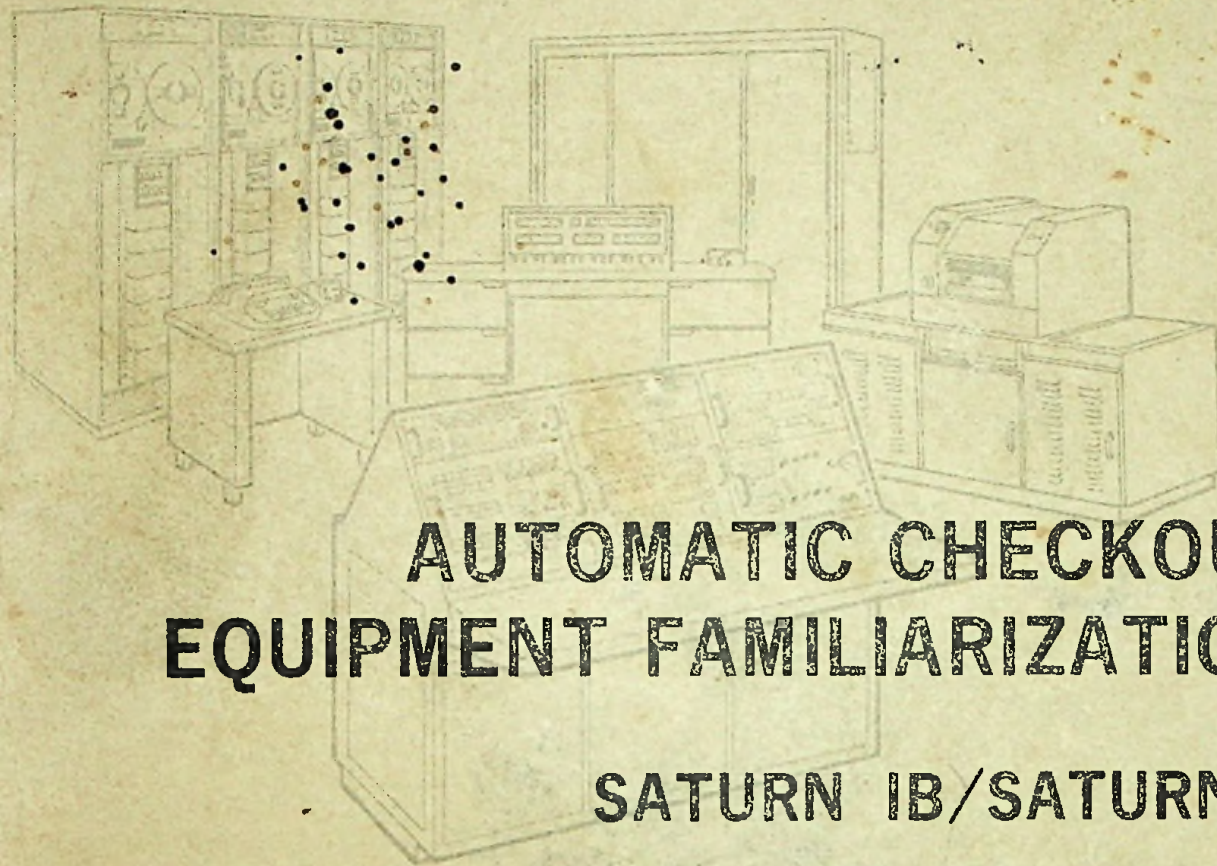


LOCKEN

SATURN S-IVB TRAINING GRAPHICS



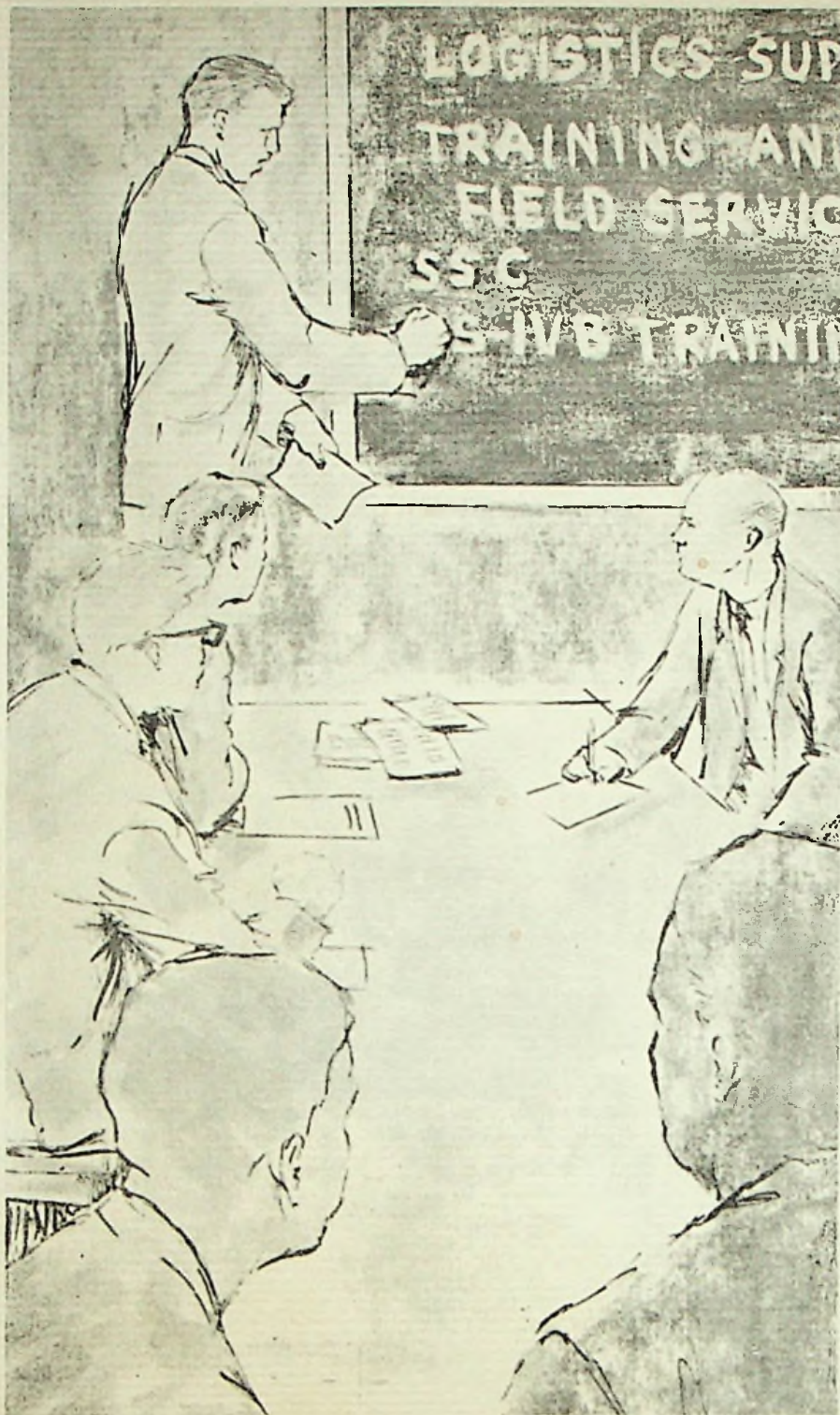
AUTOMATIC CHECKOUT EQUIPMENT FAMILIARIZATION

SATURN IB/SATURN V

REVISED SEPTEMBER 1965

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA/CALIFORNIA





SATURN S-IVB TRAINING GRAPHICS

THIS DOCUMENT PREPARED
AS A TRAINING SERVICE
BY LOGISTICS TECHNICAL
SUPPORT—TRAINING AND
FIELD SERVICE, SPACE SYS-
TEMS CENTER, HUNTINGTON
BEACH, CALIFORNIA

Training graphics in this book were
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are not meant to supersede Engineering
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to insure accuracy but due to rapid de-
sign improvements, obsolescence is in-
evitable. No revision service is planned.

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AUTOMATIC CHECKOUT EQUIPMENT FAMILIARIZATION

SATURN IB/SATURN V

REVISED SEPTEMBER 1965 • COURSE NO. GY-203-DAC



AUTOMATIC CHECKOUT EQUIPMENT - FAMILIARIZATION

TABLE OF CONTENTS

Course Description

Course Outline

Illustrations

Number System Review

Vehicle Interface

Test Control and Monitoring

System Status Display

Digital Operation

Computer Interface Unit

Stimuli

Responses

Safety Features

System Power

Telemetry Systems

System Timing

System Programming

APPENDICES

1 Typical System Operation

2 Number Systems

LIST OF ILLUSTRATIONS

<u>Title</u>	<u>Illustration No.</u>
Number System	795-110
Decimal to Octal Conversion	795-114
Decimal to Binary Conversion	795-111A
Octal Conversion (Octal to Decimal)	795-115
Binary Conversion (Binary to Decimal)	795-112
.	795-113
Octal Tables	795-116
Vehicle Inputs	795-94A
