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DRIVER PERFORMANCE MEASUREMENT AND ANAYLSIS SYSTEM (DPMAS)
Volume I Description and Operations Manual

Contract No. DOT-HS-359-3-733

August 1976

Final Report

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16. Abstract

A prototype Driver Performance Measurement and Analysis System (DPMAS) has been developed for the National Highway Traffic Safety Administration (NHTSA). This system includes a completely instrumented 1974 Chevrolet Impala capable of digitally recording, onboard, driver control and activity measures, vehicle motion variables, vehicle lane position, and driver psychophysiological measures. It also has a three-camera video system, including video tape, for recording the external visual scene and interior driver actions, and an electrohydraulic servo steering system for varying vehicle dynamics and steering ratio and applying external disturbances which force driver control.

This prototype system is intended to provide a research and application tool to demonstrate contemporary instrumentation and data acquisition techniques and to permit the effective execution of varied experimental and application programs such as driver behavior in various control tasks, studies of driver/vehicle/environment interactions, driver training and education, driver licensing and proficiency testing, and experiments on driver impairment such as induced by alcohol, drugs, medicines, or other stressors.

Documentation for the DPMAS is contained in 4 reports. The first, DOT HS-801 234, published in October 1974, develops and summarizes the measurement and hardware requirements which specified the original design concept and projected use of the system. This report, or manual, gives a general description of the completed DPMAS and shows how it should be operated to perform various experimental test scenarios. Although the manual is user oriented and directed toward the experimenter, the overall system description is of general interest. A second manual, entitled "DPMAS Design and Maintenance Manual," describes the technical details of the component subsystems for purposes of repair, modification, or duplication of all or parts of the DPMAS. The third manual, entitled "DPMAS Digital Data Sorting Program," provides detailed information on tape unpacking and data reduction required by user programmers and/or computer operators.

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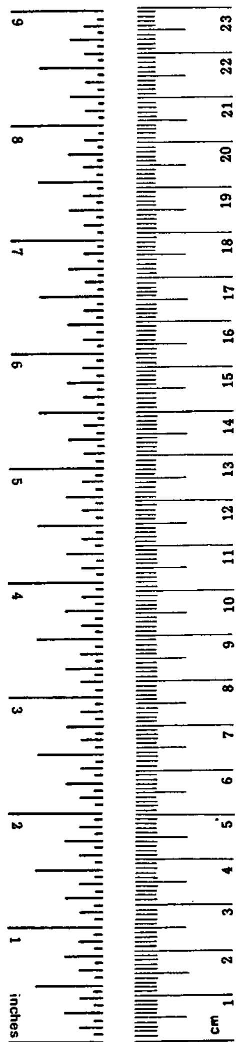
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

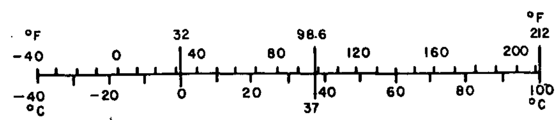
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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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Driver Performance Measurement and Analysis System

SECTION I

INTRODUCTION

The development of the prototype Driver Performance Measurement and Analysis System (DPMAS) has been accomplished for the National Highway Traffic Safety Administration by Systems Technology, Inc., under Contract DOT-HS-359-3-733. The first phase of this contract involved developing the functional requirements for such an instrumented vehicle system, and those results are documented in Ref. 1. The second phase was to build a prototype system, and this report documents the final results.

This prototype system is intended to provide a research and application tool to demonstrate contemporary instrumentation and data acquisition techniques, and to permit the effective execution of varied experimental and application programs such as:

- Driver behavior in various control tasks.
- Studies of driver/vehicle/environment interactions.
- Driver training and education.
- Driver licensing and proficiency testing.
- Experiments on driver impairment by alcohol, drugs, medicines, and other stressors.

This manual describes the DPMAS in general and how it operates to perform various experimental test scenarios. A second manual entitled "DPMAS Design and Maintenance Manual," Ref. 2, describes the technical details of the component subsystems for purposes of repair, modification, or duplication of all or parts of the DPMAS.

This manual is <u>user oriented</u>, and is directed toward the experimenter or other user. It assumes that all operations will be performed from the front panel controls. Changes to the basic system configuration such as scale factors, data rates, and sensor selection that require mechanical adjustments or electronic changes would be based on the design and maintenance manual and should be accomplished by a skilled technician.

The output of the DPMAS is a fixed point, multiplex format digital tape, and this tape must be "unpacked" as the first stage in data analysis and processing. Details of the unpacking program are contained in a third document entitled "DPMAS Digital Data Sorting Program," Ref. 3. Since each user will have differing analysis requirements, the user provides his own data analysis and interpretation programs.

Prior to using the DPMAS vehicle it is imperative that specific sections of this report should be well understood. All users should read Sections II and VI as a minimum since these describe the overall system and provide an operational checklist. Section III presents a summary of the sensors and instrumentation available, their scale factors, sample rates, groupings for specific experimental scenarios, and installation instructions for physiological measures. Sections IV and V detail two specific subsystems — the video system and the front wheel steering servo, respectively. These sections should be referred to when needed. The final section describes the unpacked digital data and discusses processing possibilities.

Appendix A contains the specifications and performance of the DPMAS vehicle. These data provide the necessary reference for vehicle handling or driver/vehicle response tests.

Appendix B provides example test scenarios covering open loop vehicle dynamics tests, closed loop driver/vehicle handling quality tests, driver training and licensing tests, and long term driving tests. These test descriptions should aid the user in selecting data to measure, setting up the vehicle, performing the tests, and checking the final data.

SECTION II

OVERALL SYSTEM DESCRIPTION

The prototype DPMAS is installed in a 1974 Chevrolet Impala four-door sedan. In general, this vehicle has a 121 in. wheelbase, weighs 5580 lb with full fuel and no passengers, and is equipped with automatic transmission, power steering, power disc front brakes, air conditioning, heavy duty suspension (and other heavy duty options such as radiator, battery, transmission cooler, etc.), and steel belted radial ply tires, size HR78-15, TPC 1001. Additional vehicle specifications and performance are contained in Appendix A.

This section begins with a general overview of the DPMAS equipment, where it is located, what its function is, and how it is operated. Section III describes the specific sensors, instrument scaling, and other details necessary to set up an experimental test with DPMAS.

Section VI describes how to turn the system on and prepare for testing. Section VI should be studied before attempting to operate the several parts of the system described later in this section.

A. GENERAL LAYOUT

The basic car has been modified by removing the rear seat and installing a small jump seat for the observer/technician. The original right front seat has been replaced with a swivel bucket seat for the experimenter/observer. An interior and equipment installation sketch is shown in Fig. II-1. An important design feature is that the Central Electronics Console containing all the control panels is mounted so that the experimenter in the front seat can reach back to access these panels. Installation and removal for maintenance is facilitated when the rear observer seat is removed. The video monitor and remote Status Control Panel are located between the front seats to facilitate control of the video and data acquisition systems by the driver or experimenter.

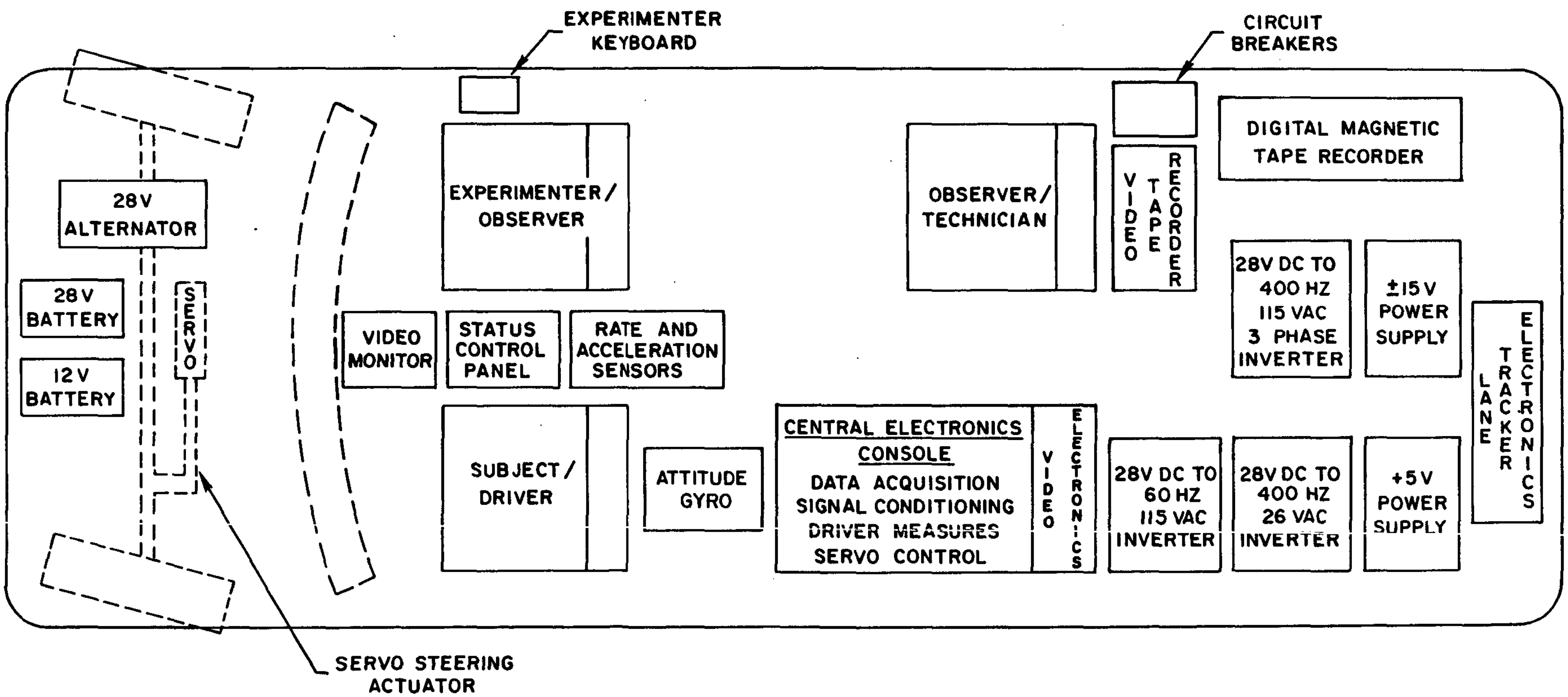


Figure II-1. Physical Equipment Layout in Vehicle

The inertial measurement sensors (rate gyros and accelerometers) are located above the drive shaft tunnel near the vehicle mass center. The attitude gyros to measure roll, pitch, and heading angle are located directly behind the driver's seat.

The driver's physiological instrumentation is contained in a belt pack. It is then magnetically coupled to the Driver Measures Unit in the Central Electronics Console. This method prevents any possible shock hazard since the sensors and signal leads attached to the driver are electrically isolated from the system electrical power and ground.

The video tape recorder is mounted on the rear window ledge, behind the rear seat. The electronics of the Video System are to the left of the observer/technician.

Primary DC power is supplied by a 28 v battery and a 28 v alternator under the hood which drive the various power supplies and inverters in the trunk area. The digital magnetic tape recorder of the Data Acquisition System is also in the trunk.

B. CENTRAL ELECTRONICS CONSOLE

The signal processing heart of DPMAS is the Central Electronics Console (CEC), which is a large chassis located behind the driver's seat. As shown in Fig. II-2 this chassis houses the following modular units:

- Data Acquisition Unit
- Signal Conditioning Unit
- Driver Measures Unit
- Servo Control Unit

The CEC serves as the main interface for the various sensors and recording system modules as is shown in Fig. II-3. The control panels of the console face toward the center of the car. They can be addressed either by the observer/technician in the right rear seat or by the experimenter/observer in the right front seat. The experimenter/observer must turn to his left (by swiveling the right front seat) and reach behind the subject driver's seat. Since this action might be somewhat awkward during an experimental

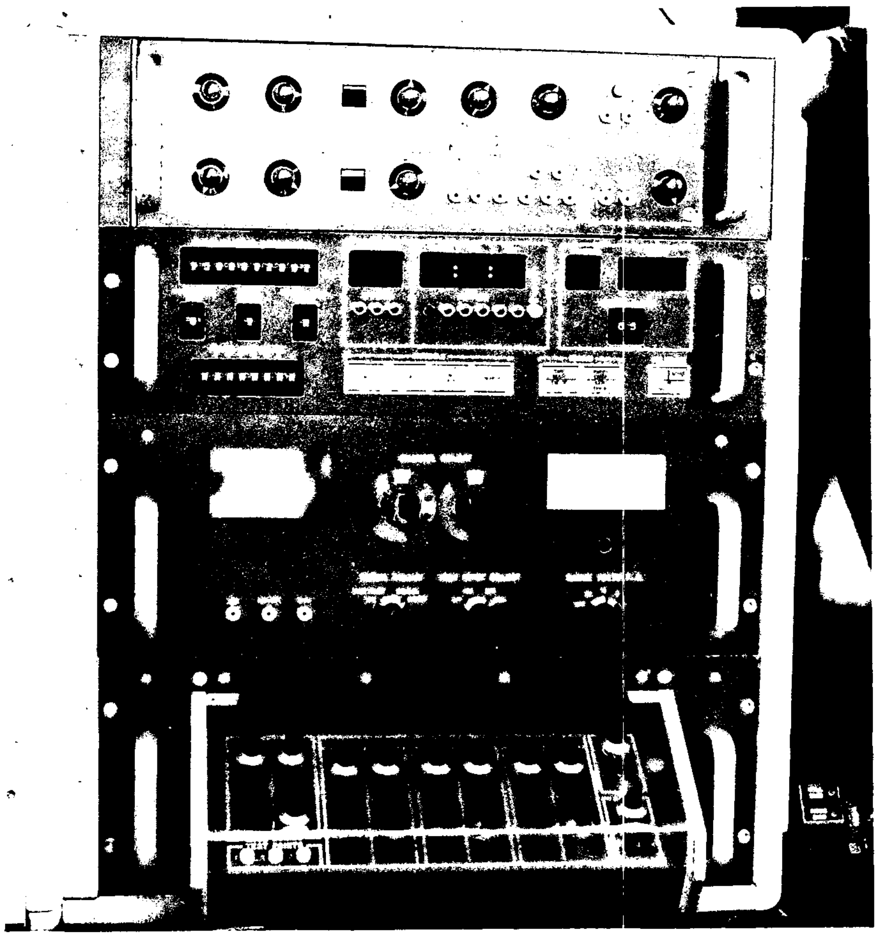


Figure II-2. Central Electronics Console

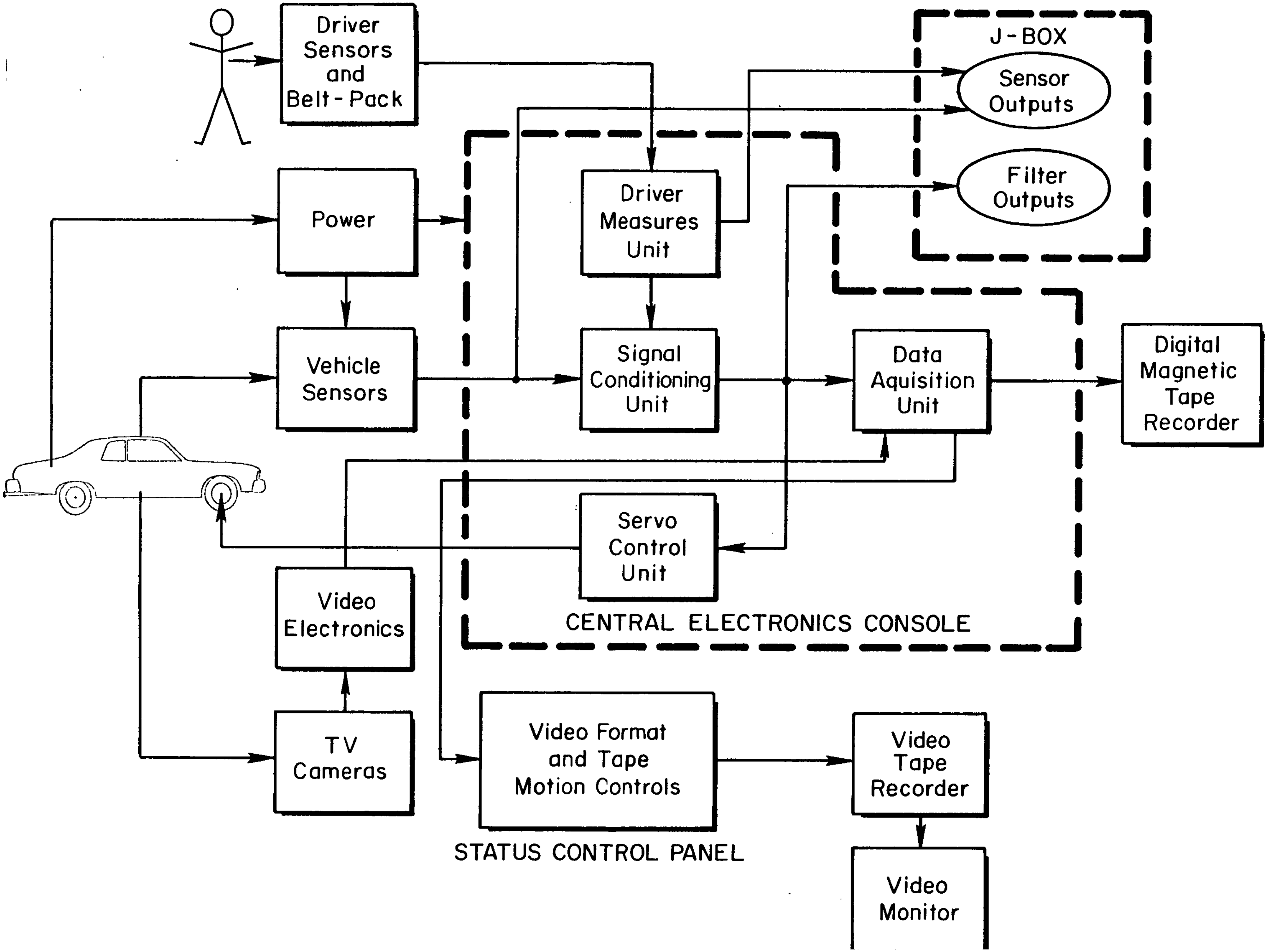


Figure II-3. Functional Instrumentation Layout run, the primary controls and displays of the Data Acquisition Unit are repeated on the Status Control Panel located between the two front seats.

The controls available on the panels of the CEC are described below. The user should refer to Section VI for overall operating instructions before attempting to operate the controls described below.

1. **Signal Conditioning Unit** (Fig. II-4)

The signal conditioning unit provides five main functions:

- Scaling, buffering, and bandpass filtering of all analog signal channels prior to analog to digital conversion.
- Nulling of the electronic offsets produced in sensor packages and signal processing buffers.
- Applying calibration voltages to all input stages, for use when calibration is being performed. This calibration provides verification and recording of gain settings, and allows continuity testing of all signals from the sensor outputs to the digital recorder.
- Selecting a signal channel for on-line monitoring. This monitoring capability consists of a switch panel that allows any data channel to be connected to the digital voltmeter (DVM) and/or to the analog voltmeter on the panel.
- Demodulation of rate gyro and attitude gyro synchro outputs to produce analog signals proportional to vehicle angular rates and attitudes.

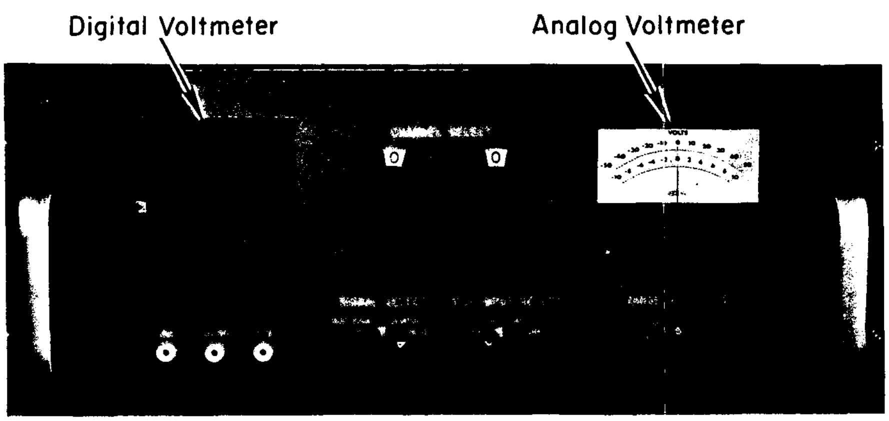


Figure II-4. Signal Conditioning Unit Control Panel

Except for signal channel selection, these functions are all accomplished automatically and the user need not be concerned with the details of their operation.

On the righthand side of the Signal Conditioning Unit is an analog voltmeter and a voltage range switch (RANGE VOLTS F.S.). On the left is an autoranging digital voltmeter. A signal is selected for display on the two meters with the aid of two rotary switches identified as CHANNEL SELECT (the two rotary switches provide for a single two-digit number), and a third single switch, SIGNAL SELECT. The experimenter must consult the signal channel identification table presented in the next section (Table III-2, page 48) to determine the numerical switch settings for the desired signal. With the SIGNAL SELECT switch the experimenter may examine the data channel at a number of places in its signal flow path to facilitate monitoring and troubleshooting, i.e.,

- OFF — turns off the on-line monitoring function
- TEST POINT — when Channel 11 is selected, TEST POINT displays the signal input at the test point input jack (TP IN). The test point function also displays the following signals when other channels are selected:

  06: +15 v supply

  07: −15 v supply

  08: +10 v supply

  09: −10 v supply

  10: +5 v supply

  11: frees DVM for remote use (through TP IN jack)
- SENSOR — displays the signal at the sensor output prior to scaling.
- FILTER — displays the scaled signal at the bandpass filter output.

In addition, a banana plug, SIG OUT, below the digital voltmeter provides access to the selected signal channel for test purposes. The TP IN plug allows a low voltage DC signal to be connected to the meters.

A four-position rotary switch, TEST INPUT SELECT, provides positive (POS), negative (NEG), or zero (GND) voltages to all the signal channels simultaneously for purposes of manual calibration and determining zero offsets. During data recording, this switch must be in the OFF position; otherwise the sensor inputs to the signal conditioning filters are disconnected and only the calibration signal is recorded. When this switch is not off, a red warning light identified as TEST ALARM is illuminated on the Status Control Panel.

Manual calibration provides a check of the functional status of all data channels. The following steps are used in manual calibration:

- Prepare the system for operation, as described in Section VI.
- Set voltage range switch to 5 V, full scale.
- Select channel number to be checked.
- Select FILTER.
- Select POS as test input.
- Read +4.20 volts on DVM or analog meter.
- Select NEG as test input.
- Read −4.20 volts on DVM or analog meter.
- Select GND as test input.
- Read 0.00 volts on DVM or analog meter.
- Place the TEST INPUT SELECT switch in the OFF position.

If desired, this process can be recorded as a separate file on digital tape since the test voltage is applied to all channels simultaneously.

A functional schematic of the Signal Conditioning Unit will help to understand where the various signal processing occurs. This is shown in Fig. II-5. Note that the sensor and offset bias pot are disconnected from the signal conditioning when TEST INPUT is selected. Selecting POS, NEG, or GND then applies this reference voltage (scaled through a gain pot) to the signal conditioning. The gain pot is adjusted so that the filter outputs

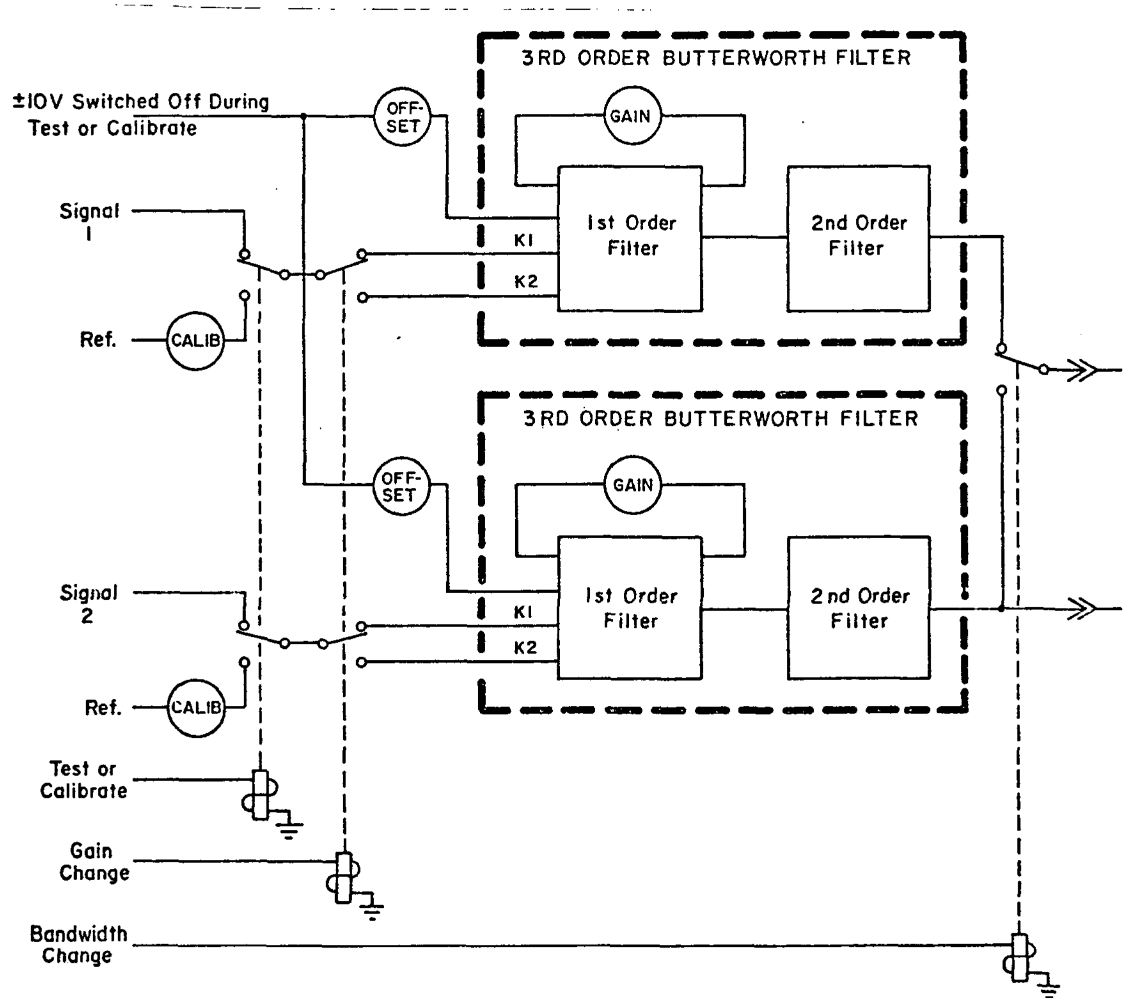


Figure II-5. Signal Conditioning Filter Card

are ±4.20 volts. Selecting HI or LO gain in the Data Acquisition Unit (described next) changes the input resistor to the filter amplifiers to effect a scale change. Since a HI or LO sample rate can also be selected in the Data Acquisition Unit the Butterworth filter bandwidths must also be changed appropriately. This is done by having a parallel sensor path to a second filter network. Scaling is the same in both paths. The sample rate relay then simply switches output paths.

2. Data Acquisition Unit (Fig. II-6)

The complete Data Acquisition System (DAS) consists of three units: the Data Acquisition Unit, including the control panel, electronics, and digital logic; the Digital Magnetic Tape Recorder; and the portable Experimenter

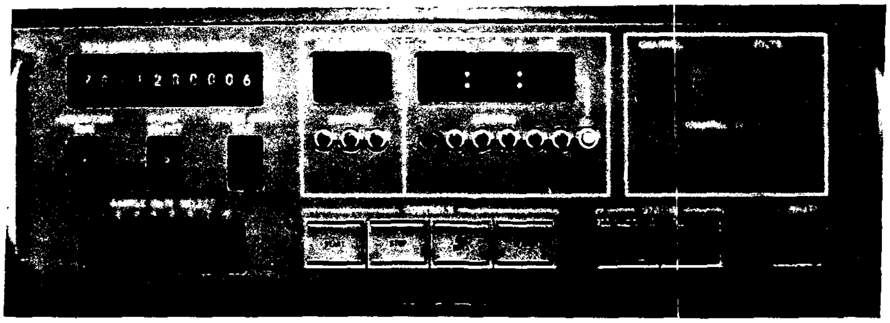


Figure II-6. Data Acquisition Unit Control Panel

Keyboard assembly. Elements of the Data Acquisition Unit are discussed below. Details are presented in the DPMAS Design and Maintenance Manual, Ref. 2.

The system has provision for up to 64 analog signal channel inputs with the full scale range of ±10 v. At this time only 37 signal channels are implemented (as described in Section III). The signal channels can be arranged in as many as 6 different groups. The selection of the group to be recorded is made with a front panel thumbwheel switch, GROUP SELECT in Fig. II-6. The sensors making up any one group are determined by switches located inside the Data Acquisition Unit. Selection of the sensors comprising a group must be made by a technician using the DPMAS Design and Maintenance Manual.

Analog to digital conversion is done with 12 bit binary resolution including sign. The sample rate for each signal channel has already been set, but this may be changed by switches in the Data Acquisition Unit similar to group signal selection. Eight of the 64 analog channels have variable sample rates which are selectable from front panel thumbwheel switches labelled SAMPLE RATE SELECT in Fig. II-6. These 8 channels are specified in Table III-2. When these switches are used, the bandpass filters also change to a suitable new value. The sample rates on the other channels should not be changed, because the bandpass filters in these other channels do not change automatically.

The system also accepts up to 32 discrete level (on-off) inputs of which 13 are currently implemented. These signals are used to denote the status of various controls such as windshield wipers, turn indicators, lights, and horn. A complete list is given in Section III-G.

A third type of input signal is accepted from the portable Experimenter's Keyboard which allows the entry into the DAS of a two digit number at times selected by the experimenter. This numeric code can be anything the user defines it to be. It might denote the occurrence of a traffic event, such as the vehicle stopping at an intersection, or indicate that the experimenter has given the driver some instruction, such as turning right at the next intersection. The keyboard allows successive entries of such coded numbers in the data record at intervals of no less than 2 seconds. This keyboard is described in more detail in Subsection II-D, page 25.

Controls and displays of the Data Acquisition Unit are explained below by referring to Fig. II-6 which portrays the control panel.

a. Run Identification

Each experimental run can be identified and encoded by 10 thumbwheel switches in the upper left corner of the control panel. These are set up to denote YEAR, MONTH, DAY, and a four digit sequential RUN NUMBER. They can be reassigned at the experimenter's option, since they simply create a numeric code on the tape. This run identification information is recorded as a header on the digital tape, see Ref. 3 and Section VII.

b. Acquisition Time

A single thumbwheel switch on the control panel identified as ACQUISITION TIME permits the experimenter to select a discrete recording interval (from 5 seconds to 16.7 minutes) or to select continuous recording. Table II-1 shows the time code which can be selected. The discrete recording intervals are initiated manually and terminated automatically (although they can also be terminated manually). Continuous recording (Code 0) is initiated and terminated manually.

Provision is made to terminate data recording by a switch closure acting in parallel with the STOP buttons on the Data Acquisition Unit panel and Status Control Panel. This switch closure may be set up to be activated by, for example, a sensor reacting to an event external to the vehicle. When the

TABLE II-1

DATA ACQUISITION CODES

CODE	TIME
0	Continuous
1	5 sec
2	10 sec
3	25 sec
4	50 sec
5	100 sec
6	250 sec
7	500 sec
8	1000 sec
9	External stop

Acquisition Time Select Switch is set to Position 9, data recording starts when the START button is depressed and continues until either the external event triggers the switch closure or the STOP button is depressed.

c. Group Selection of Recorded Channels

A single thumbwheel switch identified as GROUP SELECT permits the experimenter to select one of six groups of signals to be recorded. Each group of signals would correspond to a given experimental situation or scenario, and the grouping is intended to simplify the experimenter interface. The particular signals which belong to a given group are selected by binary switches on printed circuit cards inside the electronics, and this allocation can be changed if desired. One card is used for each of these six groups. This card has 64 two-position switches, one for each channel of analog data. This mechanization permits any channel to be recorded within any of the six groups. Provision is also allowed for additional groups so that a total of 10 groups could be mechanized at some future time. A group must contain at least one sensor (or discretes) in order to get keyboard entries on tape. The current group selection is given in Table III-2 in Subsection III-G.

d. Signal Conditioning Gain

Two signal gain levels (H for high, L or low) are selectable for each channel by the thumbwheel switch SIGNAL COND GAIN. Typically, a high gain setting is used for small perturbation maneuvers where high resolution is desired. Low gain is designed for driver training scenarios or tests where full sensor excursions are anticipated. Table II-2 shows the channels having differing high and low gain settings. Gains for other channels are given in Section III, page 47. Refer to Fig. II-5 for location of gain switching relays on schematic.

TABLE II-2

SIGNAL CONDITIONING GAIN CHANGES

CHANNEL	SIGNAL	SIGNAL CONDITIONING GAIN (Units/Volt), 10 Volt Maximum)	
		High	Low
1	Steering wheel angle	20 deg/v	60 deg/v
6	Heading angle	5 deg/v	20 deg/v
13	Yaw velocity	4 (deg/sec)/v	10 (deg/sec)/v

e. Sample Rate Selection

Two sets of switches control the signal channel sample rates. All of the 64 analog channels have their sample rates selected internally by switches mounted on printed circuit cards in the electronics. Generally, these sampling rates should remain fixed, but they could be changed by a technician with the aid of Ref. 2. The sample rates of 12 channels can also be controlled externally by the 8 thumbwheel switches on the front panel, SAMPLE RATE SELECT. These rates are adjustable to two levels — H for high and L for low — to suit the experimental situation. To accommodate 12 channels with only 8 switches, the sampling rate controls are grouped (per switch) as shown in Table II-3.

TABLE II-3

SAMPLE RATE SELECT GROUPS

SWITCH NUMBER	SIGNAL CHANNELS ASSIGNED	DATA CHANNEL
1	Steering wheel angle	1
	Steer angle	5
2	Steering wheel rate	2
3	Throttle position	3
4	Brake pedal pressure	4
5	Yaw velocity	13
	Lateral acceleration	14
6	Longitudinal acceleration	15
	Forward velocity	22
	Distance traveled	61-63
7	EMG_A	26
8	Pitman arm	36
	Unassigned	37

f. <u>File Counter</u>

An automatic file counter is next to the time-of-day clock. When starting a new digital tape the file counter must be manually set to 001 after mounting the tape and putting the Magnetic Tape Recorder (MTR) on line. The file count will automatically be incremented <u>after</u> the START button has been depressed; hence, after recording, the FILE NUMBER represents the file <u>just completed</u>. It is important to keep track (in Run Log) of the file number and run number, since it is possible to get out of sync between the real files on the tape and those indicated by the file counter.

g. Time-of-Day Clock

The system has an internal time-of-day clock with two 6-digit displays, one on the control panel and one on the Status Control Panel. Two digits each display HOURS, MIN, and SEC. The desired real time may be set by depressing the DISPLAY SET switch and depressing the ADVANCE pushbuttons to set the clock's digits. This internal clock switches to battery power when system power is off so that the clock continues to run when the vehicle is shut down. The time of day is also input to the Data Acquisition System in the form of six BCD digits, two digits each for hours, minutes, and seconds. It is recorded once per second.

h. Digital Data Monitor

The switches and displays in the upper righthand corner of the control panel provide for monitoring any specific signal channel during operation. The numeric display (VOLTS) provides a decimal indication of the digital data being transmitted to the MTR on that particular channel. The specific channel is selected by a two digit thumbwheel switch identified as CHANNEL SELECT in Fig. II-6. A two digit readout identified as CHANNEL provides a crosscheck on which signal is being monitored.

i. Calibration

A built-in automatic calibration mode of the Data Acquisition System checks the scaling of each of the analog channels in the selected group. Depressing the pushbutton identified as CALIBRATE on the Data Acquisition Unit control panel puts the system in the CALIBRATE mode. This is similar to the use of TEST INPUT in the Signal Conditioning Unit previously described; however, in the CALIBRATE mode only a positive reference voltage is applied to the signal conditioning amplifiers.

When in the CALIBRATE mode, the sensor signals are removed from the inputs to the filters in the Signal Conditioning Unit. A calibration voltage is substituted so as to provide a 4.2 ± 0.02 V output from each channel of the Signal Conditioning Unit as shown in Fig. II-5. The Data Acquisition

System then scans the entire array of analog channels in the selected group. If each scanned signal falls within the 0.02 V tolerance of the calibration level of 4.2 V, a light in the CALIBRATE switch identified as GO is illuminated. Should a particular channel be out of tolerance the scanning stops at that channel for 5 seconds, and the NO GO light is illuminated. The channel ID number and the data actually read on that channel are also displayed. This calibration feature checks the signal conditioning filter and gain, the multiplexer, and the A to D converter. It does not check the operation of the basic sensor.

Steps in operating the calibration mode for digital tape recording are as follows:

1. Prepare the system for operation as described in Section VI, page 72.

2. Select run number for tape identification.

3. Note file number and time of test.

4. Select data group to be calibrated (1 → 6).

5. Select H signal conditioning gain (high).

6. Press CALIBRATE pushbutton (IN PROGRESS light will illuminate).

7. Start tape.

8. Watch for NO GO light to illuminate (take note of channel number if NO GO light comes on during test).

9. Wait for tape to STOP automatically (approximately 10 sec).

10. Press CALIBRATE pushbutton a second time to extinguish IN PROGRESS light, thus completing calibration of that sensor.

For calibration without data recording, simply eliminate Steps 2, 3, and 7. If a NO GO indication has appeared, individually check this channel using the Manual Calibration Test procedure described previously on page 10 to decide whether to continue or repair. This decision will be dictated by the out of tolerance level and the importance of that particular channel to test objectives.

j. Data Acquisition Status and Controls

The data acquisition status and control buttons are associated with the Magnetic Tape Recorder (MTR). Eight control indicators are provided in the form of lighted pushbuttons on the panel. These are identified as follows:

- TAPE READY — denotes that the tape is loaded in the MTR, the write protect ring is removed, and the MTR is ready for recording.
- END OF TAPE — denotes that the tape transport is advanced to the end of the tape and must be rewound or replaced with a reel of fresh tape.
- RATE ERROR — indicates that the product of the number of channels selected and the sample rates selected is too high for the tape transport to record. The maximum rate at which characters can be sent to the magnetic tape deck is 6399 characters per second. The rate can be calculated by the sum of all the products of the number of channels at each rate, times the rate, times 2 bytes per channel. For example:

  1) A total of 31 channels can have sample rates of 100 samples/sec.

  $$\begin{aligned}&31 \text{ ch} \times 2 \text{ bytes/ch} \times 100 \text{ samples/sec}\\&\quad + 0 \times 50 \text{ samples/sec} + 0 \times 20 \text{ samples/sec}\\&\quad + 0 \times 10 \text{ samples/sec} + 0 \times 5 \text{ samples/sec}\\&\quad + 0 \times 2 \text{ samples/sec} + 0 \times 1 \text{ sample/sec}\\&\qquad = 6200 \text{ characters/sec}\end{aligned}$$

  2) All 68 channels can have sample rates up to 20 samples/sec.

  $$\begin{aligned}&68 \text{ ch} \times 2 \text{ bytes/ch} \times 20 \text{ samples/sec}\\&\qquad = 2720 \text{ characters/sec}\end{aligned}$$

- PARITY ERROR — indicates that read-after-write parity errors have been detected on the magnetic tape.
- START — commands the magnetic tape recorder to start recording. This initiates operation of the overall data acquisition system in either normal or calibrate operation.
- STOP — commands the magnetic tape recorder to stop, and terminates data acquisition.

