78.32	449	73.65	399	69.05	349	64.54	299	59.92
498	78.23	448	73.56	398	68.96	348	64.44	298	59.84
497	78.13	447	73.47	397	68.87	347	64.35	297	59.74
496	78.04	446	73.37	396	68.78	346	64.25	296	59.65
495	77.95	445	73.28	395	68.68	345	64.15	295	59.57
494	77.86	444	73.19	394	68.59	344	64.05	294	59.48
493	77.76	443	73.09	393	68.50	343	63.95	293	59.39
492	77.67	442	73.00	392	68.41	342	63.86	292	59.29
491	77.57	441	72.90	391	68.32	341	63.76	291	59.20
490	77.48	440	72.81	390	68.23	340	63.66	290	59.11
489	77.39	439	72.72	389	68.14	339	63.57	289	59.02
488	77.30	438	72.62	388	68.04	338	63.48	288	58.93
487	77.21	437	72.54	387	67.95	337	63.38	287	58.84
486	77.12	436	72.44	386	67.86	336	63.29	286	58.75
485	77.03	435	72.36	385	67.76	335	63.20	285	58.66
484	76.93	434	72.27	384	67.67	334	63.11	284	58.57
483	76.84	433	72.18	383	67.58	333	63.01	283	58.48
482	76.75	432	72.08	382	67.48	332	62.92	282	58.40
481	76.66	431	71.99	381	67.39	331	62.83	281	58.30
480	76.57	430	71.90	380	67.29	330	62.74	280	58.21
479	76.48	429	71.81	379	67.21	329	62.65	279	58.12
478	76.38	428	71.72	378	67.12	328	62.56	278	58.04
477	76.29	427	71.62	377	67.03	327	62.47	277	57.94
476	76.20	426	71.53	376	66.95	326	62.39	276	57.85
475	76.10	425	71.43	375	66.87	325	62.30	275	57.76
474	76.01	424	71.34	374	66.78	324	62.20	274	57.67
473	75.91	423	71.24	373	66.70	323	62.11	273	57.58
472	75.81	422	71.15	372	66.61	322	62.03	272	57.49
471	75.72	421	71.05	371	66.53	321	61.94	271	57.40
470	75.63	420	70.96	370	66.44	320	61.84	270	57.31
469	75.54	419	70.87	369	66.35	319	61.75	269	57.22
468	75.44	418	70.78	368	66.27	318	61.66	268	57.14
467	75.35	417	70.69	367	66.18	317	61.57	267	57.05
466	75.26	416	70.60	366	66.10	316	61.48	266	56.96
465	75.16	415	70.52	365	66.01	315	61.39	265	56.87
464	75.07	414	70.42	364	65.92	314	61.29	264	56.78
463	74.98	413	70.34	363	65.83	313	61.20	263	56.69
462	74.88	412	70.25	362	65.74	312	61.10	262	56.61
461	74.79	411	70.16	361	65.65	311	61.01	261	56.52
460	74.69	410	70.07	360	65.56	310	60.92	260	56.42
459	74.60	409	69.98	359	65.47	309	60.83	259	56.34
458	74.51	408	69.88	358	65.38	308	60.74	258	56.25
457	74.41	407	69.79	357	65.29	307	60.65	257	56.16
456	74.32	406	69.70	356	65.20	306	60.56	256	56.07
455	74.22	405	69.60	355	65.10	305	60.47	255	55.99
454	74.13	404	69.51	354	65.01	304	60.38	254	55.90
453	74.03	403	69.42	353	64.92	303	60.29	253	55.80
452	73.93	402	69.33	352	64.82	302	60.20	252	55.72
451	73.84	401	69.23	351	64.73	301	60.11	251	55.63
450	73.75	400	69.14	350	64.64	300	60.02	250	55.54

TABLE F-1 RESISTANCE VS. TEMPERATURE, 200 OHMS IN PARALLEL WITH SENSOR (Continued)

249	55.45	199	50.94	149	46.53	99	42.10	49	37.68
248	55.36	198	50.85	148	46.44	98	42.02	48	37.58
247	55.27	197	50.76	147	46.35	97	41.92	47	37.50
246	55.18	196	50.68	146	46.27	96	41.83	46	37.41
245	55.09	195	50.59	145	46.18	95	41.74	45	37.32
244	54.99	194	50.50	144	46.08	94	41.65	44	37.23
243	54.90	193	50.42	143	45.99	93	41.57	43	37.15
242	54.81	192	50.33	142	45.90	92	41.48	42	37.06
241	54.72	191	50.24	141	45.82	91	41.38	41	36.97
240	54.63	190	50.15	140	45.73	90	41.29	40	36.88
239	54.55	189	50.06	139	45.64	89	41.21	39	36.79
238	54.46	188	49.97	138	45.55	88	41.13	38	36.71
237	54.37	187	49.88	137	45.46	87	41.04	37	36.63
236	54.28	186	49.79	136	45.37	86	40.96	36	36.54
235	54.20	185	49.70	135	45.29	85	40.88	35	36.45
234	54.11	184	49.61	134	45.20	84	40.80	34	36.37
233	54.01	183	49.52	133	45.11	83	40.71	33	36.29
232	53.92	182	49.43	132	45.03	82	40.63	32	36.19
231	53.83	181	49.34	131	44.94	81	40.55	31	36.11
230	53.75	180	49.25	130	44.85	80	40.47	30	36.03
229	53.66	179	49.16	129	44.77	79	40.37	29	35.94
228	53.57	178	49.07	128	44.68	78	40.28	28	35.85
227	53.47	177	48.99	127	44.59	77	40.19	27	35.76
226	53.38	176	48.90	126	44.50	76	40.10	26	35.66
225	53.29	175	48.82	125	44.41	75	40.00	25	35.57
224	53.20	174	48.73	124	44.33	74	39.90	24	35.49
223	53.10	173	48.65	123	44.24	73	39.81	23	35.40
222	53.01	172	48.56	122	44.16	72	39.72	22	35.31
221	52.92	171	48.48	121	44.07	71	39.63	21	35.21
220	52.83	170	48.39	120	43.98	70	39.53	20	35.13
219	52.74	169	48.30	119	43.89	69	39.45	19	35.04
218	52.64	168	48.21	118	43.80	68	39.36	18	34.94
217	52.56	167	48.12	117	43.71	67	39.28	17	34.85
216	52.47	166	48.03	116	43.63	66	39.19	16	34.77
215	52.38	165	47.94	115	43.54	65	39.11	15	34.67
214	52.28	164	47.85	114	43.45	64	39.02	14	34.58
213	52.20	163	47.76	113	43.36	63	38.93	13	34.49
212	52.10	162	47.67	112	43.28	62	38.84	12	34.40
211	52.01	161	47.58	111	43.19	61	38.76	11	34.30
210	51.92	160	47.49	110	43.09	60	38.66	10	34.21
209	51.83	159	47.40	109	43.00	59	38.57	9	34.13
208	51.74	158	47.32	108	42.91	58	38.48	8	34.04
207	51.65	157	47.23	107	42.82	57	38.39	7	33.95
206	51.57	156	47.14	106	42.73	56	38.31	6	33.86
205	51.47	155	47.05	105	42.64	55	38.21	5	33.78
204	51.38	154	46.97	104	42.56	54	38.12	4	33.69
203	51.30	153	46.88	103	42.47	53	38.03	3	33.60
202	51.21	152	46.79	102	42.38	52	37.94	2	33.51
201	51.11	151	46.70	101	42.29	51	37.85	1	33.42
200	51.02	150	46.62	100	42.20	50	37.76	0	33.33

TABLE F-2 CALCULATED OUTPUT, 200 OHMS IN PARALLEL W/SENSOR; EXCITATION 5.0V; GAIN 47; OFFSET ≈ 82 mV

REFERENCE TEMPERATURE = 250 DEGREES F
SERIES RESISTOR = 2000,00 OHMS
EXCITATION = 5,000 VOLTS
GAIN = 47,04628 OFFSET = 81,96 MILLIVOLTS

499	5,0087	449	4,4989	399	3,9945	349	3,4977	299	2,9867
498	4,9988	448	4,4890	398	3,9846	348	3,4867	298	2,9778
497	4,9880	447	4,4792	397	3,9747	347	3,4768	297	2,9667
496	4,9782	446	4,4682	396	3,9648	346	3,4657	296	2,9567
495	4,9683	445	4,4584	395	3,9538	345	3,4547	295	2,9478
494	4,9585	444	4,4485	394	3,9439	344	3,4436	294	2,9379
493	4,9476	443	4,4376	393	3,9340	343	3,4326	293	2,9279
492	4,9378	442	4,4277	392	3,9241	342	3,4227	292	2,9168
491	4,9269	441	4,4168	391	3,9142	341	3,4116	291	2,9068
490	4,9171	440	4,4069	390	3,9043	340	3,4006	290	2,8968
489	4,9073	439	4,3971	389	3,8944	339	3,3906	289	2,8868
488	4,8975	438	4,3861	388	3,8834	338	3,3807	288	2,8768
487	4,8877	437	4,3774	387	3,8735	337	3,3696	287	2,8669
486	4,8779	436	4,3664	386	3,8636	336	3,3597	286	2,8569
485	4,8681	435	4,3576	385	3,8526	335	3,3497	285	2,8469
484	4,8572	434	4,3478	384	3,8427	334	3,3398	284	2,8369
483	4,8473	433	4,3379	383	3,8328	333	3,3287	283	2,8269
482	4,8375	432	4,3270	382	3,8218	332	3,3188	282	2,8180
481	4,8277	431	4,3171	381	3,8119	331	3,3088	281	2,8069
480	4,8179	430	4,3072	380	3,8009	330	3,2989	280	2,7969
479	4,8081	429	4,2974	379	3,7921	329	3,2889	279	2,7869
478	4,7972	428	4,2875	378	3,7822	328	3,2790	278	2,7780
477	4,7873	427	4,2765	377	3,7723	327	3,2690	277	2,7669
476	4,7775	426	4,2667	376	3,7634	326	3,2602	276	2,7569
475	4,7666	425	4,2557	375	3,7546	325	3,2502	275	2,7469
474	4,7568	424	4,2458	374	3,7447	324	3,2392	274	2,7369
473	4,7459	423	4,2349	373	3,7359	323	3,2292	273	2,7269
472	4,7349	422	4,2250	372	3,7260	322	3,2204	272	2,7169
471	4,7251	421	4,2140	371	3,7172	321	3,2104	271	2,7069
470	4,7153	420	4,2042	370	3,7073	320	3,1993	270	2,6969
469	4,7055	419	4,1943	369	3,6974	319	3,1894	269	2,6869
468	4,6945	418	4,1844	368	3,6885	318	3,1794	268	2,6780
467	4,6847	417	4,1745	367	3,6786	317	3,1695	267	2,6680
466	4,6749	416	4,1647	366	3,6698	316	3,1595	266	2,6580
465	4,6639	415	4,1559	365	3,6599	315	3,1495	265	2,6480
464	4,6541	414	4,1449	364	3,6500	314	3,1385	264	2,6380
463	4,6443	413	4,1361	363	3,6400	313	3,1285	263	2,6280
462	4,6334	412	4,1263	362	3,6301	312	3,1174	262	2,6191
461	4,6235	411	4,1164	361	3,6202	311	3,1074	261	2,6091
460	4,6126	410	4,1065	360	3,6103	310	3,0975	260	2,5979
459	4,6028	409	4,0966	359	3,6003	309	3,0875	259	2,5890
458	4,5929	408	4,0856	358	3,5904	308	3,0775	258	2,5790
457	4,5820	407	4,0758	357	3,5805	307	3,0676	257	2,5690
456	4,5721	406	4,0659	356	3,5706	306	3,0576	256	2,5590
455	4,5612	405	4,0549	355	3,5595	305	3,0476	255	2,5501
454	4,5514	404	4,0457	354	3,5496	304	3,0376	254	2,5401
453	4,5404	403	4,0351	353	3,5397	303	3,0277	253	2,5289
452	4,5295	402	4,0252	352	3,5286	302	3,0177	252	2,5200
451	4,5196	401	4,0142	351	3,5187	301	3,0077	251	2,5100
450	4,5098	400	4,0043	350	3,5088	300	2,9977	250	2,5000