Vehicle Outputs	795-98A
S-IVB Automatic Checkout Equipment	795-494D

LIST OF ILLUSTRATIONS (Continued)

<u>Title</u>	<u>Illustration No.</u>
Application of Stimuli (with Test Number)	795-167A
Test Numbering	795-348A
Test Operator Station (Digital Control)	795-122E
Test Operator Station (Test Station Monitor)	795-123D
Test Operator Station (Checkout System Monitor and Control)	795-514B
Test Operator Station (Computer Word Simulator)	795-303A
Propulsion System Control Console (Digital Control)	795-121D
Propulsion System Control Console (Manual Control)	795-516B
Propulsion System Control Console (APS Manual Control)	795-515B
Propulsion System Control Console (Numerical Readout)	795-519A
Electrical Networks Control Console (Digital Control)	795-120B
Electrical Networks Control Console (Mech. Sys. Monitor and Control)	795-517B
Electrical Networks Control Console (Electrical Monitor and Control)	795-518B
Telemetry System Control Console (Digital Control)	795-119B
Remote Pneumatic Checkout Control Console	795-627B
Auxiliary Control Console	795-621B
System Status Display (Video Section)	795-641
System Status Display (Functional Operation)	795-660
System Status Display Monitor Station	795-452
System Status Display (Control Panel)	795-293
Basic Types of Computers	795-15
Basic 924A Computer Organization	795-2
DSV-IVB-105 Computer Complex	795-139B
924A Computer Characteristics	795-27
924A Checkout Computer	795-650
925 Tape Synchronizer	795-651
603 Magnetic Tape Transport	795-652
161 Typewriter	795-653
1612 Line Printer	795-523A
DSV-IVB-105 Computer Channel Assignments	795-3
Computer Interface Unit	795-355
CIU Channel 5 Scanner Input	795-95A
CIU Channel 6 Output	795-99A