- END DATA — normally this button is depressed only at the end of a day's recording or whenever the tape is to be removed from the recorder. Depressing END DATA initiates a second file gap to be written and rewind of the magnetic tape to the beginning of the tape (BOT) mark. When the tape is replaced in the recorder, the operator merely depresses the SEARCH button and the recorder will advance the tape to the double file gap and stop. When recording starts, the tape is automatically locked up and the double end of file is erased. This ensures that there will never be more than one double End of File gap on the tape. Recording may then commence at the start of a section of fresh tape without the danger of rerecording over previously recorded data.

- SEARCH — this button is depressed after a partially recorded tape is reloaded in the recorder. Depressing SEARCH causes the tape transport to search forward looking for a double file gap. Upon detection of the double file gap, the tape will position itself to erase the second gap and be ready to record data.

3. **Driver Measures Unit** (Fig. II-7)

The Driver Measures Unit provides onboard processing of driver psychophysiological signals obtained from a portable biopac mounted on the subject (Section III-D). The front panel layout for this unit, shown in Fig. II-7, provides processing controls for the following signals.

a. EMG (Electromyogram)

Rectification and smoothing is provided for two separate channels of EMG. The gain and smoothing filter bandwidth of each channel can be varied.

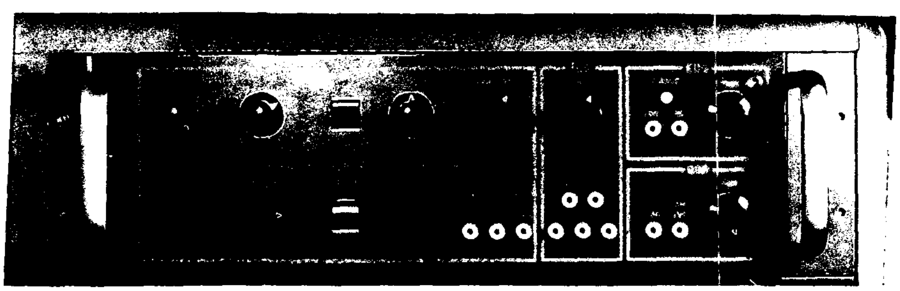


Figure II-7. Driver Measures Unit Control Panel

The sum and difference of the two channels can be selected (for agonist/antagonist musle pair processing), and the gain of these derived signals can be controlled. A bias pot is also provided to allow for counteracting the large resting activity levels found in some muscles. Finally, processed EMG signals are available on the front panel for monitoring with auxiliary equipment.

b. EEG (Electroencephalogram)

The Driver Measures Unit provides EEG processing for one site which consists of bandpass filtering, rectification, and smoothing for the four classical EEG bands (Δ, θ, α, and β). Gain control of the raw EEG signal is provided, and front panel test points are available for the raw EEG signal and the four bandpassed signals.

c. ECG (Electrocardiogram)

The Driver Measures Unit provides a cardiotachometer which detects the ECG R wave and provides a beat-by-beat measure of heart rate (beats per minute). An ECG signal gain control is provided to set the proper R-wave amplitude for the detection circuit and a panel light is included to monitor proper R-wave triggering. Both the ECG waveform and derived heart rate signal are available at test points on the front panel.

d. GSR (Galvanic Skin Response)

The Driver Measures Unit provides a log amplifier for attenuating the typically large dynamic range of this psychophysiological variable. A gain control is included to allow calibrating to a standard resistance, and both the raw and log transformed GSR signals are available through test points on the front panel.

The Driver Measures Unit interfaces with the subject-mounted biopac through a connector and long umbilical cord which leads to the interconnect panel. Background on the psychophysiological variables and instrumentation is given in Subsection III-D, and operating instructions are included in Section VI.

4. Servo Control Unit

The steering servo system consists of an electrohydraulic actuator mounted in series between the Pitman arm and the transverse link (also referred to as a "relay" rod). The purpose of the servo system is to apply steering inputs to the front tire independently of the driver's steering inputs, thus providing, among other things, a means to measure the closed loop dynamic behavior of the driver. Other inputs to the servo are an unexpected step (simulating a blown tire), steering wheel position (which effectively changes the vehicle steering ratio), and various motion feedback signals from the instrumentation (to change the vehicle's dynamic behavior). The servo steering is controlled through the control panel shown in Fig. II-8. Since the servo is a separate subsystem, details are presented in Section V and operational procedures are presented in Section VI.

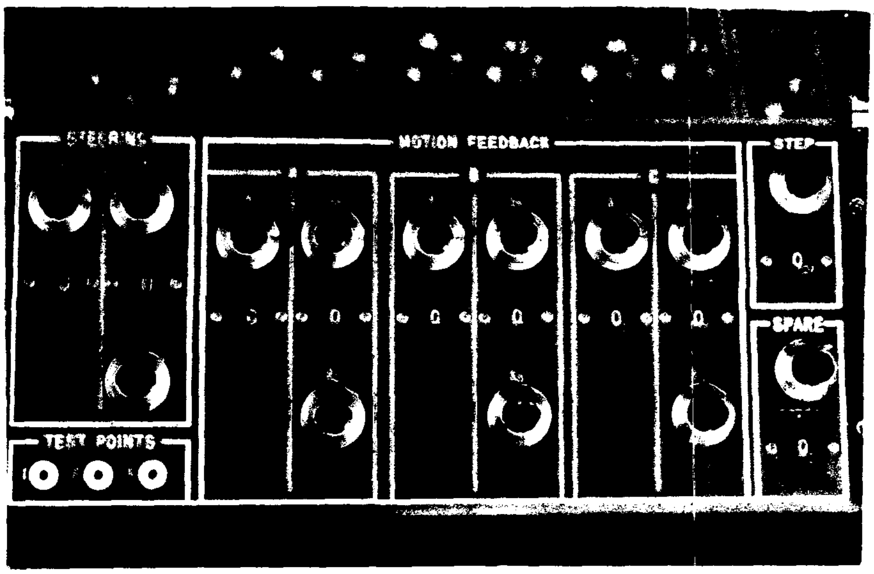


Figure II-8. Servo Control Unit Control Panel

C. STATUS CONTROL PANEL

This panel, portrayed in Fig. II-9, is located between the two forward seats and provides displays and lighted pushbutton controls which enable the experimenter to assess the status of the onboard electronics modules and to control the data acquisition and video tape recorders. The following control/displays are provided:

- POWER ON/OFF — a Master switch to preclude operation by unauthorized persons (requires special key).

- BRIGHTNESS — controls brightness of lamps in Status Control Panel only.

- STATUS WARNING — white split indicators denote power-on status of designated modules. Red full-size indicators (OVER TEMPERATURE ALARM, TEST ALARM, and ALTERNATOR ALARM) denote warnings. OVER TEMPERATURE ALARM denotes a temperature exceeding 120° F in the trunk area near the MTR. TEST ALARM denotes that the TEST INPUT SELECT switch on the Signal Conditioning Unit is not in position to enable recording of data. ALTERNATOR ALARM denotes that the 28 VDC battery is being discharged.

- FILE NUMBER — counts the files as they are recorded on the digital tape. This display is a repetition of the one on the Data Acquisition Unit.

- Clock — a time-of-day clock repeating the display on the Data Acquisition Unit.

- DATA ACQUISITION STATUS and DATA ACQUISITION CONTROLS — Parallel displays and controls found on the Data Acquisition Unit (see pages 11-20 for a detailed description).

- VIDEO TAPE CONTROLS — control recording and playback of the video tape recorder. These controls parallel those on the video tape recorder itself.

- VIDEO FORMAT CONTROLS — control the video format, i.e., the selection of video signals from different cameras, to be displayed on the monitor and recorded.

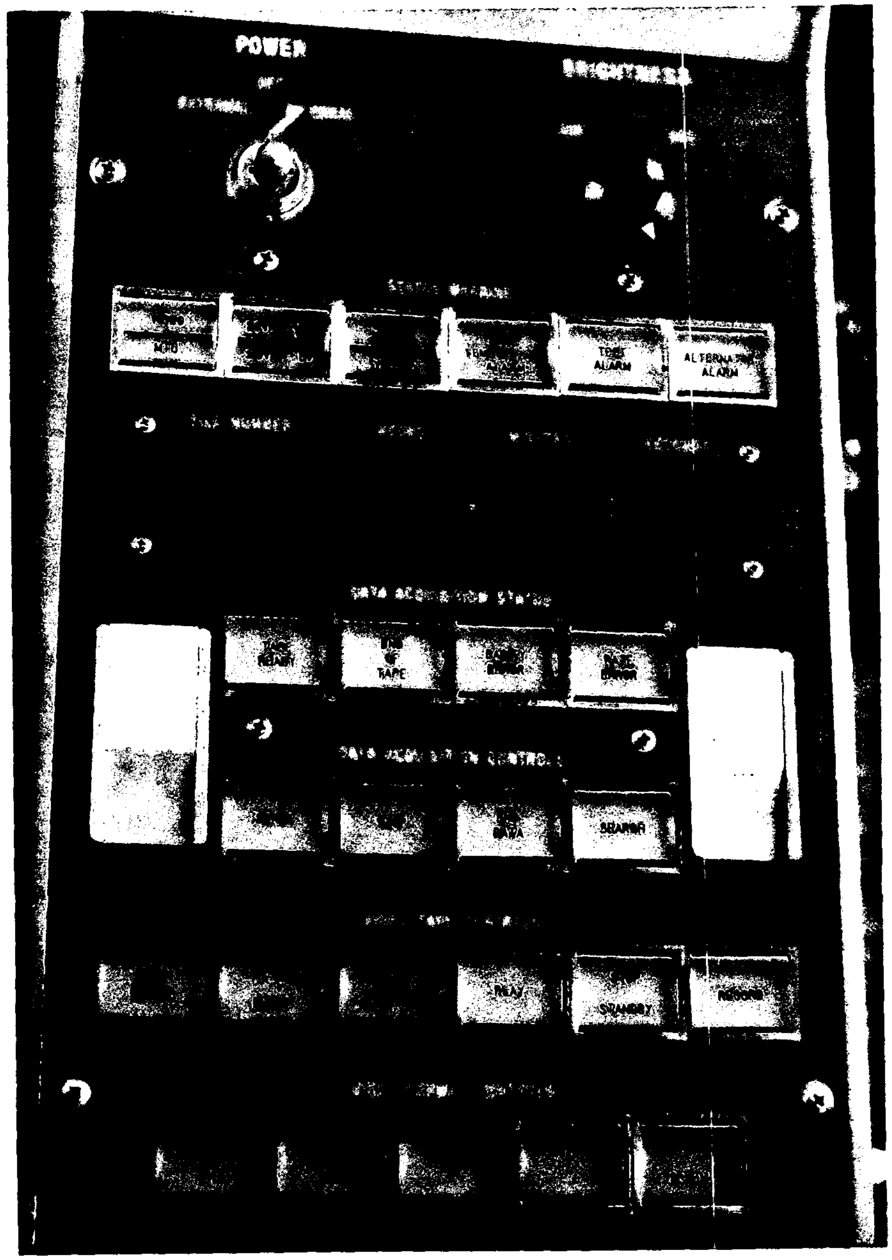


Figure II-9. Status Control Panel

D. EXPERIMENTER'S KEYBOARD

A photograph of the experimenter's encoding keyboard is shown in Fig. II-10. This is a ten decimal digit keyboard and a two digit display. The display portrays the two digits entered. The keyboard allows entry of a two decimal digit number in the data record at intervals of 2 seconds or greater. The number on the keyboard is written on the magnetic tape and displayed on the video monitor. The display is automatically cleared after entry.

Anticipated usage of the keyboard is to permit the experimenter to denote situational events, such as intersections, traffic signals, pedestrians, or objects along the roadway; or to identify instructions that the experimenter may give to the driver/subject.

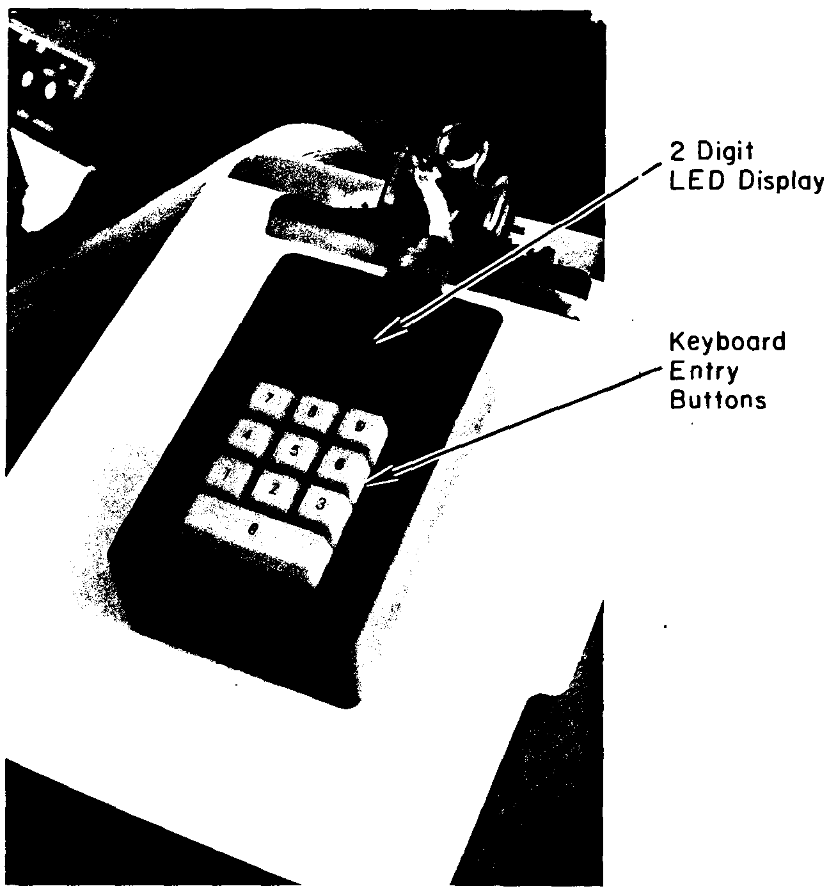


Figure II-10. Experimenter's Keyboard

E. PROVISION FOR ADD-ONS

The basic recording means in the DPMAS prototype are the Magnetic Tape Recorder (or Magnetic Tape Unit, MTU) and the Video Tape Recorder (described in Section IV). In addition, built-in analog and digital voltmeters are provided for on-line display. Aside from this apparatus, provision is made to output any of the analog channels to ancillary display devices such as a strip chart recorder, data logger, or oscilloscope via a special junction box shown in Fig. II-11. None of these display devices are part of the DPMAS package.

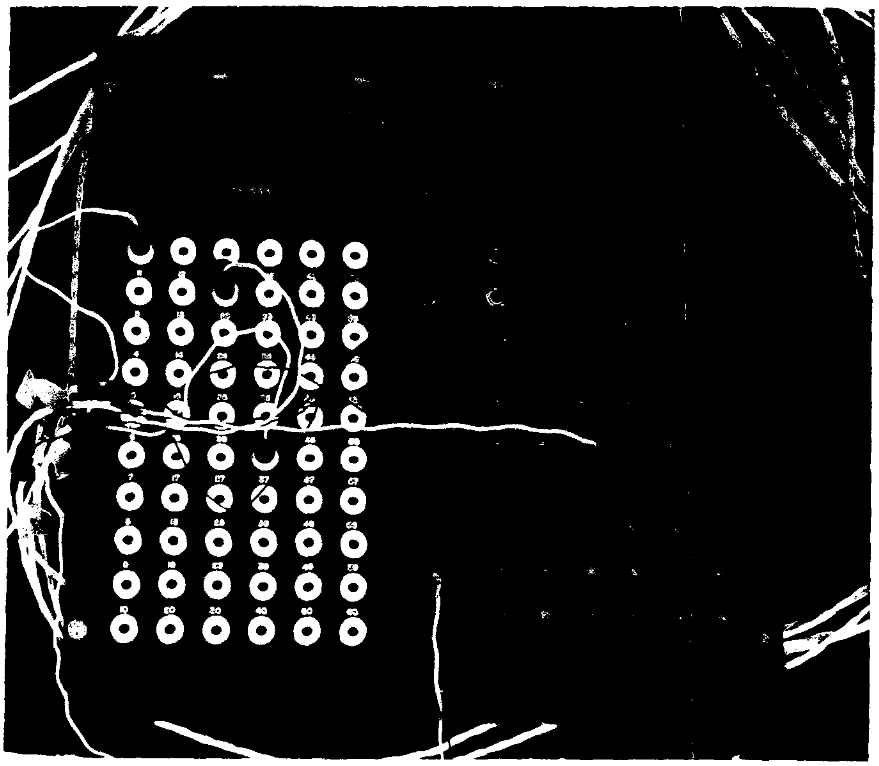


Figure II-11. Junction Box

SECTION III

SENSORS AND INSTRUMENTATION

This section describes the available sensors, scaling, and instrumentation associated with the driver control actions, vehicle motions, and driver psychophysiological measures. The video system and steering servo system are discussed separately in Sections IV and V, respectively.

A. DRIVER CONTROL AND ACTIVITY MEASURES

The driver control measures are summarized in the following list.

- Steering wheel position (δ_{SW}): A standard, commercially available potentiometer is attached to the steering column below the steering wheel as shown in Fig. III-1.

- Steering wheel rate ($\dot{\delta}_{SW}$): Steering wheel rate is obtained directly from a tachometer/generator also driven by the steering wheel column as shown in Fig. III-1.

Figure III-1. Installation of Steering Wheel and Steering Wheel Rate Sensors

- Throttle pedal position (δ_T): The transducer is a linear potentiometer mounted on the carburetor and driven by the throttle linkage motion as shown in Fig. III-2.

- Brake system pressure (P_B): Pressure transducers are used to monitor the line pressures of the two independent hydraulic braking systems of the automobile. These are a standard, commercially available type employing a temperature compensated strain gauge element to generate the electrical signal proportional to the pressure difference between the hydraulic line and the atmosphere. They are mounted on the master cylinder as shown in Fig. III-2.

- An auxiliary override brake, i.e., "experimenter's brake," is installed for use by the right front seat occupant. Modulation of this brake is measured by a potentiometer mounted on the firewall as shown in Fig. III-3.

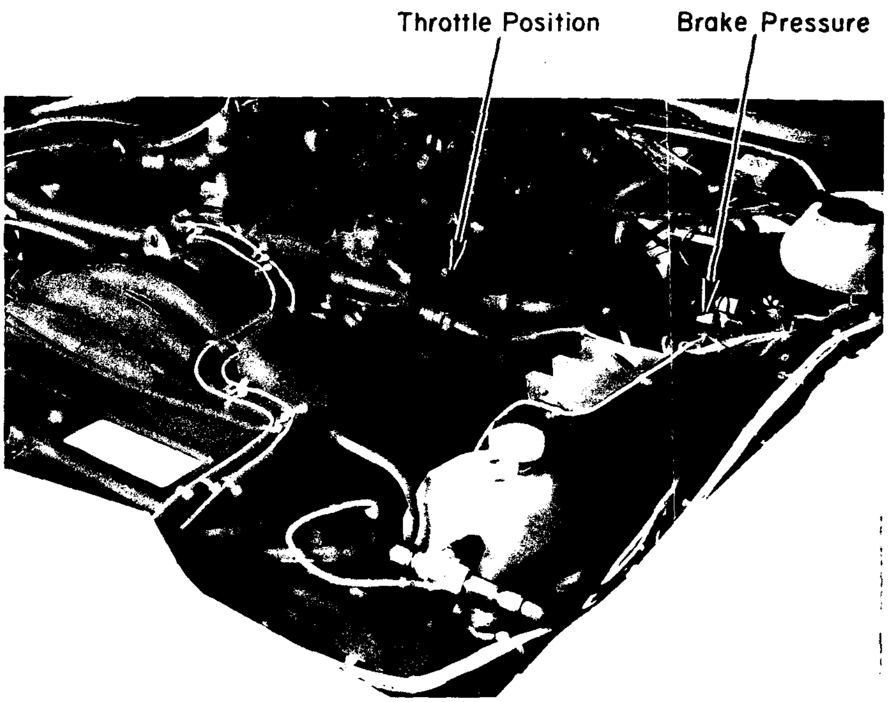


Figure III-2. Installation of Throttle Position and Brake Pressure Sensors

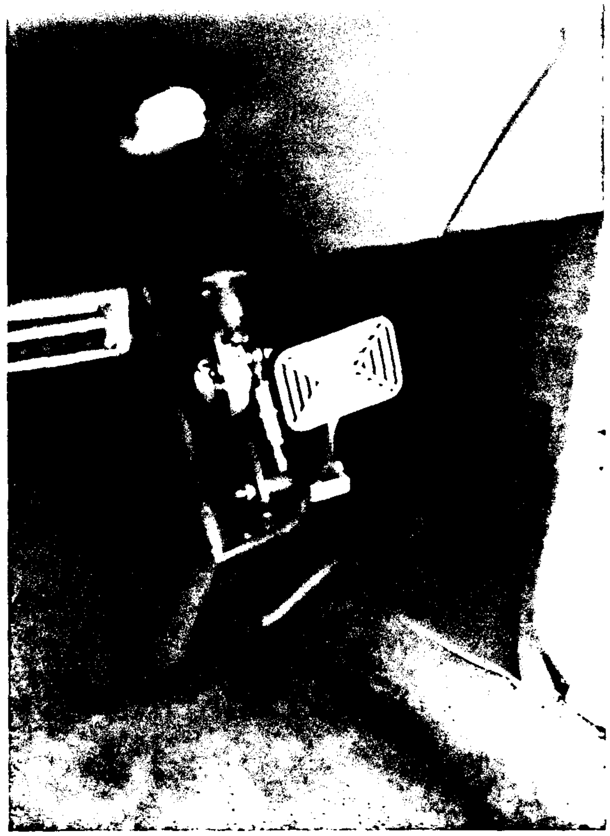


Figure III-3. Installation of Experimenter's Brake

- Discrete control activity measures: The driver's activity with respect to the various discrete controls involved with the driving task are as follows:
  - Engine on (oil pressure light)
  - Headlights (low beam)
  - Dimmer switch (high beam)
  - Turn signal, left
  - Turn signal, right
  - Parking lights
  - Windshield wipers
  - Horn
  - Brake actuation (as when brake lights come on)
  - Radio
  - Air conditioning
  - Parking brake
  - Driver in (seat pressure sensor)

B. VEHICLE MOTION VARIABLES

The vehicle motion variables include forward velocity (U); body axis angular rates for roll (p), pitch (q), and yaw (r); inertial attitudes for roll (φ), pitch (θ), and heading (ψ); and the body axis linear accelerations for longitudinal (a_x), lateral (a_y), and vertical (a_z). The sensors and associated computation procedures are discussed below.

1. Forward Velocity (U)

Forward speed is sensed by an optical pickup from the transmission. An extension of the speedometer cable drives the optical sensor which is located on the side of the Central Electronics Console directly behind the driver's seat.

2. Wheel Rotation Velocities (ω_i)

Individual wheel rotation velocities provide a redundant or alternative measure of speed or, in braking maneuvers, for sensing wheel lockup. Tachometers are mounted externally on the hubcap center as shown in Fig. III-4. The quick disconnect pin holding the spring loaded reference cable allows the wheel tachometers to be removed easily for tests not requiring these sensors.

3. Inertial Measurement Unit (IMU)

This unit consists of a set of triaxially mounted accelerometers and triaxially mounted rate gyros mounted behind the front seats on the driveshaft tunnel as shown in Fig. III-5. This location is in close proximity to the vehicle center of gravity. The three accelerometers measure longitudinal acceleration (a_x), lateral acceleration (a_y), and vertical acceleration (a_z). These are sub-inertial-navigation grade quality, force rebalance type accelerometers. The three rate gyros measure body axis rates about roll (p), pitch (q), and yaw (r).

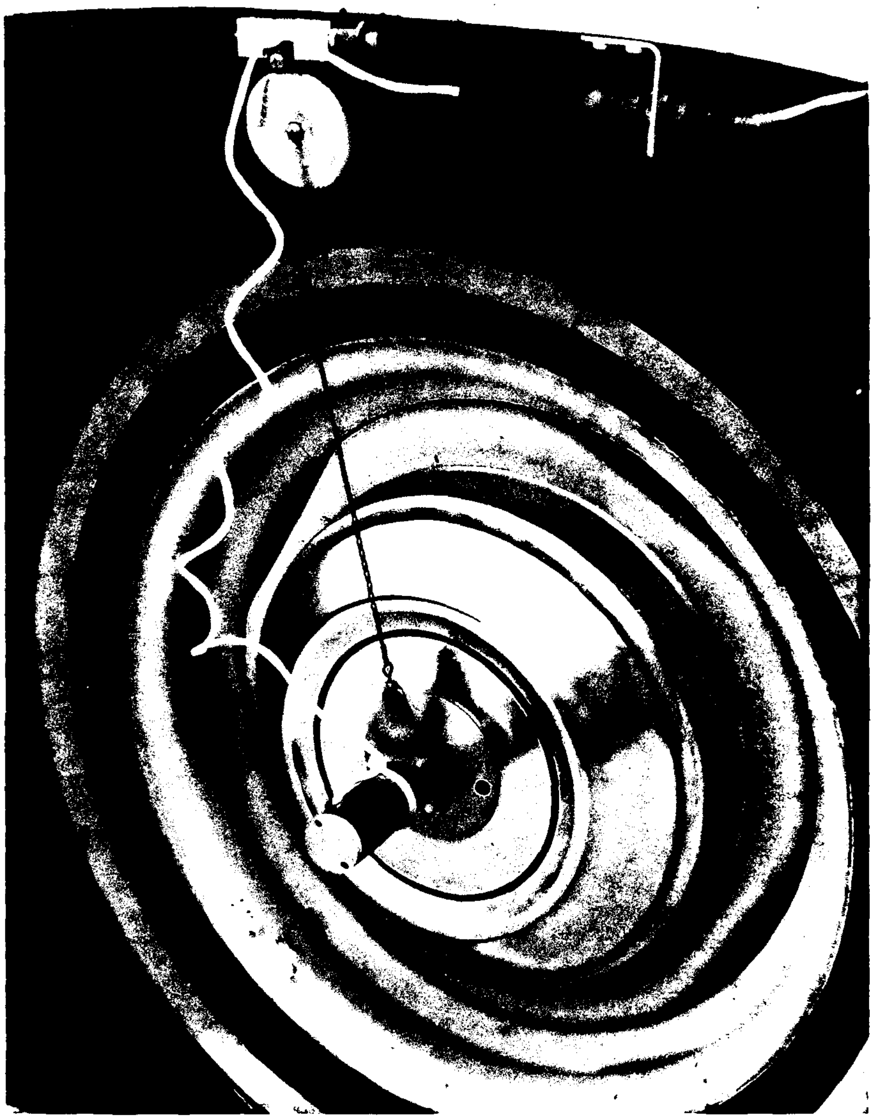


Figure III-4. Installation of Wheel Tachometer Sensors

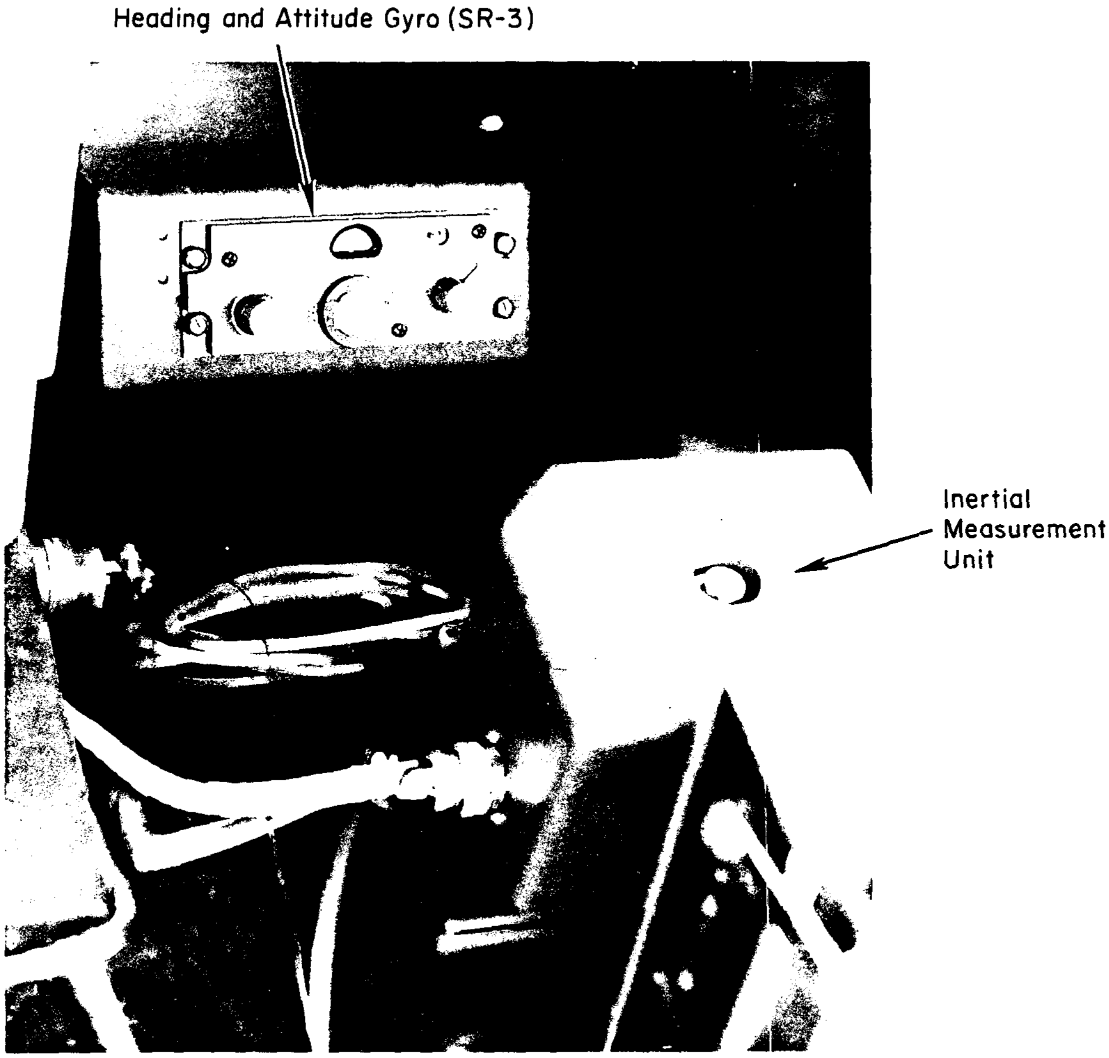


Figure III-5. Installation of Inertial Measurement Unit
and SR-3 Heading and Attitude Gyro
Behind Driver's Seat

4. Heading and Attitude Gyro

This unit, the General Electric SR-3, consists of a directional gyro mounted on the inner gimbal of a vertical gyro. The unit, together with the associated control electronics, provides a direct measure of body attitude in pitch (θ), and roll (φ) and a highly accurate heading (ψ) reference. It is built to Military Specification MIL-C-38418B(USAF). The SR-3 erection mechanism corrects to the local vertical at a rate of 5.0 deg/min under normal circumstances. When the longitudinal acceleration

(a_x) exceeds 0.065 g the erection rate in pitch is reduced by a factor of 4, and when the lateral acceleration (a_y) exceeds 0.13 g the erection rate in roll is reduced by the same amount. In addition, provision is made for external erection cutouts and external slaving (to a flux gate) of the directional element. The cutout feature is most useful in experiments involving sustained turning rates which would cause the vertical gyro to erect to a false vertical. The heading reference has a free drift of less than 1 deg/hr when corrected for earth rate. The SR-3 is also mounted behind the driver's seat as shown in Fig. III-5.

C. VEHICLE LANE POSITION MEASURE

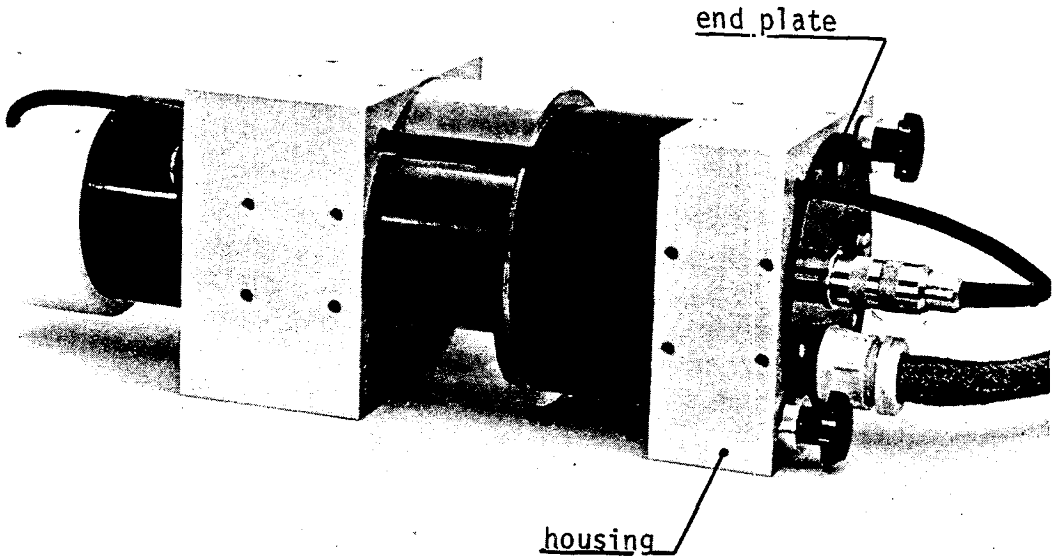
Vehicle lane position is measured by a specialized device developed by the Institute of Perception TNO in the Netherlands. This device, referred to as a lane position tracker, consists of two basic elements, the position transducer and the control unit. These are shown in Fig. III-6. The position transducer is mounted on the side of the car as shown in Fig. 7. Although this installation is shown on the righthand side it can be put on either side by simply moving the base plate assembly on the roof rack.

The position transducer measures the distance between the vehicle and a reference line on the road. Any marker on the road which contrasts sufficiently with the background can be taken as reference; therefore, normal lane delineation stripes or edge stripes can be used very effectively.

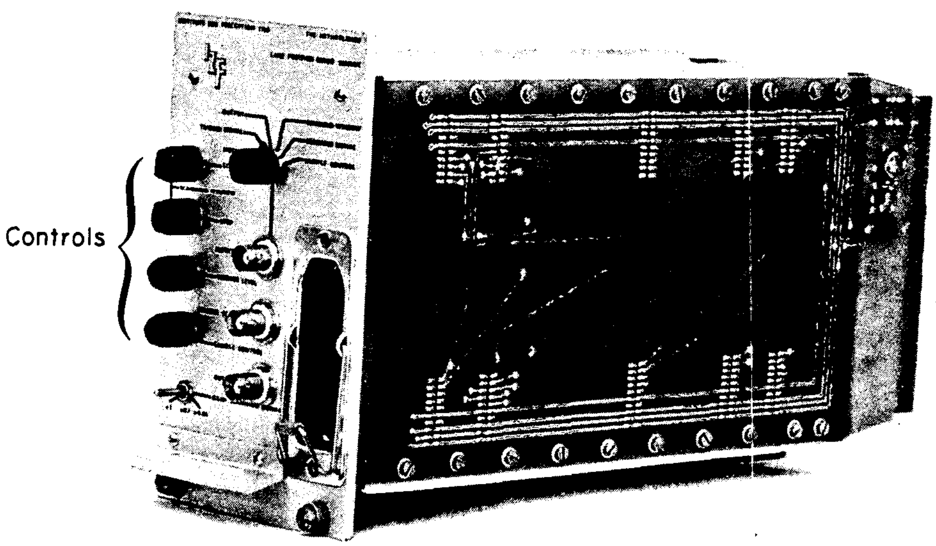
The transducer operates by scanning the intensity of reflected light in a lateral plane across the road using a rotating prism in parallel with the longitudinal axis of the vehicle. The prism scans the intensity of the road from the vehicle edge outward and reflects light to a photoamplifier.

The output of the photoamplifier is processed in the control unit. Points in the lateral plane with contrasting light reflections cause peaks in the scanning signal. Peak values above an adjustable trigger level are detected and used to measure the prism rotation angle at that specific moment.

The prism rotation angle is measured relative to an adjustable zero position. The measured angle is converted to an equivalent output voltage



a) The Position Transducer



b) The Control Unit

Figure III-6. Components of the Lane Position Tracker

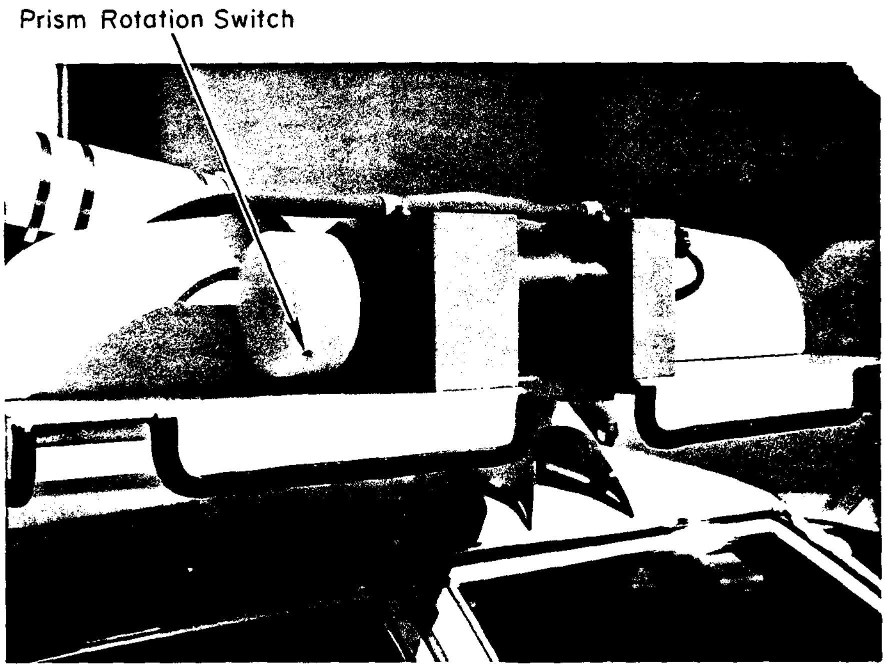


Figure III-7. Installation of Lane Position Tracker on Righthand Side of Vehicle

which is maintained up to the detection of the reference line during the next prism revolution; consequently, every prism revolution results in an updating of the output voltage. The output voltage can be transformed to the lateral distance between vehicle and reference line by assuming that the zero position of the prism angle corresponds to the position of the reference line straight below the transducer. Then, if

α = Measured prism rotation angle

h = Height of prism axis above the road surface

ℓ = lateral distance between prism axis and reference line

then

$$\ell = h \tan \alpha$$

A calibration of the output voltage for several different lateral distances is shown in Fig. III-8. This calibration is used to transform the measured voltages to the actual lateral distances.