TABLE F-2 CALCULATED OUTPUT, 200 OHMS IN PARALLEL W/SENSOR; EXCITATION 5.0V; GAIN 47; OFFSET ≈ 82 mV (Continued)

249	2.4900	199	1.9867	149	1.4924	99	0.9937	49	0.4939
248	2.4800	198	1.9766	148	1.4822	98	0.9846	48	0.4826
247	2.4699	197	1.9665	147	1.4721	97	0.9734	47	0.4735
246	2.4599	196	1.9576	146	1.4631	96	0.9632	46	0.4633
245	2.4499	195	1.9475	145	1.4530	95	0.9530	45	0.4531
244	2.4387	194	1.9374	144	1.4418	94	0.9429	44	0.4429
243	2.4287	193	1.9285	143	1.4317	93	0.9339	43	0.4339
242	2.4187	192	1.9184	142	1.4216	92	0.9237	42	0.4237
241	2.4087	191	1.9083	141	1.4126	91	0.9124	41	0.4135
240	2.3986	190	1.8983	140	1.4025	90	0.9022	40	0.4033
239	2.3897	189	1.8882	139	1.3923	89	0.8932	39	0.3930
238	2.3797	188	1.8781	138	1.3822	88	0.8842	38	0.3840
237	2.3697	187	1.8680	137	1.3721	87	0.8740	37	0.3749
236	2.3596	186	1.8580	136	1.3620	86	0.8650	36	0.3647
235	2.3507	185	1.8479	135	1.3530	85	0.8559	35	0.3545
234	2.3407	184	1.8378	134	1.3429	84	0.8469	34	0.3454
233	2.3295	183	1.8277	133	1.3327	83	0.8367	33	0.3363
232	2.3195	182	1.8176	132	1.3237	82	0.8277	32	0.3250
231	2.3094	181	1.8076	131	1.3136	81	0.8187	31	0.3159
230	2.3005	180	1.7975	130	1.3035	80	0.8096	30	0.3068
229	2.2905	179	1.7874	129	1.2945	79	0.7983	29	0.2966
228	2.2804	178	1.7773	128	1.2844	78	0.7882	28	0.2864
227	2.2693	177	1.7684	127	1.2742	77	0.7780	27	0.2762
226	2.2592	176	1.7583	126	1.2641	76	0.7678	26	0.2648
225	2.2492	175	1.7493	125	1.2540	75	0.7565	25	0.2546
224	2.2392	174	1.7392	124	1.2450	74	0.7452	24	0.2455
223	2.2280	173	1.7302	123	1.2348	73	0.7350	23	0.2353
222	2.2179	172	1.7202	122	1.2258	72	0.7248	22	0.2251
221	2.2079	171	1.7112	121	1.2157	71	0.7147	21	0.2137
220	2.1979	170	1.7011	120	1.2056	70	0.7034	20	0.2046
219	2.1878	169	1.6910	119	1.1954	69	0.6943	19	0.1944
218	2.1766	168	1.6809	118	1.1853	68	0.6841	18	0.1831
217	2.1677	167	1.6708	117	1.1752	67	0.6751	17	0.1728
216	2.1577	166	1.6607	116	1.1661	66	0.6649	16	0.1637
215	2.1476	165	1.6506	115	1.1560	65	0.6559	15	0.1524
214	2.1364	164	1.6405	114	1.1459	64	0.6457	14	0.1422
213	2.1275	163	1.6304	113	1.1357	63	0.6355	13	0.1319
212	2.1163	162	1.6203	112	1.1267	62	0.6253	12	0.1217
211	2.1063	161	1.6102	111	1.1166	61	0.6162	11	0.1103
210	2.0962	160	1.6001	110	1.1053	60	0.6049	10	0.1001
209	2.0862	159	1.5900	109	1.0952	59	0.5947	9	0.0910
208	2.0761	158	1.5811	108	1.0850	58	0.5845	8	0.0808
207	2.0660	157	1.5710	107	1.0749	57	0.5744	7	0.0705
206	2.0571	156	1.5609	106	1.0647	56	0.5653	6	0.0603
205	2.0459	155	1.5508	105	1.0546	55	0.5540	5	0.0512
204	2.0359	154	1.5418	104	1.0455	54	0.5438	4	0.0410
203	2.0269	153	1.5317	103	1.0354	53	0.5336	3	0.0307
202	2.0169	152	1.5216	102	1.0252	52	0.5234	2	0.0205
201	2.0057	151	1.5115	101	1.0151	51	0.5132	1	0.0102
200	1.9956	150	1.5025	100	1.0049	50	0.5030	0	0.0000

APPENDIX G STRUCTURES

G1 STRAIN MEASUREMENT SYSTEM
G2 POTENTIOMETER MEASUREMENT SYSTEM
G3 NON-CONTACT DISPLACEMENT MEASUREMENT SYSTEM

G1. STRAIN MEASUREMENT SYSTEM

G1.1 DESCRIPTION

The Strain measurement system is used to determine the static and dynamic loads in specific components of a test vehicle. The measurement is generally specified as a structures test with the location of each measurement determined on a case-by-case basis by the test initiator. Analysis of the dynamic loading can also result in an estimate of the fatigue life of a component.

The Strain measurement system consists of the following items:

a. Strain Gage....................Commercial Unit (Depending on Installation)

b. Strain Connector Assembly.....TSC Model SCA-1

c. GVT Cable......................Style A

d. Signal Conditioner............Endevco 4470/4476.2AM3

A drawing of a typical strain connector assembly is shown in Figure G1-1. The electrical schematic of this connector, configured with external voltage sense and external calibration, is shown in Figure G1-2.

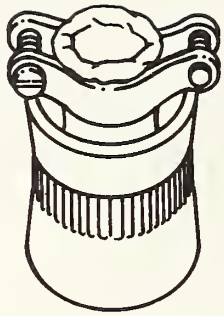
The supporting documentation file (Bin 22) contains a system error analysis.

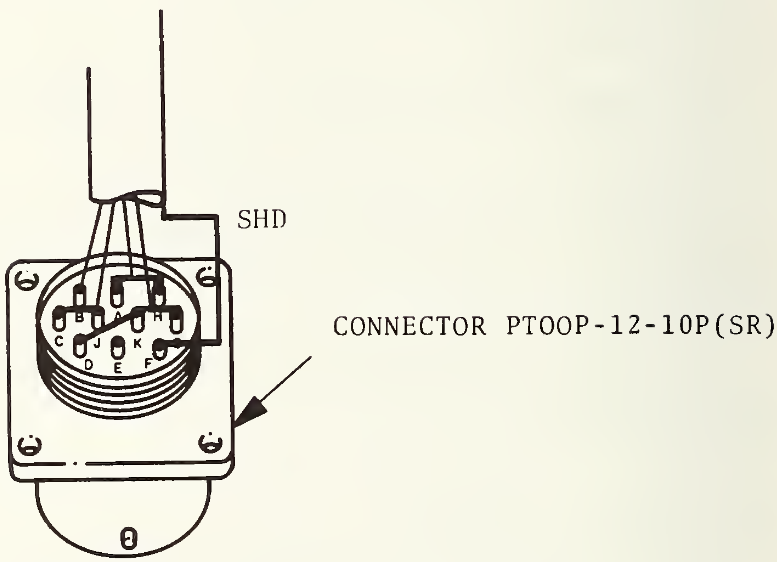
G1.2 SPECIAL HANDLING

In accordance with commercially available gage installation instructions, extreme care should be used during the gage installation.

G1.3 THEORY OF OPERATION

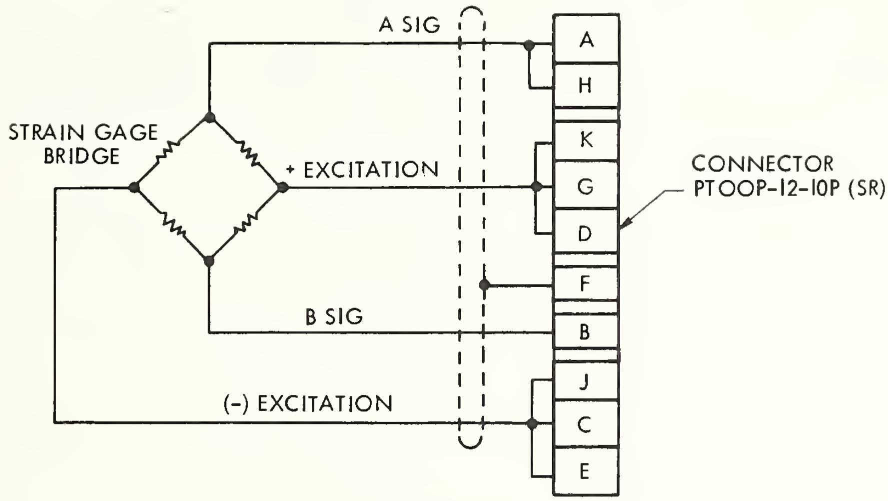
The Strain measurement system operates on a variable resistance principle. The resistance of the gage, nominally 120 or 350 ohms,





NOTE: POT ASSEMBLED MODULE WITH DOW CORNING SYLGARD 186 OR EQUIVALENT

FIGURE G1-1. STRAIN CONNECTOR ASSEMBLY, TSC MODEL SCA-1



4 ACTIVE ARMS 10 WIRE HOOK-UP
EXTERNAL SENSE
EXTERNAL SHUNT CALIBRATION

Figure G1-2. Strain Gage Electrical Hookup, TSC Model SCA-1 varies as a function of the gage elongation. By bonding the gage to the test piece, the actual strain in the test piece is transmitted to the gage. To increase the sensitivity of the system, the gage is mounted in a bridge circuit. Additional amplifying circuits produce a usable signal level.

G1.4 SHIELD/GROUND TECHNIQUE

The proper shield and ground connections are shown in Figure G1-3. It is noted that the strain connector assembly case is not connected to the circuitry. As a result, grounding of this case is optional.