LIST OF ILLUSTRATIONS (Continued)

<u>Title</u>	<u>Illustration No.</u>
Data Flow from Computer	795-159
Stimuli Data Flow	795-158B
Stimuli Decode	795-162A
Data Flow (Type I Bi-Level - Vehicle)	795-163C
Data Flow (Type I Bi-Level - Facilities)	795-164C
Matrix Control	795-512B
Type II - Remote Automatic Calibration System (Group 1)	795-174B
Type II - Frequency and Function Measurements (Group 2)	795-173A
Type II - Switch Selector (Group 3)	795-172A
Type II - Propellant Utilization (Group 4)	795-175A
Type II - Telemetry Calibration Voltage (Group 5)	795-176A
Data Flow (Engine Gimbaling Signals)	795-166B
Data Flow (Analog Self-Test)	795-165A
Simplified Self Test	795-492A
Patchboard Programming Concept	795-513
Response Data Flow	795-490
Discrete Response Request and Reply	795-183A
Discrete Response from Vehicle	795-181B
Discrete Response from GSE	795-182A
Analog Response Request and Reply	795-189
Analog Response from Vehicle	795-184A
Analog Response from GSE	795-185
Period Counter Request and Reply	795-186B
Response Conditioner and Safety Item Monitor	795-187
Safety Item Monitor (Data Flow)	795-191
Safety Item Monitor (Discrete Control and Update)	795-193B
Analog Monitor	795-188A
Logic Power Supply	795-260A
Printed Circuit Cards (Front Panel Logic Pwr Supply)	795-475
Vehicle External Power Rack	795-549A
GND Power Distribution (Vehicle Power - Typical)	795-223
GND Power Distribution (GSE Power - Typical)	795-222

LIST OF ILLUSTRATIONS (Continued)

<u>Title</u>	<u>Illustration No.</u>
Basic Radio - Telemetry System	794-497
Typical Parameters Monitored by T/M	795-718
Vehicle Checkout Telemetry Systems	795-717
Basic Vehicle T/M Systems	795-21B
Basic Ground Station T/M Systems	795-724
Range Time Codes	795-229
Time Code Format	795-30
System Timer (2 Second Interrupt)	795-356
System Timer (Interrupt Portion)	795-237
Programming	795-495
Simplified Computer Diagram Sequence	795-6
Test Program Preparation Sequence	795-125A
ATOLL/STOL Definition	795-140A
Advantages of STOL/ATOLL	795-141A
Typical STOL/ATOLL Test Statements (Operators)	795-144B

SATURN S-IVB

AUTOMATIC CHECKOUT EQUIPMENT - FAMILIARIZATION

COURSE DESCRIPTION

This familiarization course, requiring approximately 24 hours, is intended to acquaint Saturn personnel with the functions and capabilities of the S-IVB Automatic Checkout Equipment. Prerequisite for the course is Course No. GY-104-DAC. The familiarization course is divided into ten sections which include Vehicle Interface and Number Systems Review, Test Control and Monitoring, Digital Operation, Stimuli, Responses, Safety Features, System Power, Telemetry Systems, System Timing, and System Programming. For convenience, the illustrations are grouped in the same manner. Appendix 1 contains information concerning Typical System Operation and Appendix 2 explains Number Systems.

COURSE OUTLINE

The following outline is used in the presentation of the course.

I. NUMBER SYSTEMS REVIEW

- A. Binary
- B. Octal
- C. Decimal

II. VEHICLE INTERFACE

- A. Input
- B. Output

III. TEST CONTROL AND MONITORING

- A. Test Numbering
- B. Test Operator Station
- C. System Control Consoles

IV. SYSTEM STATUS DISPLAY

- A. Operation
- B. Control

- V. DIGITAL OPERATION
 - A. Computer
 - B. Peripheral Equipment
- VI. COMPUTER INTERFACE UNIT
 - A. Input
 - B. Output
- VII. STIMULI
 - A. Data Flow
 - B. Decode
 - C. Bi-Level
 - D. Analog
- VIII. RESPONSES
 - A. Data Flow
 - B. Discrete
 - C. Analog
- IX. SAFETY FEATURES
 - A. Response Conditioner
 - B. Safety Item Monitor
- X. SYSTEM POWER
 - A. Vehicle
 - B. GSE
- XI. TELEMETRY SYSTEMS
 - A. Vehicle
 - B. Ground Station
- XII. SYSTEM TIMING
 - A. Range Time
 - B. System Timer
- XIII. SYSTEM PROGRAMMING
 - A. Preparation
 - B. Atoll
 - C. Stol