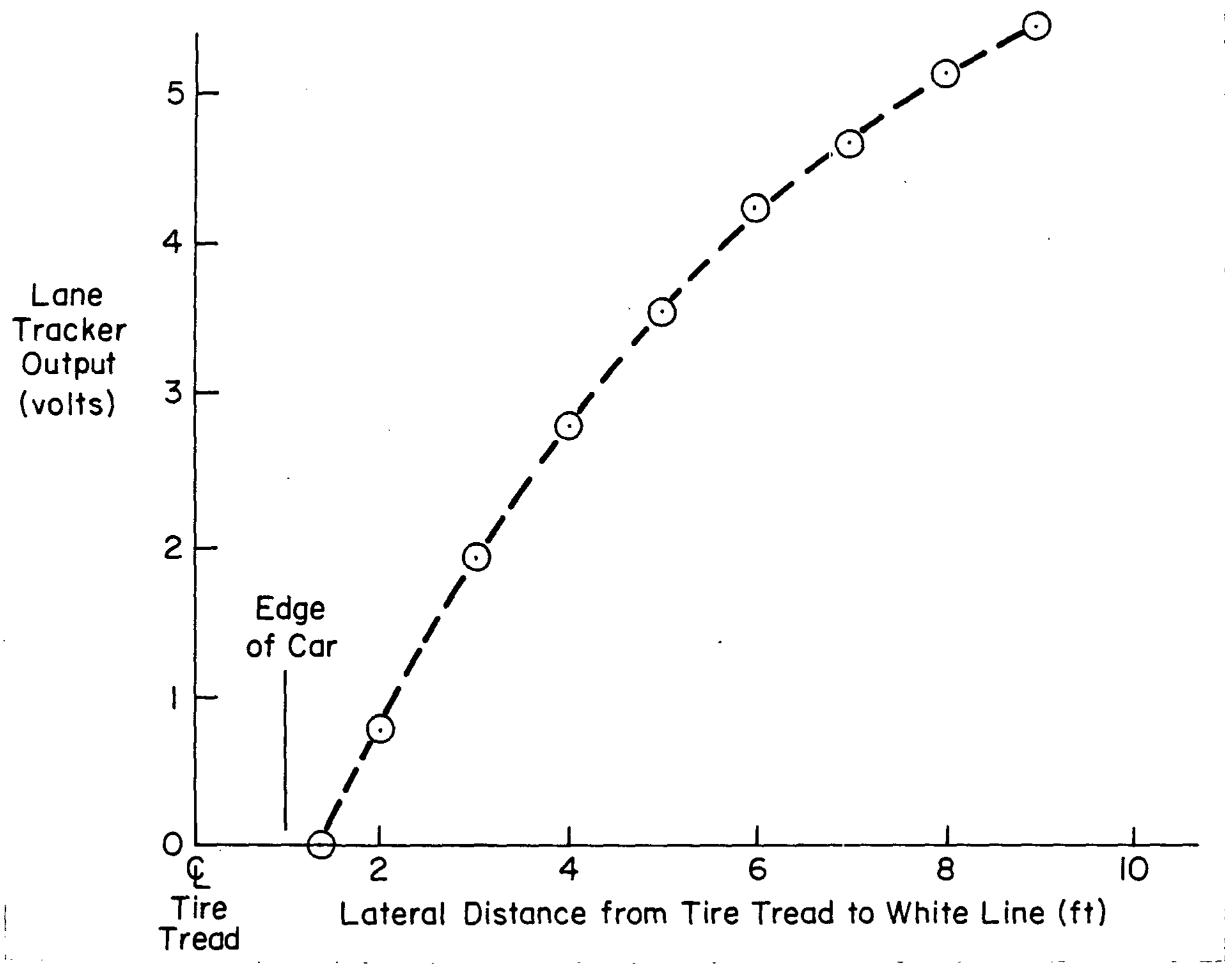


Figure III-8. Calibration of Lane Position Tracker

Since it is possible that the desired reference line may be contaminated by other disturbing reflections (passing vehicles, for example), thus triggering the transducer prematurely and resulting in a wrong output voltage, the control unit has two adjustable circuits called scanning window and sample control.

The <u>scanning window</u> limits the scanning to an adjustable sector of the lateral plane. The sector is adjusted to the range in which the reference line may be present. For example, the transducer can be adjusted to start at the edge of the car and end at a point 6 or 8 ft out to the right.

The <u>sample control</u> selects the measurements within the scanning window. In this circuit each sample is compared with the previous one. If the new value lies within an adjustable range around the previous value, it will be taken as a correct measurement; otherwise, it is skipped and the last accepted value is maintained during that prism revolution. An adjustable number of samples can be skipped in this way. This sample control adjustment allows a correct measurement of the lateral distance relative to an interrupted lane marker such as found between lanes.

The position transducer operates under a wide range of ambient light. Correct measurements can be obtained during day by an adjustable sensitivity. Small changes in light intensity within each step of sensitivity are controlled automatically. During night conditions, however, it is necessary to illuminate the scanned road in the lateral plane by additional spotlights on the vehicle.

Details of the setup and operation are discussed in Section VI.

D. DRIVER PSYCHOPHYSIOLOGICAL MEASURES

These measurements, as subsequently processed, are designed to quantify various aspects of the driver's state such as arousal, fatigue, task-induced and environmental stress, internally induced stress (e.g., alcohol or drugs), and general psychophysiological response to driving events of interest. The measures, the associated sensors, and the on-line processing are discussed below.

1. Measures

A functional block diagram of the physiological measurement system is shown in Fig. III-9 which includes both the sensor signals that are available for analog recording via the J-box and the filtered signals which are recorded by the digital Data Acquisition System. The bandwidths of the signals at primary and processed levels are also given in Fig. III-9. It should be noted that for ECG, EMG, and EEG the onboard derived quantities have considerably reduced bandwidths over the primary sensed signals as a result of the on-line processing. This greatly reduces the bandwidth requirements of the recording system with only a small increase in onboard processing equipment.

A function description of each of the various measurements is given below.

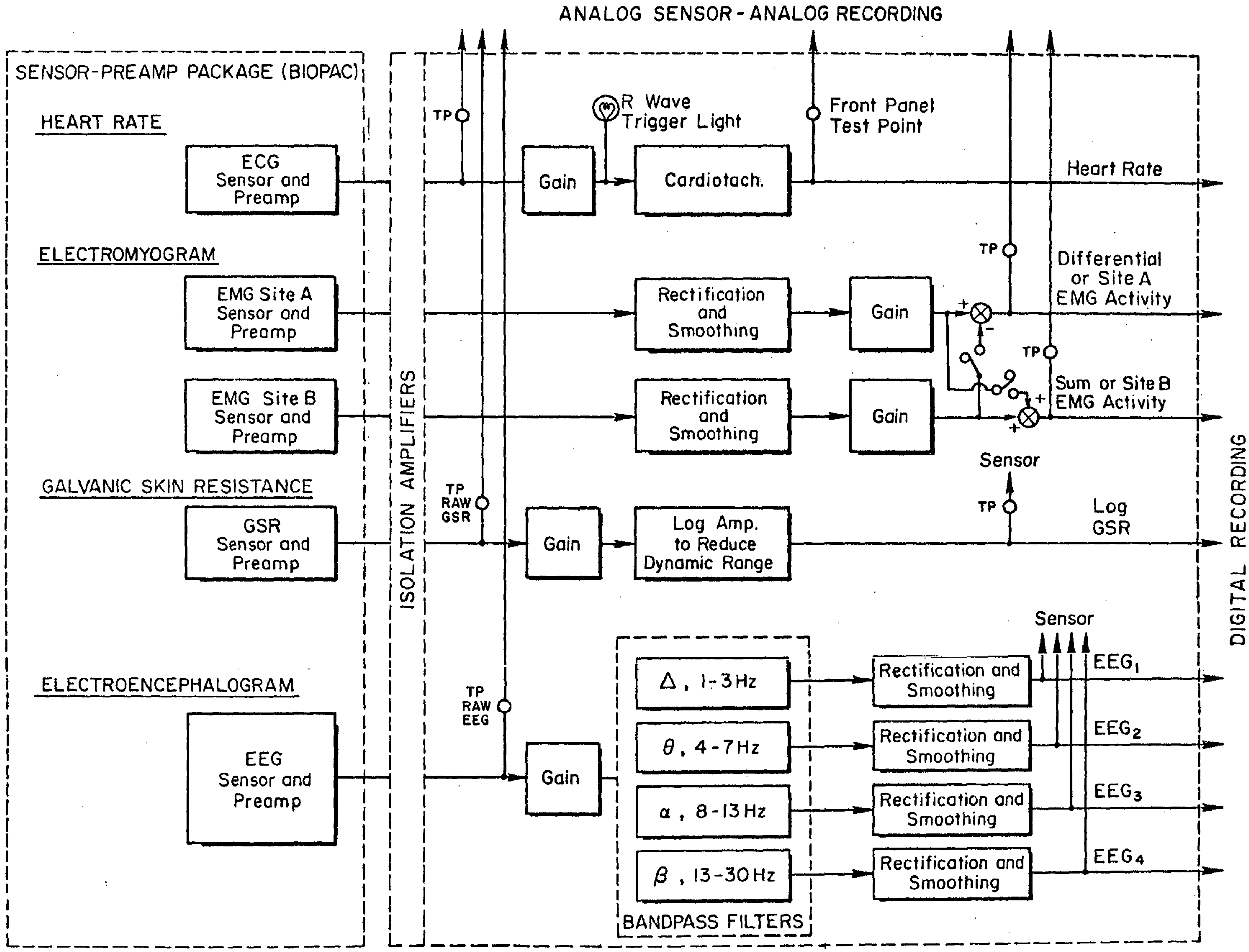


Figure III-9. Psychophysiological Measurement System Block Diagram

a. Electrocardiogram (ECG)

ECG gives a gross measure of the electrical activity of the heart as obtained with surface electrodes. The detailed nature of the ECG waveform (Fig. III-10) is available as a sensor output only and is not recorded digitally. By on-line processing, the heartbeat rate is obtained by measuring the repetition rate of the ECG R-wave spike (Fig. III-10). The stress of critical automobile driving situations may show up in the level and variability of heart rate.

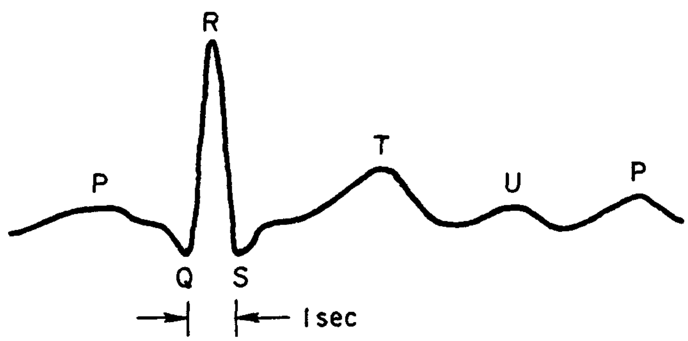


Figure III-10. ECG Waveform

Previous investigators have found that heart rate variability, or "sinus arrhythmia," is a function of mental workload. Research has shown it to be affected by psychomotor task load, as illustrated in Fig. III-11, as well as by driving stress. A cross spectral analysis of the Fig. III-11 data indicates that the change in variability results from a change in breathing frequency, which corresponds to the findings of previous investigators regarding the interaction of respiration and heart rate.

b. Electromyogram (EMG)

The physiological measurement system provides for recording muscle action potentials at two independent sites. Electrode signals are preamplified in the biopac and input to the Driver Measures Unit (Section II) where additional EMG processing is provided (see Section II and Fig. III-9). Within the Driver Measures Unit the EMG signals are rectified and smoothed to give a signal whose magnitude is proportional to average muscle activity.

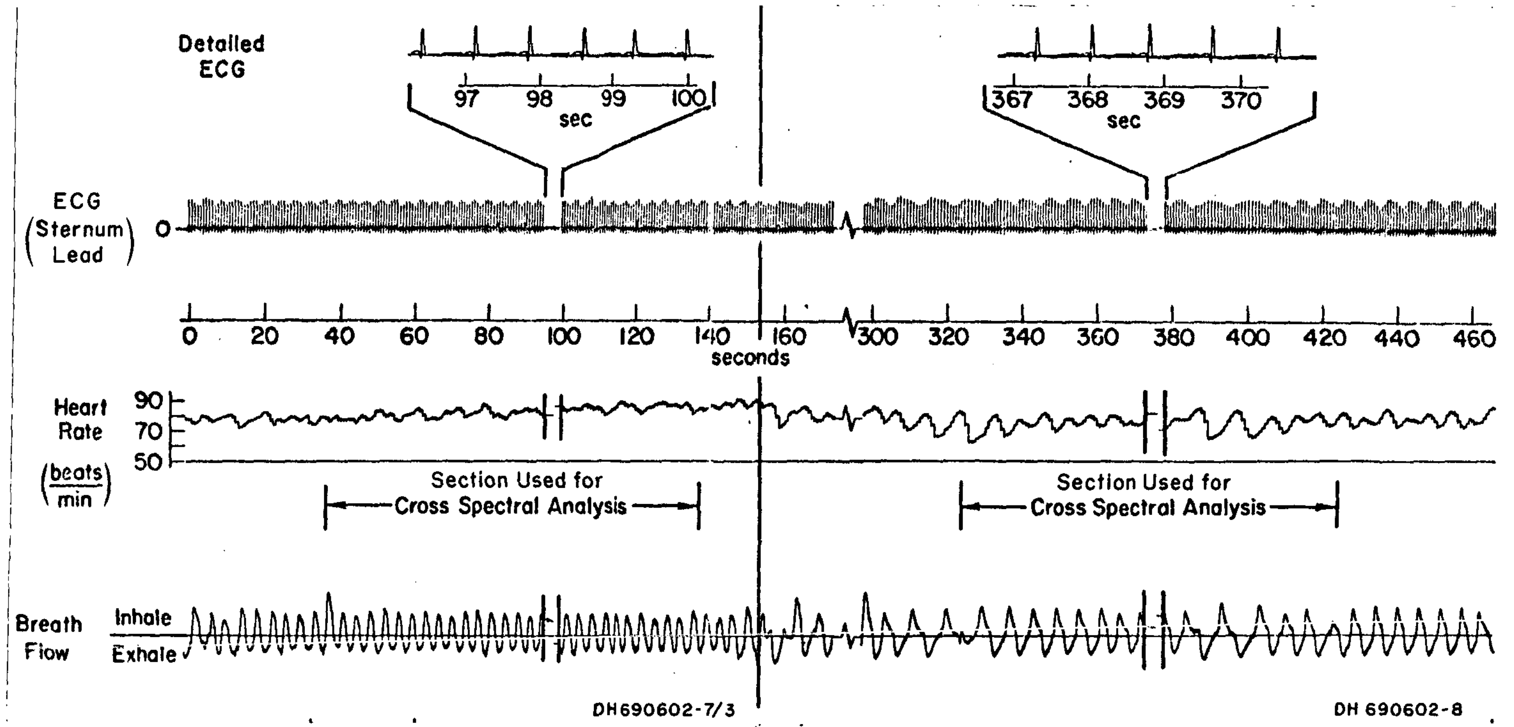


Figure III-11. Typical Time Histories of Heart and Breath Data Showing the Effect of Psychomotor Task Load

Both the gain and smoothing time constant for each EMG signal can be set, and the sum and difference of an agonist/antagonist muscle pair can be selected in order to indicate both average tension levels and differential muscle activity that correlate with limb activity. Previous research has shown that the tension measurement gives an indication of how tightly a human operator is closing the manual control loop he is operating. In the absence of other dynamic response measures, the tension data can be used as an indication of manual control effort in critical driving situations.

Processed EMG signals are available on the front panel of the Driver Measures Unit in order to allow monitoring with a CRT or strip chart recorder when initially setting up gains and bandwidths. The gains of the individual EMG signals can be controlled as well as the gain of the sum and difference signals if selected. Finally, a bias is provided for the differential signal to counteract EMG signals with large resting activity levels.

c. Electroencephalogram (EEG)

Provision is made to record EEG potential in the frontoparietal region using bipolar leads. The frequency content of this signal will be of primary interest, as implied by the mechanization previously shown in Fig. III-9. Here, the signal is decomposed by filtering into four different frequency bands. The results give a measure of the subject's state of arousal. EEG recordings of three of the states of arousal of interest in automobile driving are shown in Fig. III-12. As shown in Fig. III-9, the output of each of the four bandpass filters is rectified, smoothed, and recorded at one time.

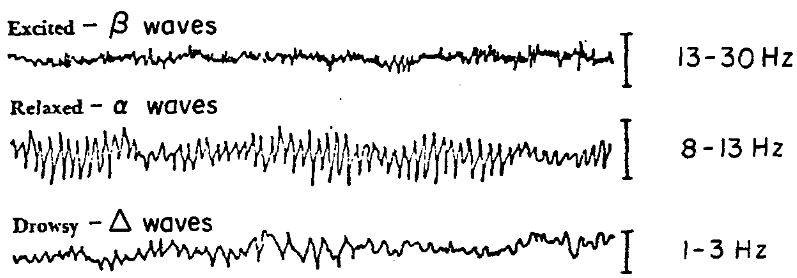


Figure III-12. Examples of Output from Bandpass Filters

d. Galvanic Skin Response (GSR)

The galvanic skin response (GSR) represents the changing or dynamic part of skin resistance and includes "spontaneous" responses related to general arousal plus responses to specific external stimuli. This measurement is made in the standard manner by applying a small constant current between two electrodes on the hand and recording the resultant voltage drop. A log amplifier is provided to reduce the GSR dynamic range for recording purposes. GSR is available only at the sensor box and at front panel test point. Log GSR is recorded digitally.

2. Electrode Sensors

The type and application of the electrode sensors is extremely important in obtaining artifact-free signals. For ECG, EMG, and EEG bipolar pairs of Ag/Ag Cl electrodes with a neutral, non-irritating, long-term electrode gel should be used. Skin preparation is the key to success here, in order to achieve as low a skin contact resistance as possible. The ECG bipolar electrode pair is located on the sternum to minimize EMG artifact. The frontoparietal bipolar EEG placement is located on the midline of the head to minimize EMG artifact and is used with an additional reference electrode. Finally, for the GSR measurement, Ag/Ag Cl pellets are employed in direct skin contact on opposite sides of the palmar surface of one finger. Installation and details of the electrode sensors are discussed in Section VII.

3. Preamplifier Package

The driver measures described above utilize a small subject-mounted "biopac" which includes biopotential preamplifiers and prefiltering circuits. A photo of the biopac installed on the belt of a test subject is shown in Fig. III-13. The biopac provides adequate signal levels (0.1 to 1 volt) for input to the Driver Measures Unit of the Central Electronics Console described in Section II. The ECG, EMG, and EEG preamplifiers are high gain, low noise differential amplifiers with high common mode rejection. The GSR electronics provide a constant current source and measure the resulting voltage drop across the GSR electrode. Finally, each of the preamplifiers has a high frequency output filter than has been set to provide clean strip chart or CRT records.

Figure III-13. Installation of Electrode Sensors and Biopac on Belt of Test Subject

4. Onboard Processing in Driver Measures Unit

In order to reduce the tape recording bandwidths of physiological signals, the onboard processing shown in Fig. III-9 is included. The signal processing functions are packaged in the Driver Measures Unit and produce voltages proportional to activity in the various channels.

The cardiotachometer consists of two integrators, hold circuits, and a divider which generate a voltage proportional to heart rate, thus reducing the bandwidth of this channel to frequencies on the order of the heartbeat rate. Muscle tension is directly related to the magnitude of EMG, so this signal is rectified and filtered to give a voltage proportional to muscle activity. The differential EMG activity signal can be used to correlate with limb movement and thus has a higher bandwidth than the second channel used to measure general neuromuscular tension.

Changes in skin resistance are quite slow, so this channel has an inherently low bandwidth. Large magnitude changes can occur, however, so that a log amplifier is used to compress the dynamic range of the GSR data channel. Finally, EEG activity in certain frequency bands is of interest, and provision for four bandpass filters with associated rectification and smoothing to detect this activity is included.

E. ADDITIONAL SENSOR CAPABILITY

The basic DPMAS prototype described in this report has built-in provision for growth including the addition of data sensors and other apparatus. This provision includes the following types of considerations: anticipated power requirements, physical space in the vehicle, and processing and recording channels. The likely add-on sensors and associated considerations are discussed briefly below.

1. Sideslip and Path Angle Sensors

Provision for vehicle sideslip (β) and path angle (λ) sensors have been dedicated to Channels 08 and 07, respectively. Sideslip has a selectable high/low sample rate of 50/20 samples/second. Path angle has only one sample rate (20 samples/second). Scaling and allocation of these channels to specific sensor groups will be done when a sensor is installed.

2. Eye Point of Regard (EPR)

The driver subject's eye point of regard relative to the surround can be a useful measure in many experimental scenarios. Although such a sensor is not part of the basic DPMAS, power and data channel capacity have been dedicated for this add-on provision. In addition to two digital channels (1 horizontal and 1 vertical), provision is made to superpose the EPR as a circular symbol on the video monitor.

3. Spare Channels

Twenty-four additional channels are non-dedicated and available for other continuous data sensors. These channels are numbered 37 through 60, as shown in the following subsections. Thirty-two discrete inputs are available on Channels 64 through 67 (8/channel). Currently, only the 13 discussed in Subsection III-A are being used.

F. SENSOR GROUPINGS

In order to conduct efficient experimental tests, not all sensors are needed at all times. This separation is accomplished with 6 selectable sensor groups. The allocation of sensors in each group is as shown in Table III-1. In general, the following classification of test types has been assigned:

- Group 1 — Open Loop Vehicle Identification Tests
- Group 2 — Closed Loop Driver/Vehicle Response and Handling Tests
- Group 3 — Driver Training and Evaluation Tests
- Group 4 — Long-Term Driver Fatigue Tests
- Group 5 } Unassigned
- Group 6 }

Results of demonstration tests using these groups are discussed in Appendix B.

G. INSTRUMENTATION SCALING AND CHANNEL ALLOCATION

A complete list of signals, gains, sample rates, sample rate switches, group allocations, and sign conventions is presented in Table III-2. Of particular note is the separation between the filter channel in the lefthand column and sensor channel in the righthand column. The filter channels represent the data channels being recorded on digital tape, thus having been passed through third-order Butterworth filters to minimize noise and digital aliasing. The sensor channels represent unscaled sensor outputs available at the junction box (for strip chart recording) except for the 5 scaled quantities

TABLE III-1. SENSOR GROUP ALLOCATION

MEASURE	QUANTITY	GROUP 1	2	3	4	5	6
Driver Control Outputs	Steering wheel	√	√	√			
	Steering rate		√	√	√		
	Throttle		√	√			
	Brake	√		√			
	Experimenter brake			√			
	Discretes	√	√	√	√		
Driver Psychophysiological	Heart rate		√	√	√		
	EMG			√	√		
	GSR			√	√		
	EEG			√	√		
Vehicle Control Variables	Total steer	√	√				
	Pitman arm		√				
	Servo input	√	√				
	Steering error		√				
Vehicle Motion Variables	Roll angle	√	√				
	Pitch angle	√					
	Heading angle	√	√	√			
	Roll rate	√		√			
	Pitch rate	√					
	Yaw rate	√	√	√			
	Longitudinal acceleration	√		√	√		
	Lateral acceleration	√	√	√	√		
	Vertical acceleration	√		√			
	Forward speed	√	√	√	√		
	Wheel velocities	√					
	Lateral position		√	√			
	Distance travelled	√	√	√	√		

with subscript "R". These quantities have been scaled and are designed for use with the Describing Function Analyzer in Group 2 Driver/Vehicle Response Tests. These five scaled quantities have only been passed through 50 rad/sec first-order filters. Use of these quantities is discussed further in conjunction with the servo steering system in Section V. For reference, a list of sensors and raw scale factors is given in Table III-3.

TABLE III-2. DPMAS SIGNALS, GAINS, SAMPLE RATES, GROUP SELECTION, ETC.

FILTER CHANNEL	QUANTITY	SYMBOL	HI/LOW GAIN (BIAS)	SAMPLE RATE HI/LOW	SAMPLE RATE SWITCH	GROUP						SIGN CONVENTION, COMMENTS	SENSOR CHANNEL	SCALED QUANTITY
						1	2	3	4	5	6			
1	Steering Wheel Position, δ_{SW}	DSW	$\frac{20.}{60.}\ \frac{deg}{v}$	50/20	1	✓	✓	✓				Positive-right	23	δ_{sw_R}
2	Steering Wheel Rate, $\dot{\delta}_{SW}$	DSWD	50. $\frac{deg/sec}{v}$	50/20	2		✓	✓	✓			Positive-right	—	
3	Throttle Pedal Position, δ_T	DT	0.4 $\frac{in.}{v}$	20/2	3		✓	✓				Always positive Foot off = 0 v Max travel = ?	—	
4	Brake Line Pressure, P_B	PBRK	5. lb/v (0 lb = −10 v; 100 lb = +10 v)	20/2	4	✓		✓				Foot off = −10 v	—	
5	Steer Angle, δ_{W_T}	DWT	4. deg/v	50/20	1	✓	✓					Positive-right	25	$\delta_{W_{T_R}}$
6	Heading Angle, ψ	PSI	$\frac{5.}{20.}\ \frac{deg}{v}$	20		✓	✓	✓				0V-Initial Setting NEGATIVE -10V POSITIVE +10V	18	
7	Path Angle, λ	PATH	No sensor	20									—	
8	Sideslip Angle, β	BETA	No sensor	50/20									—	
9	Pitch Angle, θ	THE	1. deg/v	20		✓							16	
10	Roll Angle, φ	PHI	1. deg/v	20		✓	✓						17	
11	Pitch Rate, Q	Q	4. $\frac{deg/sec}{v}$	20		✓							13	
12	Roll Rate, P	P	4. $\frac{deg/sec}{v}$	20		✓		✓					14	
13	Yaw Rate, R	R	$\frac{4.}{10.}\ \frac{deg/sec}{v}$	50/20	5	✓	✓	✓				Positive-right	15	
14	Lateral Acceleration, a_{Y_I}	AYI	.1 $\frac{g}{v}$	50/20	5	✓	✓	✓	✓				—	
15	Longitudinal Acceleration, a_{X_I}	AXI	.1 $\frac{g}{v}$	20/2	6	✓		✓	✓				—	
16	Vertical Acceleration, a_{Z_I}	AZI	.2 $\frac{g}{v}$	20		✓		✓					—	
17	Lane Position, Y	Y	Tangent function ≈1 ft/v	20			✓	✓					—	
18	LF Wheel Velocity, w_{LF}	LFWV	10 $\frac{mph}{v}$	20		✓						Always positive Stopped = 0 v	—	
19	RF Wheel Velocity, w_{RF}	RFWV	10 $\frac{mph}{v}$	20		✓						Always positive Stopped = 0 v	—	
20	LR Wheel Velocity, w_{LR}	LRWV	10 $\frac{mph}{v}$	20		✓						Always positive Stopped = 0 v	—	
21	RR Wheel Velocity, w_{RR}	RRWV	10 $\frac{mph}{v}$	20		✓						Always positive Stopped = 0 v	—	
22	Forward Velocity, U_o	VEL	10 $\frac{mph}{v}$	20/2	6	✓	LO ✓	LO ✓	LO SR ✓			Always positive Stopped = 0 v	—	
23	Experimenter Brake, PEX	XBRK	5. lb/v (0 lb = −10 v; 100 lb = +10 v)	2				✓				No input = −10 v	—	
24	External Servo Command, δ_{i_R}	DIR	$\frac{.5^{\circ}\ \delta_w}{v}$	5		✓	✓						22	δ_{i_R}
25	Derived Steering, Error, e_{m_R}	EMR	$\frac{10^{\circ}\ \delta_{sw}}{v}$	5			✓						24	e_{m_R}
26	EMG_A or ΔEMG	EMGA	±10 v FS	50/5	7			✓	✓				03	
27	EMG_B or ΣEMG	EMGB	±10 v FS	5				✓	✓				04	
28	Log GSR	LGSR	±10 v FS	5				✓	✓				05	
29	EEG_1	EEG1	±10 v FS	5				✓	✓				08	
30	EEG_2	EEG2	±10 v FS	5				✓	✓				09	
31	EEG_3	EEG3	±10 v FS	5				✓	✓				10	
32	EEG_4	EEG4	±10 v FS	5				✓	✓				11	

(Continued)

TABLE III-2 (Concluded)

FILTER CHANNEL	QUANTITY	SYMBOL	HI/LOW GAIN (BIAS)	SAMPLE RATE HI/LOW	SAMPLE RATE SWITCH	GROUP 1	2	3	4	5	6	SIGN CONVENTION, COMMENTS	SENSOR CHANNEL	SCALED QUANTITY
33	EPR HOR	EPRH	No sensor	50			✓	✓					—	
34	EPR VERT	EPRV	No sensor	50			✓	✓					—	
35	Heart Rate, HR	HR	20 bpm/v	5			✓	✓	✓					
36	Pitman Arm, δ_{PIT}	PITA	4 deg/v	50/20	8		✓					Positive-left 10 deg/v	25	δ_{PIT_R}
37	Not used				8									
38-60	Not used		SPARE CONTINUOUS CHANNELS											
61-63	Distance Travelled, X	DIST TRAV FEET	1 count/foot	20/1	6	✓	LO ✓	LO ✓	LO ✓			Always positive 0 at ? Reset? 100,000 maximum		
64	1) Parking Lights	PKLT	1-off, 0-on	1		✓	✓	✓	✓				28	
	2) Not used	NU		1		✓	✓	✓	✓				—	
	3) Brake Lights	BKLT	1-off, 0-on	1		✓	✓	✓	✓				30	
	4) Radio	RADI	1-off, 0-on	1		✓	✓	✓	✓				31	
	5) RT Turn Indicator	RTTI	1-off, 0-on	1		✓	✓	✓	✓				32	
	6) LT Turn Indicator	LTTI	1-off, 0-on	1		✓	✓	✓	✓				33	
	7) Hi Beam	HIBM	1-off, 0-on	1		✓	✓	✓	✓				34	
	8) Low Beam	LOBM	1-off, 0-on	1		✓	✓	✓	✓				35	
65	1) Horn	HORN	1-off, 0-on	1		✓	✓	✓	✓				36	
	2) Windshield Wiper	WWIP	1-off, 0-on	1		✓	✓	✓	✓				37	
	3) Air Conditioner	AIRC	1-off, 0-on	1		✓	✓	✓	✓				38	
	4) Engine Oil Pressure	OILP	1-on, 0-off	1		✓	✓	✓	✓				39	
	5) Emergency Brake	EMBK	1-off, 0-on	1		✓	✓	✓	✓				40	
	6) Seat Pressure	SEAT	1-on, 0-off	1		✓	✓	✓	✓				41	
	7) Not used	NU		1		✓	✓	✓	✓				—	
	8) Not used	NU		1		✓	✓	✓	✓				—	
66-67	Not used		SPARE DISCRETE CHANNELS											
	Servo Position, δ_{SR}	DSR	4 deg/v										27	
	Raw EEG	REEG	±10 v FS										07	
	Raw ECG	RECG	±10 v FS										01	
	Raw GSR	GSR	±10 v FS										06	
	Motion Feedback A	A	.1 g/v									Lateral acceleration feedback	19	
	Motion Feedback B	B	2 deg/sec/v									Yaw velocity feedback	20	
	Motion Feedback C	C	1 deg/v									Roll angle feedback	21	
	Test Alarm	TM	—										12	

TABLE III-3

SENSORS

SENSOR	MANUFACTURER AND MODEL NUMBER	RANGE AND SENSOR VOLTAGE SCALE
δ_{sw}	Bourns 3550-1-103	64 deg/v
$\delta_{\dot{sw}}$	Servo-Tech S-757B-1	0.332 v/rev/min
δ_T		Closed to Open, 0-5 v
P_b	Giannini 46131	100 lb = 2 v
P_{EX}		
a_x, a_y, a_z	Sundstrand QA1100-S-7	2.5 g range, 5 v/g
p, q, r	Timex CD040, CD100	8 deg/sec/v
φ, θ, ψ	General Electric SR-3	10 v = 180 deg directional gyro
Speed tachs	Servo-Tech S-757B-1	20.8 v/1000 rpm
Front steer angle	Bourns 3465 S-1-102	5 deg/v
Lane, position error sensor	TNO	1 v/ft (tangent function)
Biopac	BioCom	
Pitman Arm	Bourns 3465 S-1-102	4.8 deg/v

SECTION IV

VIDEO SYSTEM

The video system is intended to record the driver's visual environment. This includes portions of the front and rear field of view external to the automobile. At the experimenter's option it can also include part of the vehicle interior, such as the driver's face and eyes. Other video system features include:

- Split picture capability
- Display of numerical data on video monitor
- Onboard playback (i.e., instant replay)
- Synchronization with digitally recorded data

The video system comprises three cameras, video chassis, status control panel with monitor, and a video tape recorder. Two cameras mounted on the roof are used to view the driver's field of view fore and aft. The roof-mounted cameras are shown in Fig. IV-1. The third camera may be placed at the experimenter's discretion to view other portions of the external field or areas of the vehicle interior such as the instrument panel or the driver subject, as shown in Fig. IV-2.

The camera locations on the vehicle and their fields of view for the nominal 12.5 mm lens are shown in Fig. IV-3. Although not provided, the cameras have the capability for other focal length lenses to provide alternate fields of view for the cameras. For example, for those experimental situations where a wider view is needed, a wide angle (e.g., 10 mm) lens can be employed. The natural eye perspective would be that provided by a 25 mm lens.