G1.5 FUNCTIONAL WIRE LIST SUMMARY

Figure G1-4 shows the pin-to-pin connections for the system. For detailed schematics of each component, the reader is referred to the supporting documentation.

G1.6 MODE CARD SETUP

Because of the flexibility allowed when installing a strain gage system, the reader is referred to the manufacturer's instruction manual for the mode card. The card can be custom configured in the following areas:

a. Bridge completion resistors

b. Excitation programming resistors

c. Balance limiting resistors

d. Shunt calibration resistors

e. Low pass filter components

f. External voltage sensing jumpers

g. External calibration jumpers.

Provisions are not contained on the mode card for AC coupling of the strain gages. A special circuit to accomplish this coupling is shown in Figure G1-5.

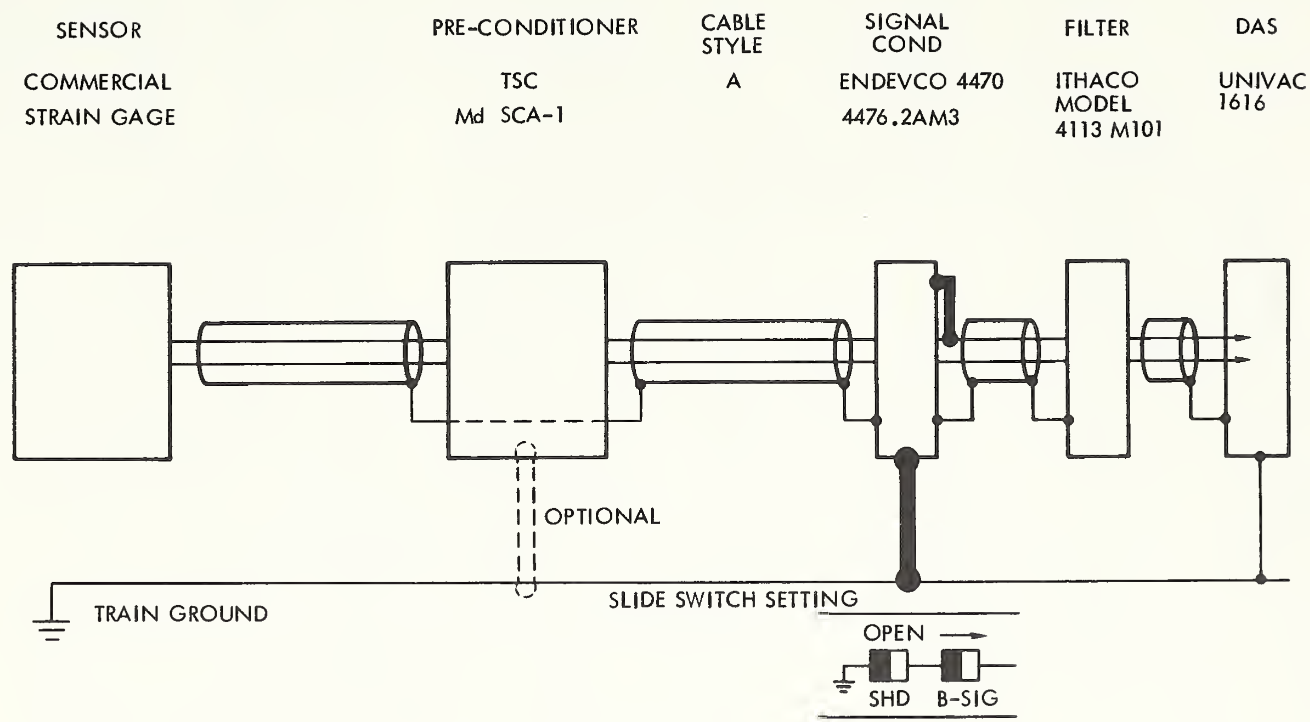


FIGURE G1-3. STRAIN MEASUREMENT SYSTEM SHIELD/GROUND CONNECTION

SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	D	+ CAL
18	X	X	C	C	- CAL
V	W	W	M	H	CAL SIGNAL
12(13)	m	MM	I	A	A SIGNAL IN
X	j	KK	N	B	B SIGNAL IN
Z	b	BB	J	J	- EXCITATION
N	c	CC	K	K	+ EXCITATION
W	d	DD	A	E	- SENSE
20	g	FF	B	G	+ SENSE
22	Y	Y	F	F	SHIELD
P	-	-	-	-	-10 VDC, POWER IN
R	-	-	-	-	+10 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT (COMMON)
22	f	EE	C	C	SHIELD

*Connector PT06-12-10P; Cable Style A

FIGURE G1-4. STRAIN MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

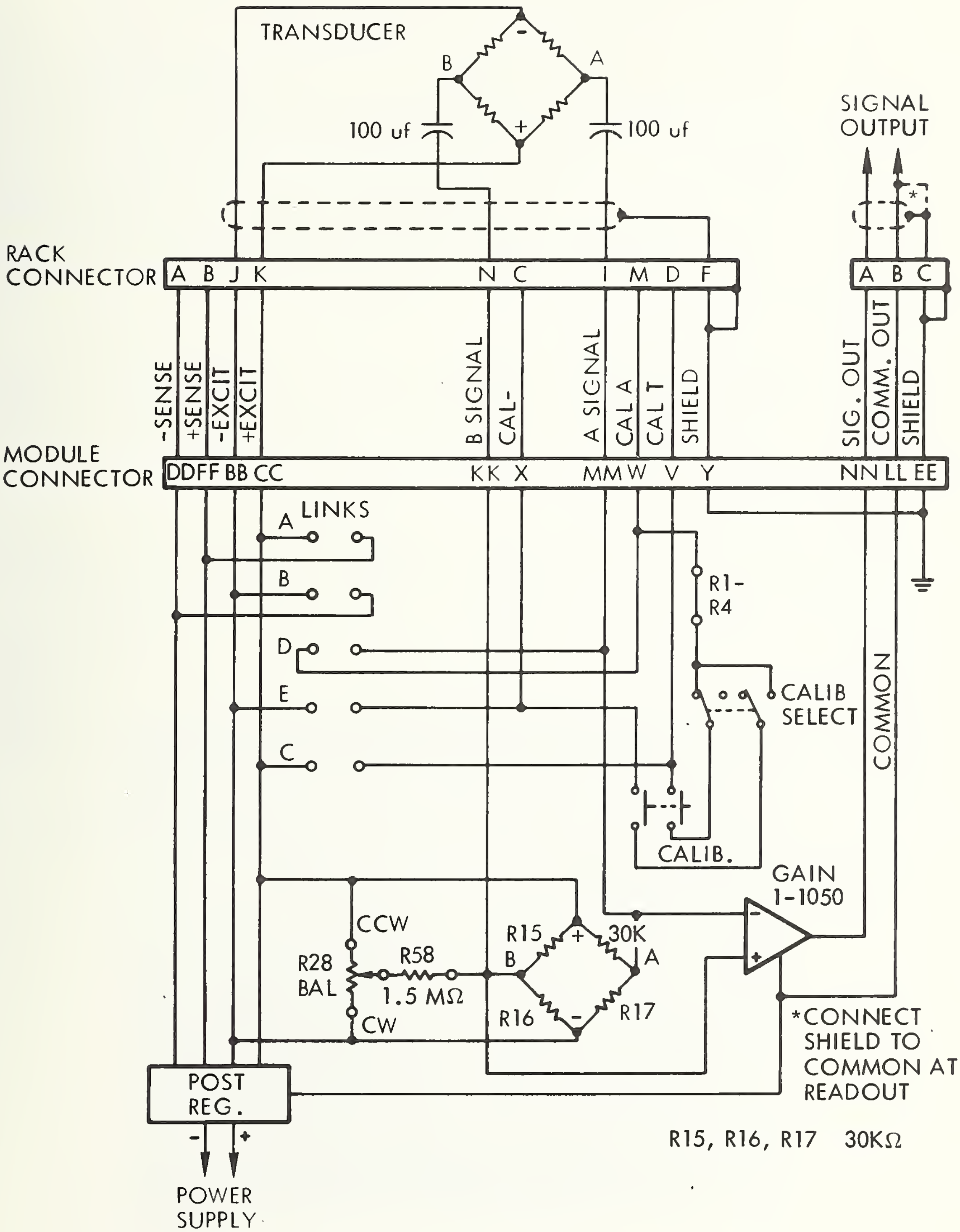


Figure G1-5. GVT Mode Card Setup for Strain Measurement

G1.7 VEHICLE MOUNTING

The installation of strain gages is an art that is well documented in manufacturer's literature. It will not be described in detail in this manual. The importance of a clean installation, proper soldering, and moisture proofing if required, is emphasized.

The location of the strain gages should be determined by a detailed stress analysis of the component or by experimentally determining areas of maximum stress using a strain indicator lacquer.

G1.8 CALIBRATION

G1.8.1 Primary. The most accurate method of calibrating a strain gage installation is to subject the test piece to a known load and observe the gage output. If possible, both static and dynamic loads should be used.

An alternate technique is to compute the sensitivity from well known first order equations. However, this technique does not account for errors in the gage installation and is not advisable.

G1.8.2 Secondary. After the gage installation is complete, shunt resistors mounted on the mode card can be used to simulate a strain. If properly chosen, the calibration resistors can be used to calibrate the mode card gain and also provide an indication of circuit continuity.

G2. DISPLACEMENT POTENTIOMETER MEASUREMENT SYSTEM

G2.1 DESCRIPTION

The Celesco Displacement Transducer is used to measure suspension system and coupler displacements under static and dynamic conditions.

Units are available in four different ranges. (0-1, 0-3, 0-5, 0-10 inch).

The displacement potentiometer measurement system consists of the following items:

a. Displacement Transducer......Celesco Md. PT-101

b. GVT Cable....................Style B

c. Signal Conditioner...........Endevco 4470/4471.3

Two views of the displacement transducer are shown in Figure G2-1.

Additional information (paragraph G2.9) includes a guide for selecting the proper sensor range and describes the test method for determining the maximum cable retraction acceleration.

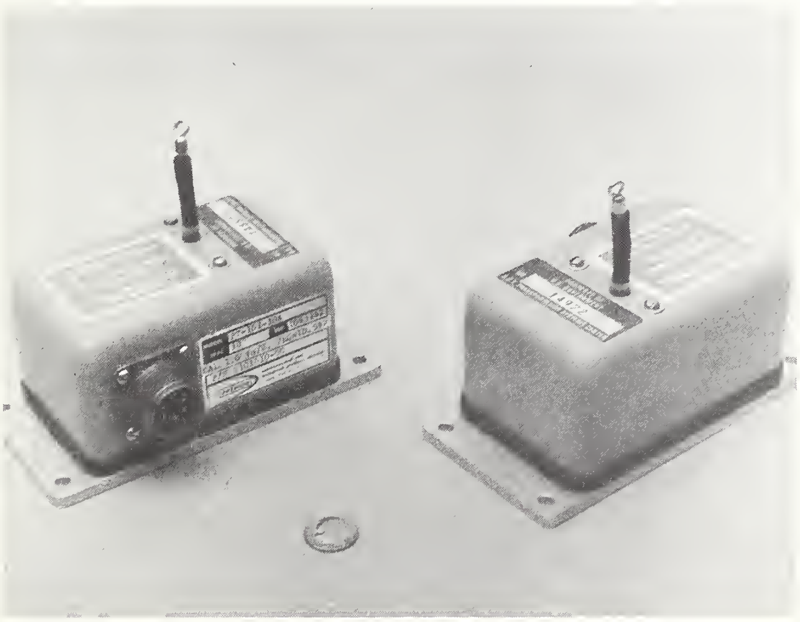


FIGURE G2-1. FRONT AND REAR VIEWS OF DISPLACEMENT TRANSDUCER MODEL PT-101

The supporting documentation file contains the following items (Bin 23):

a. System Error Analysis

b. Mfg. Data Sheet........Celesco Disp. Pot Model PT-101.