ILLUSTRATIONS

Number Systems Review

NUMBER SYSTEMS 795-110

OCTAL	BINARY	DECIMAL
00 — — — —	000000 — — — —	00
01 — — — —	000001 — — — —	01
02 — — — —	000010 — — — —	02
03 — — — —	000011 — — — —	03
04 — — — —	000100 — — — —	04
05 — — — —	000101 — — — —	05
06 — — — —	000110 — — — —	06
07 — — — —	000111 — — — —	07
10 — — — —	001000 — — — —	08
11 — — — —	001001 — — — —	09
12 — — — —	001010 — — — —	10
13 — — — —	001011 — — — —	11
:	:	:
77 — — — —	111111 — — — —	63

DECIMAL TO OCTAL CONVERSION

795-114.

$$165.73_{10} = 245.565_8$$

A

$$\begin{array}{r} 20 \\ 8 \overline{)165.} \\ \underline{16} \\ 5 \\ \underline{0} \\ 5 \end{array}$$

A

$$\begin{array}{r} 0.73 \\ 8 \overline{)5.84} \end{array}$$

B

$$\begin{array}{r} 2 \\ 8 \overline{)20.} \\ \underline{16} \\ 4 \end{array}$$

B

$$\begin{array}{r} .84 \\ 8 \overline{)6.72} \end{array}$$

C

$$\begin{array}{r} 0 \\ 8 \overline{)2.} \\ \underline{0} \\ 2 \end{array}$$

C

$$\begin{array}{r} .72 \\ 8 \overline{)5.76} \end{array}$$