The electronic video converter in the video chassis permits mixing of digital data with the video signal to permit superposition of digital data on the monitor and recording. This permits key measures to be presented on

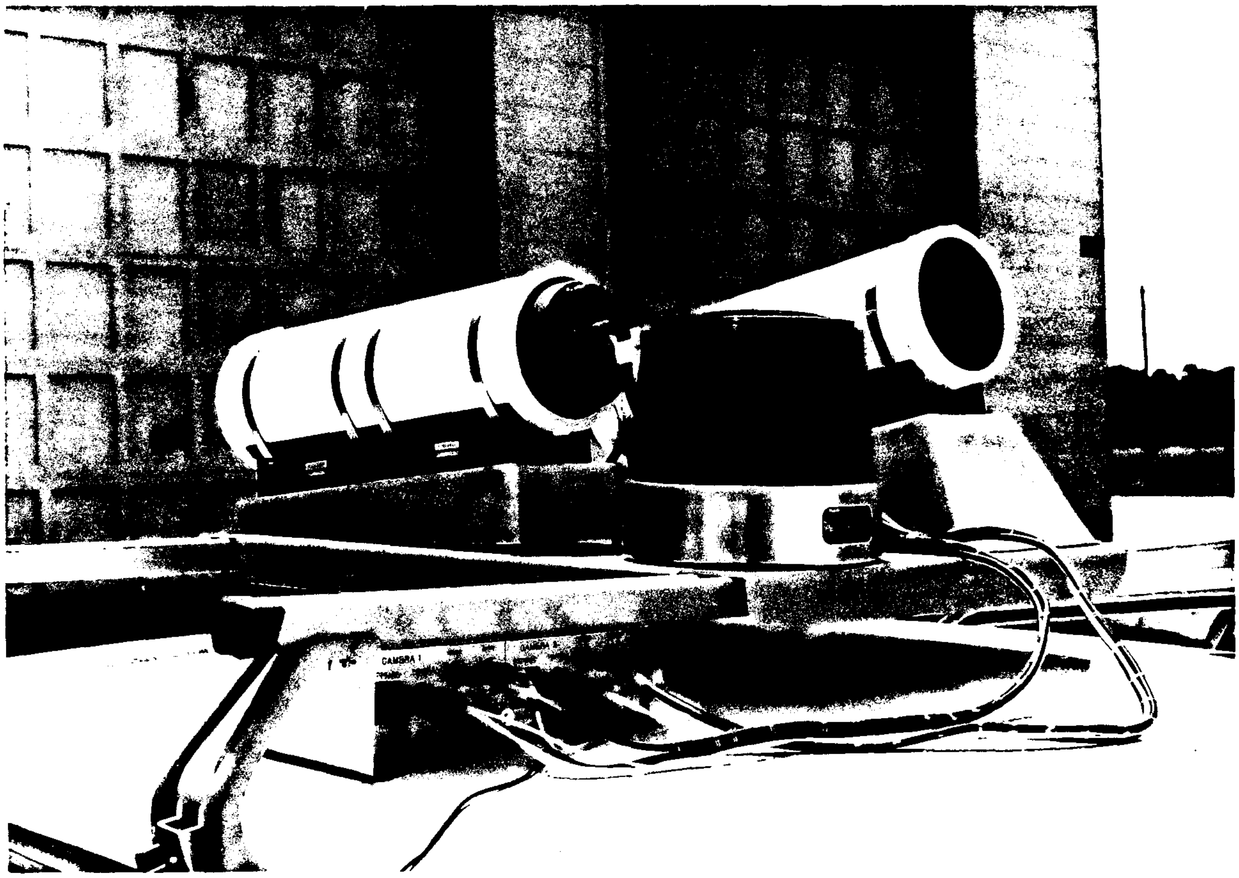


Figure IV-1. Roof-Mounted Fore and Aft Video Cameras and Connector Box

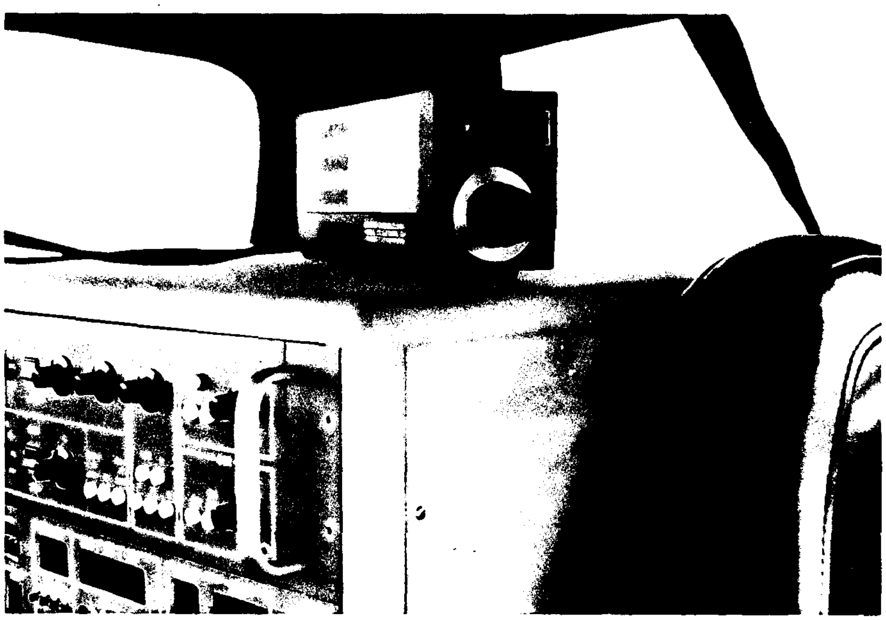
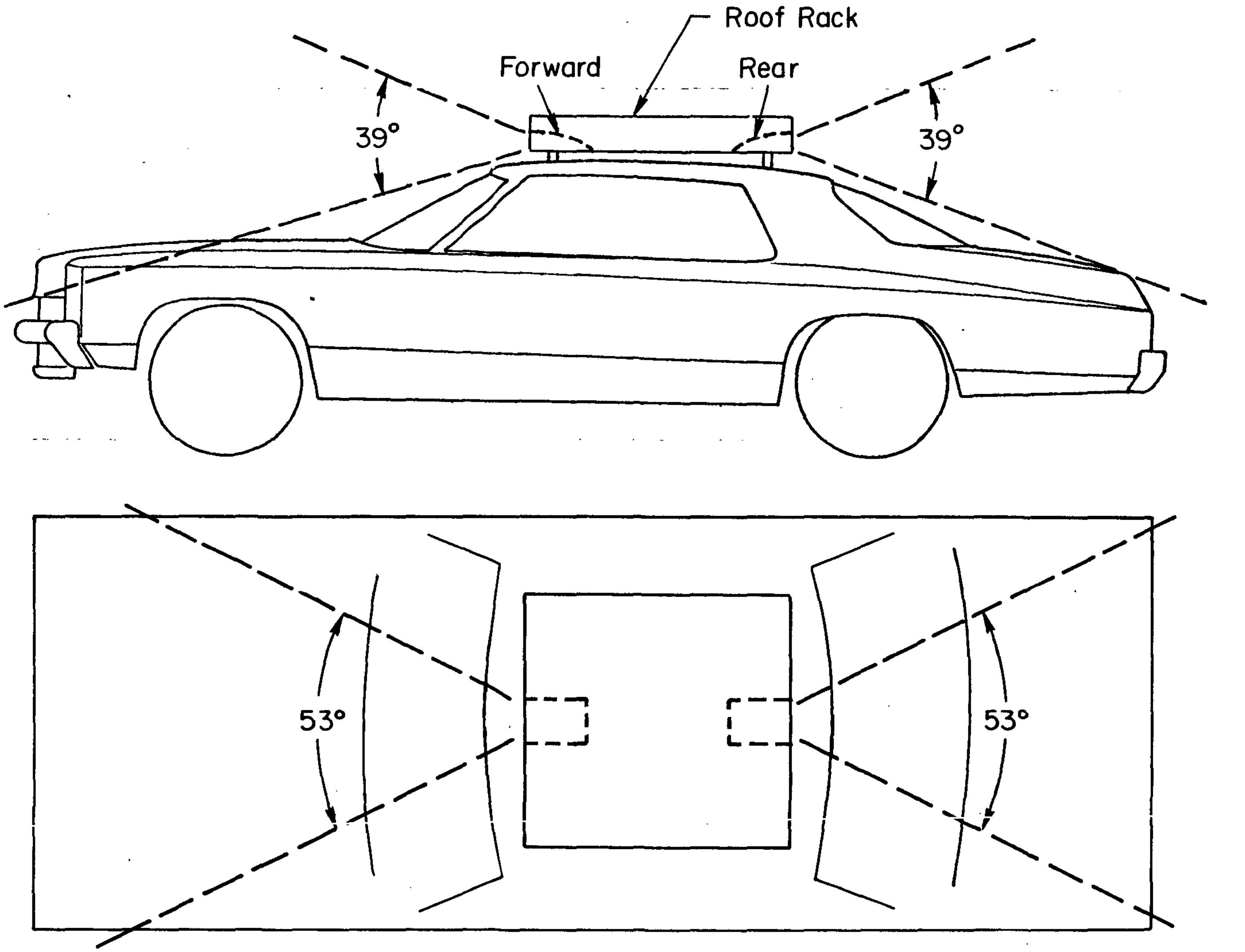


Figure IV-2. Portable Camera 3 Mounted on Top of Central Electronics Console



	Focal Length	Horizontal Angle	Vertical Angle
Natural Eye Perspective	25mm	28 deg	21 deg
Nominal Lens	12.5 mm	53 deg	39 deg
Wide Angle	10 mm	70 deg	52.5 deg

Note: Interior camera not shown

Figure IV-3. Camera Locations and Nominal Fields of View the video playback for some experimental scenarios, and provides for correlating the digital tape with the video tape. The data presented on the video includes time of day, run identification number, forward velocity, and heart rate, and two selectable channels such as shown in Fig. IV-4.

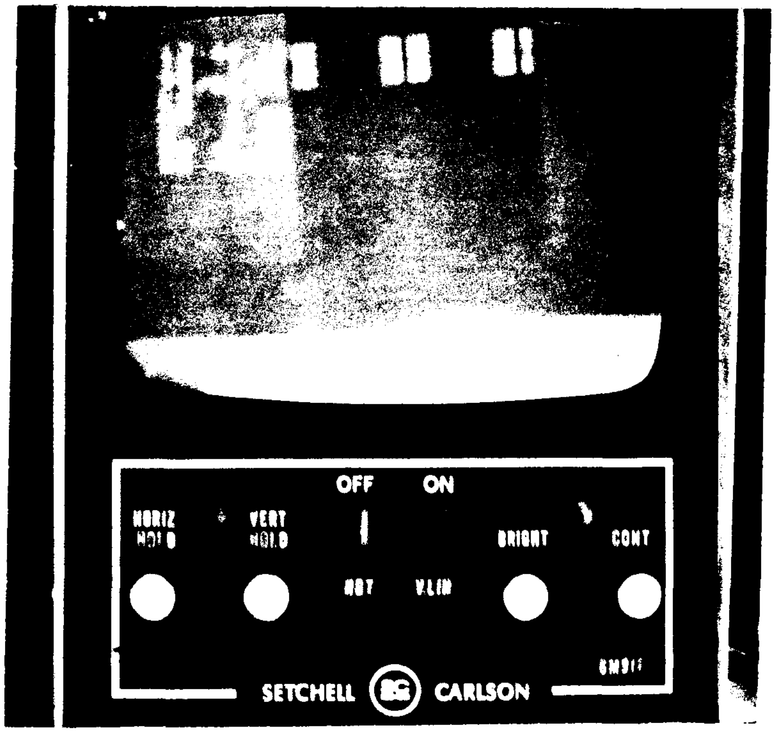


Figure IV-4. Video Display Format

The heart of the video system is contained in the video chassis located just behind the Central Electronics Console. The video chassis contains the sync generator, video distributor amplifiers, the picture split controls, and a noise cancelling microphone as shown in Fig. IV-5.

The video display format and tape motion controls are located on the Status Control Panel shown in Fig. IV-6. The lower two rows of buttons control the video tape and monitor display. Operation of the tape controls is further explained in Section VII. The split camera selection (lower right button) presents a picture such as shown in Fig. IV-7. In addition, tape motion control pushbuttons are also located on the panel of the video tape recorder itself, but these are not as accessible as those on the Status Control Panel.

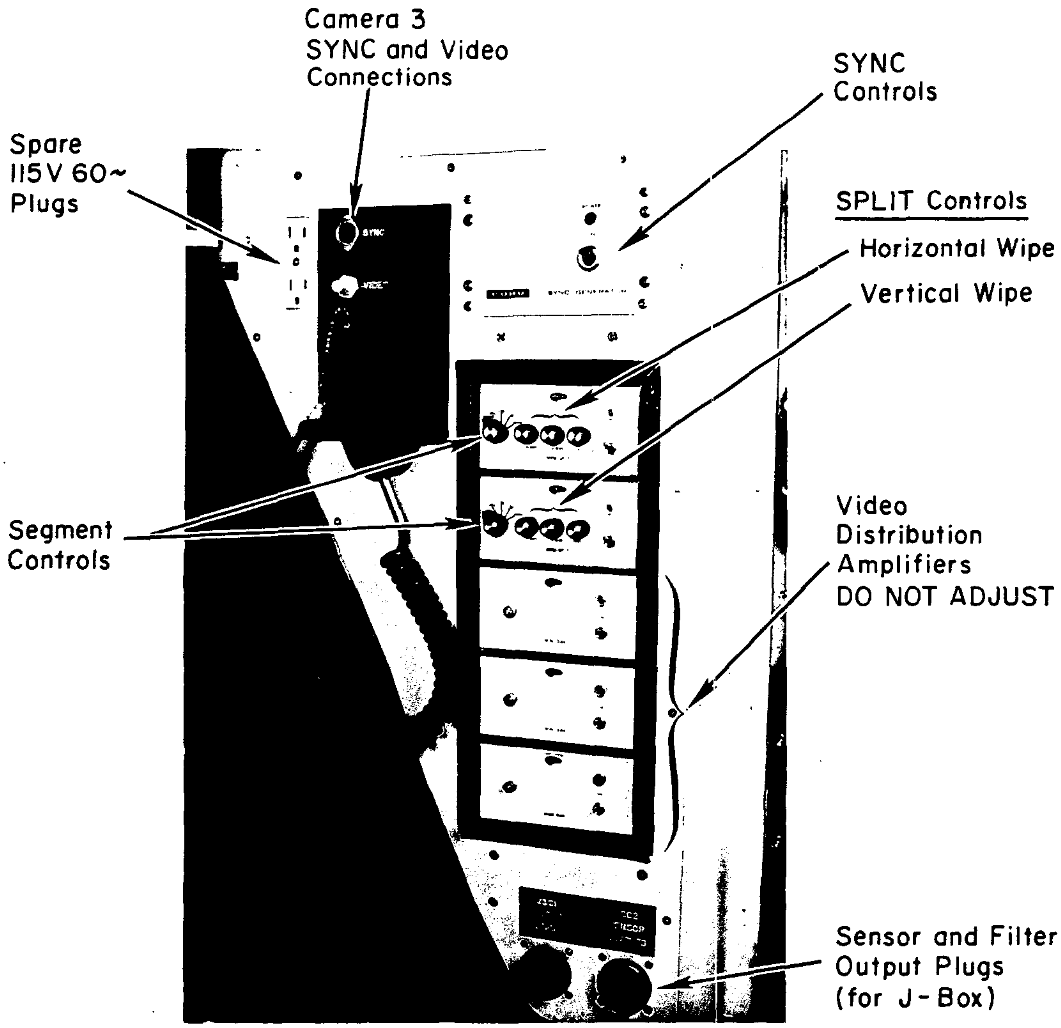


Figure IV-5. Video Chassis

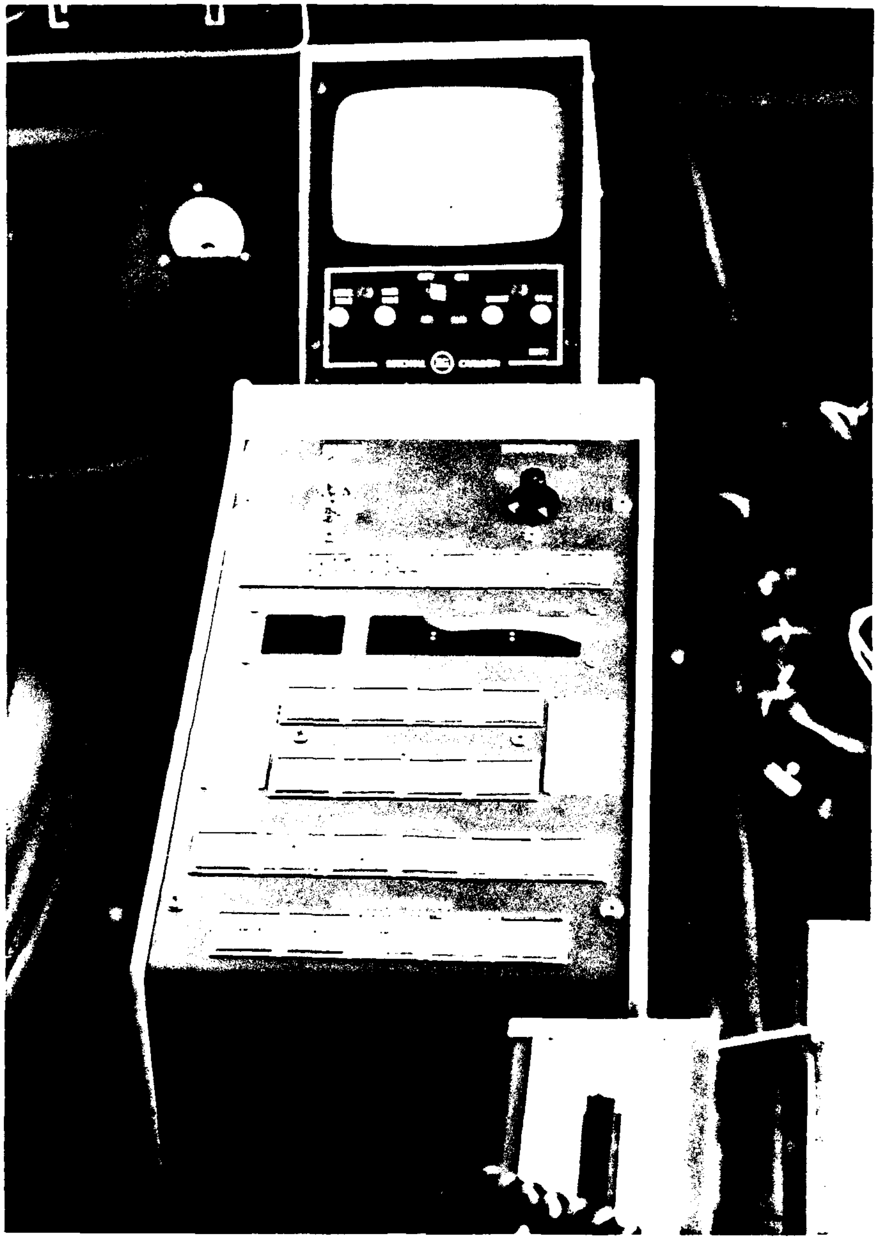


Figure IV-6. Video Controls on Status Control Panel

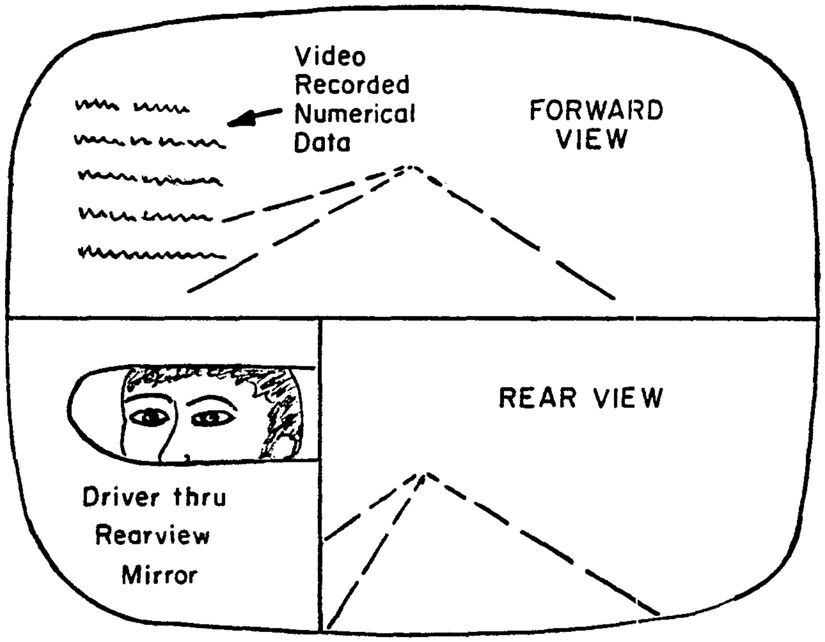


Figure IV-7. Split Camera Display

The video tape recorder is an International Video Corporation VCR-100. It operates with a cartridge (or cassette) tape having 60 min capability. Spare tapes are available as Part No. 361-1-2150-IVC-C from 3M Corp. or Part No. 02009944-010 from IVC.

When tape recording is completed the control REWIND/EJECT is depressed and the tape will automatically eject the cassette as shown in Fig. IV-8.

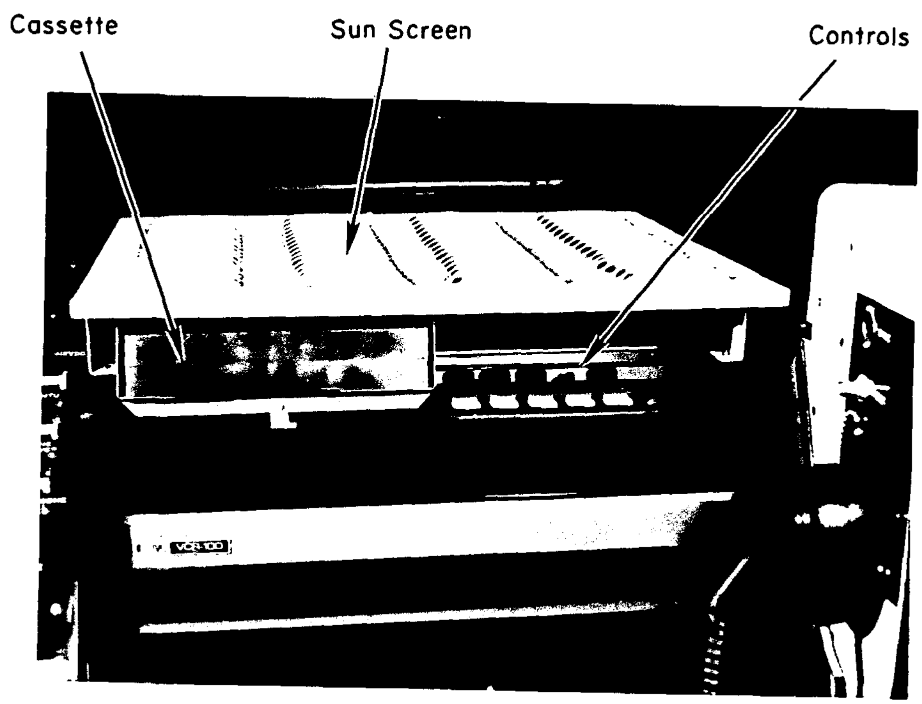


Figure IV-8. Video Tape Recorder Showing Sun Screen and Ejected Cassette

SECTION V

SERVO STEERING SYSTEM

The servo steering system is designed to allow movement of the front tires independent of the driver's steering wheel inputs. This movement is provided by an extensible link in between the Pitman arm and the relay rod as shown in Fig. V-1. The extensible link is an electrohydraulic servo actuator that extends a piston in proportion to an applied voltage. Electrical inputs to the servo can be from the steering wheel to effect changes in steering ratio, from a lateral accelerometer (or other vehicle motion sensor) to effect changes in vehicle stability factor, or from an external source which would provide an unexpected event. This section details the system design and presents some of its capability for changing vehicle properties and for making closed loop driver/vehicle measurements in regulation tasks.

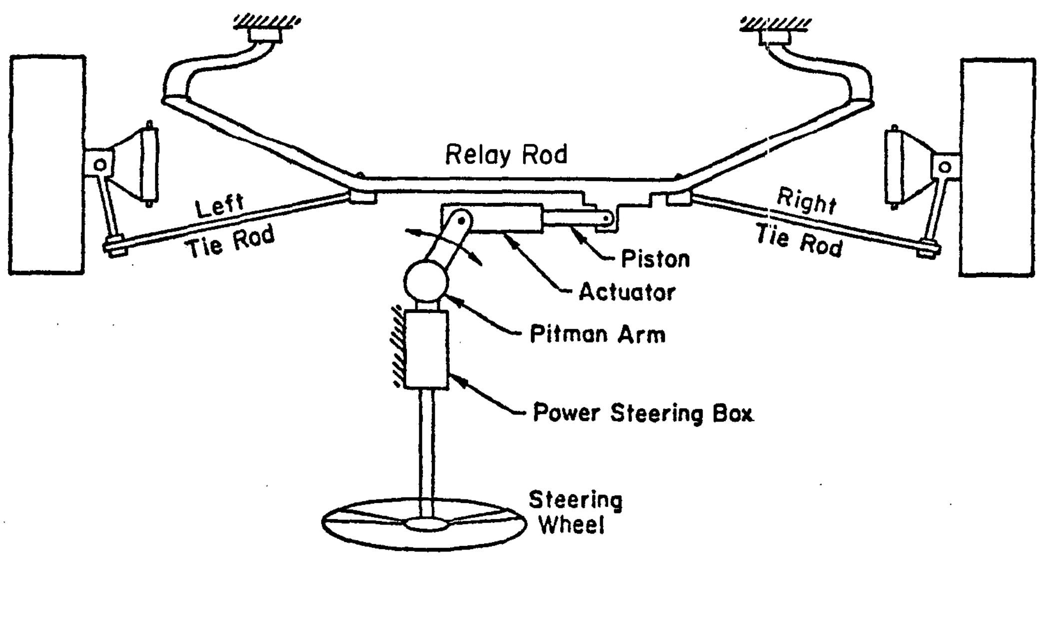


Figure V-1. Servo Steering Schematic

A. HYDRAULIC AND ELECTRONIC DESIGN

Figure V-2 shows a functional schematic of the hydraulic system. The heart of this system is the belt-driven hydraulic pump located under the hood along side the alternator. High pressure hydraulic fluid (1400 psi) is sent through a high pressure filter and pressure gauge to the high pressure side of the actuator. A nitrogen filled accumulator allows for flow changes in the high pressure line. The electric servo valve controls the flow to the low pressure side and thus is able to move the piston to any position. The electrical position pickoff is used to tell the servo valve to stop the flow when the piston has reached the desired position (thus cancelling the electrical command). Low pressure return flow is sent to the reservoir for recycling. By adjustments of the servo control loop the dynamics of the servo can be described by the first-order wheel-to-wheel command transfer function:

$$\frac{\delta_W}{\delta_{W_c}} = \frac{20}{s + 20}$$

Maintenance for the hydraulic system includes:

- Checking fluid level in the reservoir.
- Checking belt tightness on the pump.
- Checking pressure on the gauge.

The electronic schematic is shown in Fig. V-3. This is drawn in analog block diagram form for easy interpretation. Changes to the system, such as scaling, authority limits, etc., should be made on this diagram. Particular attention is directed toward the lefthand portion of the figure where the controls are located. These controls include two-sign switches (+, 0, −) and three pots (K_1, K_2, K_3) for gain and equalization. The following paragraphs discuss their use for each feedback capability.

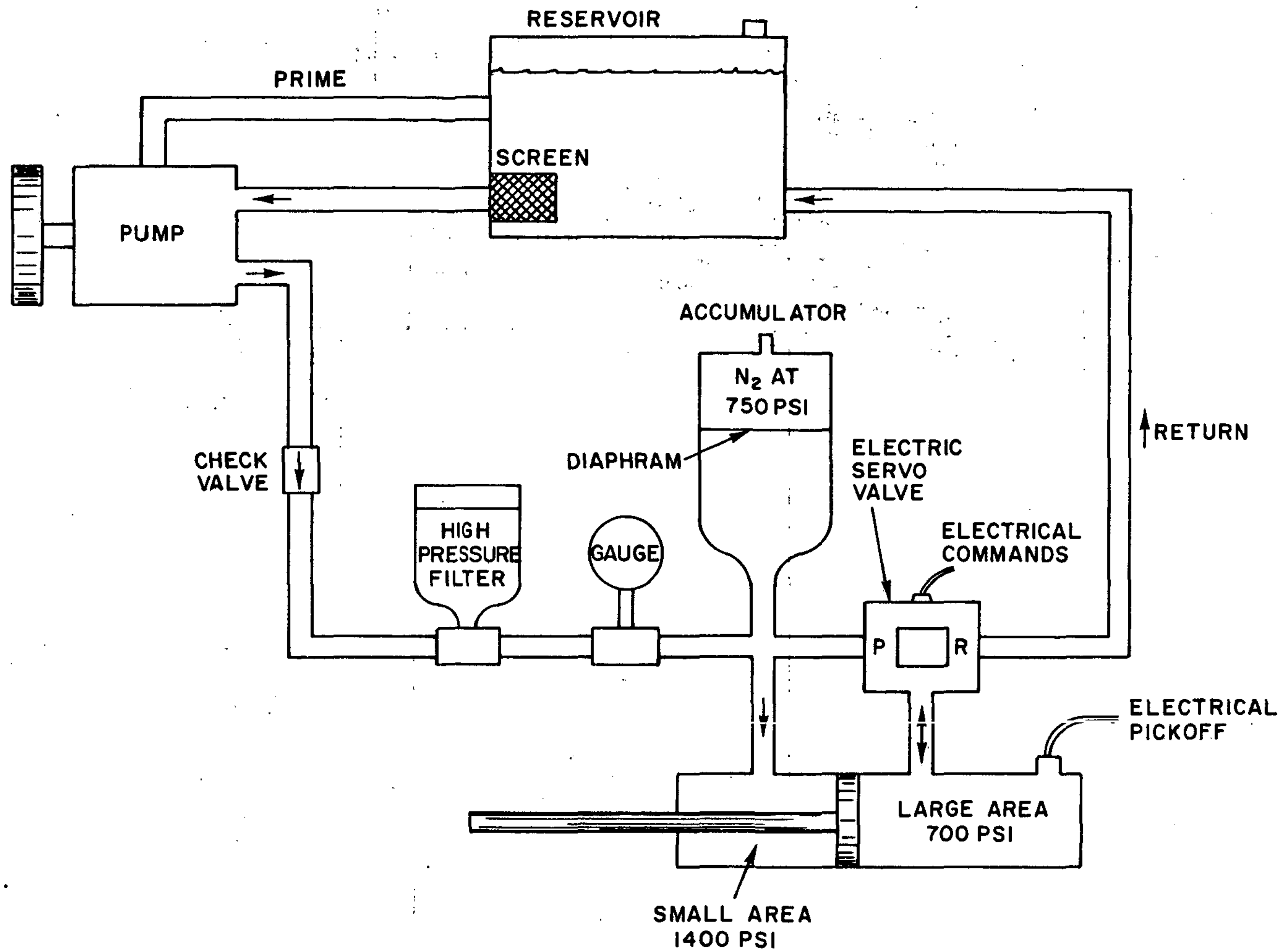


Figure V-2. Hydraulic System Schematic

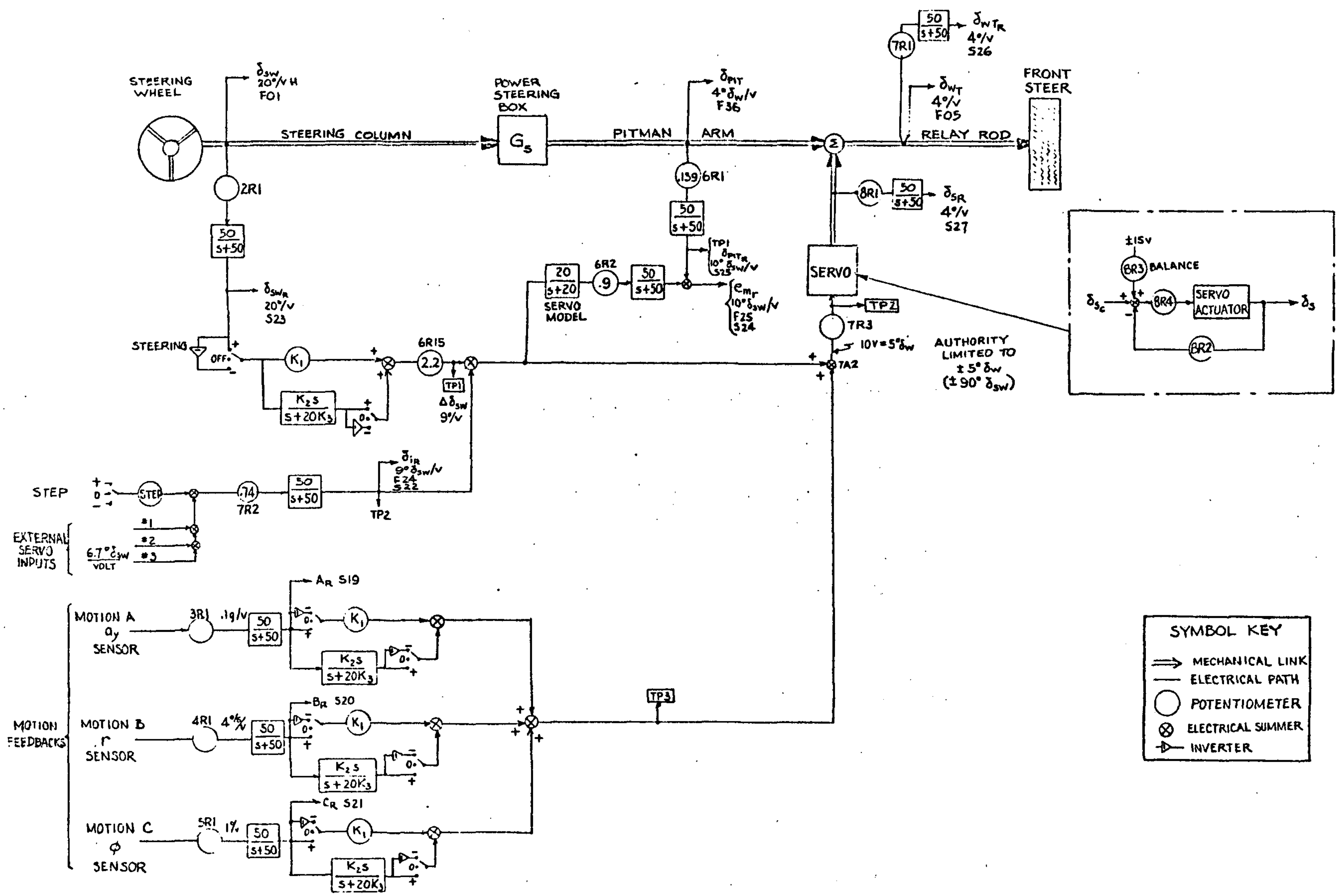


Figure V-3. Electronic Schematic of Servo System

B. STEERING

The first control, STEERING, takes a scaled steering wheel position voltage, δ_{SW_R}, at 20 deg/volt (scaled by 2R1 on Fig. V-3) and sends it through the sign switch, external gain pot K_1, and internal scaling gain pot 6R15 to the servo command summing point, Amplifier 7A2. The gain pots K_1, K_2, and K_3 and sign switches can be seen on the lefthand side of the Servo Control Unit shown in Fig. V-4. When the equalization switch

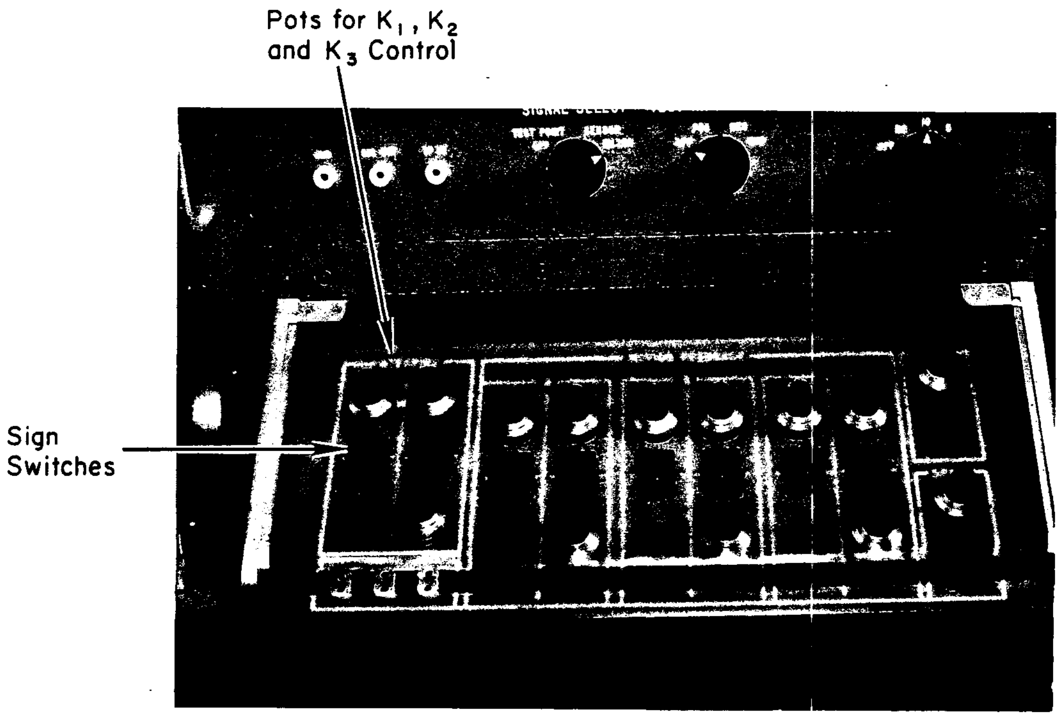


Figure V-4. Servo Control Unit

is off (i.e., 0), then the steering ratio can be changed directly by varying K_1 as shown in Fig. V-5. The analytical expression relating steering ratio, G_S, to the pot setting (PS) of K_1 is given by:

$$G_S = \frac{18}{1 \pm PS}$$

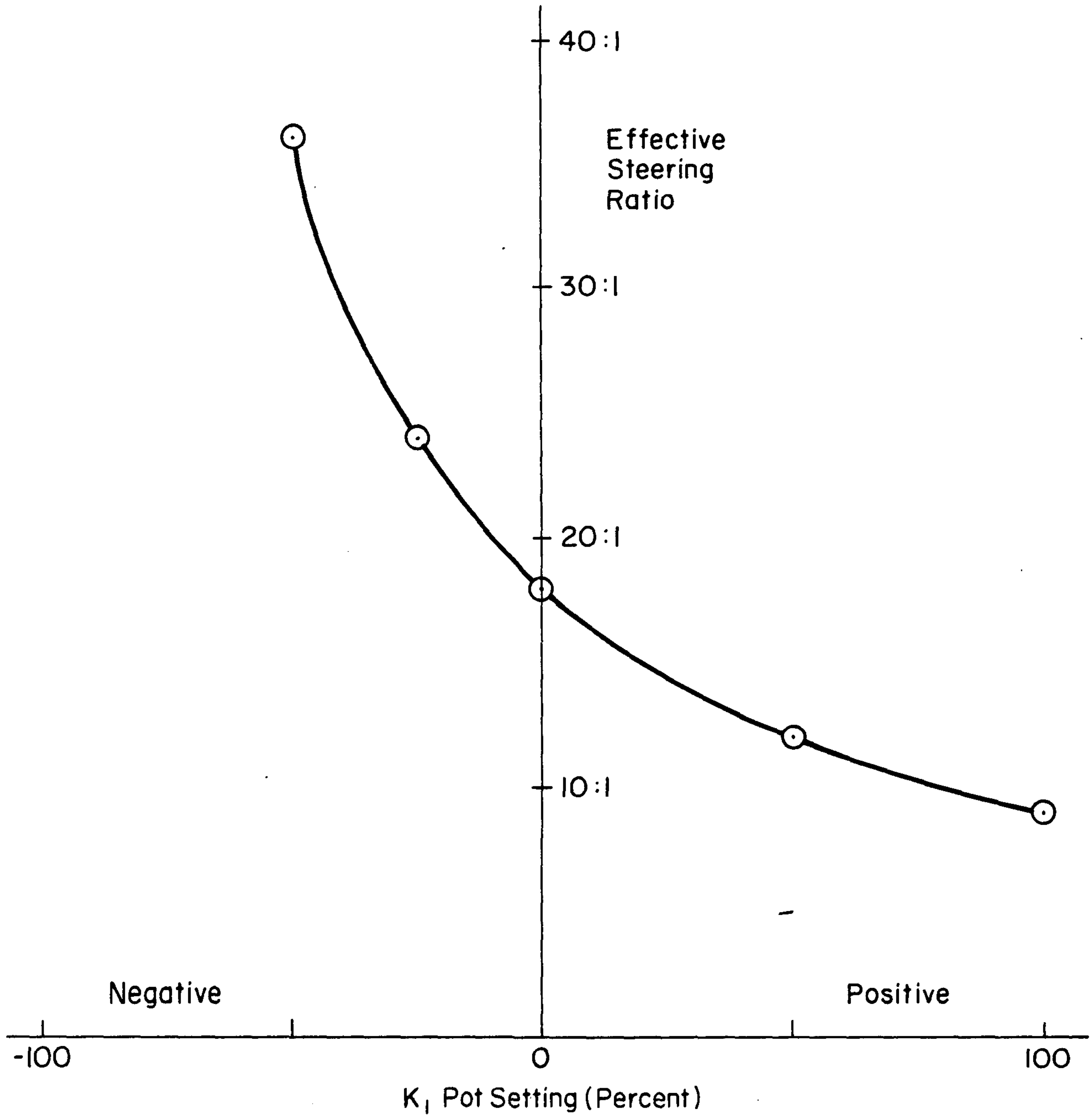
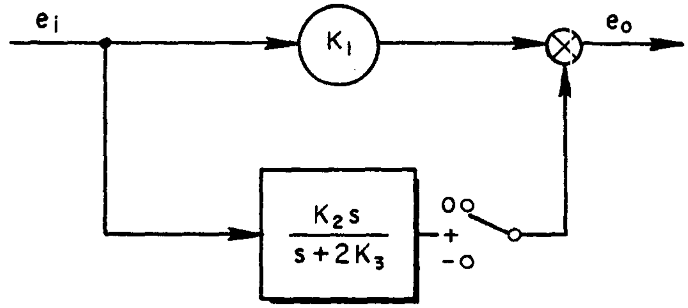


Figure V-5. Steering Ratio Range as a Function of Experimenter Control Setting, K_1

Equalization of the steering feedforward signal can be obtained by operating the equalization sign switch and adjusting the equalization pots K_2 and K_3. For example, given the equalization circuit shown below,



the following circuits are obtained:

Lead/Lag: $$\frac{e_o}{e_i} = (K_1 \pm K_2)\,\frac{[s + 2K_1K_3/(K_1 \pm K_2)]}{s + 2K_3}$$ DC gain $= K_1$

HOG $= K_1 \pm K_2$

Washout: $K_1 = 0$, $\dfrac{e_o}{e_i} = \dfrac{K_2 s}{s + 2K_3}$

Gain: $K_2 = 0$, $\dfrac{e_o}{e_i} = K_1$

C. MOTION FEEDBACKS

The same controls and switches used for STEERING are available for the three Motion Feedbacks (A, B, and C) shown in Fig. V-3. At the present time the motion quantities selected are those shown in Table V-1. Of primary importance is the lateral acceleration feedback, since this can be used to change the vehicle oversteer/understeer characteristics, i.e., stability factor (K). When no equalization is used ($K_2 = 0$) the change in K as a function of Motion Feedback Pot K_1 is as shown in Fig. V-6. Note that the nominal car has a stability factor of –5.5 deg/g and that it can be made to neutral steer when K_1 is set to full negative setting. Derivation of these stability changes was accomplished during demonstration test and is documented in Appendix B.