G2.2 SPECIAL HANDLING

Each unit has a spring restrained extension cable.

CAUTION
DO NOT LET THIS CABLE SNAP BACK INTO THE TRANSDUCER.

Damage may result. As a precaution, always grasp the extension cable around the rubber sleeve to minimize the chance for slipping.

To prevent unnecessary wear of the potentiometer, the extension cable should only be affixed to the vehicle during actual testing.

If the static position of the sensor extension cable is not at the mid-point of the sensor travel, dynamic displacements may exceed the sensor range. The changing of vehicle test weights will affect this static displacement. If the cable is too near an endpoint, a mechanical adjustment is necessary.

G2.3 THEORY OF OPERATION

The displacement transducers provide an electrical signal proportional to the linear movement of a stainless steel extension cable. The linear extension of the cable causes a spool inside the unit to unwind. Cable retraction is accomplished by a constant force spring motor acting on the spool. The rotation of the spool is detected by a potentiometer coupled to the spool. By impressing a fixed voltage across the potentiometer, the wiper provides a voltage divider effect with the output signal proportional to a cable displacement.

Adjustment of the excitation voltage and electrical zero is accomplished on the Endevco 4470 system.

G2.4 SHIELD/GROUND TECHNIQUE

The case of the sensor is electrically isolated from the sensor circuitry and may be grounded or floated at the option of the user on most applications. The signal low to shield connection is made on the 4942 rack switch buss by closing the "B SIG" switch. The connection to train ground is accomplished by closing the "SHD" switch. (See Figure G2-2.)

In areas of high electrical noise a more sophisticated low-noise shield/ground technique may be required. The case of the instrument must be floated from train ground. If noise is still being observed, electrically connect the sensor case to the GVT cable shield.

G2.5 FUNCTIONAL WIRE LIST SUMMARY

Figure G2-3 shows the pin-to-pin connections for the system. For detailed schematics of each component the reader is referred to the supporting documentation.

G2.6 MODE CARD SETUP

The potentiometer conditioner mode card 4471.3, is used with this system. A trim pot is added to allow fine adjustment of the excitation voltage. The front panel and circuit board are shown in Figure G2-4.

With Jumper "A" removed, a voltage programming resistor R12, consisting of a 30.9 kohm fixed resistor and a 5 kohm trim pot, is added. This provides a stable, fine adjustment of the excitation voltage between 9.7 and 11.2 volts DC.

Install Jumper R11, Remove R10.

Select two matched (± 1 ohm) stable resistors approximately 250 ohms each. Install in positions R1 and R9. These resistors provide an excitation midpoint reference voltage with the Cal switch depressed. In this manner, the static offset displacement of the sensor can be determined.

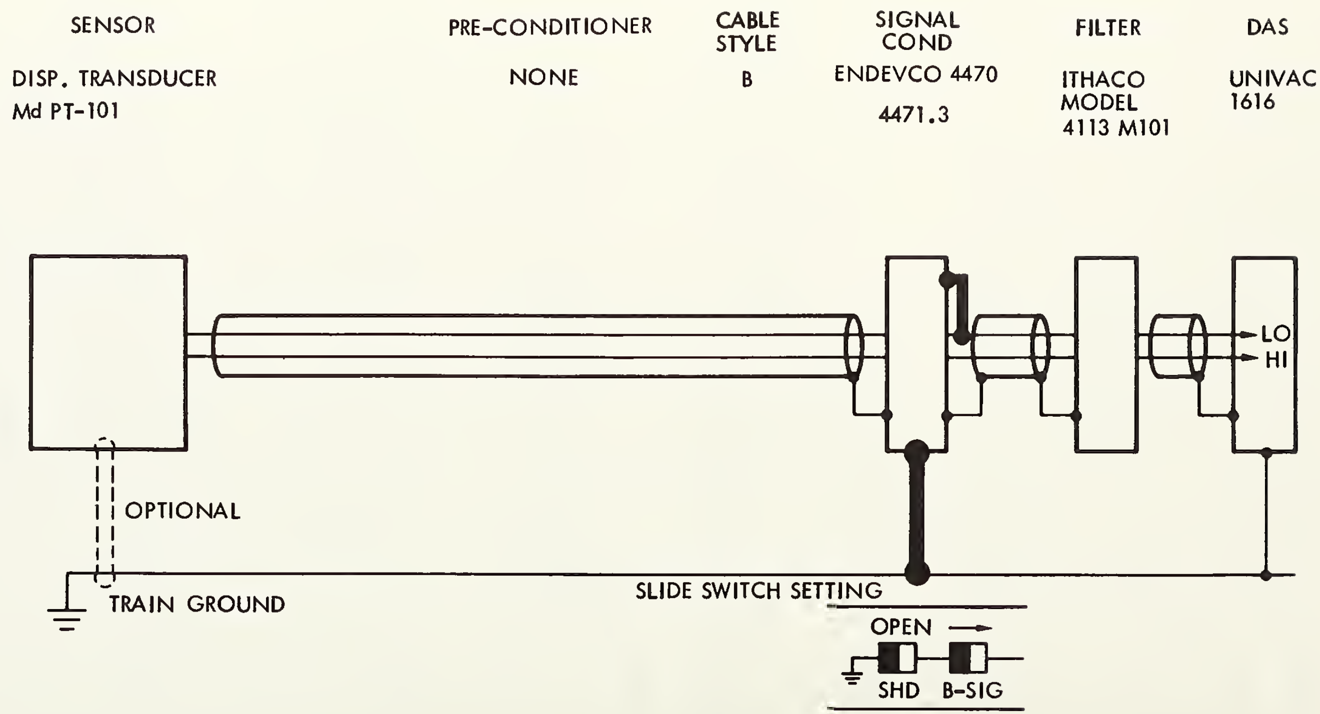


FIGURE G2-2. POTENTIOMETER DISPLACEMENT MEASUREMENT SYSTEM SHIELD/GROUND CONNECTIONS

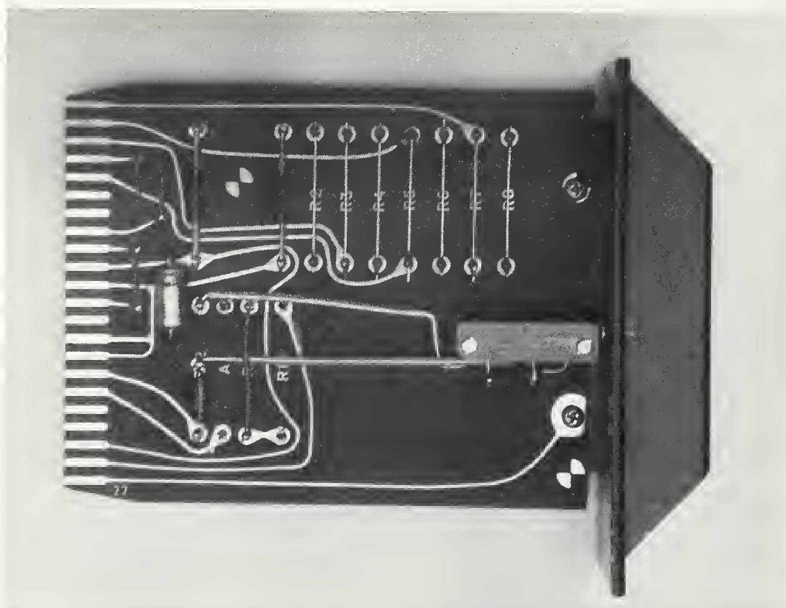
SIGNAL CONDITIONING INPUT					
MODE CARD	MASTER MOD.		SENSOR INPUT RACK	SENSOR*	FUNCTION
	MOD.	RACK			
U	V	V	D	-	
18	X	X	C	-	
V	W	W	M	-	
12(13)	m	MM	I	C	A SIGNAL IN
X	j	KK	N	-	
Z	b	BB	J	B	EXCITATION RETURN
N	c	CC	K	A	+10 VDC, EXCITATION
W	d	DD	A	-	
20	g	FF	B	-	
22	Y	Y	F	-	SHIELD
P	-	-	-	-	RETURN, POWER IN
R	-	-	-	-	+10 VDC, POWER IN

SIGNAL CONDITIONING OUTPUT					
MODE CARD	MASTER MOD.		SIGNAL OUTPUT, RACK	FILTER	FUNCTION
	MOD.	RACK			
21	n	NN	A	A	A SIGNAL OUT
Y	k	LL	B	B	B SIGNAL OUT
22	f	EE	C	C	SHIELD

*Connector MS3106E-14S-6S; Cable Style B

FIGURE G2-3. POTENTIOMETER DISPLACEMENT MEASUREMENT SYSTEM FUNCTIONAL WIRE LIST SUMMARY

Potentiometer Conditioner Unit



Circuit Board

FIGURE G2-4. POTENTIOMETER CONDITIONER MODEL 4471.3

Calibration resistors are not included in the setup because of the varying sensor sensitivities and the effects of the 60-foot long cables. A full scale signal at the mode card would not necessarily coincide with the full scale of the attached sensor.