INTEGER
CONVERSION

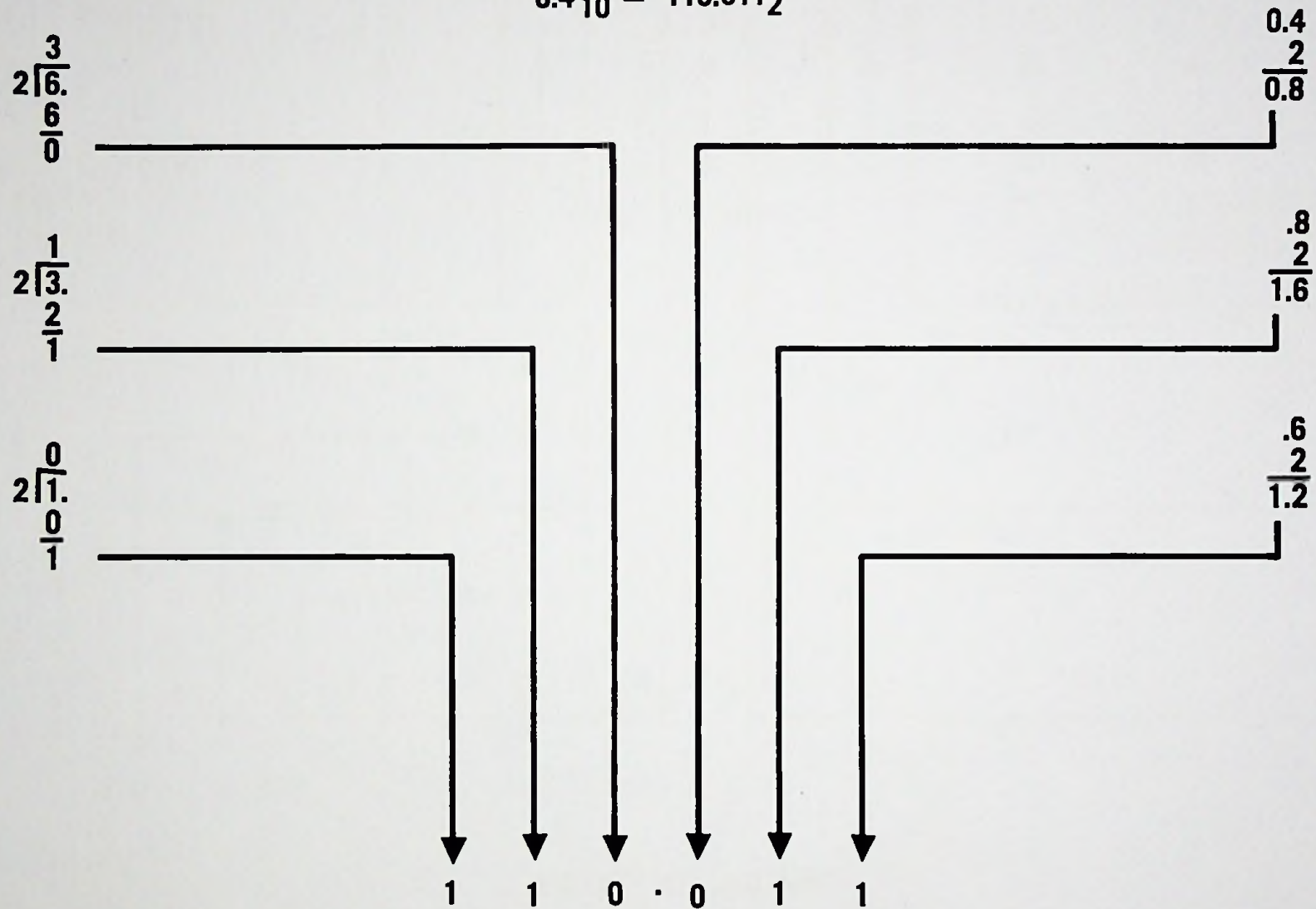
FRACTION
CONVERSION

2 4 5 5 6 5

DECIMAL TO BINARY CONVERSION

795-111A

$$6.4_{10} = 110.011_2$$



OCTAL CONVERSION

795-115

OCTAL TO DECIMAL

7	5	3	.	6	4	8	
				→	$4 \times 8^{-2} = 4 \times \frac{1}{64} =$.0625	
			→	$6 \times 8^{-1} = 6 \times \frac{1}{8} =$.75		
		→	$3 \times 8^0 = 3 \times 1 =$	3.			
	→	$5 \times 8^1 = 5 \times 8 =$	40.				
→	$7 \times 8^2 = 7 \times 64 =$	448.					
		<hr/>					
		491.8125	10				

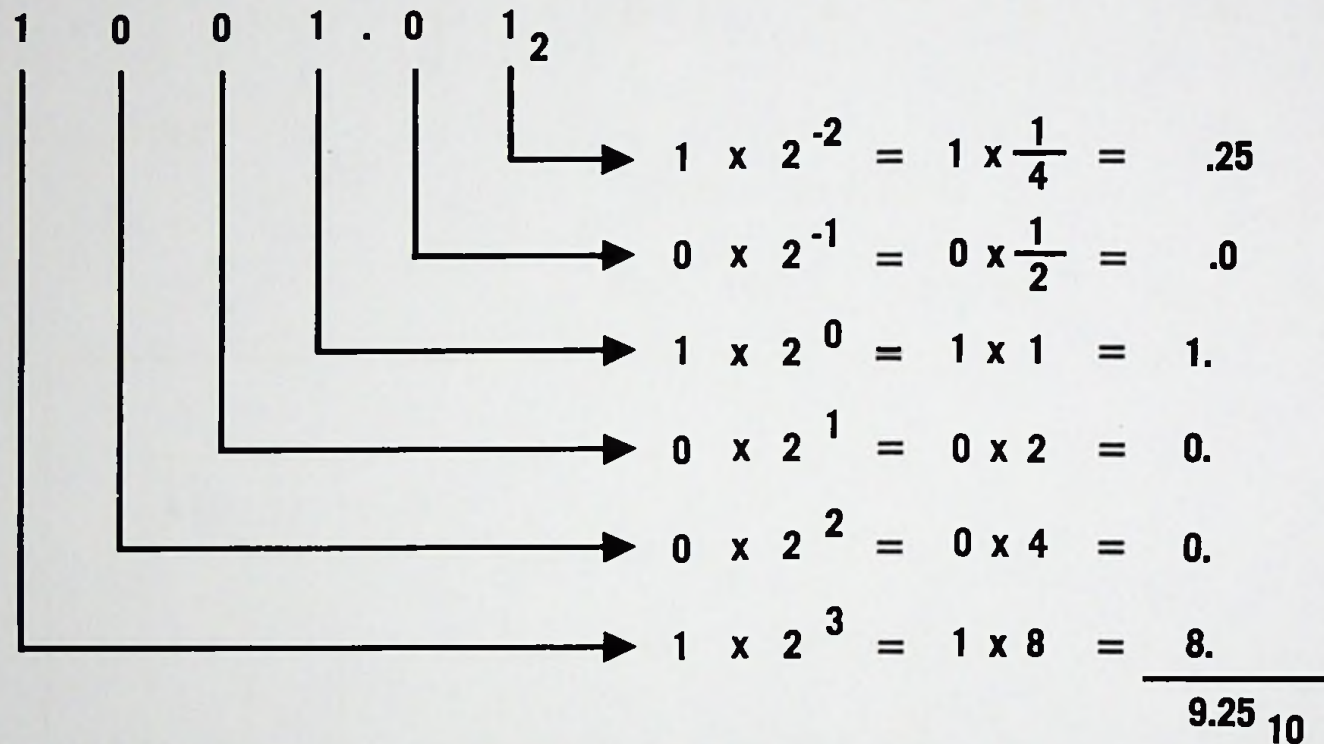
OCTAL TO BINARY

OCTAL	3	7	5	.	4	6
	↓	↓	↓	↓	↓	↓
BINARY	011	111	101	.	100	110

BINARY CONVERSION

795-112

BINARY TO DECIMAL



BINARY TO OCTAL

BINARY	<u>101</u>	<u>011</u>	<u>111</u>	<u>101</u>	<u>110</u>	<u>010</u>
OCTAL	5	3	7	5	6	2

BINARY ARITHMETIC OPERATIONS

795-113

	0	1
0	0	0
1	0	1

MULTIPLICATION
TABLEMULTIPLE 11010_2 BY 101_2

$$\begin{array}{r}
 11010 \\
 101 \\
 \hline
 11010 \\
 00000 \\
 11010 \\
 \hline
 1000010
 \end{array}$$