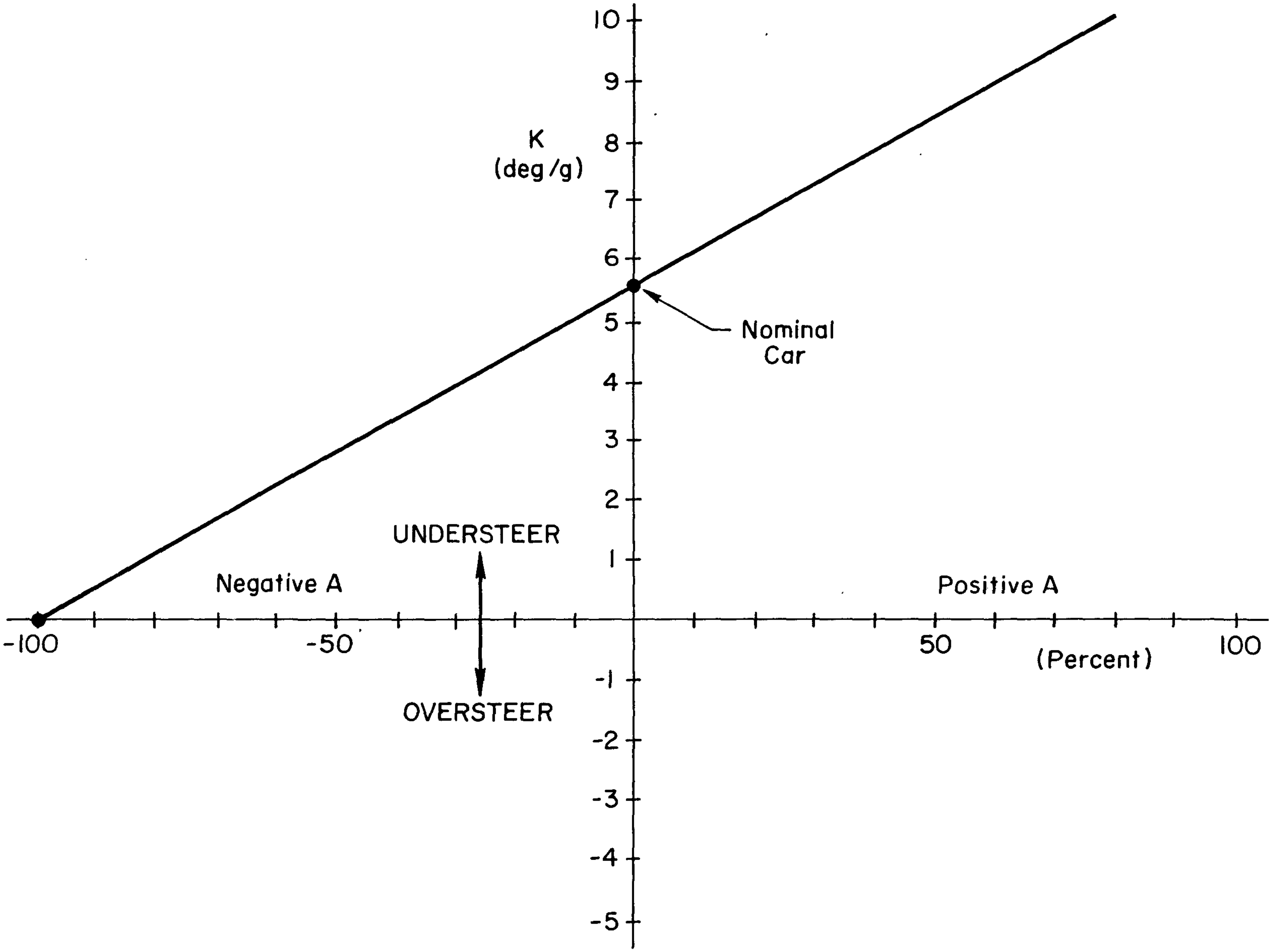


Figure V-6. Change in K vs. Motion Feedback A Pot Setting, K_1

TABLE V-1. MOTION FEEDBACKS FOR SERVO CONTROL

MOTION	QUANTITY	SCALING	MAXIMUM EFFECTIVE SERVO INPUT
A	Lateral acceleration	.1 g/volt (3R1)	$\pm 5^\circ\ \delta_W/g$
B	Yaw velocity	4 (deg/sec)/volt (4R1)	$\pm \frac{.125^\circ\ \delta_W}{\text{deg/sec}}$
C	Roll angle	1 deg/volt (5R1)	$\pm \frac{.5^\circ\ \delta_W}{0}$

D. STEP

The STEP switch applies +10 V to the gain pot. It is currently scaled so that a full 100 percent pot setting (1.0) provides a servo input equivalent to 90 deg steering wheel (e.g., $\delta i_R = 9^\circ\ \delta_{SW}$/volt; therefore, 10 V = $90^\circ\ \delta_{SW}$). This is the maximum servo authority currently set up. A photo of the STEP switch and gain pot is shown in Fig. V-7.

E. EXTERNAL INPUTS

External inputs from peripheral devices, i.e., oscillators, random input generators, etc., can be directly applied to the servo through three external input lines. These lines are not brought out to the Servo Control Unit since they could easily have inadvertent voltages applied — a very dangerous situation. Alternatively, the three lines are added on an "as needed" basis by a technician wiring directly to the terminal board of the Central Electronics Console.

Utilization of the external input capability for measurement of closed loop driver describing function measures is a primary application. To understand this application the following series of block diagrams shown in Fig. V-8 was derived. In the top figure the external input, i, is applied through a 50 rad/sec filter to the servo command summing point. The servo

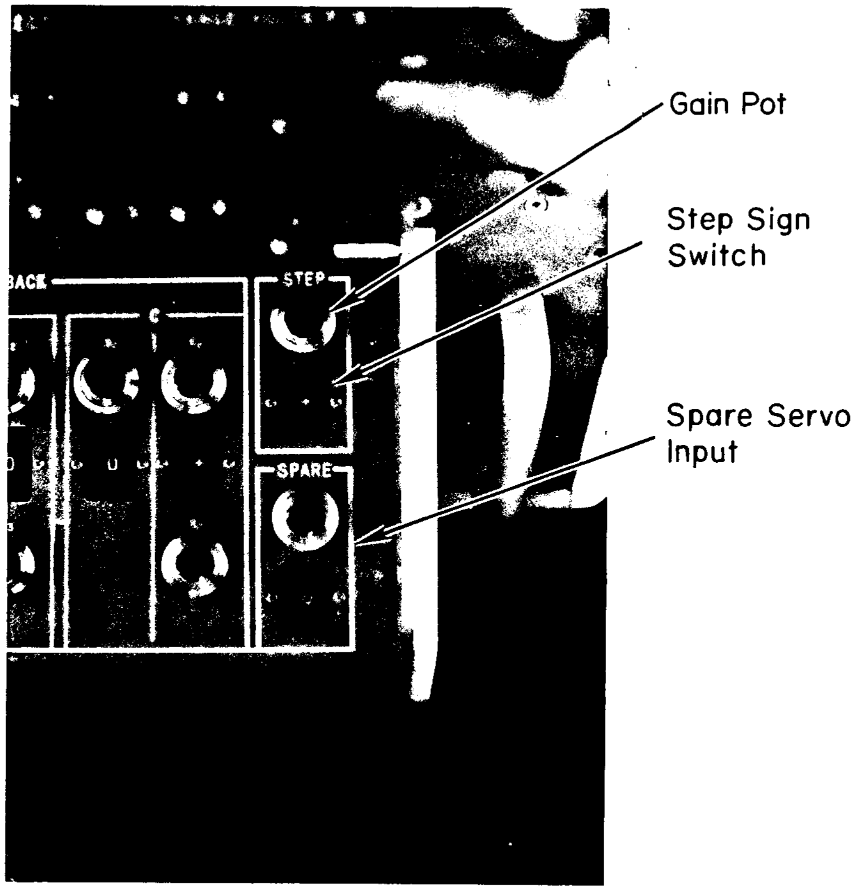
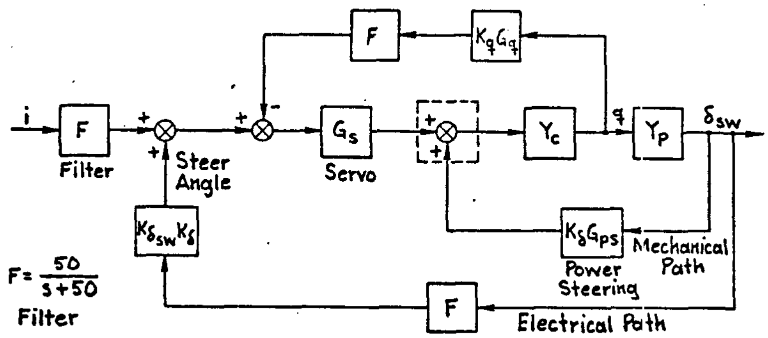
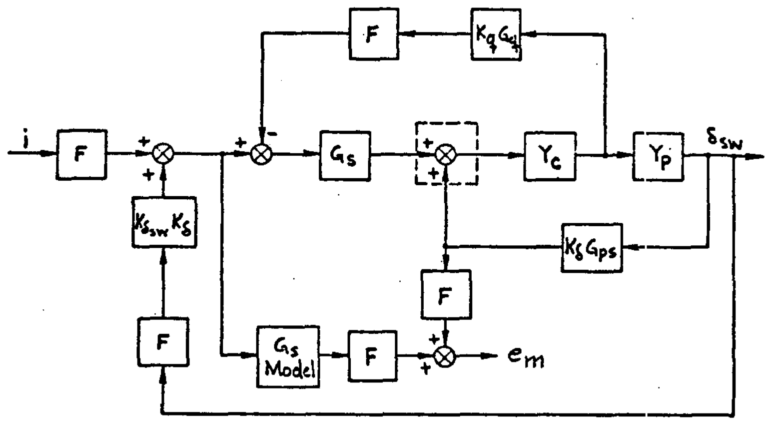


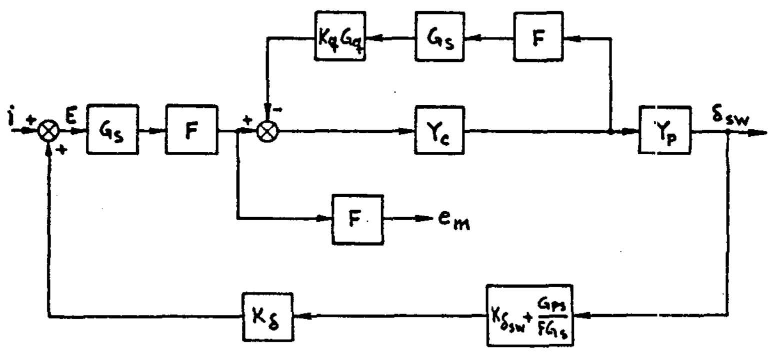
Figure V-7. Step Controls in Servo Control Unit



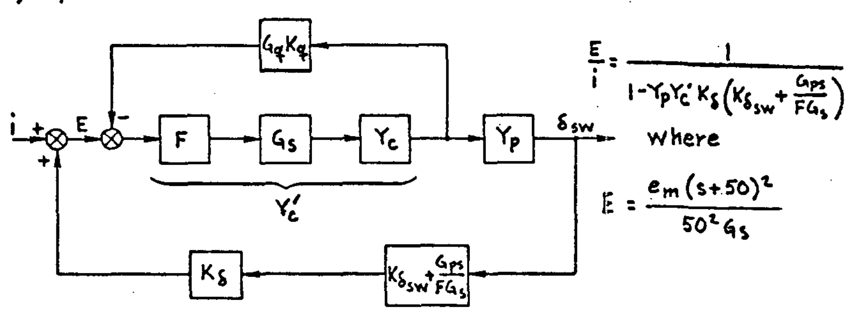
a) Actual Mechanization



b) Addition of Derived Measured Error Point, e_m



c) Equivalent Diagram, Defining Desired and Measured Error Points



d) Simplified Equivalent Block Diagram

Figure V-8. Driver/Vehicle/Servo Closed Loop Block Diagrams also receives commands from the steering wheel pickoff (also through a 50 rad/sec filter) and from the motion quantities, q (again through a 50 rad/sec filter). The servo output is mechanically added to the driver's steering wheel motions and thus moves the front tires. The front tire motions represent the input to the controlled element, Y_c, or in this case, the <u>vehicle</u>. Vehicle outputs are then sensed by the driver, Y_p, and by the various motion sensors onboard. The driver, in turn, moves the steering wheel to correct the vehicle motions to those he desires.

In order to pull out an electrical error measurement point that is not contaminated by changes to the vehicle characteristics via motion feedbacks, the servo system is designed as shown in the second block diagram. In this schematic the external input and electrical steering wheel feedback are sent through a "servo model" which does not contain the motion feedbacks. To this is added the mechanical steering displacement to derive an error signal, e_m, equivalent to the mechanical summing point but <u>without</u> the motion feedback contamination. This measurement error point can also be identified in Fig. V-3.

Block diagram algebra can be used to derive the equivalent and simplified block diagrams shown in the lower half of Fig. V-8. The end result is a classical closed loop block diagram relating error to input from which the closed loop quantity $Y_p Y_c'$ can be derived mathematically.

F. SERVO SCALING AND AUTHORITY LIMITS

Although the servo actuator can provide a steering input equivalent to ±25 deg front tire, this magnitude would be very dangerous if it were to suddenly fail hard over. To avoid such a catastrophe, an adjustable mechanical and electrical limit capability has been designed in the system.

The mechanical limiter consists of a metal bolt inserted in the piston actuator assembly as sketched in Fig. V-9. Three slot positions are possible. The first slot (just a hole in this case) gives the servo <u>no</u> authority and is used when driving the car on public roads where other vehicles are present. The remaining slots allow for ±0.6 in. and ±1.2 in., which correspond to about ±6 deg and ±12 deg front wheel travel. With no bolt the servo has ±2.5 in. authority or about ±25 deg front wheel angle.

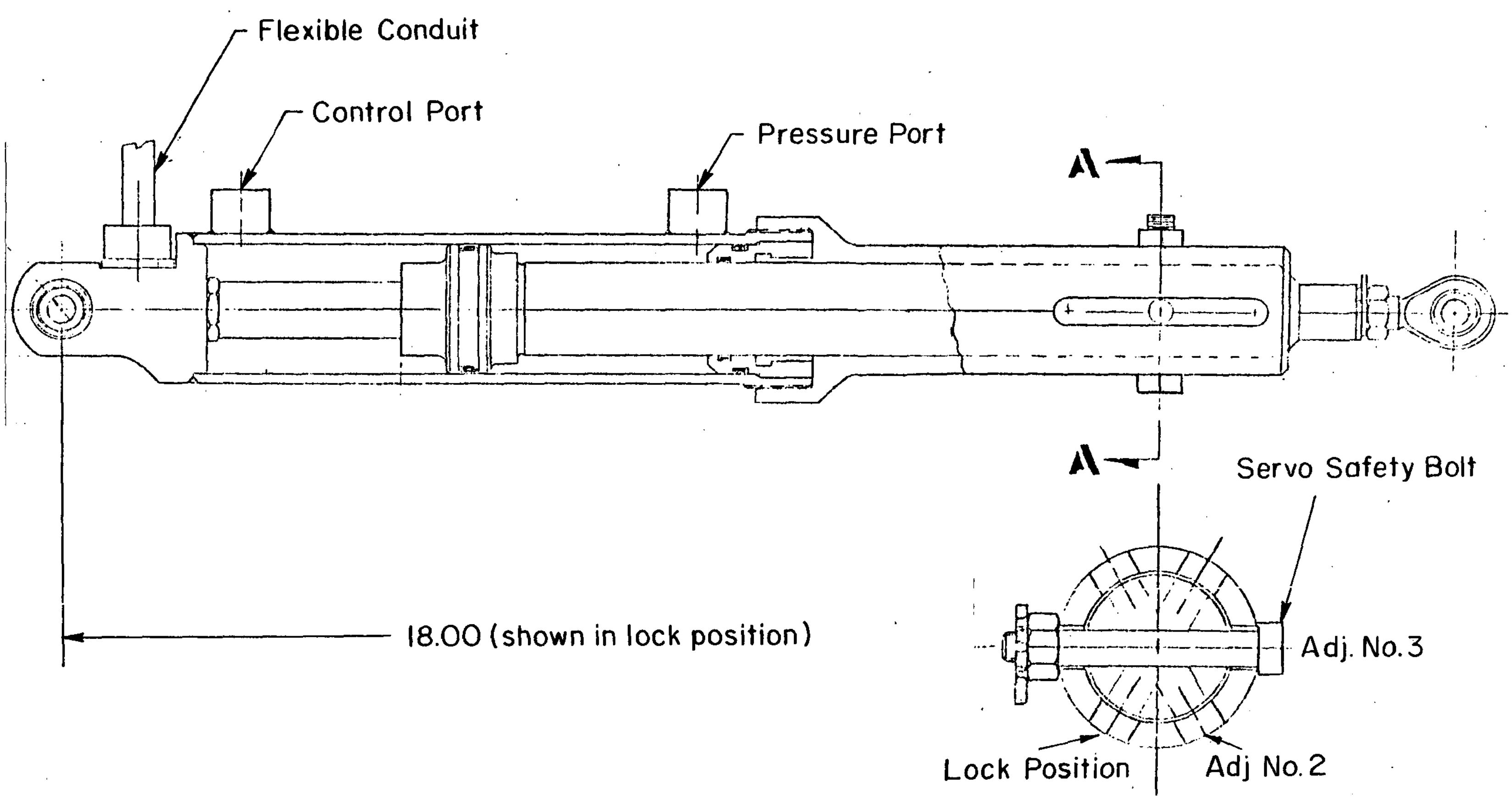


Figure V-9. Servo Limiter Assembly

The electrical limits are set by the scaling factor of the servo command signal. Referring back to Fig. V-3 it can be seen that the servo scale pot 7R3 is set so that 10 volts output from amplifier 7A2 provides a servo output equivalent to 5 deg front wheel. Since the amplifier saturates at about 11 volts, the servo is electrically limited to about 5.5 deg. To change servo authority from its current electrical limits of ±5 deg front wheel, the internal servo control pot 7R3 must be changed. This should only be accomplished by a technician using the Design and Maintenance Manual.

G. TEST POINTS

To aid in setting scale factors and checking feedback signals to the servo, three external TEST POINTS are provided on the Servo Control Unit. These are designated TP1, TP2, and TP3 in Fig. V-3 and are located directly below the STEERING controls shown in Fig. V-4. Test Point 1 is used to set the steering wheel scale factor in the servo command loop independently of the recorded steering wheel signal, δ_{sw_R}, on Sensor Channel 23. Test Point 2 is used to determine the servo authority scale factor set by 7R3. Test Point 3 checks the equalization and gain settings of the motion feedbacks A, B, and C.

SECTION VI

OPERATING CHECKLISTS

This section is designed for the user who is now ready to conduct an experiment. It is assumed that Section II has been thoroughly digested and the capability of the DPMAS is understood. From here on, the report presents a step-by-step procedure, including example test scenarios in Appendix B, that must be followed to insure proper operation and successful data taking.

A. BEFORE STARTING THE CAR

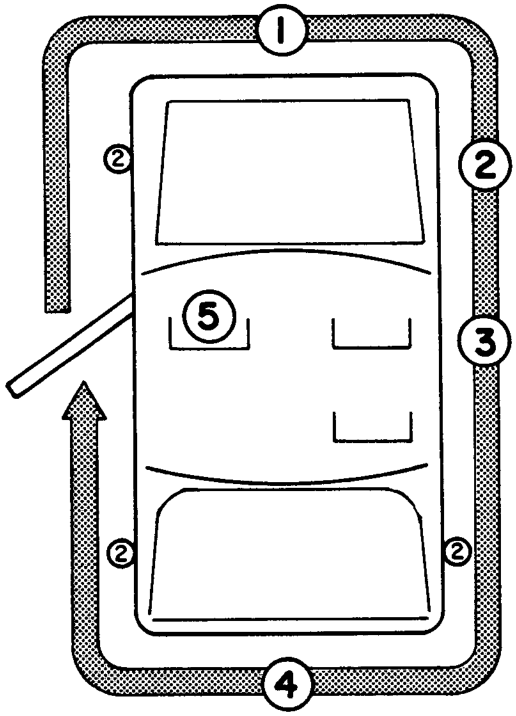
The walk-around procedure is outlined in Fig. VI-1.

B. POWERING UP (INTERNAL POWER)

1. Start car.
2. Turn on only those circuit breakers necessary for instrumentation to be used. These are labeled in Fig. VI-2.
3. Turn Master Switch (on Status Control Panel) to INTERNAL.
4. Turn on LANE POSITION power (in trunk area as shown in Fig. VI-3).

   CAUTION: LANE POSITION SENSOR POWER MUST BE OFF WHENEVER MASTER SWITCH IS OFF.
5. Check that all individual components are on (for example, video monitor, video sync generator, video tape, magnetic tape). These are normally always left ON.

If operating without the car running, i.e., EXTERNAL, the portable 28 VDC power supply and 115 VAC power line must be connected to the sockets in the trunk shown in Fig. VI-3. This replaces Step 1 above. The power switch is placed in the EXTERNAL position and Steps 2-5 are followed.



EXTERIOR
INSPECTION
DIAGRAM

- NOTE -

If night tests are planned check operation of all lights.

① Under Hood
   a. Check oil and water levels
   b. Check servo fluid in reservoir.
   c. Check suspension pots for freedom of rotation.
   d. Inspect for loose wires.
   e. Inspect for leaks in servo lines.
   f. Check tightness of belts.
   g. Leave hood open to check servo pressure after starting car.
   h. Remove servo safety pin if servo steering is to be used.

② Front Right
   a. Check tire pressures for 28 psi cold.
   b. Check wheel tachs for freedom of rotation and string tension. Remove tach if no braking tests are to be conducted.

③ Right Side
   a. Remove video camera caps.
   b. Check Lane Position Tracker rotation switch for UP position (scans from car outward).

④ Trunk Area
   a. Check air shock pressure for 10 psi (65 psi maximum for filling with car unloaded, 90 psi maximum for filling with car loaded).
   b. Check lane position sensor plug in and power OFF.
   c. Select INTERNAL or EXTERNAL power position.
   d. Plug in external power cables if EXTERNAL.
   e. Check brake lights.

⑤ Interior
   a. Check Master Switch OFF.
   b. Check circuit breakers OFF.

Figure VI-1. Preliminary Inspection

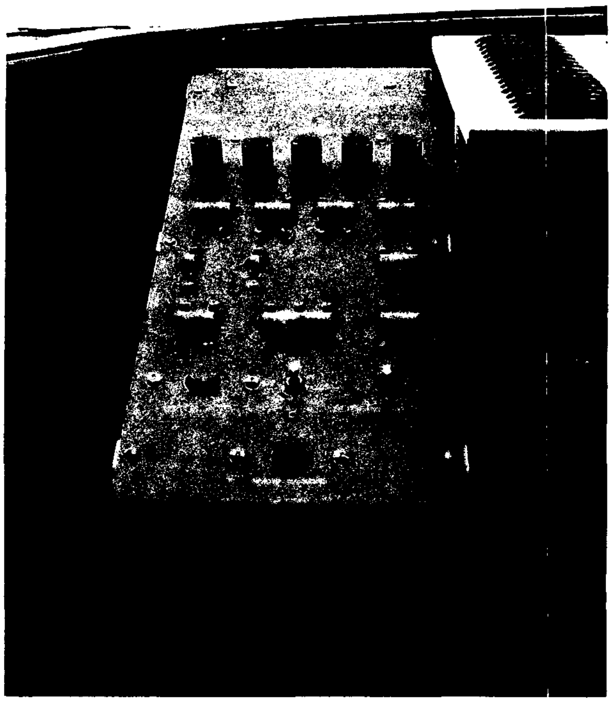


Figure VI-2. Circuit Breaker Panel

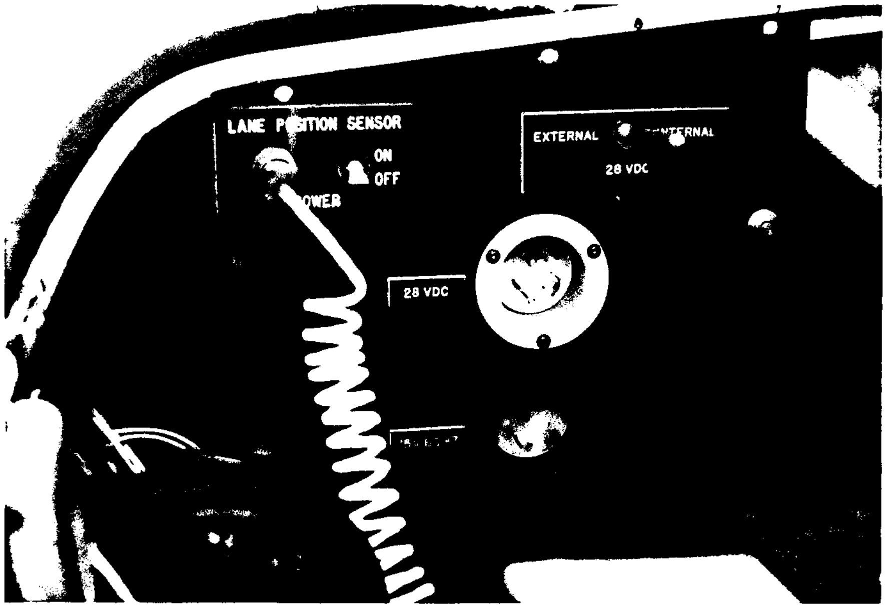


Figure VI-3. Photo of Lane Position Sensor Switch and Internal/External Switch

C. LOADING SYSTEM

There are three data-taking sources that may be used. These are the digital magnetic tape recorder, video tape recorder, and junction box (when using a strip chart recorder).

1. Magnetic Tape Recorder

For a new tape reel:

a. Mount tape on lefthand reel, wind around heads as shown on illustration on recorder door and take 2 turns on righthand reel.

b. Close door.

c. Press LOAD button. Tape will advance to Beginning of Tape (BOT) marker near start of tape.

d. Press ON LINE button. Tape will be positioned to start.

e. Press END OF FILE. This puts initial file mark on tape for rewind purposes. This is always called File 01.

f. Tape is now ready to record File 02. File counter in Data Acquisition Unit should be set to 01.

For previously recorded tape:

a. Proceed with mounting, LOAD, and ON LINE, as in Steps a-d.

b. Set file counter on Data Acquisition Unit to 00.

c. Press SEARCH button on Data Acquisition Unit and note file count as tape automatically advances. It will automatically stop at the end of the last recorded file.

2. Video Tape Recorder

a. Press REWIND/EJECT button to open lid and expose loading chute.

b. With label up (facing operator), push tape cartridge into loading chute.

c. Close chute lid and firmly press down until lid passes a perceptible detent. This initiates the loading cycle.

d. After 20 seconds, the automatic threading cycle is completed and the STOP/STANDBY indicator lights.

NOTE: If the tape is not properly threaded within 25 seconds, the recorder enters an abort cycle — that is, the tape and leader are rewound into the cartridge and it is ejected. Should this repeatedly happen, check leader for tears, splits, or other deformities; if leader is in good shape, the recorder should be referred to qualified maintenance personnel for service.

e. Before using a new tape, a tape pack run is recommended. Once the cartridge is loaded and threading is complete, press the FAST FWD pushbutton to transfer tape from the supply cartridge to the captive takeup reel — then press the REWIND pushbutton to return tape to cartridge. The transfer will provide a consistent tape pack and minimize the possibility of stretch, jitter, and other distortions.

f. If loading a prerecorded tape, follow Steps a-d above. To find the last recorded run use FAST FWD to position the tape at the approximate position. Use of turn counter (discussed under Video Operating Procedures) is a more exact method. After positioning the tape, press STOP/STANDBY, then PLAY, to check location. The tape will automatically stop from the PLAY mode when last recorded run is completed.

CAUTION: DO NOT PRESS ANY BUTTONS UNTIL TAPE IS THREADED AND STOP/STANDBY LIGHT IS ON.

3. Junction Box

Connect J-box to SENSOR and FILTER plugs on low portion of Video Console, shown in Fig. VI-4.

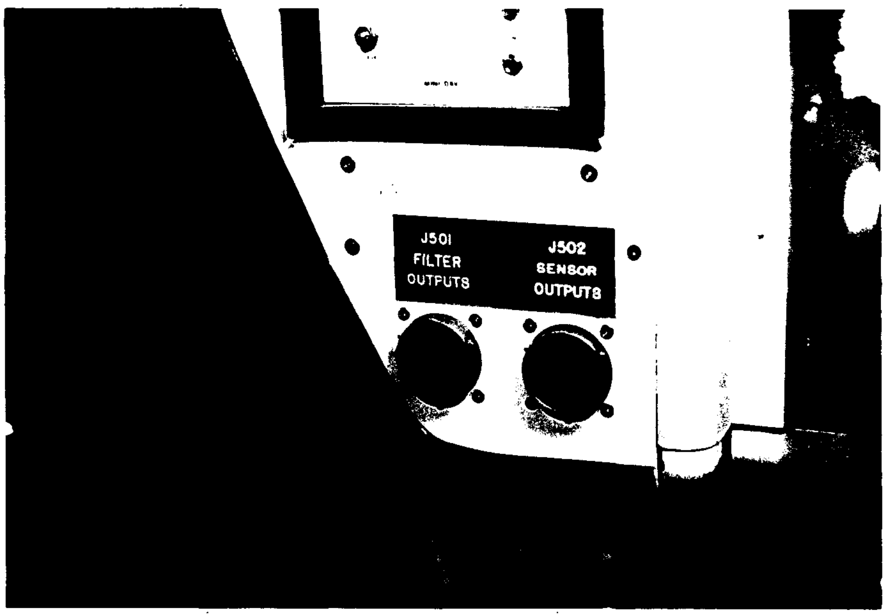


Figure VI-4. Sensor and Filter Plugs

D. OPERATING SUBSYSTEMS

Four subsystems require special operating instructions to set up prior to data taking. These are the servo system, video system, driver measures, and lane tracker system.

1. **Servo System Procedures**

a. Check servo pressure for 1400 psi.

b. Insert servo safety bolt for desired authority limits.

c. Select steering gain sign (Section V).

d. Select motion feedback (Section V).

e. External inputs are applied through two wires patched into Central Electronics Console (leads are stored under driver's seat).

f. Instruct subject/driver on hard-over failure recovery.

CAUTION: DUE TO RESTRICTED SERVO CLEARANCE UNDER CAR DO NOT DRIVE OVER BUMPS OR ROAD PROJECTIONS LARGER THAN 2 INCHES.

g. Leaks in servo lines may be repaired under the following conditions:

Blue to silver lines Blue to blue lines	}	Tighten
Blue to red lines	:	Replace only

CAUTION: DO NOT DRIVE CAR ON PUBLIC ROADS UNLESS SERVO IS LOCKED OUT.

2. **Video System Procedures**

a. Load video tape (see loading instructions).

b. Select two optional data channels for video monitor presentation (performed by technician).

c. Connect three lines to enable Portable TV Camera 3. These are the power line, sync line, and video line which plug into video chassis.

d. Select video presentation on Status Control Panel, i.e., CAMERA 1, CAMERA 2, CAMERA 3, or 1/2/3.

e. Adjust split picture presentation using video controls (see Section IV).

f. Before recording, lift sun screen over video recorder and check controls. These are shown in Fig. VI-5 and have been preset.

- Press turns counter reset button (8) to zero the counter (7).

- Set METER SELECTOR switch (1) to VIDEO and adjust VIDEO LEVEL control (6) so that average reading of meter is about midscale — video peaks in upper one-third of scale.

- Check AUDIO 2 ONLY switch (10) for normal operation (down position) and set METER SELECTOR switch (1) to AUDIO 1. Refer to Video Manual for special use of AUDIO 2.

- Check AGC/MAN switch (11) for AGC position.

- Check AGC/MAN switch (25) for AGC — in this mode, the AUDIO 1 control is disabled and recording level is completely automatic.

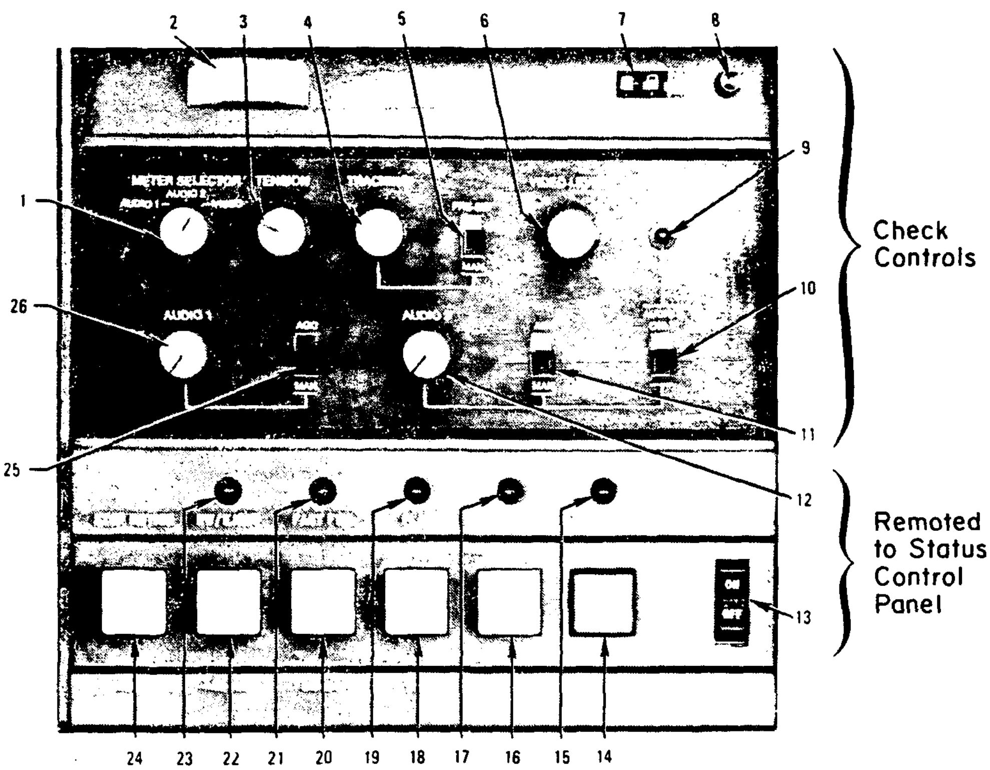


Figure VI-5. Video Tape Recorder Controls and Indicators, Front Panel

- Check PRESET/MAN switch (5) for PRESET position. This disables the TRACKING control (4) which is not needed unless tapes from another recorder are to be played.

- TENSION control (3) may be adjusted during <u>replay</u> only for least pulling at top of picture.

g. To record: Simultaneously press PLAY and RECORD push-buttons on Status Control Panel. Observe that the RECORD pushbutton lights. At the end of recording, press STOP pushbutton. If playback of tape is desired, rewind tape until turns counter is at 000 — at this time, simply press the PLAY pushbutton.

h. To play back: Insert preloaded cartridge (label up) into chute. Close the chute door and wait about 20 sec for the STOP/STANDBY indicator to light. (Note: If tape has just been recorded and the turns counter used as a "starting" indicator, simply press REWIND until counter reads zero and then press STOP — the recorder is now in a ready-to-play condition.)

i. During playback, STOP MOTION can be used as a pause to allow close inspection of a particular scene. To limit wear DO NOT hold STOP MOTION down for more than 5 min. Releasing switch returns recorder to normal operating speed.

j. Adjust speaker volume by SPEAKER VOLUME control knob located on rear recorder panel at lower lefthand side (closest to car's passenger side).

k. Forward and reverse winding of tape: The purpose of the FAST FWD and REWIND pushbuttons is to move the tape rapidly from one reel to the other. Using these push-buttons, a full reel of tape can be wound from one reel to the other in 180 sec or less. In conjunction with the turns counter, the fast forward and rewind functions can be used to rapidly locate a particular segment of tape.

  NOTE: If, during the rewind cycle, the operator forgets to press the STOP pushbutton, both tape and leader wind into the cartridge and the chute door will open. Should this happen, reseat cartridge in chute and firmly press down on door and wait for reloading to be completed.

l. After completing video recording press REWIND/EJECT to save tape.

3. Installation of Driver Measures (ECG and GSR)

Since requirements by various researchers for measurements of EMG and EEG will be different, only the placement and installation of ECG and GSR electrodes is discussed below.

a. Select a pair of electrodes for ECG.

b. Install electrode collars on each electrode.

c. Fill electrodes (to level) with gel, and remove protective collar.

d. Clean skin surface at positions shown in Fig. VI-6 with abrasive strips, and install electrodes.

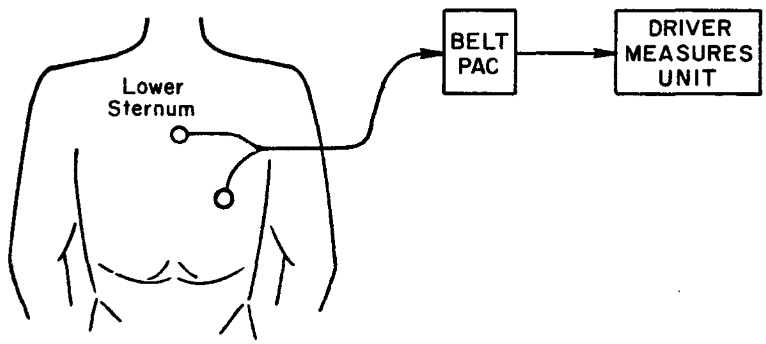


Figure VI-6. ECG Electrode Placement

e. Install biopac on subject's belt.

f. Select special GSR electrode pair.

g. Temporarily connect GSR electrode plug into biopac socket tagged GSR.

h. Connect a 2 megohm resistance between GSR electrodes and adjust gain in Driver Measures Unit to 10 volts output on Channel 28.

i. Remove resistor and unplug electrodes from biopac.

j. Apply small amount of K-Y jelly to back of hand (for palmar skin resistance measurement) or to one side of middle finger. This is for ground electrode.

k. Attach ground electrode with adhesive tape to either location.

l. Apply small amount of K-Y jelly to palm of hand or to opposite side of middle finger for active electrode.

m. Attach active electrode with adhesive tape. If using middle finger, one piece of tape will hold both electrodes in place.

n. Connect ECG electrode plug into biopac socket tagged ECG.

o. Reconnect GSR electrode plug into biopac socket tagged GSR.

p. Adjust ECG gain pot on Driver Measures Unit until R-wave trigger light flashes one time for each pulse beat.