G2.7 VEHICLE MOUNTING

The recommended mounting technique is shown in Figure G2-5. A solder lug is affixed to the member to be measured with an epoxy adhesive (Hysol 73C or equivalent) or mechanical fastener. The sensor is mounted as near as possible to the attachment lug with the extension cable axially aligned with the expected displacement to minimize sensor extension cable friction. Special

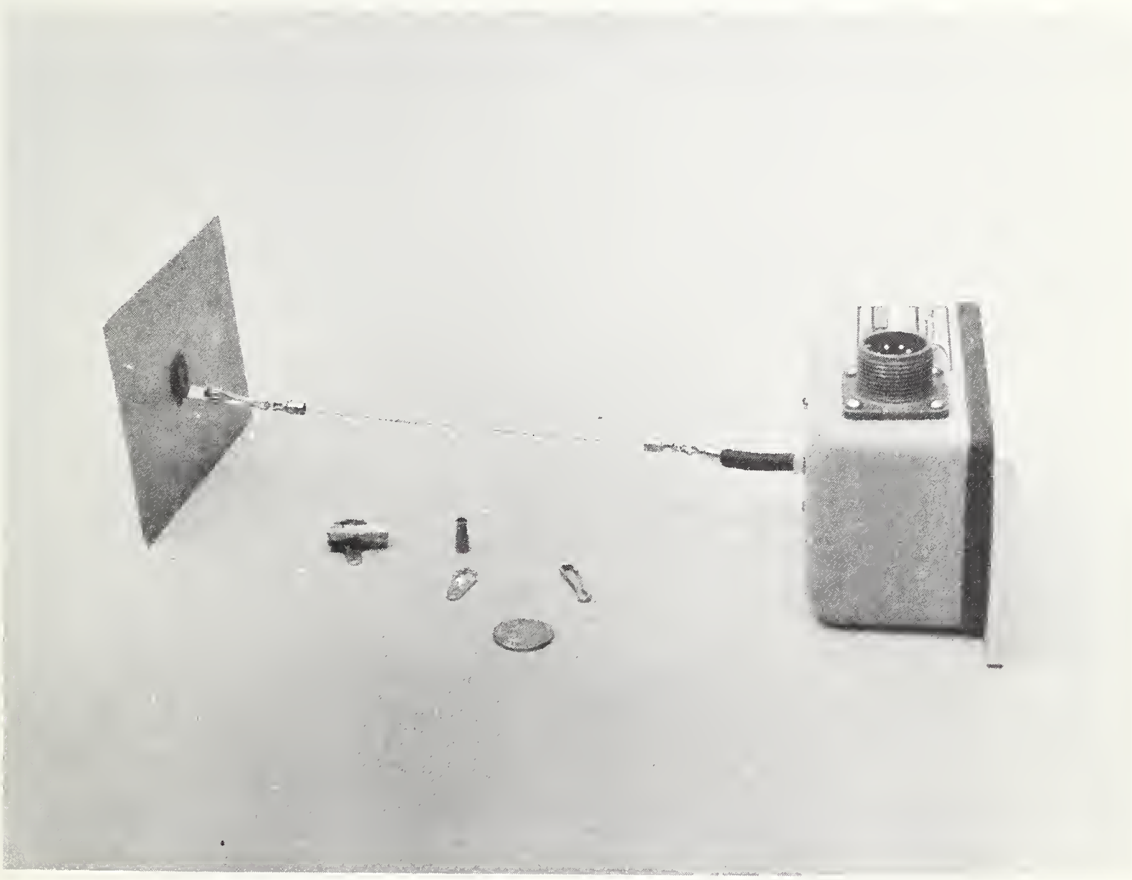


FIGURE G2-5. RECOMMENDED MOUNTING TECHNIQUE purpose brackets may be required to facilitate mounting of the sensor case. These brackets may be mounted to the vehicle with existing fasteners or with an epoxy adhesive.

NOTE

> Prior to the use of an adhesive, the area must be thoroughly cleaned to remove rust, oil or other surface contaminants.

The sensor extension cable must be attached to the vehicle member such that the midpoint of the expected displacement amplitude corresponds to the midpoint of the sensor travel. This will minimize the possibility of exceeding the sensor range and damaging the sensor. When measuring spring systems, the midpoint may be assumed to be the static position. On other measurements such as coupler or carbody motions, the displacement midpoint must be estimated prior to the attachment of the sensor cable.

If possible, the cable eyelet should be directly attached to the member lug. In most cases, however, the sensor/lug orientation will not permit a direct attachment. Use of an auxiliary coupling cable is dictated in this event. The coupling cable (0.011 diameter) has approximately 75 percent of the strength of the sensor cable and acts as a fusible link if the sensor cable is overextended.

To minimize lateral vibration of the auxiliary and extension cable, the natural frequency of the cable system should be significantly above the natural frequencies of the member to be measured (typically 10 Hz max for suspension systems). The natural frequency of the cable system can be conservatively estimated by the following formula referring to Figure G2-6.

$$\frac{1}{f_n^2} = \frac{4}{Tg_c}\left[\frac{(\ell_1\ell_2)\ \pi^2 m}{\ell} + \ell^2 e\right]$$

where f_n = Natural Frequency, Hz

T = Spring Force, lbf

m = mass of the eyelet and rubber sleeve on the extension cable 0.0066 lbm

p = mass per unit length of extension cable 4.7×10^{-5} lbm/in. for 0.14 in. dia. cable

$$g_c = 32.17 \frac{\text{lbm ft}}{\text{lbf } S^2}$$

The tension, T, of the available units is a function of the range. The experimentally determined values are listed in Table G2-1. Also listed are the maximum sinusoidal peak accelerations that each sensor can track.

TABLE G2-1. EXPERIMENTAL TESTS RESULTS

Range in.	Tension T lb.	Peak Retraction Accel. G
1	1.15	30
3	0.93	25
5	0.51	15
10	1.19	30

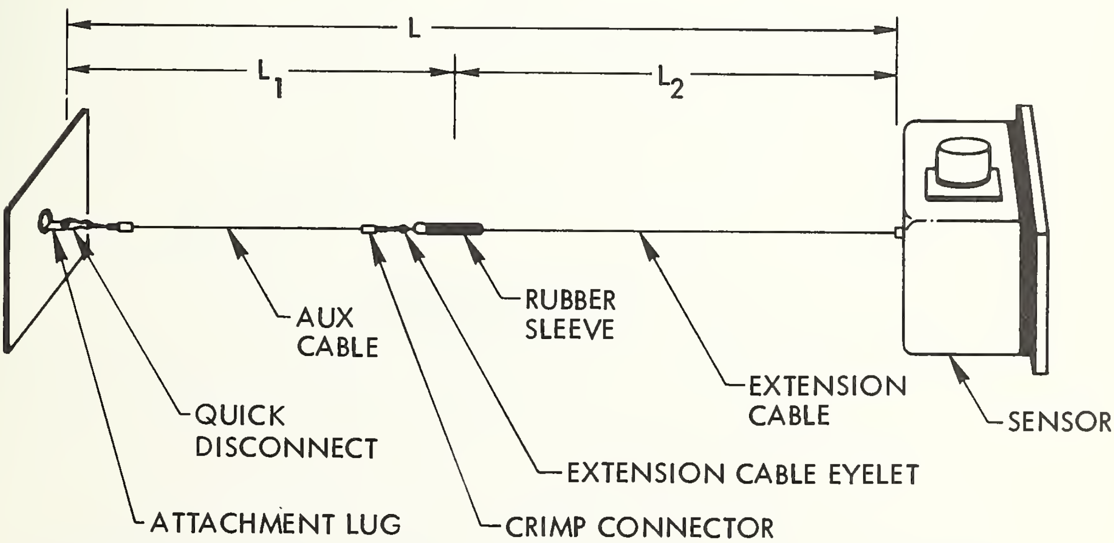


FIGURE G2-6. AUXILIARY COUPLING CABLE AS USED IN WIDELY SEPARATED PARALLEL PLANES SITUATION

From the equation, it is obvious that large masses such as heavy connecting links should not be placed on the extension/auxiliary cable system. Consequently, the mass of the crimp connectors should be kept small and any quick disconnect features should be attached to the lug, not the eyelet. In addition, the length of the cable system should also be minimized.

To further minimize the measurement error the loops used to attach the auxiliary cable should be kept tight. If the loops are loose, a spring deflection effect results. This is shown in Figure G2-7.

If the axial alignment of the sensor cable is not possible, the use of pulleys or guide bars may be required. To prevent undue wear on the extension cable, utilize the guides only on auxiliary coupling cables. In addition, use only large radius (<1/2 in.) guides.

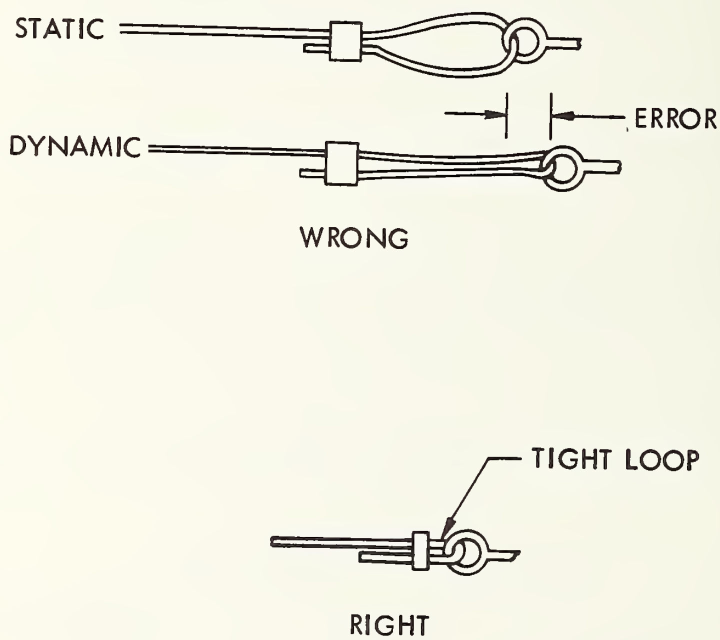


FIGURE G2-7. AUXILIARY COUPLING CABLE END-LOCK TECHNIQUE

The special equipment needed to mount the sensor system is listed below:

a. Epoxy kit with surface prep tools

b. Attachment lugs (solder type may be used)

c. Quick disconnect fittings

d. Crimp tubes (electrical variety may be used)

e. Auxiliary cable, stainless steel

f. Sensor mounting bracket.

No permanent modification to the test vehicle is required as the epoxy adhesive may be removed after the test. It may be necessary to reapply a protective paint finish to the test members depending upon the method of surface preparation.

G2.8 CALIBRATION

G2.8.1 <u>Primary</u>.

a. <u>Equipment Required:</u>

1. Power Supply 10 VDC (4470 System)

2. Digital Voltmeter - 0.01% Differential Floating

3. Oscilloscope

4. Height Gage - Starrett No. 254 or equivalent

5. Misc. Hardware

6. Test Cable and Mode Card

b. <u>Procedure</u>

1. Setup the system as shown in Figure G2-2 with proper shield and ground connections. A floating, differential voltmeter should be connected to the Endevco 4470 monitor terminals.

2. Attach the sensor extension cable to the height gage slider arm.

3. Record the excitation voltage used during the test, VET, and the sensor serial number on the data sheet. (See Figure G2-8).

4. Set the height gage such that the sensor extension cable is in the midpoint of its travel.

5. Zero the Endevco 4470 using the Balance pot.

6. Raise the height gage slider arm to fully extend the sensor cable.

7. Record the output signal, Y, in this position opposite Xprog - 5. (Refer to Figure G2-8).

8. Lower the height gage slider arm in increments corresponding to 0.1 full range and record the output signals at these points.

9. Determine the hysteresis by approaching the same gage setting from different directions. Enter in column Y' test. Record maximum value in millivolts opposite "hysteresis" on data sheet.

10. Slowly raise the height gage and note any steps in the output voltage. Record the maximum value at "Resolution."

11. Viewing the output trace on the scope, record the maximum peak-to-peak noise level.

12. The actual sensitivity of the sensor system is a function of the excitation voltage, cable length, and sensor pot characteristics. To normalize the sensitivity, that is, to cause the system to output exactly 1.000 volt per inch for a 10 inch range sensor, a computer program was generated to determine the optimal excitation voltage for each sensor system.