	0	1
0	0	1
1	1	10

ADDITION
TABLEADD 1010_2 TO 1101_2

$$\begin{array}{r}
 1010 \\
 1101 \\
 \hline
 10111
 \end{array}$$

OCTAL TABLES

795-116

	0	1	2	3	4	5	6	7
0	0	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7	10
2	2	3	4	5	6	7	10	11
3	3	4	5	6	7	10	11	12
4	4	5	6	7	10	11	12	13
5	5	6	7	10	11	12	13	14
6	6	7	10	11	12	13	14	15
7	7	10	11	12	13	14	15	16

OCTAL ADDITION TABLE

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	1	2	3	4	5	6	7
2	0	2	4	6	10	12	14	16
3	0	3	6	11	14	17	22	25
4	0	4	10	14	20	24	30	34
5	0	5	12	17	24	31	36	43
6	0	6	14	22	30	36	44	52
7	0	7	16	25	34	43	52	61

OCTAL MULTIPLICATION TABLE



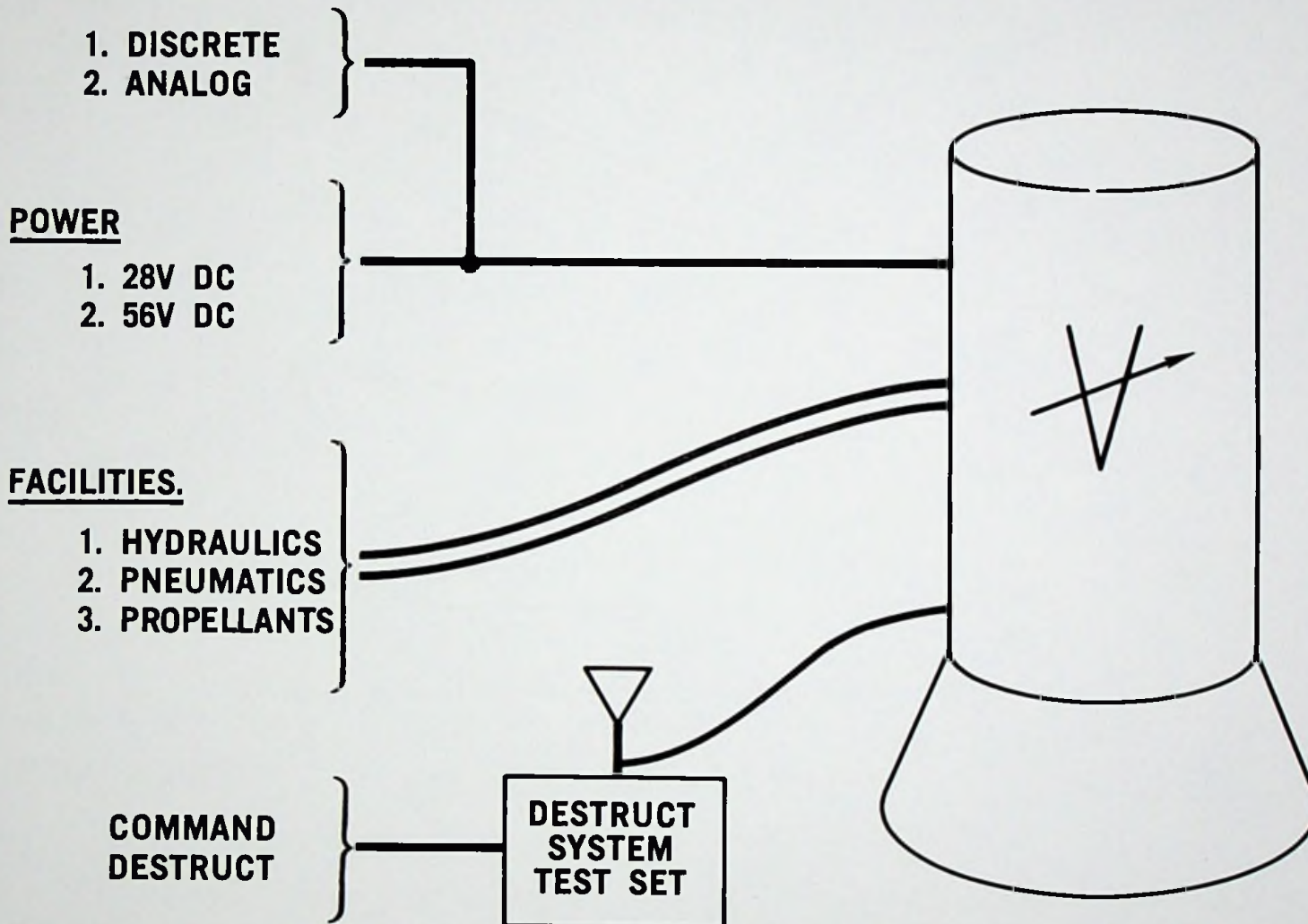
ILLUSTRATIONS