Reference to Fig. III-13, page 43, shows the installation of a complete battery of electrodes on a test subject.

4. Lane Position Tracker Setup

To adjust the lane position sensor system it is necessary to use an oscilloscope (with external trigger) and a white lath (2" W × 4' L).

a. Connect oscilloscope to control unit shown in Fig. VI-7 with two cables having BNC connectors on both ends.

- Connect BU1 (MONITOR) to Y-axis (2 v/cm).
- Connect BU2 (TRIGGER SCOPE) to trigger input — external.
- Set scope sweep at 5 ms/cm (change to 10 ms/cm when monitoring motor control).

A 110 VAC outlet is available on video console.

b. Move car to location where measurements are likely to be taken so that weather and background are realistic.

c. Place white lath on ground about three feet from side of car adjacent to lane position sensor.

d. Power up in accordance with Subsection VI-B. Check lane position power ON and sensor rotation switch UP.

e. Select SCANNING WINDOW on the control unit (Switch SK10) and monitor the scope trace.

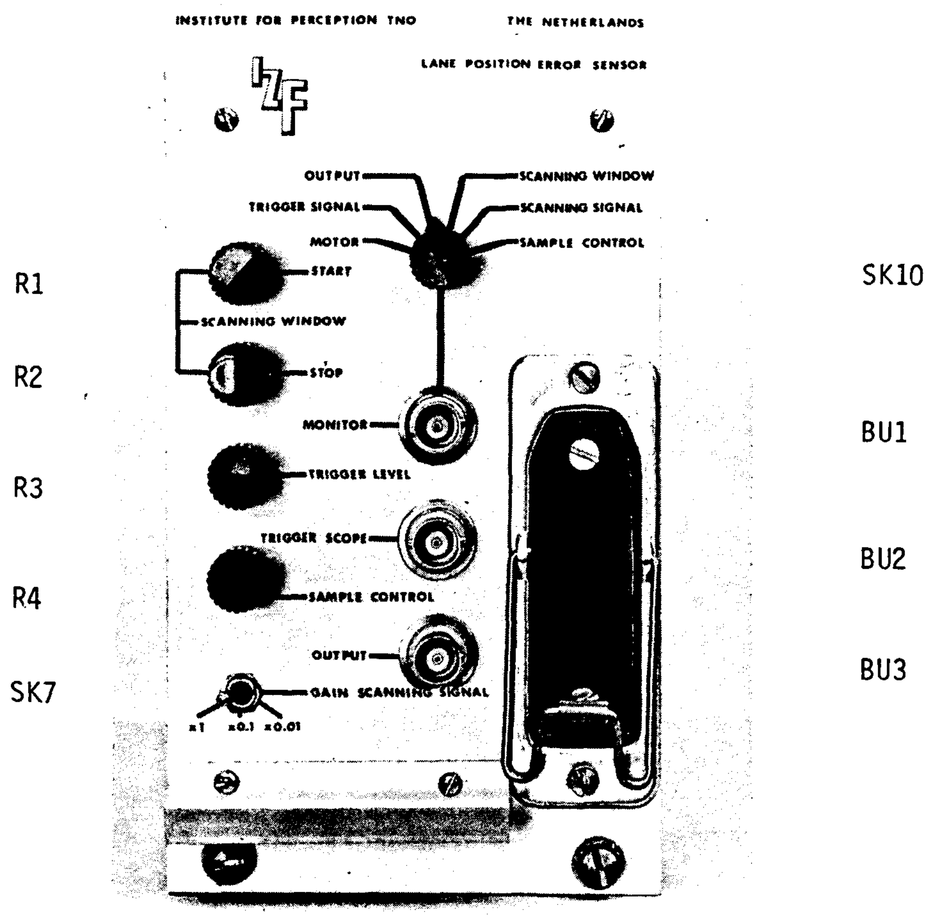


Figure VI-7. Front Panel of the Lane Position Sensor Control Unit

f. The scanning window (or look angle sector) is made as large as possible by rotating the potentiometers R1 (start looking) and R2 (stop looking) clockwise and counterclockwise, respectively. The scope will show a signal according to Fig. VI-8. The first peak on the left is generated by the side of the car and is cut out by rotating R1 counterclockwise. The second peak is generated by the white lath. Additional

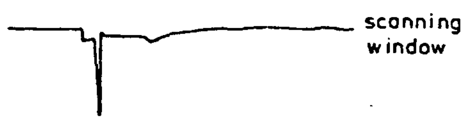


Figure VI-8. Scanning Window

peaks to the right are generated by surrounding objects and can be cut out by rotating R2 clockwise from the initial wide-open setting.

g. Due to changes in ambient light it is necessary to verify if the photoamplifier is set to a correct sensitivity value. A correct sensitivity is achieved when the white lath causes a peak amplitude of about 12 volts in scanning window trace. If the sensitivity is too low (amplitude smaller) or too high (disturbed peak), the correct value can be achieved by Switch SK7 (gain scanning signal).

   It may be possible that a correct sensitivity is achieved in more than one position of Switch SK7. Then the smallest value of SK7 has to be taken.

   Within each step of sensitivity, changes in ambient light are controlled automatically (range 1:70).

h. Adjustment of the trigger level provides a trigger pulse from the light reflected from the desired reference line. Set Switch SK10 to TRIGGER SIGNAL and lay one white lath on the road within the scanning window.

   Potentiometer R3 (TRIGGER LEVEL) has to be set in such a manner that one trigger pulse is just observable on the scope (see Fig. VI-9). Noting this value of R3, rotate R3 again to achieve one or more disturbing pulses. A correct trigger level is selected by setting Potentiometer R3 just between both derived values.

Figure VI-9. Trigger Signal

i. The sample control unit compares each sample with the previous one. The range in which samples are accepted as correct is adjustable by Potentiometer R4.

   Set Switch SK10 to SAMPLE CONTROL and turn potentiometer R4 in a maximum clockwise direction (minimum range). Then, the scope will show a signal in accordance with Fig. VI-10. The width of the pulse is always constant.

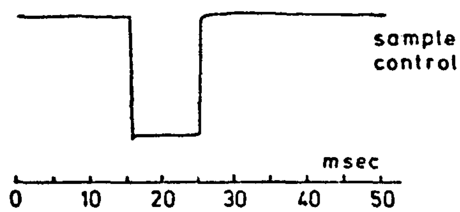


Figure VI-10. Sample Control Signal

The range to accept samples can be simulated in a practical way by moving one white lath with a lateral velocity just greater than the expected maximum lateral velocity for the vehicle.

Then, Potentiometer R4 has to be rotated in a counterclockwise direction up to the moment that the pulse on the scope is just not disappearing.

j. The number of extremely deviating samples which may be skipped in accordance with Section III is adjustable from 0 up to 63. This number of samples can be adjusted by Switches SK1-SK6. These switches are placed behind the front panel (at the upper side) and can be set by pulling out the control unit partially. However, these switches need no frequent readjustments. The switches can be set following Table VI-1. As a practical rule the number of samples to be skipped may be set at a value as high as possible.

k. During Operation it is desirable to monitor the functions of the position transducer frequently. This can be done by Switch SK10 and an oscilloscope in an easy way. Monitoring is recommended especially during the following conditions:

- Reference line in bad condition.
- Interrupted reference line.
- Great changes in ambient light level.
- Vehicle shadow crosses the scanned plane.

TABLE VI-1

FUNCTION OF THE SWITCHES SK1-SK6 IN SKIPPING A NUMBER OF SAMPLES

SWITCH						FUNCTION
LEFT					RIGHT	
SK6	SK5	SK4	SK3	SK2	SK1	
Up	Up	Up	Up	Up	Down	0 samples skipped; each sample accepted (no sample control)
Up	Up	Up	Up	Down	Up	Maximum of 1 sample skipped
Up	Up	Up	Up	Down	Down	Maximum of 2 samples skipped
Up	Up	Up	Down	Up	Up	Maximum of 3 samples skipped
↓	↓	↓	↓	↓	↓	↓
Down	Down	Down	Down	Down	Down	Maximum of 62 samples skipped
Up	Up	Up	Up	Up	Up	Maximum of 63 samples skipped

The terms "Up" and "Down" are the physical positions of the switches. They correspond to binary digits: Up = 0, Down = 1.

l. To check operation of the rotating prism, switch SK10 to MOTOR and monitor the motor output trace. It should appear as shown in Fig. VI-11. Note that the scope sweep must be changed to 10 ms/cm to get this trace.

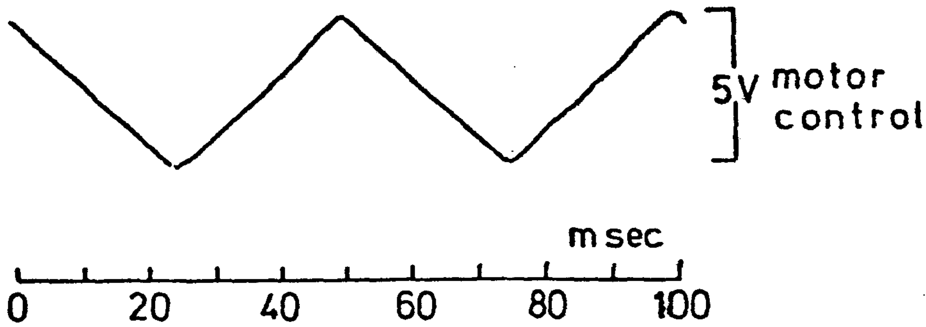


Figure VI-11. Motor Control Trace

E. CALIBRATING PROCEDURES

There are two methods of calibration. These are manual calibration for checkout and automatic calibration for data recording purposes. The electronics for this are described in Section II, and only the calibration steps are repeated here.

1. Manual Calibration Using Signal Conditioning Unit

a. Set voltage range switch to 5 V, full scale.

b. Select channel number to be checked.

c. Select FILTER.

d. Select POS as test input.

e. Read ±4.20 V on DVM or analog meter.

f. Select NEG as test input.

g. Read −4.20 V on DVM or analog meter.

h. Select GND as test input.

i. Read 0.00 V on DVM or analog meter.

j. Place the TEST INPUT SELECT switch in the OFF position.

If desired, this process can be recorded as a separate file on digital tape since the test voltage is applied to all channels simultaneously.

2. Automatic Calibration Using Data Acquisition Unit

a. Select run number for tape identification.

b. Note file number and time of test.

c. Select data group to be calibrated (1-6).

d. Select H signal conditioning gain (high).

e. Press CALIBRATE pushbutton (IN PROGRESS light will illuminate).

f. Start tape.

g. Watch for NO GO light to illuminate (take note of channel number if NO GO light comes on during test).

h. Wait for tape to STOP automatically (approximately 10 seconds).

i. Press CALIBRATE pushbutton a second time to extinguish IN PROGRESS light, thus completing calibration of that sensor group.

For calibration without data recording, simply eliminate Steps b, c, and g. If a NO GO indication has appeared, individually check this channel using the Manual Calibration Test procedure described in Subsection II-b, page 10, to decide whether to continue or repair. This decision will be dictated by the out of tolerance level and the importance of that particular channel.

F. DAILY CHECKLIST

1. Walk Around Inspection.
2. Power up.
3. Load system.

4. Set up subsystems.

5. Test preparation:

   a. Set Data Acquisition Unit (see Subsection II-B-2, page 11, for details).

      - Date
      - Run code
      - Acquisition time
      - Group select
      - Sample rate
      - Gain set
      - Clock check

   b. Make calibration test — File 02

      - Check all channels without tape running.
      - Make calibration file.

6. Take first data file — File 03

   a. Set run number

   b. Complete run log (see example in Fig. VI-12).

   c. Start tape.

   d. Start video.

   e. Perform test.

   f. Stop tape.

   g. Stop video.

   h. Complete run log.

7. Take additional data files — File 04 → X

   a. Change run number.

   b. Check file count.

   c. Start tape.

   d. Stop tape.

Tape ______________ RUN LOG Date ______________

TEST NUMBER	MOVIE FILM	FILE NUMBER	GROUP	ACQ. CODE	GAIN	SAMPLE RATE	TIME	STRIP CHART RECORDER (Variable, Channel, Gain)	REMARKS

Figure VI-12. Sample Run Log

8. "End data" when power down.

   a. Press END DATA button.

   b. Remove tape from recorder.

9. Power down.

   a. Lane tracker off.

   b. Main switch off.

   CAUTION: AFTER POWER DOWN DO NOT MOVE CAR FOR 30 MINUTES IF SR-3 GYROS WERE USED. IF CAR MUST BE MOVED, SR-3 MUST BE POWERED BACK UP FOR AT LEAST 2 MINUTES BEFORE MOVING CAR.

G. CAUTION NOTES

- Always turn off ignition last.
- Always turn off Lane Position Sensor power before turning off Master Switch.
- Always wait for STOP/STANDBY light on video controls before selecting another mode.
- Always drive car on smooth roads due to restricted road clearance from servo.
- Always lock out servo when driving on public roads.
- Always leave car stationary for 30 minutes after powering down gyros unless they are relit for at least 2 minutes.
- Do not forget END DATA after completing tests or else last data file will be lost.

SECTION VII

DATA PROCESSING

The DPMAS includes a Kennedy Model 170B digital tape recorder installed in the trunk of the automobile. The system records data on 9-track standard digital magnetic tape (8.5 in. reels) at 800 bpi in a highly compact format. The packed data tape format and detailed information for users, programmers, and computer operators are given in Ref. 3, DPMAS Data Sorting Program (DPMASDSP). This section describes DPMASDSP in general and presents typical outputs of the program.

Data from the various analog, discrete, and distance traveled channels of DPMAS are put on tape in a mixed sample rate, multiplexed manner with a packed sample format. The basic purpose of DPMASDSP is to sort the data into individual data sets for each of the channels. The program has the capability to either plot the data, tabulate the data, or generate individual data files which the user can access for additional processing. Although the above capability exists within DPMASDSP, the user can also make use of the program as a front-end to his own program, thus tailoring it to his own particular requirements. DPMASDSP has been structured with this intent and complete information for a FORTRAN programmer is provided in Ref. 3; a tailored program would result in more efficient overall DPMAS usage.

DPMASDSP provides line printer (or terminal) output documenting the data sort for each tape file. This documentation includes the Tape Date, the File Number, and Run Number set by the user which are contained within the tape file header records. The channel number, mnemonic name, and sample rate for each channel selected for the particular run are listed. The initial and final time and distance traveled for the run are also given. If keyboard entries were made during the run, their values and times of occurrence are listed. The program recognizes calibration runs, and the corresponding documentation includes recorded calibration voltages for each channel. Extensive data tape checking is done by the software; and warnings, diagnostics, and suggested remedial action will be included in the documentation if warranted. An example of the DPMAS data tape sort is presented in Fig. VII-1.

After documenting the data sort, the program (at the user's option) will either quit, plot all the data, tabulate selected channels, or create disk files for selected channels. If plots are requested, DPMASDSP assumes a Zeta Plotter (Model No. 230 or equivalent) is connected to the computer system being used. If a Calcomp plotter is available instead, simple program modifications are required. These program changes are described in detail in Ref. 3. If the plot option is selected, the only additional information required by the program from the user is a time scale factor (seconds per inch). Example plotter output, for the sort documented in Fig. VII-1, is given in Fig. VII-2.

The user may elect to direct a tabulation of a data channel to the processing computer's line printer, terminal, disk file, magnetic tape unit, or most other output peripheral devices. In this case, the program requires input of the DPMAS channel number and the processing computer's FORTRAN output data set reference (device) number. An example terminal tabulation is given in Fig. VII-3. Disk files created by this DPMASDSP option can be accessed by other user software. The format of these files is described in Ref. 3; also provided in Ref. 3 is information required by a user's programmer if the DPMASDSP output file format is to be modified for compatibility with other, existing user software.

DPMASDSP is written in the FORTRAN language per IBM System/360 and System/370 FORTRAN IV Language, Pub. No. GC28-6515-10. It was developed and run on an IBM 370-158 computer under CMS [see IBM VM/370 (CMS) Terminal User's Guide for FORTRAN IV Program Products, Pub. No. SC28-6891-0]. The program can either access the data tape directly or read the packed data from disk files created from the data tapes by the computer's operating system utilities. Our experience indicates that the latter mode is more efficient. The program uses only a small amount of packed (input) data at one time but requires complete storage of the unsorted output data. The total core storage required by the program therefore is dependent on the amount of data in the file being sorted. This, in turn, is dependent on the group selected, the high/low sample rate, and the run length selected by the user. The standard program requires 600,000 bytes of core storage on an IBM 370-158.

The cost of running the program is also a function of the amount of data taken; the following indicates typical costs experienced in running the program on a commercial timesharing system.

Group Selected	Sample Rate Selected	10 Sec Runs		25 Sec Runs	
		Sorting Cost	Sorting + Plotting Cost	Sorting Cost	Sorting + Plotting Cost
1	High	$0.42	$7.35	$0.74	$10.88
2	High	0.40	7.10	0.68	10.25
3	Low	0.30	5.98	0.43	7.43
4	Low	0.25	5.45	0.31	6.11

DPMAS DATA TAPE SORT

TAPE DATE: NOV 17 1975   FILE NO.   7   RUN NO.   3

THE FOLLOWING 24 CHANNELS WERE SELECTED FOR THIS RUN:

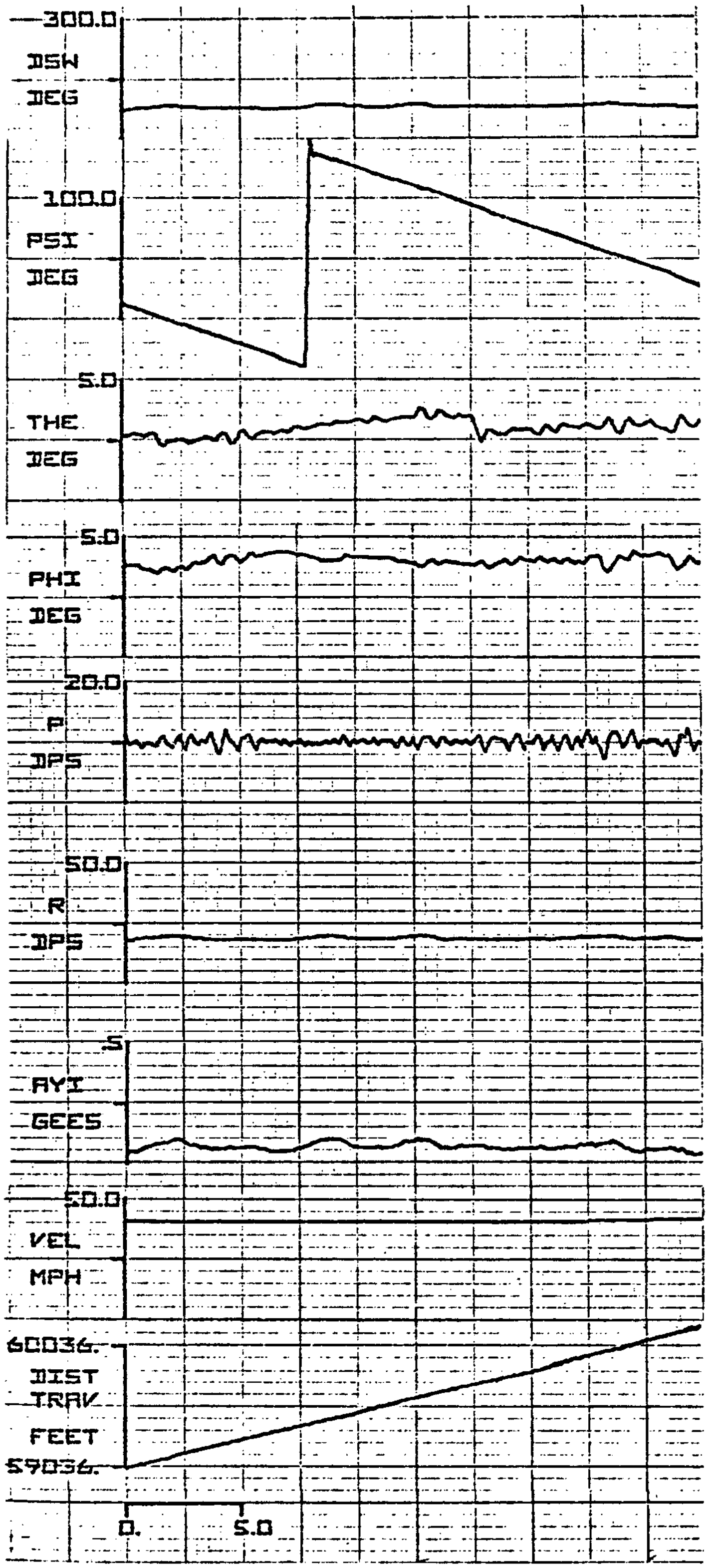
CH NO.	NAME	RATE	CH NO.	NAME	RATE	CH NO.	NAME	RATE
1	DSW	20	4	PBRK	2	5	DWT	20
6	PSI	20	9	THE	20	10	PHI	20
11	Q	20	12	P	20	13	R	20
14	AYI	20	15	AXI	2	16	AZI	20
18	LFWV	20	19	RFWV	20	20	LRWV	20
21	RRWV	20	22	VEL	2	24	DIR	5
26	EMGA	5	61	DIST	1	62	TRAV	1
63	FEET	1	64	PKLT	1	65	HORN	1

THE TOTAL NO. OF DATA SAMPLES PER SEC IS   301
THE INITIAL TIME IS 13:49:42
DISTANCE TRAVELED IS 59036. FEET.
THE NUMBER OF SECS OUTPUT IS   25.05
THE FINAL TIME IS 13:50: 7
DISTANCE TRAVELED IS 60192. FEET.

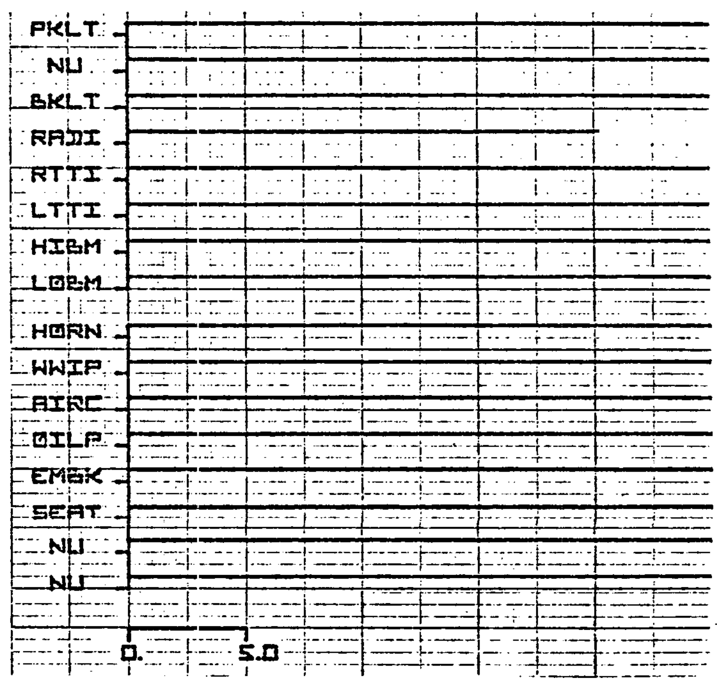
NO KEYBOARD ENTRIES

```
   ENTER 0 TO QUIT, 1 FOR PLOTS, 2 FOR LISTING
>1
                        DPMAS DATA TAPE TIME HISTORY PLOTS

ENTER TIME SCALE FACTOR
>5.
\P\ .

   ENTER 0 TO QUIT, 1 FOR PLOTS, 2 FOR LISTING
>0
```

Figure VII-1. Typical DPMASDSP Data Sort Documentation



a) Continuous Measures



b) Discrete Measures

Figure VII-2. Typical DPMASDSP Time History Plots
for Steady Circle

```
  ENTER 0 TO QUIT, 1 FOR PLOTS, 2 FOR LISTING
>2
ENTER CHANNEL NUMBER
>63
ENTER OUTPUT DATA SET REFERENCE (DEVICE) NUMBER
>06

   CH. NO.  63 DIST TRAV FEET  20 SAMPLES PER SEC      1785 SAMPLES

  14:41: 1
          123007        123007        123007        123007        123007
          123007        123007        123007        123007        123007
          123007        123007        123007        123007        123007
          123007        123007        123007        123008        123008

  14:41: 2
          123008        123008        123008        123008        123009
          123009        123009        123009        123010        123010
          123010        123011        123011        123011        123012
          123012        123013        123013        123013        123014

  14:41: 3
          123014        123015        123016        123016        123017
          123017        123018        123018        123019        123020
          123021        123021        123022        123023        123023
          123024        123025        123026        123027        123028

  14:42:29
          128705        128708        128712        128715        128718
          128722        128725        128729        128732        128735
          128739        128742        128746        128749        128752
          128756        128759        128763        128766        128769

  14:42:30
          128773

  ENTER 0 TO QUIT, 1 FOR PLOTS, 2 FOR LISTING
>0
```

Figure VII-3. Typical DPMASDSP Terminal Tabulation

REFERENCES

1. McRuer, D. T., R. A. Peters, R. F. Ringland, et al., Driver Performance Measurement and Analysis System (DPMAS). Task I: Requirements and Plans for Prototype Equipment, DOT HS-801 234, Oct. 1974.

2. "DPMAS Design and Maintenance Manual" (forthcoming).

3. "DPMAS Digital Data Sorting Program" (forthcoming).

4. McRuer, D. T., R. H. Klein, et al., Automobile Controllability — Driver/Vehicle Response for Steering Control. Vol. I: Summary Report. Vol. II: Supporting Experimental Data, DOT HS-801 407 and DOT HS-801 406, Feb. 1975.

APPENDIX A

VEHICLE SPECIFICATIONS AND PERFORMANCE

SPECIFICATIONS

Vehicle

Wheelbase	121.5 in.
Weight (full fuel, no occupants)	5580 (Max GVWR 5800)
Tires	HR-78-15 (1770 lb capacity at 32 psi)
Fuel capacity	26 gal
Weight distribution (front/rear)	51/49 with driver
Track, front/rear	
Length	222.6 in.
Width	79.5 in.
Height	6 ft 6 in. (including TV cameras)
Ground clearance	3 in. (under servo)

Engine and 12 V Electrical

Type	V-8
Bore × stroke	4.00 × 3.48
Displacement	350 cu in.
Compression ratio	8.5:1
80 amp alternator	
70 amp hr battery	Lifetime sealed

Chassis and Body

Heavy duty suspension . . . .

Power disc front brake . . . . . .

Steering type — recirculating ball . . . .

Turns, lock to lock . . . . . .

Turning circle, ft . . . . . .

Front suspension . . . .

Rear suspension . . . .

Drive Train

Transmission . . . . Automatic, 3 speed

Differential

Limited slip, ratio . . . . . .

Accessories

Air conditioning

Oversize cooling

Transmission cooler

Air shocks

VEHICLE PERFORMANCE

Acceleration

0 → 100 ft . . . .

0 → 500 ft . . . .

0 → 1350 ft (1/4 mi) . . . .

Speed at end 1/4 mi . . . .

Time to speed

0 — 20 . . . .

0 — 40 . . . .

0 — 60 . . . .

0 — 80 . . . .

Stopping

Distance

From 60 mph . . . .

From 80 mph . . . .

Pedal effort

For 0.5 g (lb) . . . .

Speedometer Error

30 mph indicated is actually . . .

50 mph indicated is actually . . .

60 mph indicated is actually . . .

70 mph indicated is actually . . .

Odometer, 10.0 mi . . . .

Handling

Speed on 100 ft radius, mph (Fig. A-1) . . . .

Lateral acceleration, g (Fig. A-1) . . . .

Speed through 700 ft slalom at 100 ft intervals . . . . . .

Understeer

Yaw response (Fig. A-2) . . . .

Stability factor
(Fig. A-3) . . . .

Directional Dynamics

Transient response at 50 mph
(Fig. A-4)

Two-degree-of-freedom yaw
velocity to steer angle
transfer function at
50 mph . . . . $\frac{r}{\delta_w} = \frac{12.1(2.45)}{[.62;\ 3.25]}$

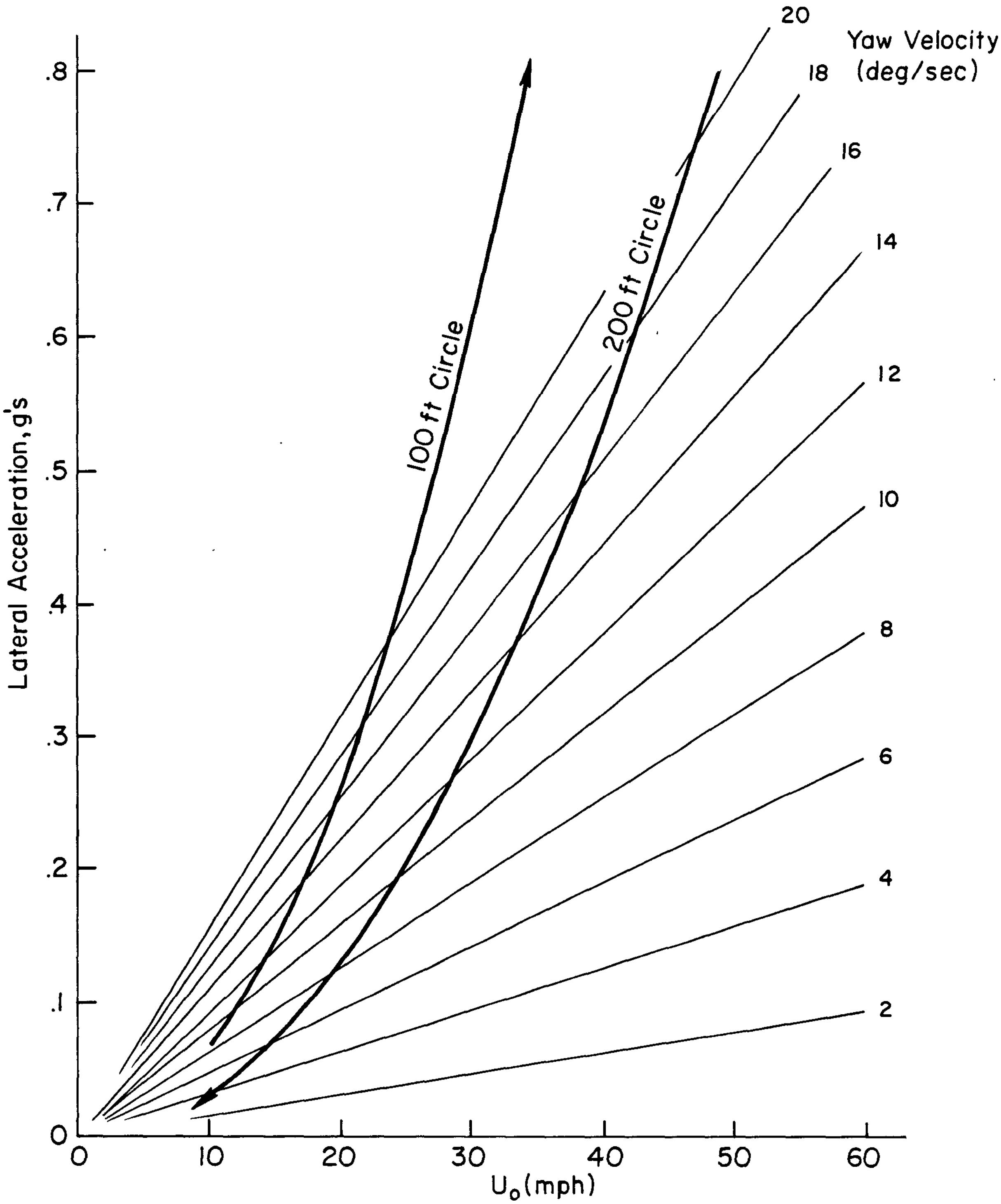


Figure A-1. Lateral Acceleration vs. Speed on 100 ft and 200 ft Circle

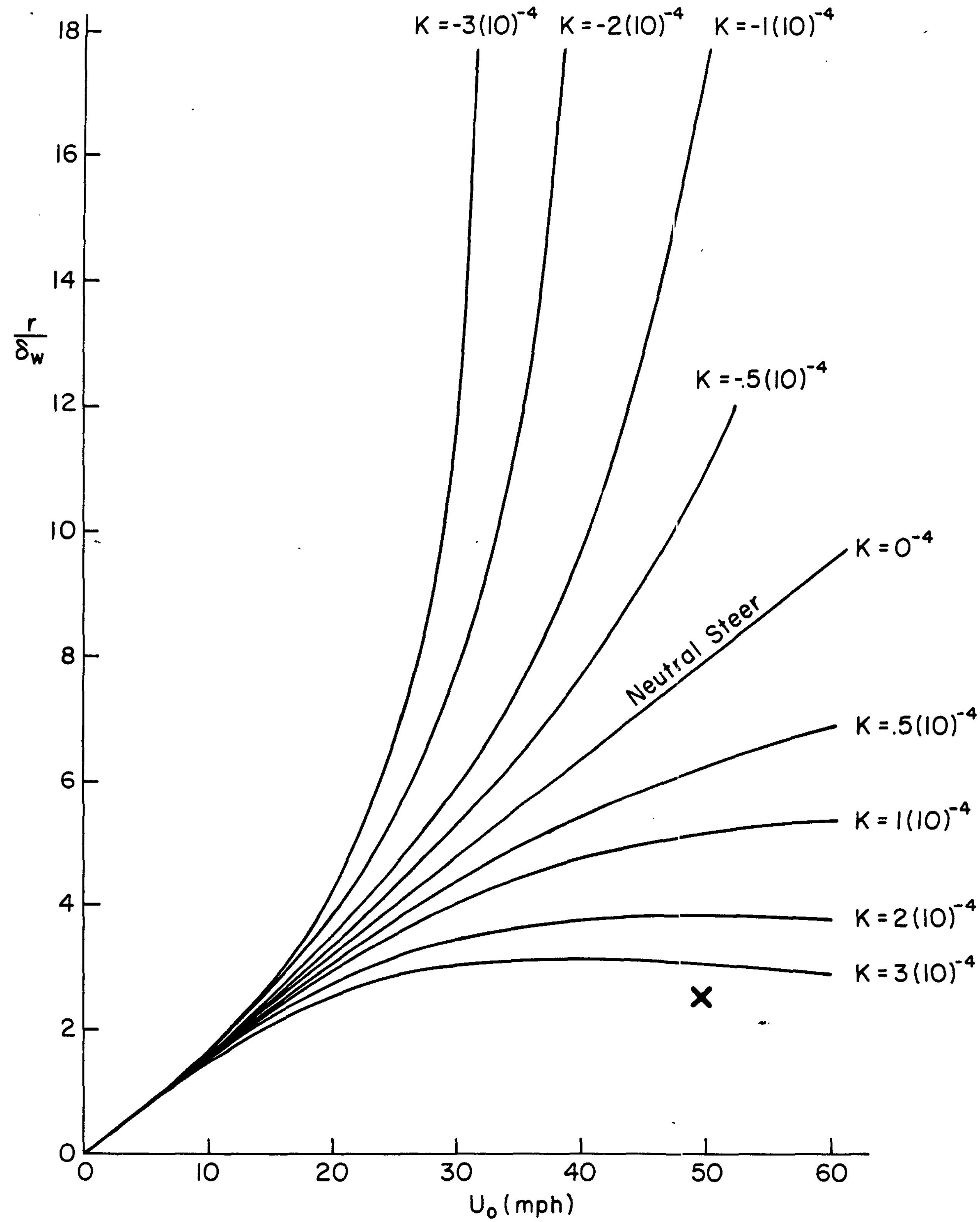


Figure A-2. Yaw Velocity Steady-State Response

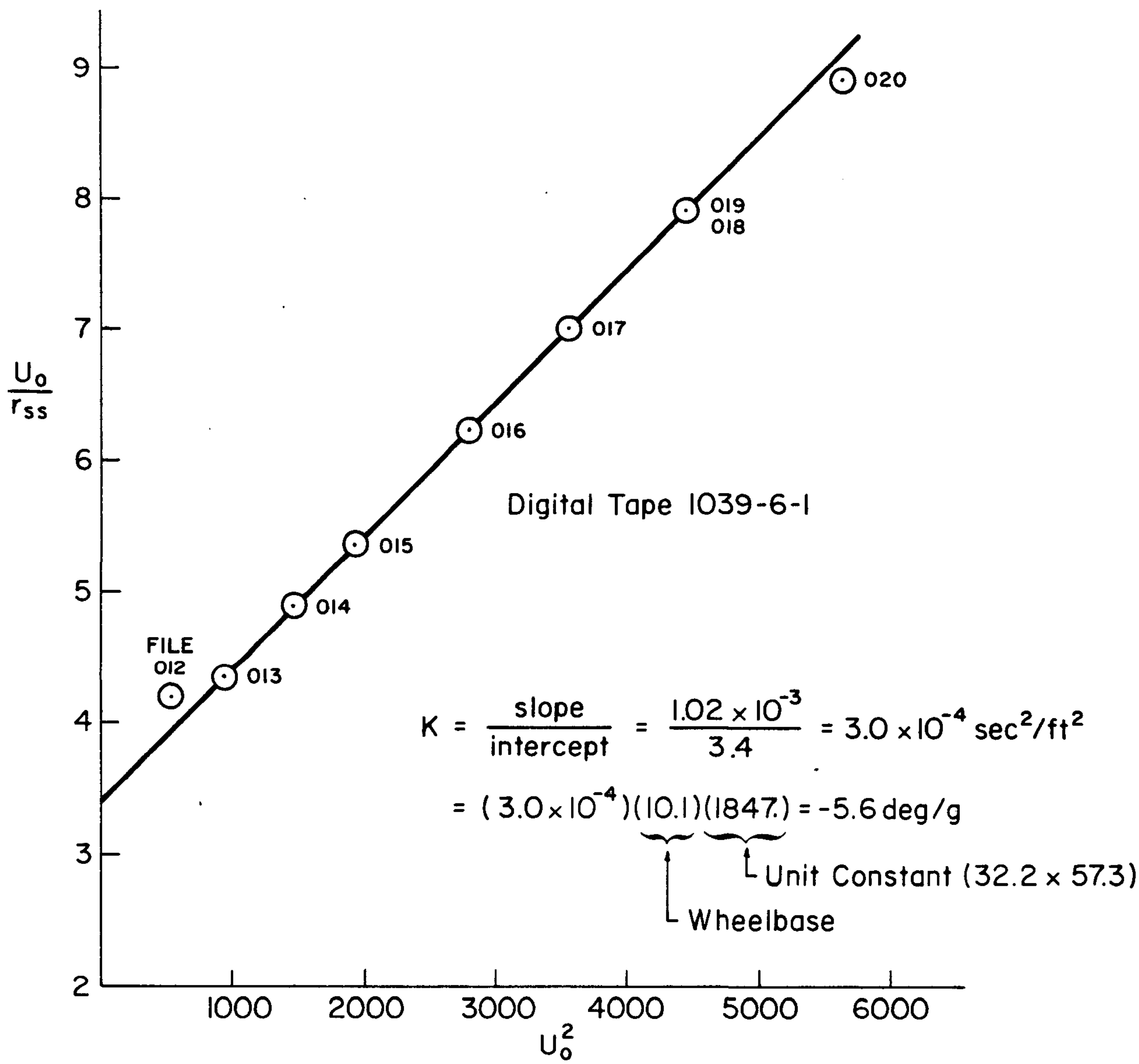


Figure A-3. Stability Gradient Plot for 3 deg
Left Step Steer Test

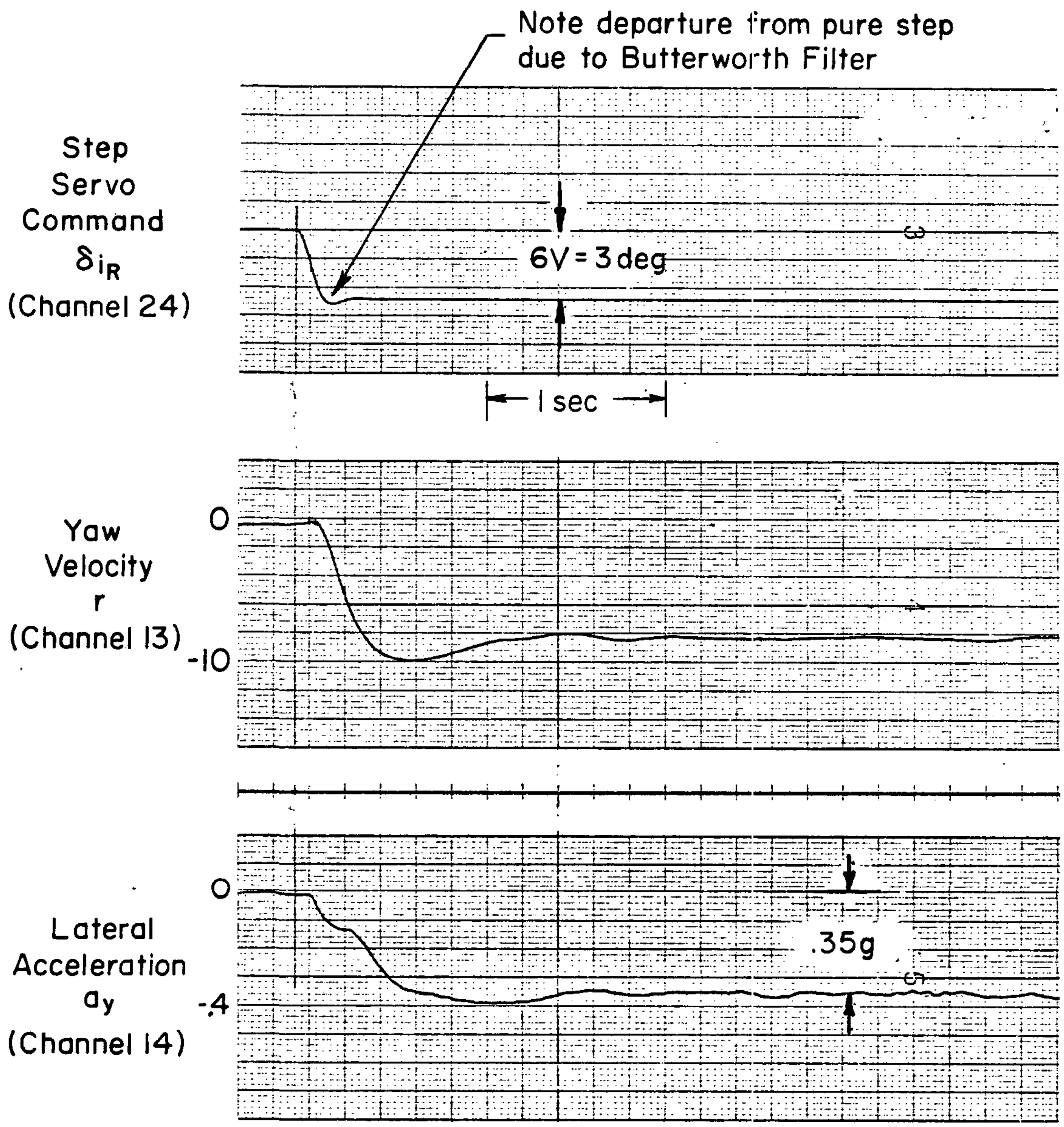


Figure A-4. Yaw Velocity and Lateral Acceleration Transient Response Characteristics to Step Steer Input at 50 mph

APPENDIX B

EXAMPLE DEMONSTRATION TESTS

The purpose of this appendix is to present some initial guidance to new users in setting up DPMAS for their test objectives. To do this we have treated four test scenarios:

1. A standard repertoire series for checkout.
2. Vehicle identification tests (open loop tests).
3. Driver/vehicle response tests (handling qualities tests).
4. Driver training and evaluation tests.