The program also calculates the output deviation error from a best fit straight line (least squares).

DISPLACEMENT POTENTIOMETER DATA SHEET DATE__________
CELESCO MODEL PT101_______ TECH__________

COMPUTED OPTIMAL EXCITATION VOLTAGE__________ S/N__________

X in. Test	X Prog	Y Volt Test	Y Test			
	5.					
	4.					
	3.					
	2.					
	1.					
0.00	0.					
	-1.					
	-2.					
	-3.					
	-4.					
	-5.					
	TEST EXCITATION VOLTAGE (VET)__________					
	Resolution__________ mV					
	Hysteresis__________ mV					
	Noise__________ mV p-p					
	Linearity__________ % FS					

FIGURE G2-8. SAMPLE DATA SHEET

A copy of the FORTRAN program is shown in Figure G2-9. The test excitation voltage and serial number are input followed by the y values in order. The computer optimal excitation voltage, VEC, and the max linearity error are output.

Affix a tag to each sensor stating the sensitivity at the optimal excitation voltage as shown below.

0.1 inv @ V_{ex} = 10.597

Sample Cal Label

G2.8.2 <u>Secondary</u>. Calibration of the displacement measurement system consists of noting the "Cal" label on the sensor and getting the appropriate excitation voltage on the mode card. The static displacement of the sensor can be determined by depressing the Cal pushbutton switch and adjusting the Balance pot to obtain a zero volt output. Release the Cal switch and the sensor output voltage may be read. If the value exceeds $\pm$4.0 volts, a mechanical adjustment of the sensor extension cable may be necessary.

NOTES

1. Depressing the Zero pushbutton switch reduces the excitation voltage to zero.

2. No calibration resistors are added to the cards so that erroneous Cal readings would not be obtained if the sensor was changed.

G2.9 ADDITIONAL INFORMATION

G2.9.1 <u>Selection of Proper Sensor Range</u>. Each of the four sensor ranges exhibit distinct chracteristics which will dictate the selection. The primary calibration sheets clearly indicate that each sensor has a different set of values for resolution, linearity, hysteresis and noise. In addition, the maximum cable retraction acceleration rates vary with different ranges.

```
=TYPE LSDISP
C       PROGRAM WILL COMPUTE THE OPTIMAL EXCITATION VOLTAGE AND ZERO
C       OFFSET VOLTAGE TO MAXIMIZE LINEARITY.
        REAL LIN
        DIMENSION X(11),Y(11),YN(11),LIN(11)
  5     TYPE 1Ø
 1Ø     FORMAT(1X,'TYPE TEST EXCITATION VOLTAGE & SERIAL NUMBER',/)
        ACCEPT 15,VET,SN
 15     FORMAT(F,I)
        TYPE 20,VET,SN
 2Ø     FORMAT(1X,'VET=',F6.3,2X,'SN=',I8)
        XS=Ø
        XX=Ø
        XY=Ø
        YS=Ø
        X(1)=5.
        DO 24 J=2,11
        X(J)=X(J-1)-1.
 24     CONTINUE
        DO 5Ø N=1,11
        TYPE 25,N
 25     FORMAT(1X,'TYPE Y(',I2,')',/)
        ACCEPT 3Ø,Y(N)
 3Ø     FORMAT(F)
        TYPE 35,N,X(N),N,Y(N)
 35     FORMAT(1X,'X(',I2,')=',F6.3,2X,'Y(',I2,')=',F6.3,/)
        XS=XS+X(N)
        XX=XX+(X(N)*X(N))
        XY=XY+(X(N)*Y(N))
        YS=YS+Y(N)
 5Ø     CONTINUE
        C=N*XX-XS*XS
        A=(N*XY-XS*YS)/C
        B=(YS*XX-XY*XS)/C
        VEC=VET/A
        ZC=(Y(6)-B)/A
        TYPE 55,A,B,VEC,ZC
 55     FORMAT(/,1X,'A=',F7.3,2X,'B=',F7.3,2X,'VEC=',F7.3,2X,'ZC=',F7.3)
        TYPE 6Ø
 6Ø     FORMAT(1H-,1X,'I',5X,'YN',6X,'LIN',/)
        DO 7Ø I=1,N
        YN(I)=(Y(I)-B)/A
        LIN(I)=(YN(I)-X(I))*1Ø.
        TYPE 65,I,YN(I),LIN(I)
 65     FORMAT(1X,I2,1X,F7.3,2X,F7.3,/)
 7Ø     CONTINUE
        BLIN=AMAX1(LIN(1),LIN(2),LIN(3),LIN(4),LIN(5),LIN(6),LIN(7),
     1  LIN(8),LIN(9),LIN(1Ø),LIN(11))
        SLIN=AMIN1(LIN(1),LIN(2),LIN(3),LIN(4),LIN(5),LIN(6),LIN(7),
     1  LIN(8),LIN(9),LIN(1Ø),LIN(11))
        XLIN=(BLIN-SLIN)/2.
        TYPE 75,XLIN
  75    FORMAT(1X,'SYSTEM LINEARITY IS + OR -',F7.3,1X,'%'/////)
        GO TO 5
        END
```

FIGURE G2-9. FORTRAN PROGRAM TO DETERMINE OPTIMAL TEST EXCITATION VOLTAGE (VET)

NOTE

> The most important consideration is to select a range adequate to prevent damage to the transducer during static and dynamic loading.

To facilitate sensor selection, the useful measurement range versus frequency is plotted in Figures G2-10 through G2-13 for the four different ranges, respectively. The minimum displacement represents the root-sum-square value of the experimentally determined resolution, linearity, hysteresis and noise. This value is the minimum displacement of the sensor cable that can be accurately measured independent of frequency.

The upper boundary of the curve is the maximum cable acceleration plotted as peak displacement versus frequency. A sinusoidal acceleration is assumed to derive the coordinates.

The maximum peak displacement of a sinusoidal motion that can be measured forms the right boundary of the useful sensor range. It is assumed that the displacement midpoint coincides exactly with the sensor midpoint.

No lower boundary to the curve exists as the sensors will measure static (DC) displacements.