Vehicle Interface

VEHICLE INPUTS

795-94A

VEHICLE CONDITIONING SIGNALS



FOR TRAINING USE ONLY

VEHICLE OUTPUTS

795-98A

VEHICLE RESPONSES

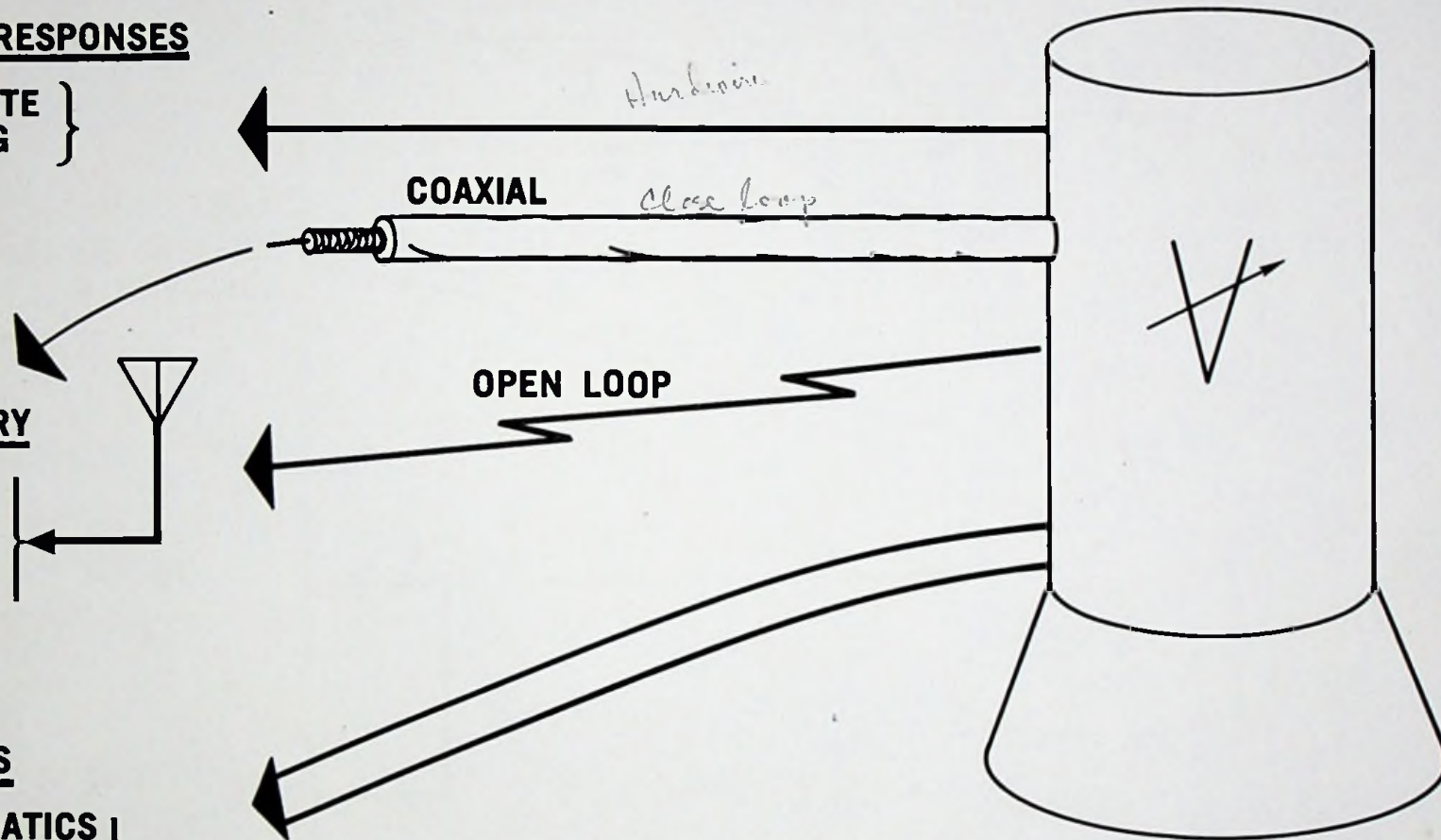
- 1. DISCRETE
- 2. ANALOG

TELEMETRY

- 1. DDAS
- 2. PAM
- 3. PCM
- 4. SSB

FACILITIES

- 1. PNEUMATICS
- 2. PROPULSION

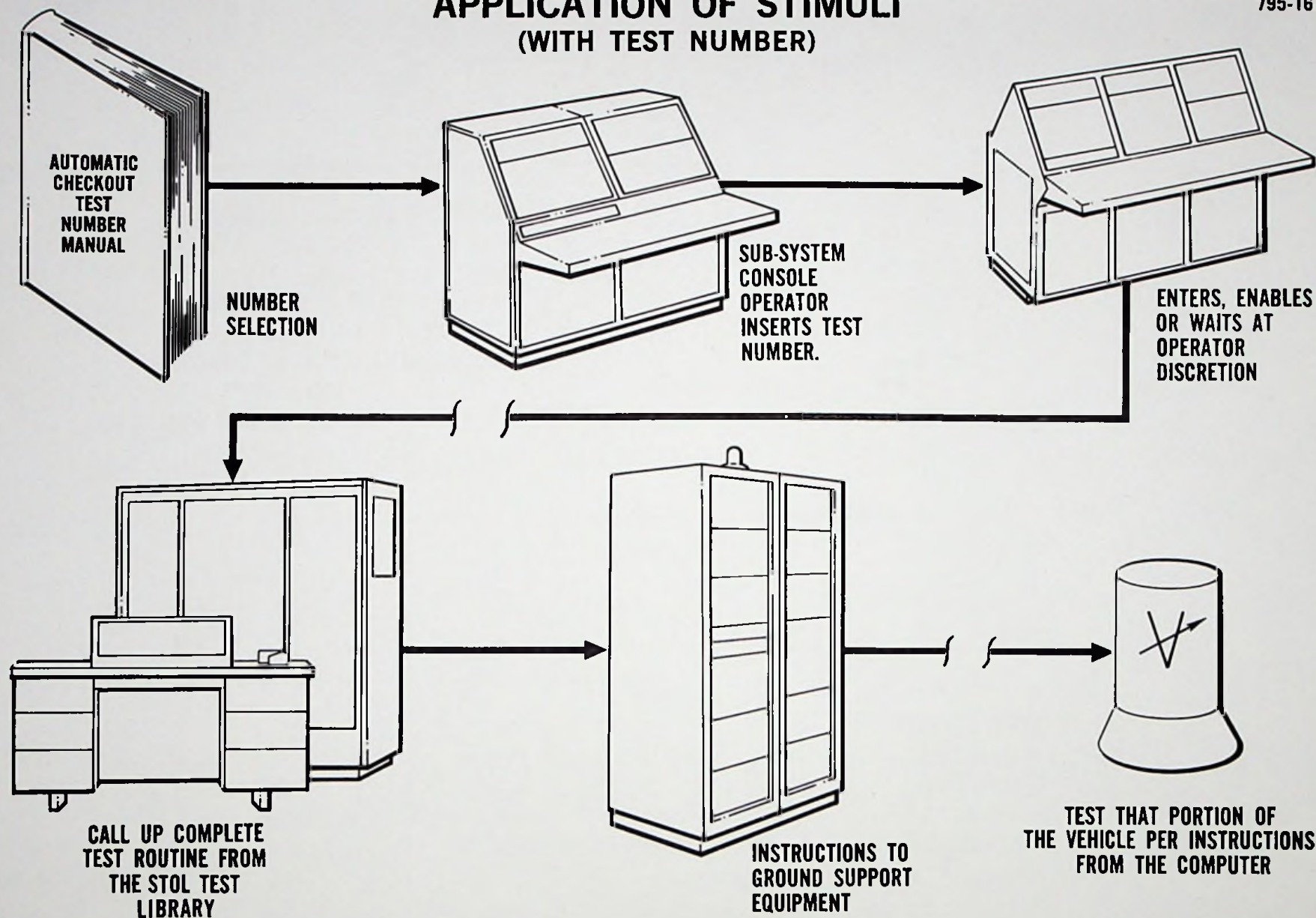


ILLUSTRATIONS

Test Control and Monitoring

APPLICATION OF STIMULI (WITH TEST NUMBER)

795-167A



FOR TRAINING USE ONLY

TEST NUMBERING

795-348A

FIRST DIGIT DEFINES THE CLASSIFICATION OF THE TEST AND INDICATES WHICH TEST STATION HAS COGNIZANCE OVER THAT TEST.

THE SECOND DIGIT REPRESENTS A MAJOR TEST NUMBER DEFINING A FURTHER CLASSIFICATION BREAKDOWN OF THE FIRST DIGIT.