Each uses different capabilities of DPMAS and outputs different data sets as seen by the data group summary in Table B-1. The tests for each group are described in the following subsections.

STANDARD REPERTOIRE SERIES

The standard repertoire exercises all modes of the Data Acquisition System and Signal Conditioning System, and general operation of the vehicle itself and servo system. Video or driver measures are <u>not</u> checked in this series. A digital tape in this series forms a reference for data processing and troubleshooting.

The standard repertoire is composed of the 10 files presented in Table B-2 and is self-explanatory. Note that the file count starts at 02. This is consistent with operating procedures of Section VII which use File 01 for a reference end of file mark.

VEHICLE IDENTIFICATION TESTS (GROUP 1)

Vehicle identification tests include step steer tests to determine the car's directional dynamic characteristics, steady circle tests to check lateral sensor calibrations, and straight line brake tests to check longitudinal sensor calibration.

TABLE B-1. DATA GROUP CORRESPONDENCE TO DEMONSTRATION TEST SCENARIOS

VEHICLE IDENTIFICATION GROUP 1			DRIVER-VEHICLE RESPONSE GROUP 2			DRIVER TRAINING AND EVALUATION GROUP 3			LONG TERM RUNS GROUP 4		
SENSOR	HI/LO GAIN*	S/R SWITCH†	SENSOR	HI/LO GAIN	S/R SWITCH†	SENSOR	HI/LO GAIN	S/R SWITCH†	SENSOR	HI/LO GAIN	S/R SWITCH
δ_{SW}	200/600	1[a]	δ_{SW}	✓	1[a]	δ_{SW}	✓	1[a]	$\delta_{\dot{S}W}$		2[a]
P_b		4	$\delta_{\dot{S}W}$		2[a]	$\delta_{\dot{S}W}$		2[a]	a_y		5[a]
δ_{WT}		1[a]	δ_T		3[b]	δ_T		3[b]	a_x		6[b]
ψ	50/200		δ_{WT}		1[a]	P_b		4	U_o		6[b]
θ			ψ	✓		ψ	✓		B_{10}		
φ			φ			p			HR		
q			r	✓	5[a]	r	✓	5[a]	X		
p			a_y		5[a]	a_y		5[a]			
r	40/100	5[a]	y			a_x		6[b]			
a_y		5[a]	U_o		6[b]	a_z					
a_x		6[b]	δ_{SC}			U_o		6[b]			
a_z			e_{m_r}			P_{EX}					
ω_{1-4}			HR			B_{10}					
U_o		6[b]	δ_{PIT}		8[a]	X					
δ_{SC}			X								
X											

*Gain values represent <u>maximum</u> number of degrees or degrees per second that can be recorded.

†Superscript a = sample rate changes from 20/50 samples per sec; superscript b = sample rate changes from 2/20 samples per sec.

TABLE B-2. STANDARD DPMAS REPERTOIRE FILES

FILE	SETTINGS	INITIAL CONDITIONS	PROCEDURE
02 Calibration	GR 1 GAIN HI	Stopped	Monitor CALIBRATE indicator lights for NO GO.
03 Calibration	GR 3 GAIN LO	Stopped	
04 Discretes	GR 1 AQ 0 (cont) GAIN HI S/R LO for all	Stopped	Start recorder; operate parking lights, brake lights, radio, right turn, left turn, lights on high beam and low beam, horn, windshield wipers, air conditioning, emergency brake, driver out-in; stop recorder.
05 Step Steer	GR 1 AQ 2(10 sec) GAIN HI S/R HI for 1, 4, 5	U_o = 30 mph ψ_o = −10 v δ_{sw} = 0	Accelerate 30 mph, start recording. Apply +60° $\Delta\delta_{sw}$ until $\Delta\psi$ = 90° right turn. Steer straight at ψ = 90 until recorder stops automatically.
06 Brake In Turn	GR 1 AQ 0 (cont) GAIN LO S/R HI for 1, 4, 5, 6	U_o = 0 ψ_o = 0 δ_{sw} = 0	Start recorder; accelerate to 30 mph. Apply step servo equal to 60° δ_{sw} (hold $\delta_{sw}=0$). Apply step brake to lock one wheel. Stop recorder after car stops.
07 Slalom	GR 2 AQ 4(50 sec) GAIN LO S/R HI for all	U_o = 0 ψ_o = 0	Align lane tracker to white line. Start recorder, accelerate to 30 mph. Weave ±30° δ_{sw} to ±90° δ_{sw} slowly in lane. Recorder stops automatically.
08 Lane Change	GR 2 AQ 1(5 sec) GAIN HI S/R HI for all	U_o = 50 ψ_o = 0	Accelerate to 50 mph. Start recorder. Change lanes rapidly. Recorder stops automatically.
09 90° Turn	GR 3 AQ 3(25 sec) GAIN LO S/R LO	U_o = 0 ψ_o = 0	Start recorder. Accelerate to 30 mph. Turn right 90°, δ_{sw} = 180° slowly. Apply exp. brake to stop. Recorder stops automatically.
10 360° Turn	GR 3 AQ 4(50 sec) GAIN LO S/R LO for all	U_o = 0 ψ_o = 0	Start recorder, lights on. Accelerate to 20 mph, right turn signal. Turn right 360° Stop at ψ = 0. Reverse as in parallel parking. Stop, lights off, recorder stops automatically.
11 Keyboard	GR 4 AQ 0 (cont) GAIN LO S/R LO for 5, 6	U_o = 0 ψ_o = 0	Start recorder. Accelerate to 30 mph. Drive 1 mile, hit keyboard 01-10 each 0.1 mile. Stop car, stop recorder.

END DATA

Step Steer Tests

These tests use the steering servo to apply steer angle steps of 1, 3, and 5 deg in one direction. The experimental conditions are as follows:

1. Set up turn area with minimum 300 ft inside radius.

2. Set servo authority limits to 0.6 in. (small slot).

3. Set Data Acquisition Unit for:

Group:	1	
Sample Rate:	High	
Gain:	High	
Acquisition Code:	0	(Manual Start and Stop)

4. Set heading gyro zero to −10 V when heading for start of test.

5. Set servo STEP pot to initial value, i.e., 1 deg left.

6. Drive down straight road with STEP in and record (via panel meter) what steering wheel angle is required to steer car in straight line.

7. Prepare for digital recording.

8. Start recorder. Accelerate to 20 mph. Hold steering wheel fixed and apply STEP steer input to servo. Hold step in until car rotates 90 deg, then remove. Stop recorder. Complete run log.

9. Repeat for 25, 30, 35, 40, 45, 50, and 55 mph.

10. Repeat all speeds for 3 deg step and 5 deg step.

11. Stability factor plots such as shown in Appendix A, Fig. A-3, can now be calculated to determine the basic vehicle stability gradient. This was found to be −5.6 deg/g (understeer) up to 0.5 g. Yaw velocity transient responses are then used to determine the dynamic parameters in the yaw velocity to steer angle transfer function at various speeds. An example response at 50 mph is presented in Appendix A, Fig. A-4, along with the lateral acceleration response.

12. The vehicle static stability can be changed from its basic −5.6 deg/g to 0 deg/g (neutral steer) or to −11 deg/g (understeer) with the current servo Motion Feedback control gain settings (see Section V). An example yaw velocity time response of the neutral steer car is shown in Fig. B-1 (note the lack of heading rate overshoot as compared to Fig. A-3).

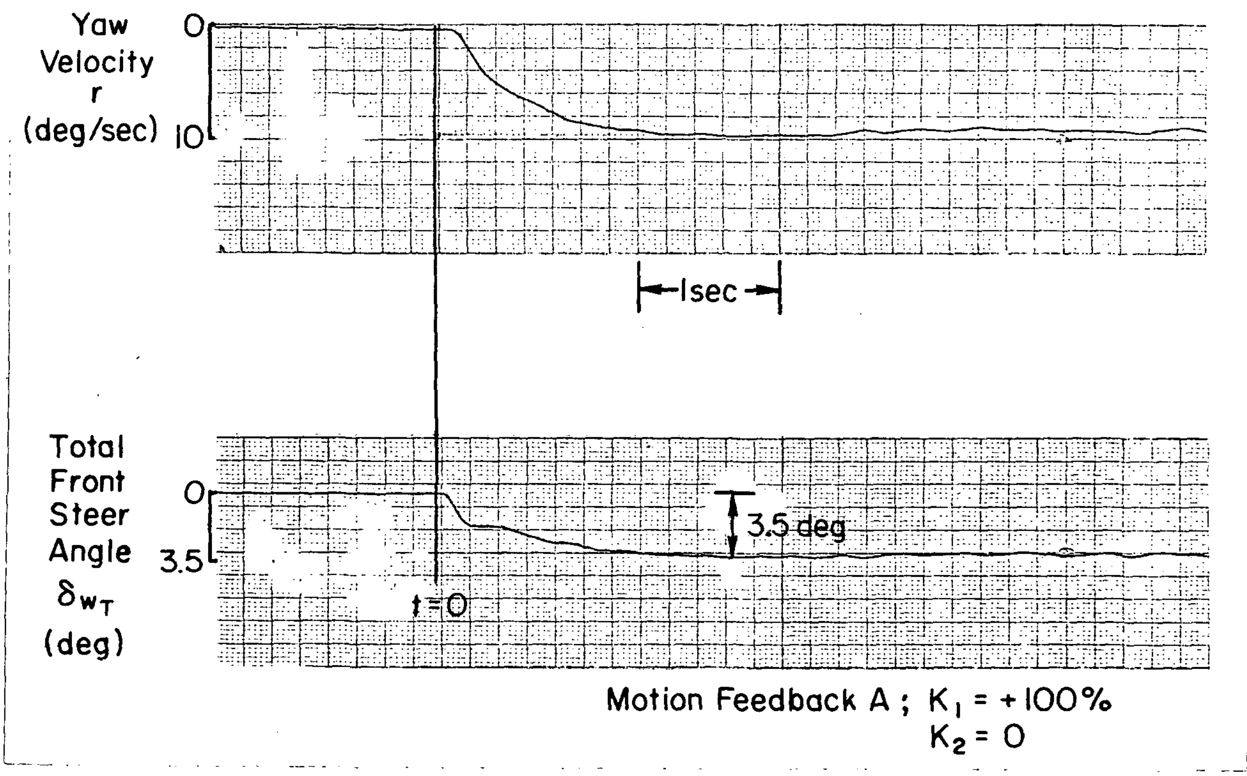


Figure B-1. Neutral Steer Response for 1.5 deg Step Steer at 50 mph (Experimenter Control Set for +5 deg/g)

The neutral steer response shown in Fig. B-1 defines the yaw velocity numerator time constant, T_r. This parameter, in conjunction with the stability factor, K, allows the yaw velocity to steer angle transfer function to be computed (see Ref. 4, Section III). This was found to be:

$$\left.\frac{r}{\delta_w}\right|_{50\text{ mph}} = \frac{12.1(s + 2.45)}{[s^2 + 2(.62)(3.25)s + (3.25)^2]}$$

where

$$1/T_r = 2.45 \Rightarrow T_r \cong 0.4 \text{ sec}$$

$$\zeta_1 = 0.62$$

$$\omega_1 = 3.25 \text{ rad/sec}$$

13. The primary variables for strip chart recording would include U_o, r, a_y, δ_{w_T}, δ_i, φ, and ψ.

Steady Circle Tests

These tests use no servo steering. They do require at least a 100 ft radius circle, although 200 ft radius is preferable. The test procedure is as follows.

1. Prepare for digital recording.
2. Set Data Acquisition Unit for:

Group:	1
Sample Rate:	Low
Gain:	Low
Acquisition Code:	2 (10 sec)

3. Accelerate to 20 mph, hold steady.
4. Start recorder (stop automatically).
5. Accelerate to 30 mph, hold steady.
6. Start recorder (stops automatically).
7. Accelerate to 40 mph, hold steady.
8. Start recorder (stops automatically).
9. Change to Acquisition Code = 0.
10. Start recorder and accelerate until car cannot maintain radius (maximum lateral acceleration).
11. Stop recorder after maximum lateral acceleration achieved.
12. Primary variables for strip chart recording are U_o, r, ψ, φ, a_y, δ_{SW}, δ_{W_T}.
13. Check data for:
    - $\Delta\psi/\Delta t = r$
    - $a_y - g\varphi = U^2/R$
    - $U_o r = a_y - g\varphi$
    - Maximum lateral acceleration
    - Maximum speed on circle
    - Roll angle per lateral g
    - Steady state steer angle vs. speed

Straight Line Brake Tests

Approximately 1/8 mile is needed to acceleration to 40 mph and then stop. The test procedure is as follows.

1. Prepare for digital recording.
2. Set Data Acquisition Unit for:

Group:	1
Sample Rate:	High
Gain:	High
Acquisition Code:	0

3. Set heading gyro to 0 V when heading in test direction.
4. Accelerate to 30 mph, stabilize.
5. Start recorder.
6. Apply brakes until incipient lockup of any one wheel.
7. Stop recorder after car stops.
8. Repeat test for 50 mph and at various brake pressures.
9. Primary variables for strip chart recording are ω_1, ω_2, ω_3, ω_4, P_B, θ, q, a_y. Distance traveled is only available on digital output.
10. Check data for:
    - Wheel lockup
    - $\omega_1 \approx \omega_2 = \omega_3 = \omega_4$ in steady state
    - P_B vs. a_x
    - P_B vs. X

DRIVER/VEHICLE RESPONSE TESTS

Driver/vehicle response tests are closed loop handling quality tests where various performance measures are compared to changes in vehicle characteristics. In the example tests described herein the vehicle dynamics and steering gain were varied. In addition, this demonstration test was designed to:

- Evaluate data quality and compatibility between on-line analog recording and off-line digital playback.
- Exercise servo steering features.
- Evaluate effects of different maneuvers on system operation.

This sequence of tests utilized three basic maneuvers to simulate nominal driving, transient maneuvering, and emergency conditions. These were lane regulation in the presence of an external input, double lane change at 45 mph, and 100 ft slalom course, respectively. A diagram of the double lane change and slalom is shown in Figs. B-2a and B-2b.

The variables of importance for these maneuvers were selected as "Data Group 2" in the Data Acquisition System. These were similar to those recorded in our previous driver/vehicle response research, Ref. 4. For reference they are listed in Table B-3 along with the signal gains and sample rate for those channels having two selectable levels.

Peripheral equipment utilized in the tests include a 6-channel Brush strip chart recorder and electronic oscillator (to simulate a gusting cross-wind input).

Test variables were steering ratio (G_S) and stability factor (K), as derived from the steering servo by feeding back steering wheel position and lateral acceleration, respectively. Specific values were:

G_S: 9:1 (quick), 18:1 (normal ratio), 24:1 (slow)

K: 0 (neutral steer), −5.5 deg/g (normal understeer), and −11 deg/g (drastic understeer)

To simplify data reduction procedures these three maneuvers were run in one continuous lap. Each maneuver was represented by one file on digital recording by using the Manual Start and Stop feature of the Data Acquisition System at the start and end gates shown in Fig. B-2 (i.e., Acquisition Code = 0). Each lap was then given one run number which included three digital files.

Due to the transient nature of the maneuvers, HIGH sample rate and LOW gain should be used. Examples of results obtained are presented in the

Note: All Dimensions in Feet

○ Small (18 in.) Cones

⊗ ⊗—⊗ Delineator Cones (4 ft)

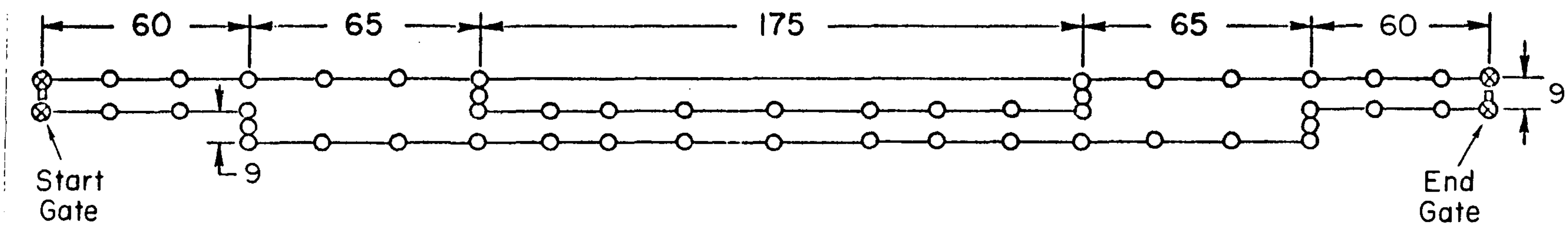


Figure B-2a. High-Speed Lane Change Course

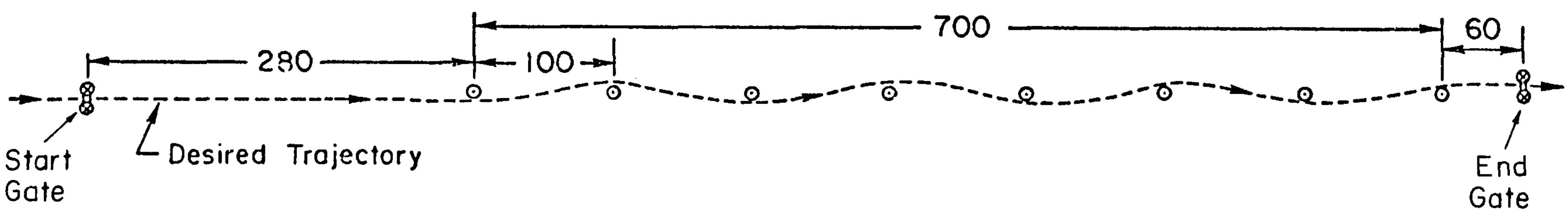


Figure B-2b. Slalom Course

TABLE B-3

SIGNAL SELECTION FOR DATA GROUP 2

DRIVER/VEHICLE RESPONSE — GROUP 2				
SENSOR		HI/LO GAIN	SAMPLE RATE	S/R SWITCH
Steering Wheel	δ_{SW}	20/60 (deg/volt)	20/50	1
Steering Wheel Rate	$\dot{\delta}_{SW}$		20/50	2
Throttle	δ_T		2/20	3
Front Steer Angle	δ_{W_T}		20/50	1
Heading Angle	ψ	5/20 (deg/volt)		
Roll Angle	φ			
Yaw Velocity	r	4/10 (deg/sec)/v	20/50	5
Lateral Acceleration	a_y		20/50	5
Lateral Position	y			
Forward Speed	U_o		2/20	6
Servo Command	δ_{sc}			
Steer Angle Error	e_{m_r}			
Heart Rate	HR			
Pitman Arm	δ_{PIT}		20/50	8
Distance Travelled	X		1/20	6

following series of strip chart recordings. In the first figure, Fig. B-3, we see a comparison of the steering wheel activity and vehicle yaw velocity in a double lane change maneuver when the steering ratio is varied from 9:1 to 18:1 to 24:1. Note the reduction in steering wheel amplitude while yaw velocity increased slightly. The quick steering ratio also exhibits a more well defined precognitive signature than the slower ratios.

Figure B-4 shows the same lane change maneuver but this time with three different stability factors at one steering ratio. Again, this comparison shows the higher gain, neutral steer configuration to exhibit a more well defined steering response and fewer steering reversals (axis crossings of steering wheel rate channel). Note also that the lateral acceleration peak values are about 0.5 g for all configurations.

Figure B-5 shows the same three configurations in a 45 mph slalom (100 ft cone spacing). The higher overall gain of the neutral steer configuration again forces smaller peak steering wheel activity. This figure also shows the limiting circuitry in the yaw velocity channel (at 19 deg/sec) and good sensor outputs at 0.75 lateral g peaks.

Figure B-6 shows the response of other vehicle sensors in the lane regulation task. The third channel shows the servo command input of about ±1.5 deg

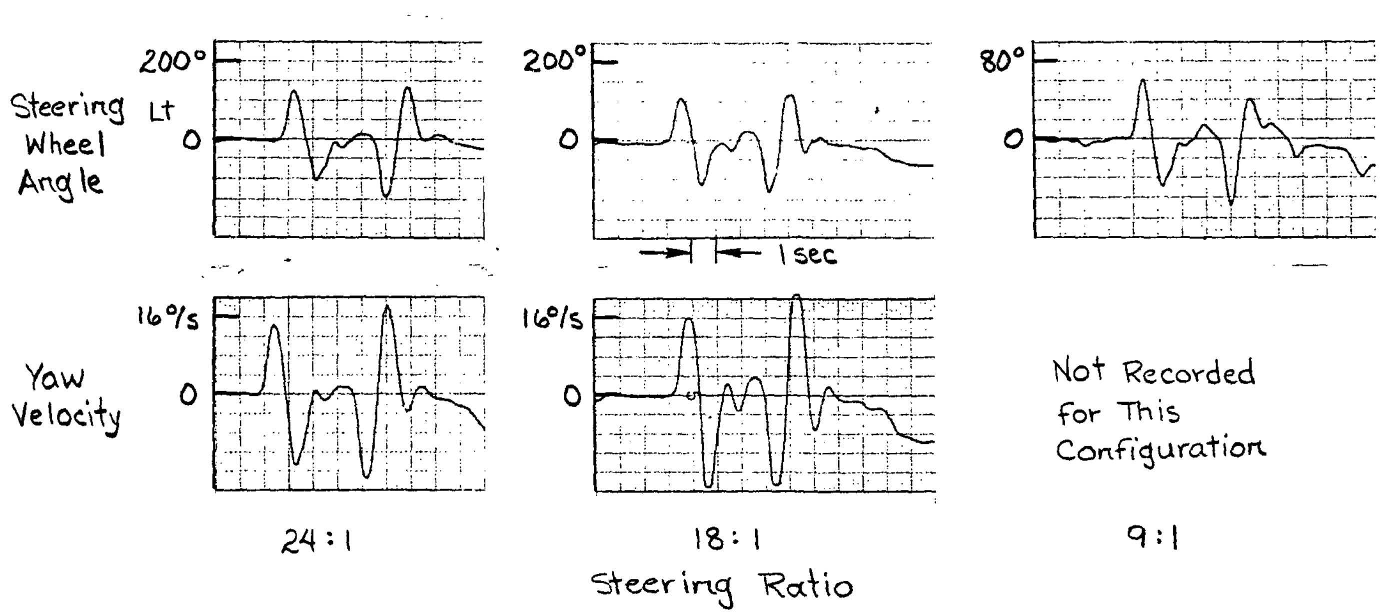


Figure B-3. Comparison of Driver/Vehicle Responses at Three Different Steering Gains in 45 mph Double Lane Change Maneuver

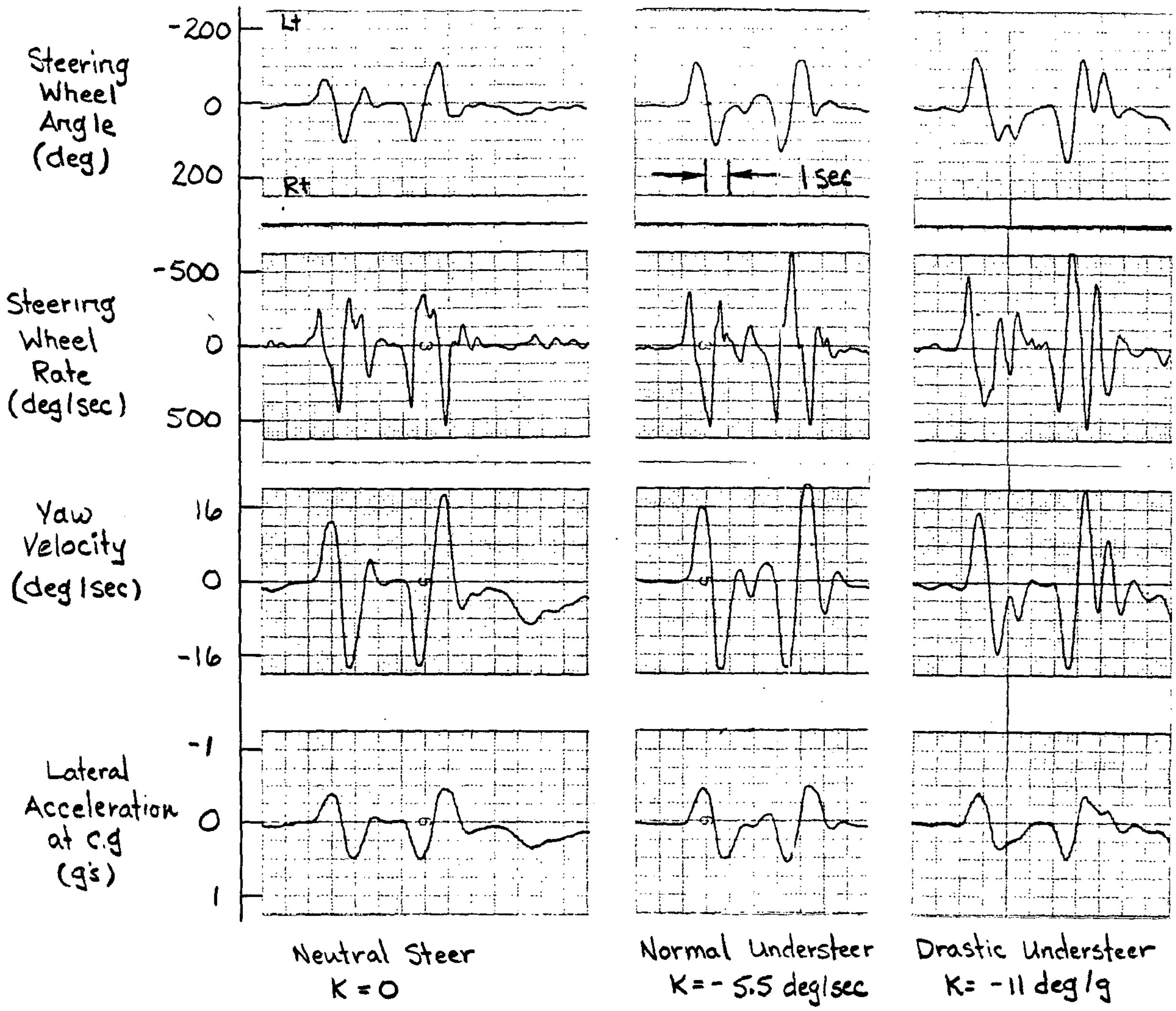


Figure B-4. Comparison of Driver/Vehicle Responses in 45 mph Double Lane Change for Various Stability Factor Vehicle Configurations

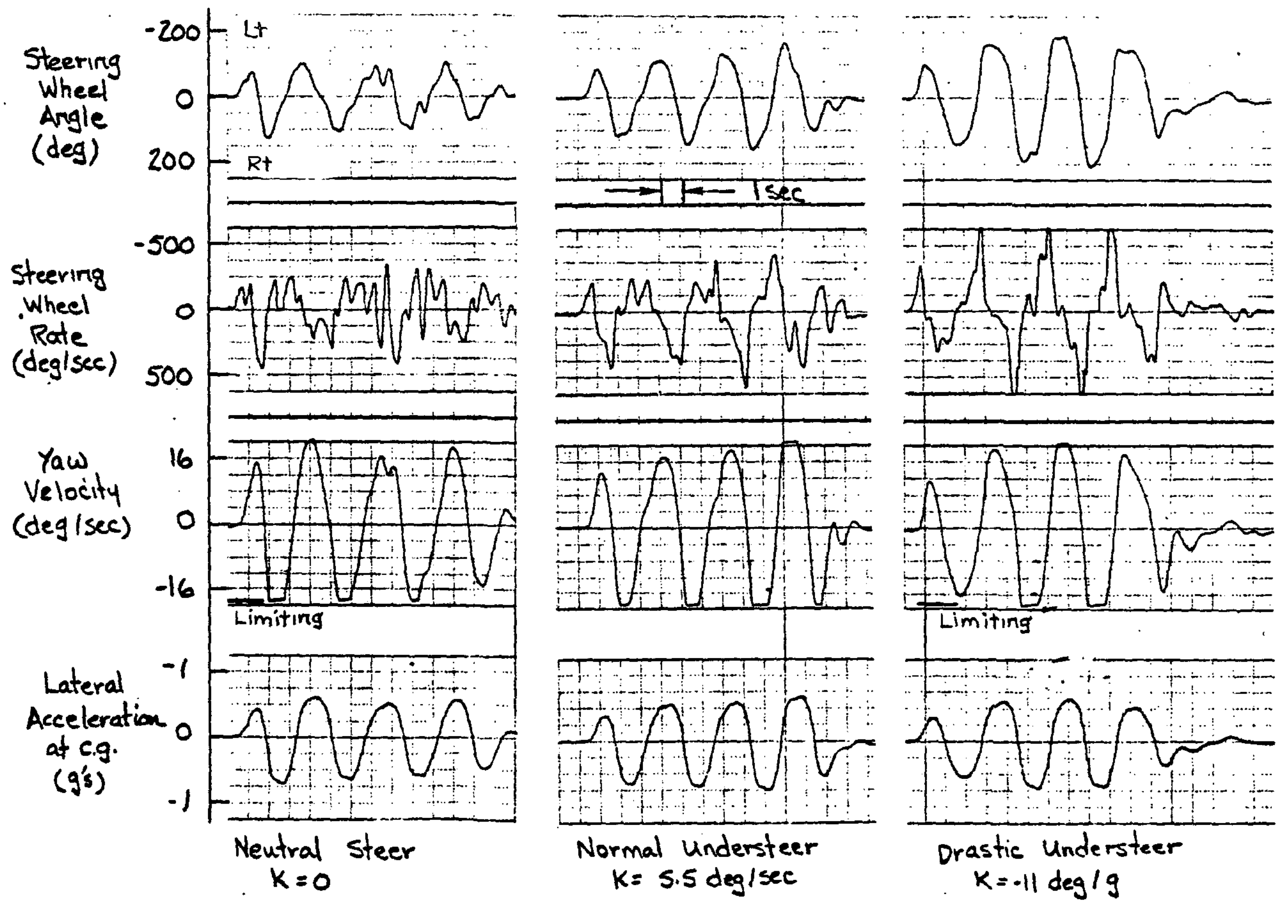


Figure B-5. Comparison of Driver/Vehicle Responses in 45 mph Slalom with Various Stability Factor Vehicle Configurations

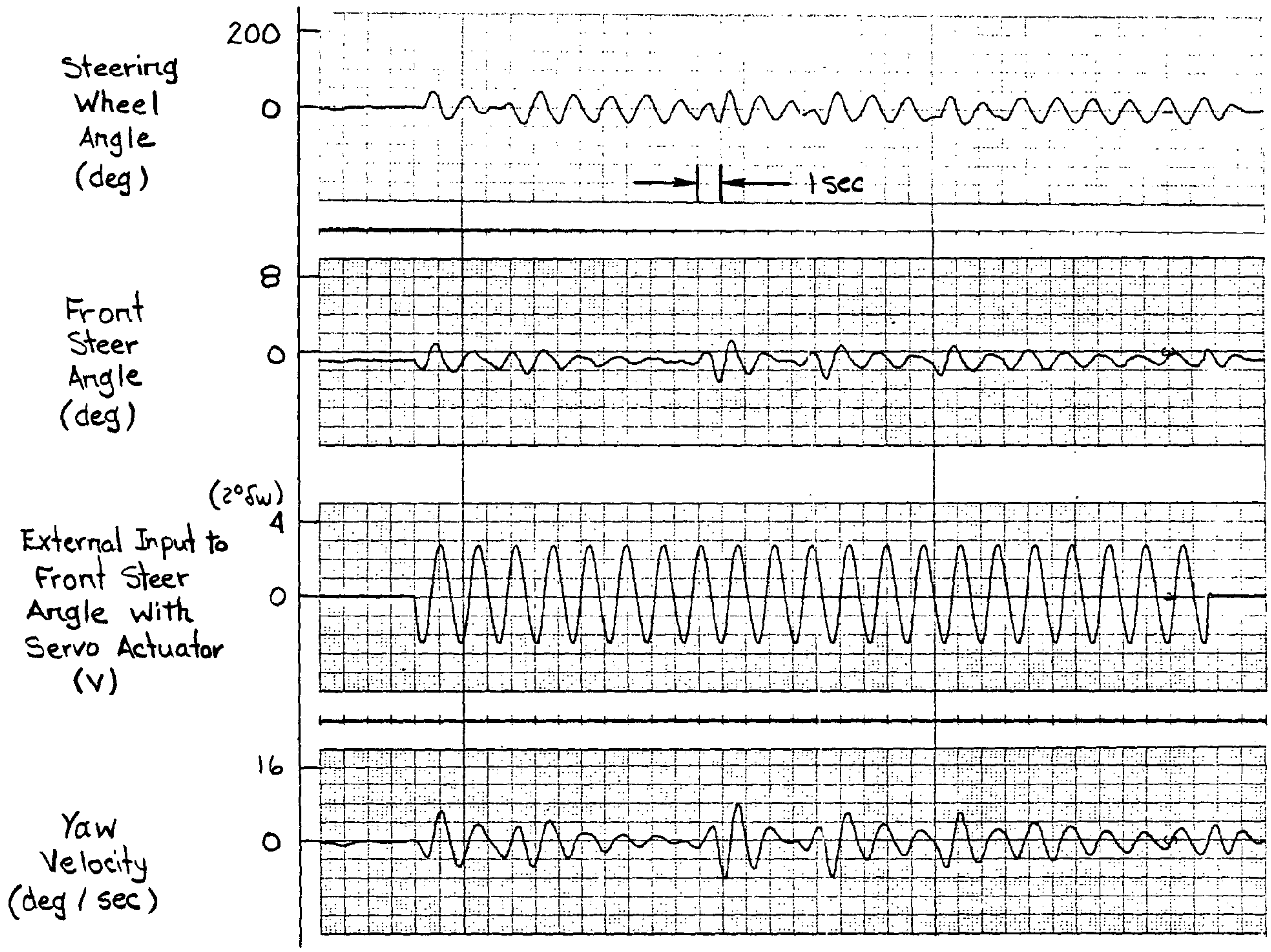


Figure B-6. Example Driver/Vehicle Closed Loop Response to External Input Applied with Servo Steering System at 30 mph front steer angle which the driver attempts to counteract by equal and opposite steering wheel movements. This would be relatively easy to do if the driver recognized the sinusoidal nature of the input. However, the front steer angle (which actually moves the car) becomes contaminated with the driver's uncorrelated steering actions (remnant), and the resulting vehicle motion is quite erratic as shown by the yaw velocity trace.