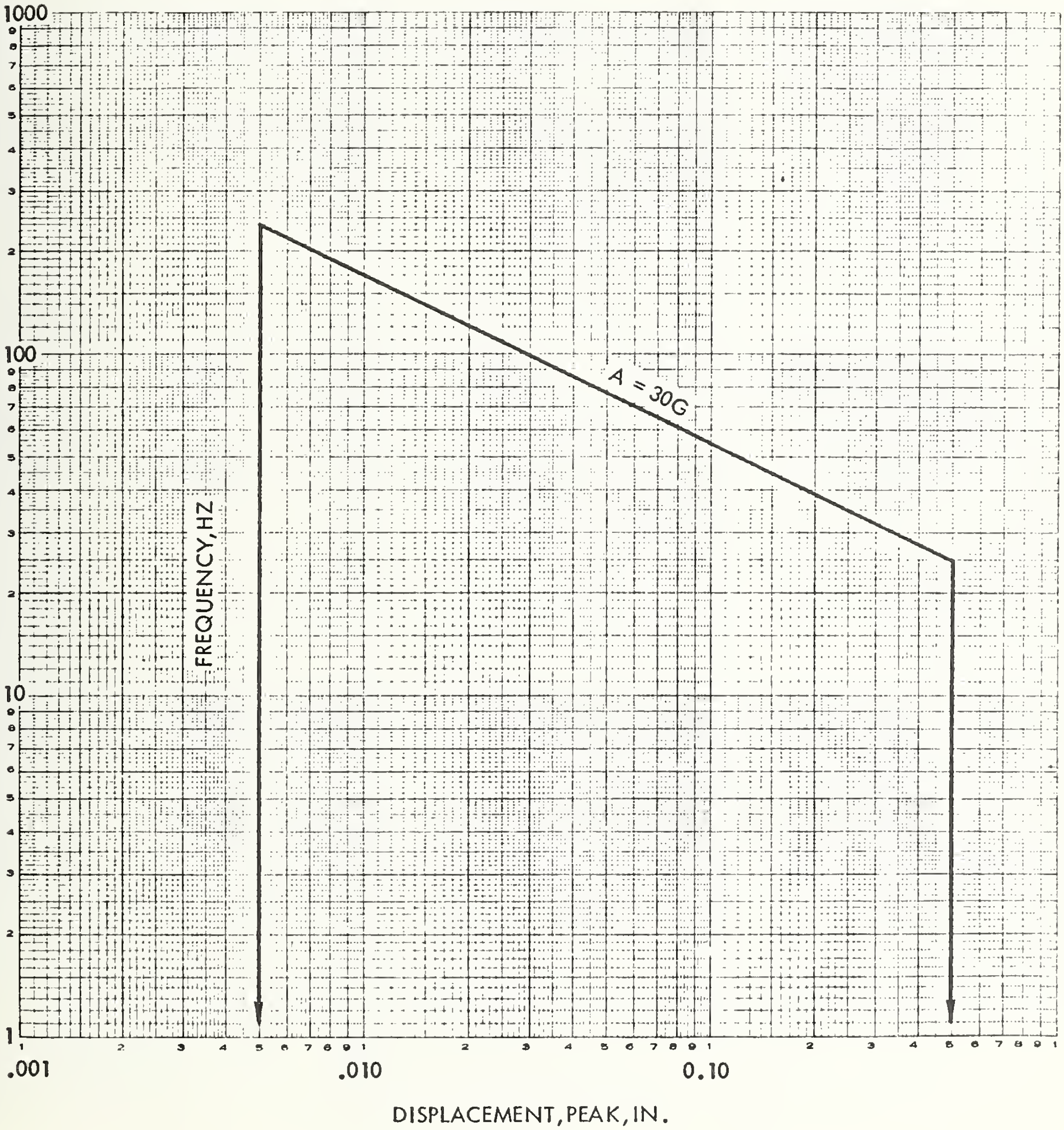


FIGURE G2-10. USEFUL MEASUREMENT RANGE FOR MODEL PT101-1A POTENTIOMETER DISPLACEMENT SENSOR

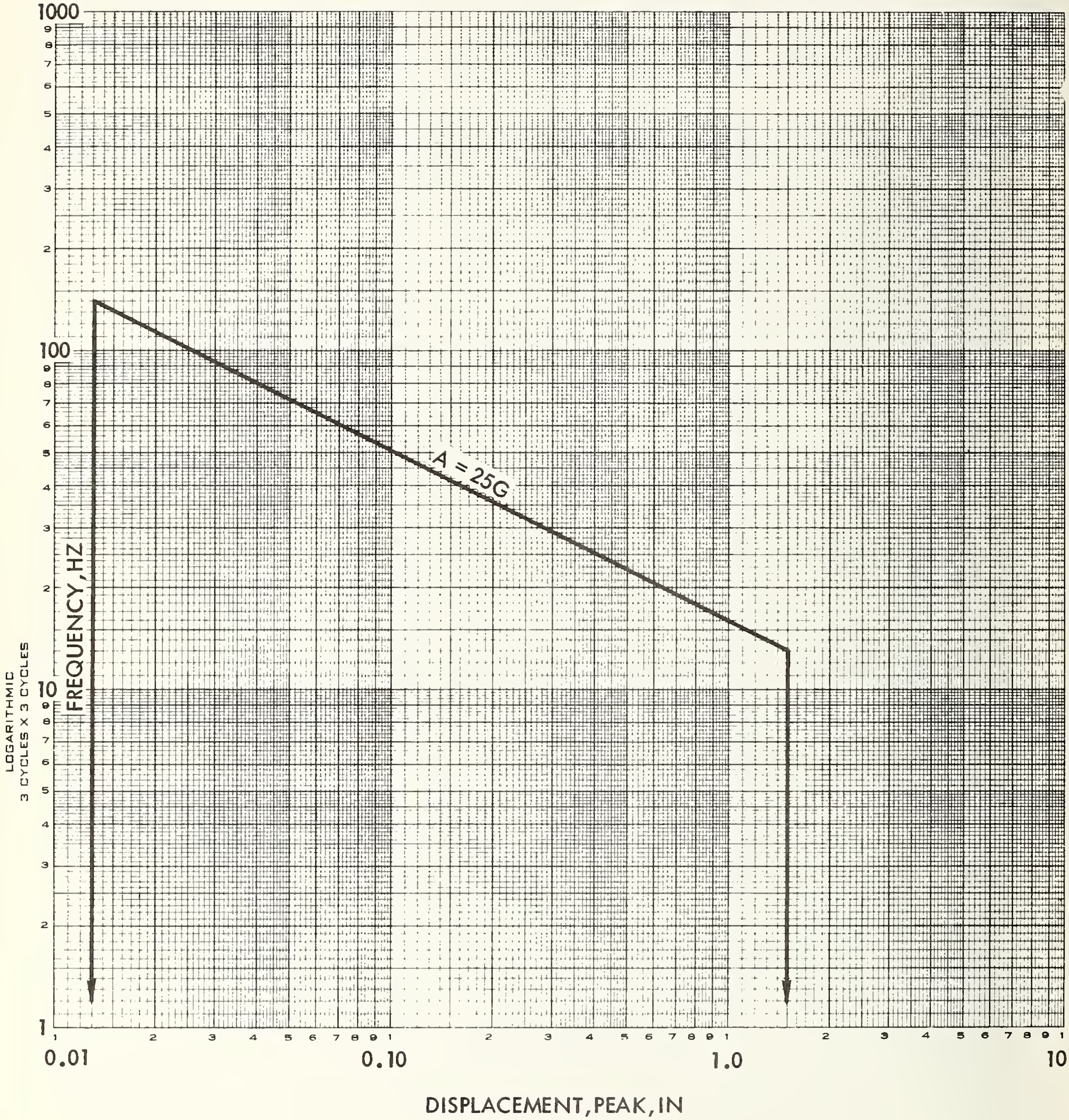


FIGURE G2-11. USEFUL MEASUREMENT RANGE FOR MODEL PT101-3A
POTENTIOMETER DISPLACEMENT SENSOR

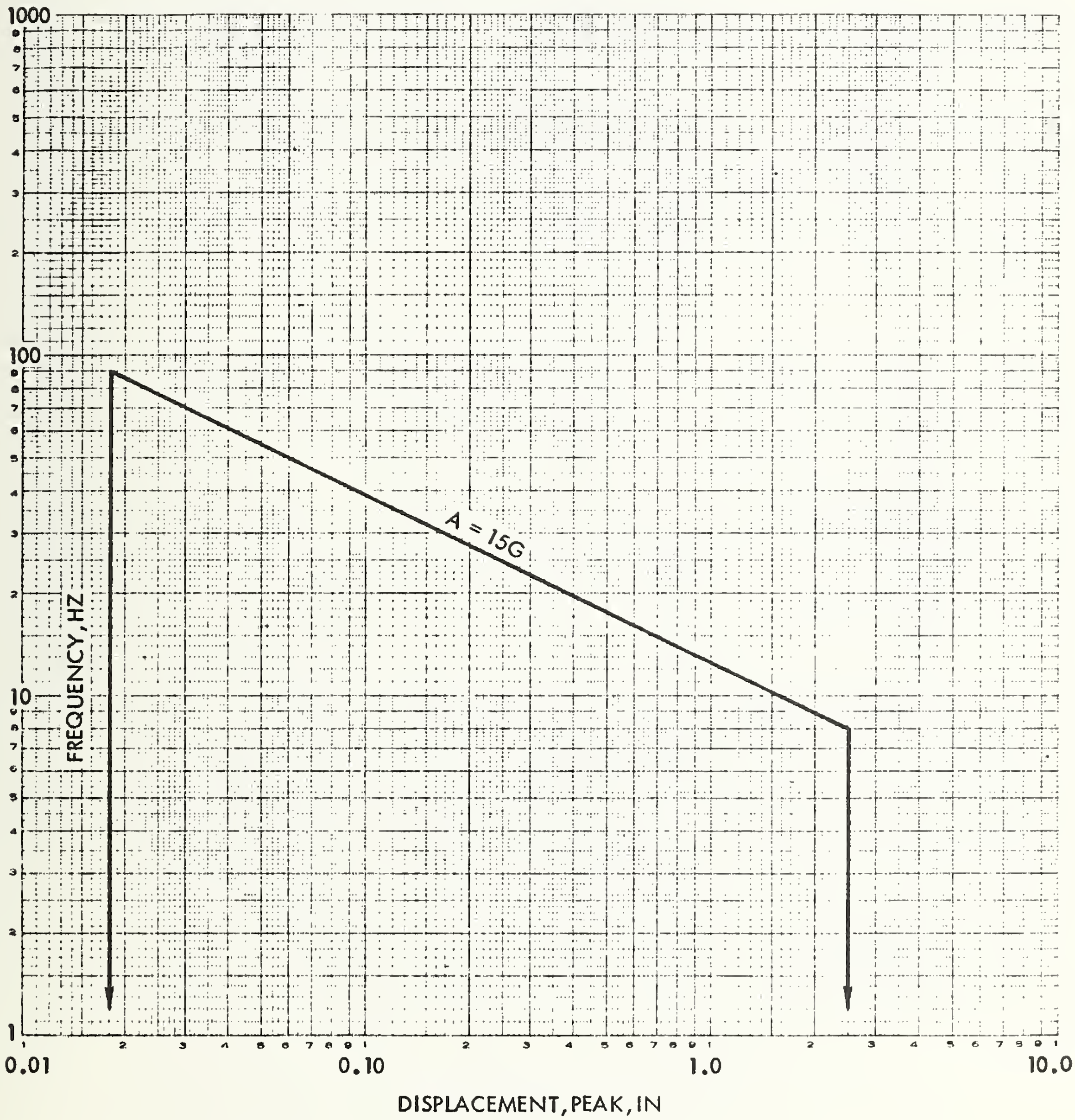


FIGURE G2-12. USEFUL MEASUREMENT RANGE FOR MODEL PT101-5A POTENTIOMETER DISPLACEMENT SENSOR

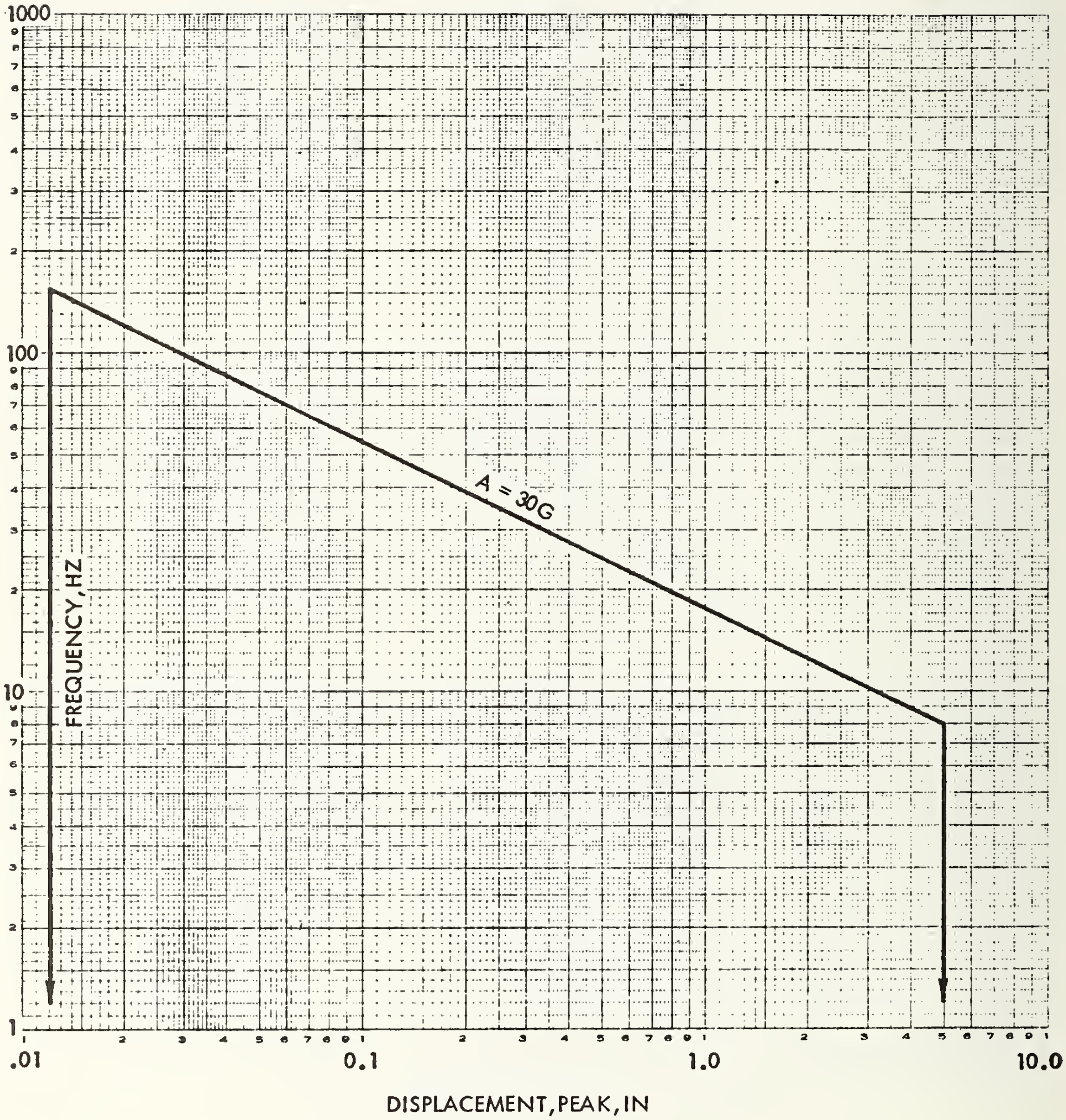


FIGURE G2-13. USEFUL MEASUREMENT RANGE FOR MODEL PT101-10A POTENTIOMETER DISPLACEMENT SENSOR

G3. NON-CONTACT DISPLACEMENT MEASUREMENT SYSTEM

G3.1 DESCRIPTION

The KAMAN Sciences KD2300 measurement systems are used to measure the distance between a sensor face and a metallic target. Sensors with linear ranges from 0.05 to 0.5 inch; 0.1 to 1.1 inches and 0.2 to 2.2 inches, are available. Two of the low-range sensors are shown in Figure G3-1. The systems can be used to measure car body, suspension, or even rotating wheel measurements. The greatest limitation on their use is that they must be calibrated in-situ or in simulated in-situ conditions. Factors to be simulated include target material and shape and surrounding metallic features.