The last figure, Fig. B-7, presents the output of five additional sensors not seen in the previous figures. These are forward speed, Pitman arm displacement, servo output displacement, roll angle, and heading angle (from SR-3 gyro). All but the forward speed have excellent signal quality with no visible noise contamination. The forward speed sensor was binding in the cable, thus causing signal scalloping as seen on Channel 1.

An example run schedule for Groups 1 and 2 tests is given in Table B-4. This shows typical strip chart recorder variables (along with their J-box filter output number), acquisition times, gains, and sample rates.

DRIVER TRAINING AND EVALUATION TESTS (GROUP 3)

Driver training and evaluation tests primarily utilize the video and Experimenter's Keyboard capability of DPMAS; although LOW gain, LOW sample rate digital data may be desired. In the tests described herein both systems were used. The tests consist of driving in an urban/suburban traffic situation in which driver responses to critical incidences such as encroaching or conflicting cars, cyclists, pedestrians, etc., could be measured. The driver was instrumented for heart rate, EMG, and GSR, and the interior video camera was set up to monitor driver eye point of regard through the rearview mirror.

The video camera split was set up as shown in Fig. B-8 to record prevailing traffic conditions combined with the direction of driver view. The numerical information combined on the video scene consisted of the date, time, run number, keyboard entries, vehicle speed, and heart rate. Steering wheel angle and brake line pressure were added to the two selectable video channels. On the digital tape a variety of driver measures and vehicle response variables were recorded as summarized in Table B-5.

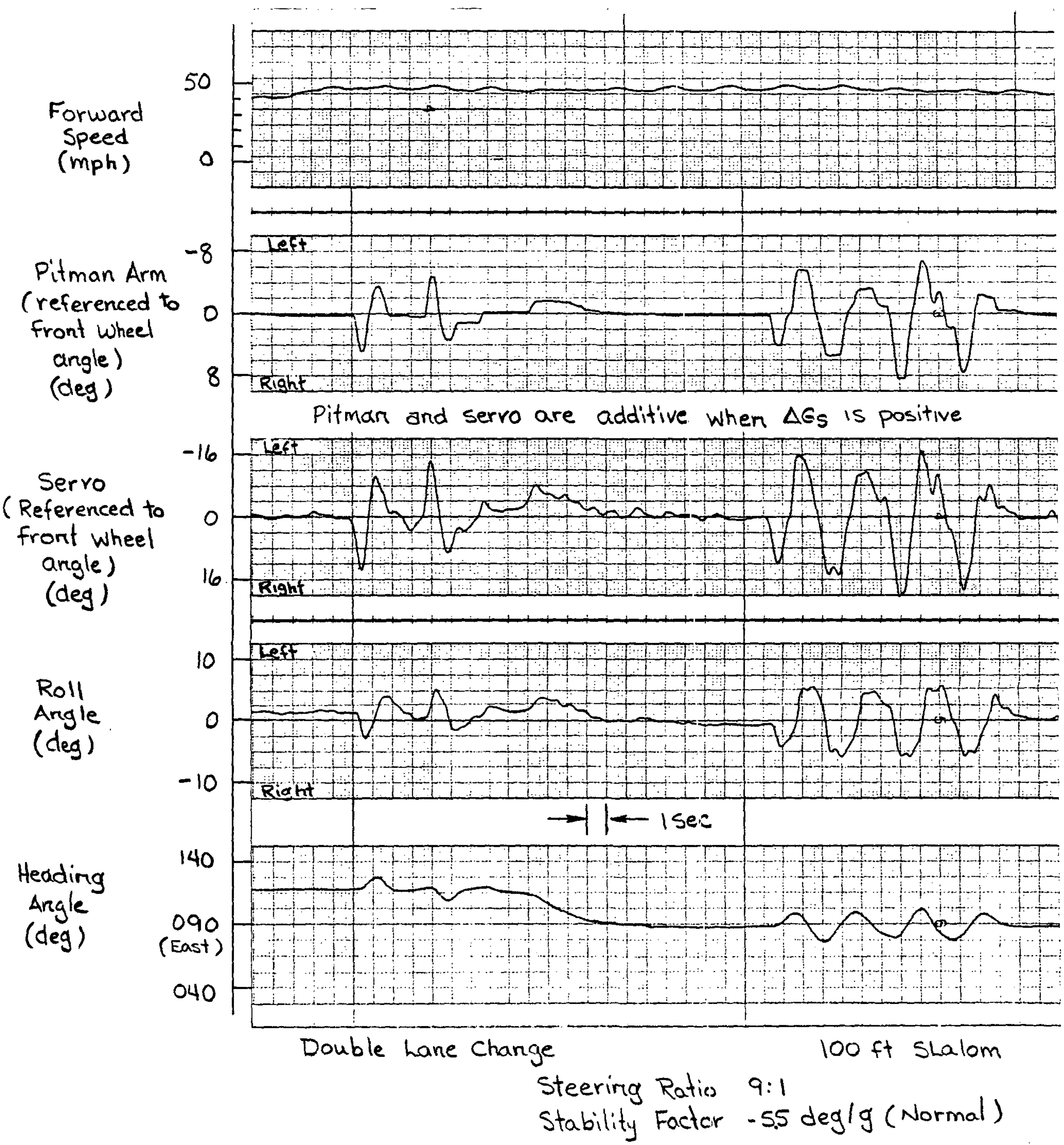


Figure B-7. Example of Other Sensor Outputs

TABLE B-4

TEST RUN SCHEDULE FOR DATA GROUPS 1 AND 2

RUN	FILE NUMBER	TEST	STRIP CHART SENSOR	STRIP CHART FILTER	GROUP	ACQ	GAIN	SAMPLE RATE
1	02 03 04 05	CALIBRATION	NA		1 2 3 4	1	High	High
2	06	CIRCLE at 25 mph	δ_{SW} δ_{WT} φ p r U_o	F01 F05 F10 F12 F13 F22	1	3 (25 sec)	Low	Low on 3, 4, 6, 7, 8
3	07	CIRCLE at 25 mph Increase Brush scales to get better resolution	δ_{SW} δ_{WT} φ p a_y U_o	F14	1	3 Same as 06		
4	08 09	STEP 40 mph ψ_o = +10V (left) 90^o δ_{SW}	δ_{SW} δ_{WT} ψ r a_y U_o	F06 F13	1	3	High	Low on 3, 4, 7, 8
5	10	STEP SERVO 40 mph K = -90% Check zeros	δi_r δ_{WT} φ p a_z U_o	F24 F10 F12 F16	1	0	Low	High Low on 3, 4, 7, 8
6	11 12 13	STRAIGHT BRAKE 40 mph	P_b θ q a_x W_{LF} W_{RF}	F04 F09 F11 F15 F18 F19	1	2	High	High Low on 1, 2, 3, 5, 7, 8
7	14	STRAIGHT BRAKE 40 mph Increase θ, a_z scales	P_b θ a_z U_o W_{LR} W_{RR}		1	2	High	Low on 1, 2, 3, 5, 7, 8

(Continued on following page)

TABLE B-4 (Concluded)

RUN	FILE NUMBER	TEST		STRIP CHART SENSOR	STRIP CHART FILTER	GROUP	ACQ	GAIN	SAMPLE RATE
8	15 16 17	G_s = NORMAL K = NORMAL	ψ_o = E Regulation ψ_o = W Slalom Double Lane Change (DLC)	δ_{sw} $\dot{\delta}_{sw}$ δ_{WT} y r U_o	F01 F02 F05 F17 F13 F22	2	3 3 2	High	High 1, 2, 5, 6
9	18 19 20	G_s = 9.1 K = NORMAL	ψ_o = E Regulation ψ_o = W Slalom DLC	δ_{sw} δ_{PIT} δ_{WT} y a_y δ_{i_r}	 F36 F14 F24	2	4 3 2	High	High on 1, 2, 5, 6
10	21 22 23	G_s = NORMAL K = +100% (Neutral steer)	ψ_o = E Regulation ψ_o = W Slalom DLC	δ_{sw} δ_T HR y ψ φ	 F03 F35 F06 F10	2	4 3 2	High	
11	24	1 MI DRIVE Keyboard RT LTS EPR		U_o EPR_H EPR_V ECG RT LTS	F22 F33 F34 S01 S32 S35	2	0	Low	Low High on 6
		END DATA							
		RELOAD AND SEARCH							
12	25	CALIBRATION				1	1	High	High
13	26 27 28	DVR TESTS Regulation Slalom DLC		δ_{sw} HR ψ y r U_o	F01 F35 F06 F17 F13 F22	2	0	Low	High 1, 2, 5, 6
14	29 30 31								
15	32 33 34								
16	35 36 37								
17	38 39 40								
18	41 42 43								

END DATA

TABLE B-5

GROUP 3 RECORDED VARIABLES

NAME	VARIABLE
DSW	Steering wheel angle
DSWD	Steering wheel rate
DT	Throttle position
PBRK	Brake line pressure
PSI	Heading angle
P	Roll rate
R	Heading rate
AYI	Lateral acceleration
AXI	Longitudinal (fore/aft) acceleration
AZI	Vertical acceleration
Y	Lateral position
VEL	Forward speed
XBRK	Experimenter's brake
EMGA	Electromyogram A (right bicep instrumented)
EMGB	Electromyogram B (right thigh instrumented)
GSR	Log skin resistance (middle finger of left hand)
HR	Heart rate
DIST TRAV	Distance traveled (odometer)
BKLT	Brake light
RTTI	Right turn indicator
LTTI	Left turn indicator

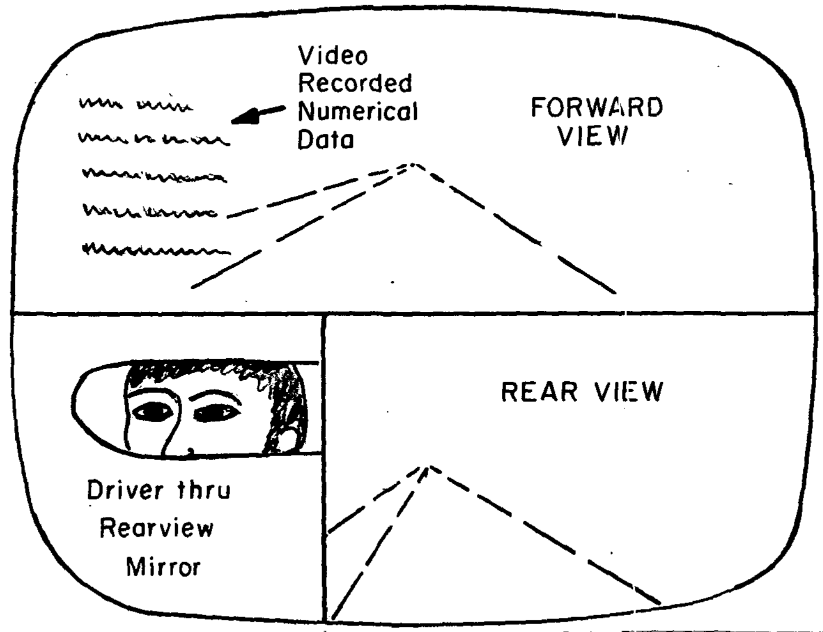


Figure B-8. Video Format for Driver Training and Evaluation Demonstration Tests

Data input was also provided by Experimenter Keyboard entries. As summarized in Table B-6 a two-number code was arranged to identify potential conflicts. The code was set up to have some direct physical correspondence between the event and key location. In each two-digit code the first number represents own vehicle action and the second number signifies other object action. Some codes represented object classification as noted, while other codes were not assigned and could have been used for further code expansion.

Data collection occurred over approximately a two-hour period. Both freeways and surface streets were covered, and areas ranging from residential through commercial/industrial were included in order to experience a range of traffic conditions. Traffic was light at the beginning of the drive and increased in volume throughout the test period. A local high school let out near the end of the drive, presenting a high driver workload due to numerous potential conflicts with pedestrians and cyclists.

TABLE B-6

TWO NUMBER KEYBOARD ENTRY CODE FOR POTENTIAL CONFLICTS/CRITICAL INCIDENCES

First number = own vehicle action	7 Left Turn	8 Straight Ahead	9 Right Turn
Second number = other object location	Left Front	Close Ahead	Right Front
	4 Left Lane Change	5 ("55") Blind Intersection	6 Right Lane Change
	Left Side	Cyclist	Right Side
	1 Not Used	2 Emergency ("22")	3 Not Used
	Bad Data (Disregard First Code)	Not Used	Not Used
	0 Stop		
	Close Behind		

Reduced digital data, printed on a teletype terminal, for a typical file are given in Table B-7. Referring to this table we see that the summary includes: 1) date, file, and run numbers which allow correspondence with written notes, log sheets, and video tapes; 2) variables recorded in file (see Table B-5 for variable descriptions); 3) comments on abnormal conditions on tape or in data processing (e.g., parity errors, data overflow, time points out of sequence, etc.); 4) data file time and distance window; and 5) keyboard codes and time of entry.

Figure B-9 presents the digital time traces of the active driver and vehicle responses occurring during the example run. As noted, this time sequence encompasses a reasonable amount of steering and throttle activity (see Table B-5 for variable definitions) including three right angle turns

TABLE B-7. DPMAS DIGITAL DATA FILE SUMMARY

DPMAS DATA TAPE SORT

1) TAPE DATE: NOV 20 1975 FILE NO. 6 RUN NO. 4

2) THE FOLLOWING 28 CHANNELS WERE SELECTED FOR THIS RUN:

CH NO.	NAME	RATE	CH NO.	NAME	RATE	CH NO.	NAME	RATE
1	DSW	20	2	DSWD	20	3	DT	2
4	PBRK	2	6	PSI	20	12	P	20
13	R	20	14	AYI	20	15	AXI	2
16	AZI	20	17	Y	20	22	VEL	2
23	XBRK	2	26	EMGA	5	27	EMGB	5
28	GSR	5	29	*EEG1	5	30	*EEG2	5
31	*EEG3	5	32	*EEG4	5	33	*EPRH	50
34	*EPRV	50	35	HR	5	61	DIST	1
62	TRAV	1	63	FEET	1	64	PKLT	1
65	HORN	1						

THE TOTAL NO. OF DATA SAMPLES PER SEC IS 315

*EEG and EPR not instrumented

END OF FILE REACHED NO FINAL HEADER RECORD

3) 155 SECS OF DATA HAVE BEEN PROCESSED NORMALLY.
AN ADDITIONAL 64 SAMPLES WERE AVAILABLE FOR PROCESSING BEFORE ATTEMPT TO READ 13 MORE DATA RECORDS. 4 RECORDS WERE READ BEFORE ERROR DETECTED.
6 ADDITIONAL SECS MAY BE AVAILABLE FOR PROCESSING

NEED MORE ROOM FOR OUTPUT DATA

4) THE INITIAL TIME IS 14:19:44
DISTANCE TRAVELED IS 121805. FEET.
THE NUMBER OF SECS OUTPUT IS 155.99
THE FINAL TIME IS 14:22:19
DISTANCE TRAVELED IS 124220. FEET.

5)

KEYBOARD ENTRY	TIME
41	14:19:51
6	14:20: 1
79	14:20: 4
83	14:20:23
76	14:20:36
8	14:20:51
94	14:21:12
94	14:21:17
94	14:21:19
86	14:21:30
48	14:21:57

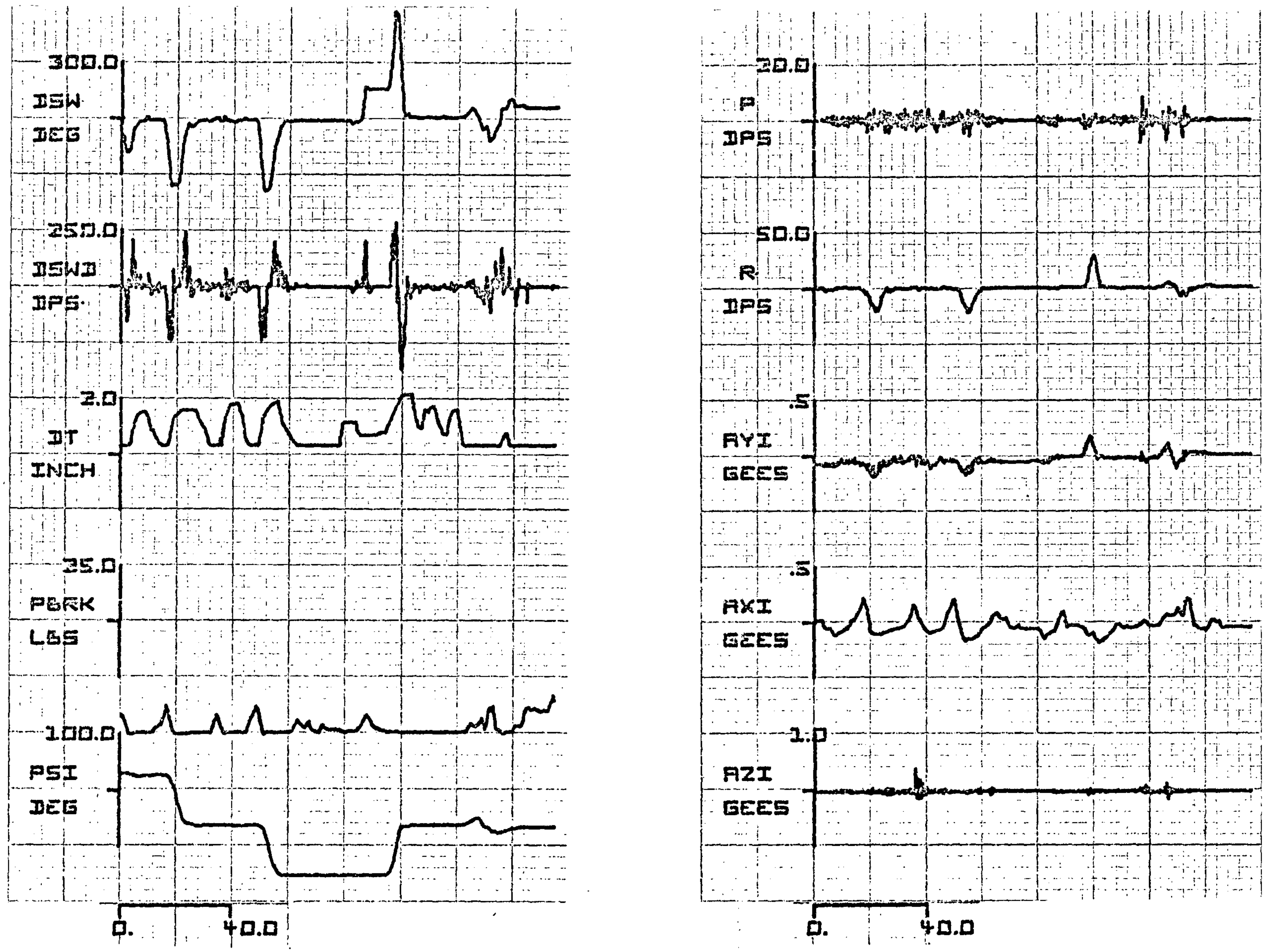
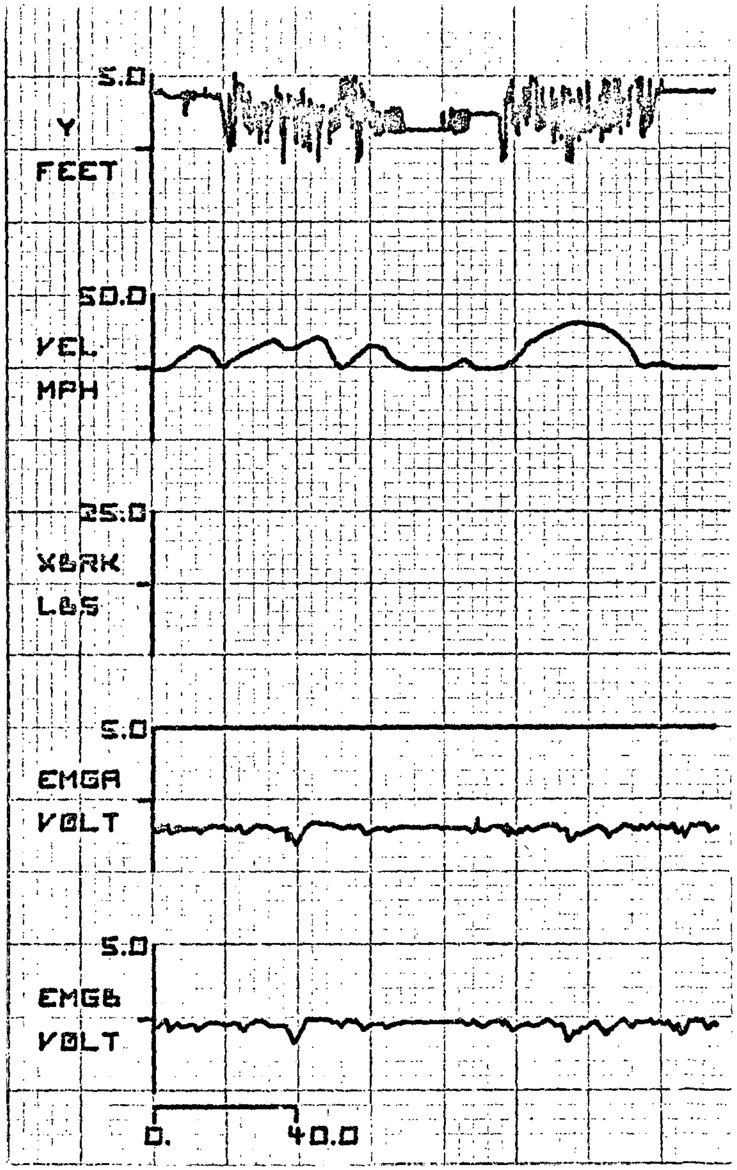


Figure B-9. Active Time Traces from Example Data File



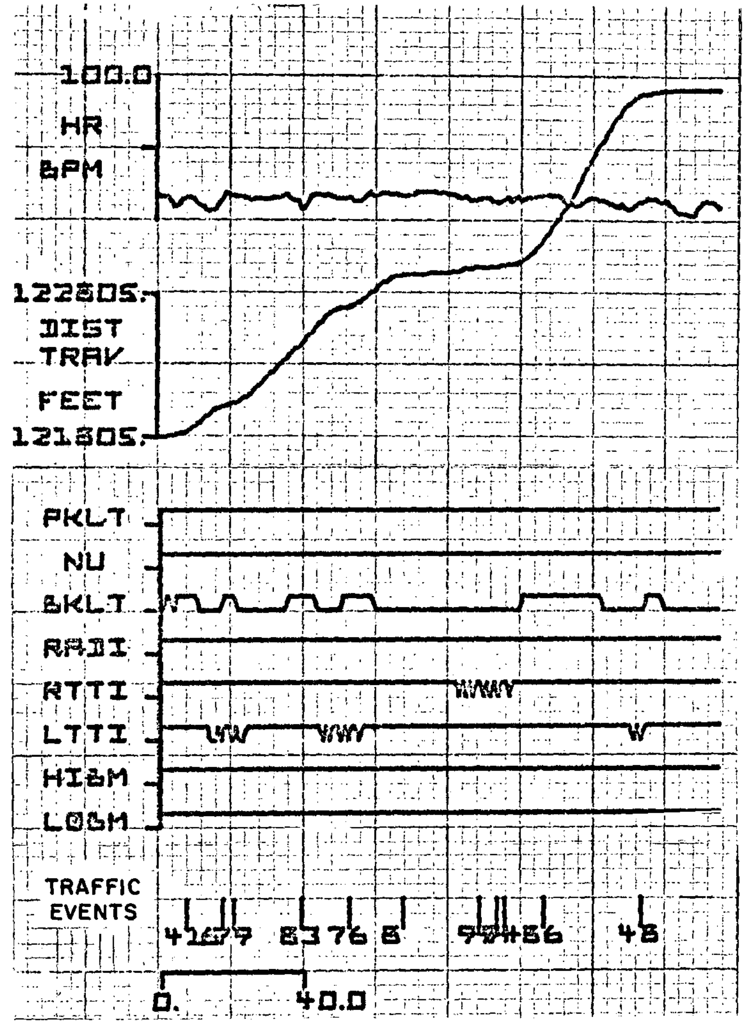


Figure B-9. (Concluded)

(see heading variable "PSI"). Also, ten critical incidences were recorded during this two-minute file (the "41" code indicates the experimenter made an error).

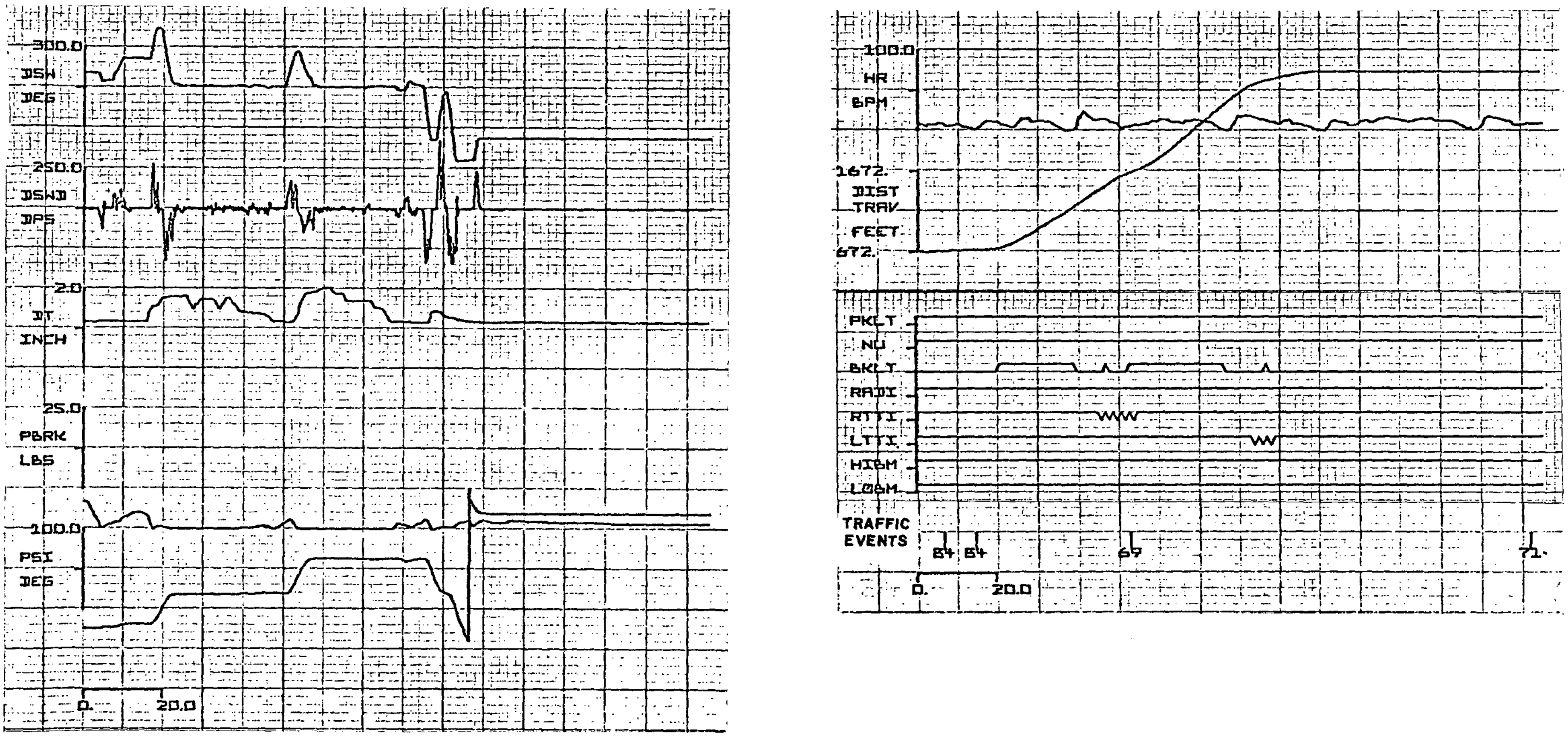
Several data files from the driver training and evaluation demonstration drive have been analyzed, and some interesting results are illustrated in Fig. B-10. The three files in Fig. B-10 were obtained under increasing levels of driver workload as follows:

FILE NUMBER	TIME WINDOW	NUMBER OF CRITICAL INCIDENCES*	INCIDENCES PER MINUTE
a) 4	1:29-1:31 PM	3	1.2
b) 5	1:52-1:54 PM	5	2
c) 8	2:56-2:59 PM	13	5

*Codes ending in 1 indicate bad data and were ignored.

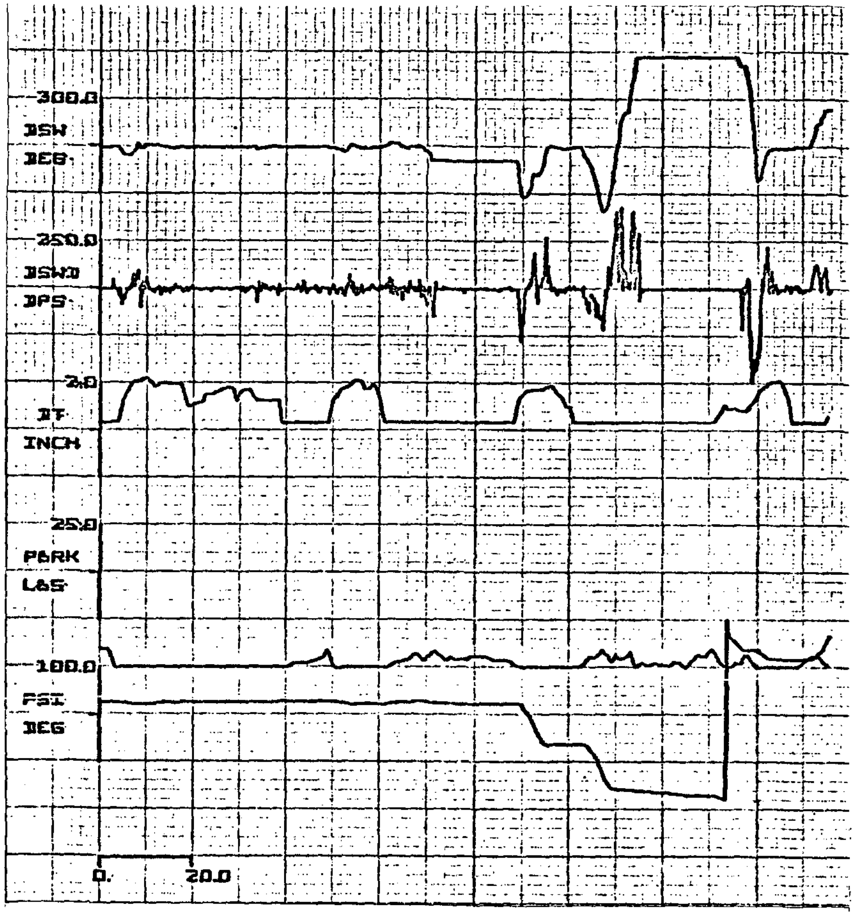
It is clear that the driver's activity and workload (as measured by critical incidences) increased in going from File 4 to 8. Referring to the heart rate traces we note a decrease in variability corresponding to increasing workload which is consistent with previous research. Also in File 5 we note a steady increase in heart rate through the midpoint of the run which corresponds to a period of concentrated traffic events. The rate of occurrence of the traffic events falls off at the middle of the file, however, and heart rate shows a corresponding reduction. Overall, the Fig. B-10 data demonstrate a good qualitative relationship between driving workload and physiological response which will be useful for DPMAS application to driver training/evaluation research.

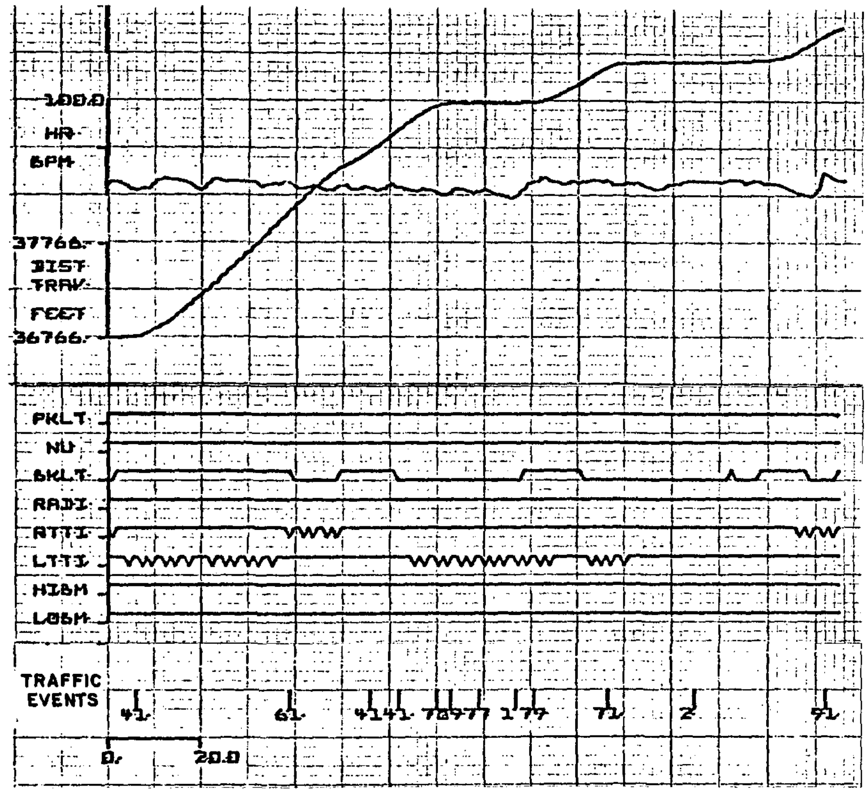
Review of the video tape showed many opportunities for potential application. The forward and rearward exterior cameras gave excellent coverage of surrounding traffic conditions. The interior camera coverage through the rearview mirror of the driver's eye and head position gave adequate indication of driver lateral scanning and looks at the rear and side view mirrors. In future application a special mirror on the dash or visor should be provided for this driver view. Digital data in the video scan were convenient to assimilate and correlate with driver/vehicle response and traffic events. It appears that the video tapes, with appropriate digital data selection, provide a comprehensive coverage of driver/vehicle performance and could be effectively used without any further data recording. Data reduction must be considered, however, and a video tape player and reasonable size video monitor (9 in. or greater) would be required for convenient data processing.



a) File 4, Low Workload

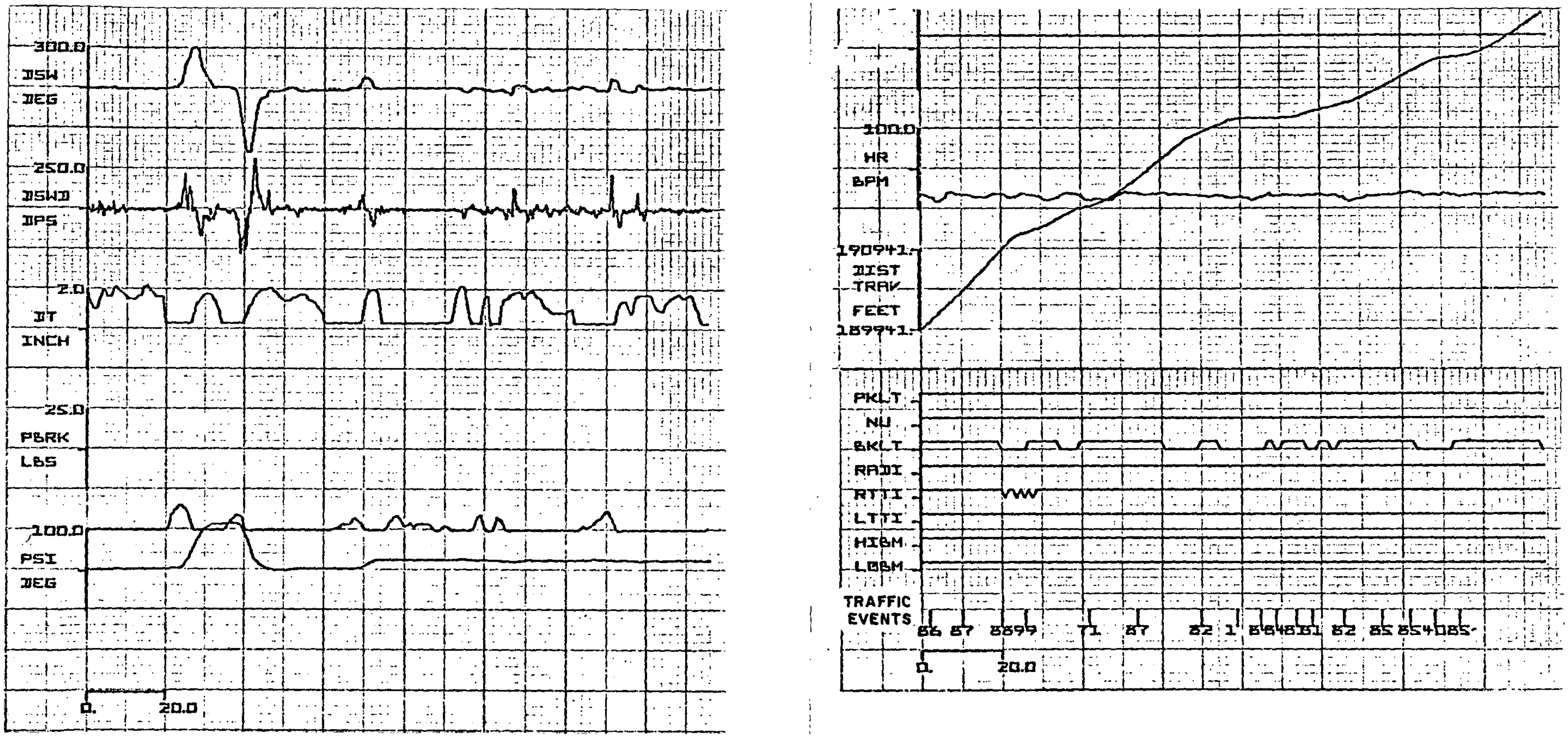
Figure B-10. Digital Time Traces Showing Driver/Vehicle Activity and Corresponding Heart Rate Response





b) File 5, Medium Workload

Figure B-10. (Continued)



c) File 8, High Workload

Figure B-10. (Concluded)

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