The Non-Contact measuring system includes the following items:

a. Probe..........................KAMAN KD1105/1106

b. Cable..........................KAMAN 850615-015

c. Oscillator/Demodulator.........KAMAN KD2300

d. GVT Cable......................Style D

e. Signal Conditioner.............Endevco 4470/4475.1 with TSC Mod K

The supporting documentation file contains the following applicable items (Bin 24):

a. System Error Analysis

b. Data Sheet.....................Kaman Disp. Systems Md KD-2300-10CU Md KD-2300-12CU

c. Mfg. Instruction Manual........Md KD-2300-10C Md KD-2300-10CU

d. Tech Note......................KAMAN Eddy Current Displacement Transducers

e. Application Note...............Synchronization of KD2300 units to prevent beating. (TSC modification description)

G3.2 SPECIAL HANDLING

Refer to Appendix A, paragraph A3-2.

G3.3 THEORY OF OPERATION

Refer to Appendix A, paragraph A3-3.

G3.4 SHIELD/GROUND TECHNIQUE

Refer to Appendix A, paragraph A3-4.

G3.5 FUNCTIONAL WIRE LIST SUMMARY

Refer to Appendix A, paragraph A3-5.

G3.6 MODE CARD SETUP

Refer to Appendix A, paragraph A3-6.

G3.7 VEHICLE MOUNTING

Refer to Appendix A, paragraph A3-7.

G3.8 CALIBRATION

G3.8.1 Primary. Because each unit must be calibrated in-situ, a primary calibration is not appropriate. However, specific checks should be performed to ensure that the following parameters are within specifications:

a. Frequency Response

b. Temperature Sensitivity

c. Noise.

G3.8.2 Secondary. Detailed calibration instructions are given in the system instruction manuals. Calibrated distances can be derived from a use of a micrometer fixture, by using ceramic spacers, or by using a machinist's height gage as shown in Figure G3-2.

FIGURE G3-1. LOW RANGE SENSORS

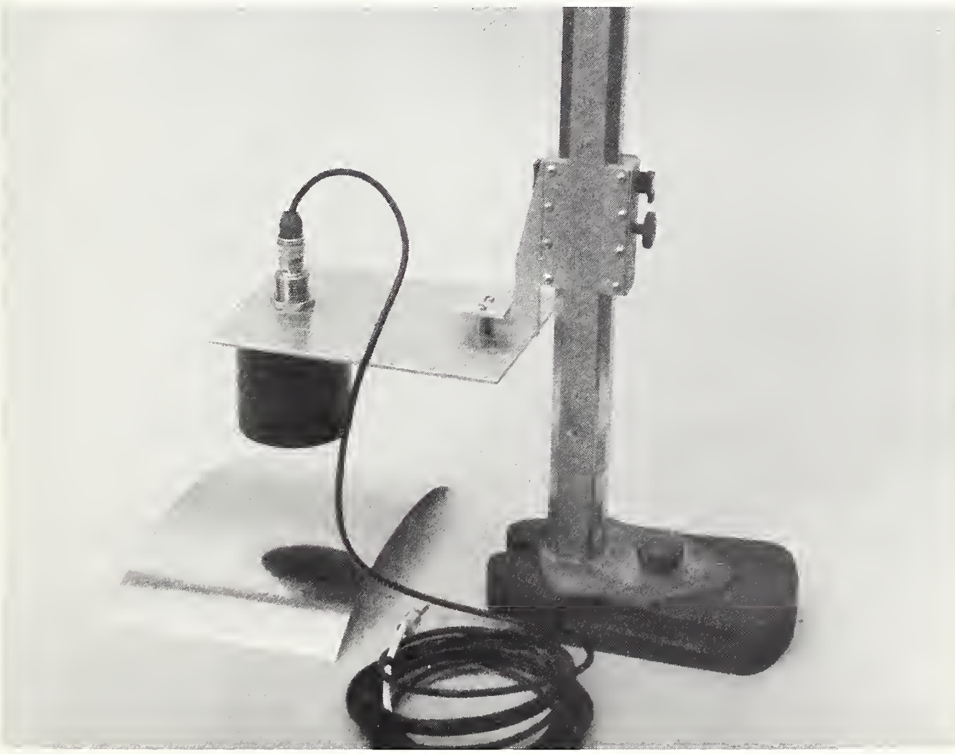


FIGURE G3-2. LABORATORY SIMULATION OF IN-SITU CALIBRATION

The previous calibration techniques require significant time as all four control potentiometers interact. A simplified swept displacement technique has been developed. Equipment required includes:

a. A second electrical displacement measurement.

b. A storage oscilloscope.

c. Sensor or target displacing means such as a slide or pivot mechanism.

A sample mechanical layout is shown in Figure G3-3. A block diagram of the electrical hookup is given in Figure G3-4.

Connect the alternate displacement measurement instrument output to the scope horizontal input. Manually exercise the probe slide lock-to-lock and adjust the horizontal gain and position until the full scale probe movement corresponds to the full horizontal trace width on the screen (usually 10 centimeters).

Input the probe output to be calibrated on the vertical scope input. Set the desired zero and scale factor using the scope controls. Manually exercise the mechanical system noting the scope trace. Adjust the O/D controls as required. Variations of this method include:

a. Move the target instead of the probe.

b. Motorize the mechanical system with a special purpose calibrator shown in Figure G3-5. A target is automatically oscillated back and forth within the probe field. A linear pot provides the horizontal axis scope input. The pot power and motor power are ±5 VDC. A control box determines the oscillation rate and provides the pot output.

Accuracy of the scope technique is estimated to be ±2 percent.

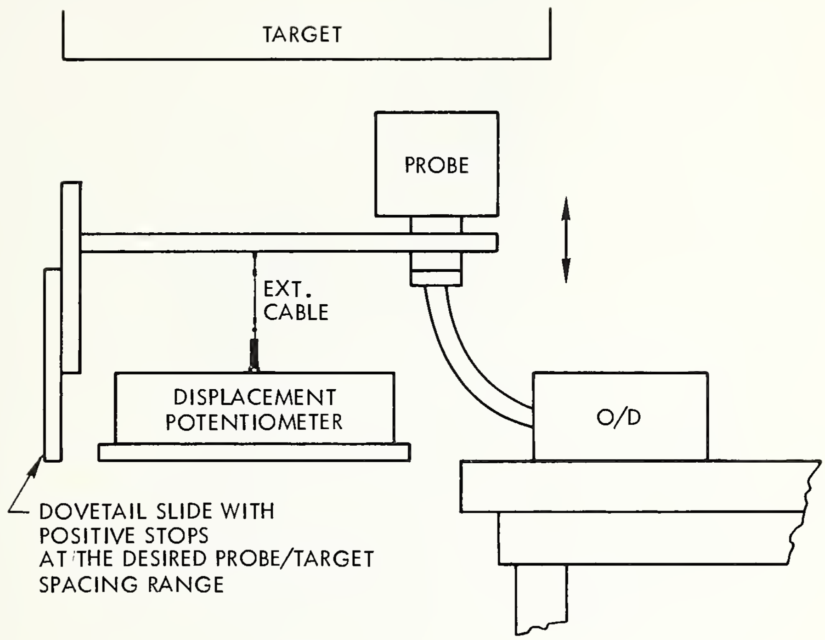


FIGURE G3-3. SAMPLE MECHANICAL LAYOUT FOR SWEPT CALIBRATION

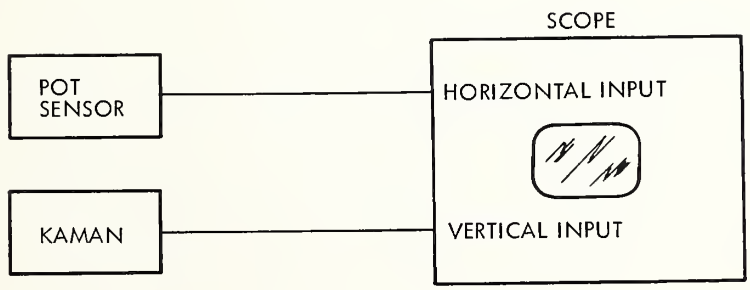


FIGURE G3-4. SWEPT CALIBRATION SETUP BLOCK DIAGRAM

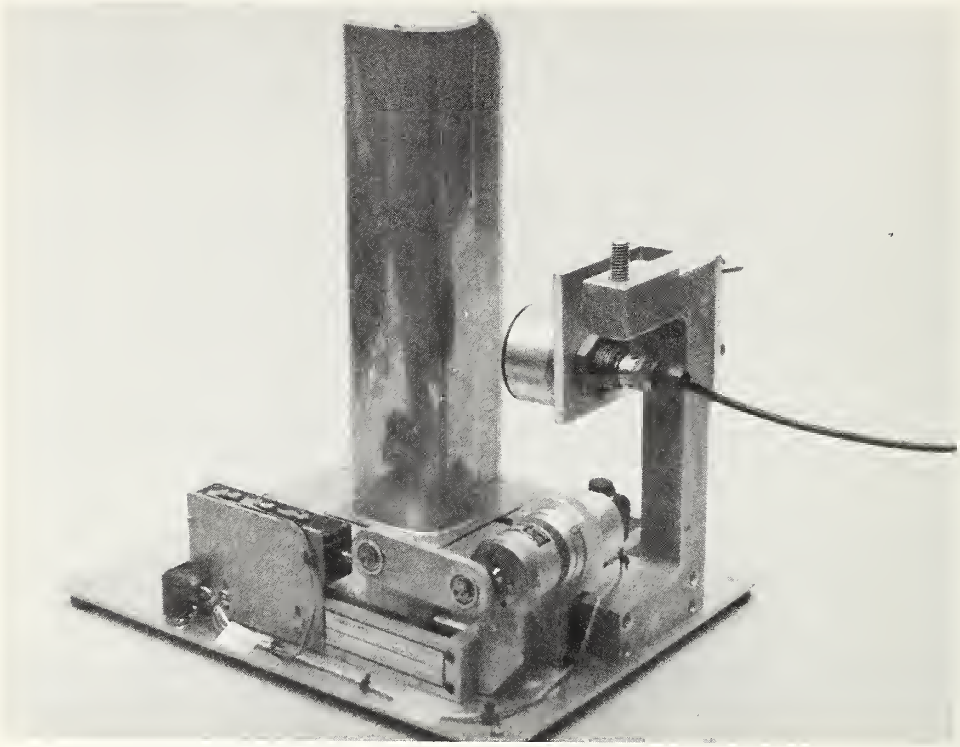


FIGURE G3-5. MECHANIZED TARGET MOVEMENT BENCH SETUP

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TRANSPORTATION SYSTEMS CENTER
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