REMAINING FOUR DIGITS REPRESENT A TEST STATEMENT OR INCREMENTAL PARTS OF THE TEST CLASSIFICATION (FIRST TWO DIGITS).

4 1 2 0 3 0

FIRST DIGIT CLASSIFICATION

- 0 NOT ALLOWED
- 1 GSE SELF TEST
- 2 PROPULSION SYSTEMS TEST
- 3 ELECTRICAL NETWORKS TEST
- 4 TELEMETRY SYSTEMS TEST
- 5 NOT USED (SPARE FOR PROPULSION)
- 6 ALL SYSTEMS TEST
- 7 TEST PECULIAR TO SACRAMENTO

EXAMPLE OF SECOND DIGIT REPRESENTATION

- 0 MISCELLANEOUS
- 1 DDAS
- 2 SSB/FM
- 3 PAM/FM/FM
- 4 MEASURING (RACS)
- 5 RANGE SAFETY
- 6 SPARE
- 7 SPARE

4 1 2 0 3 0

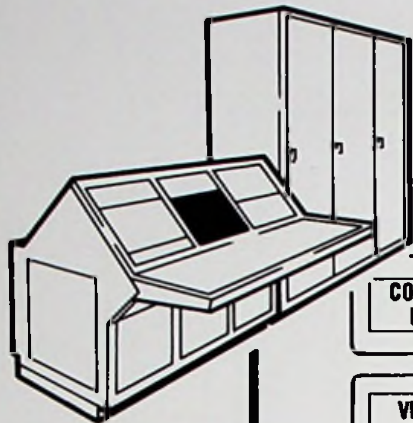
TEST STATEMENT

TEST OPERATOR STATION

DIGITAL CONTROL

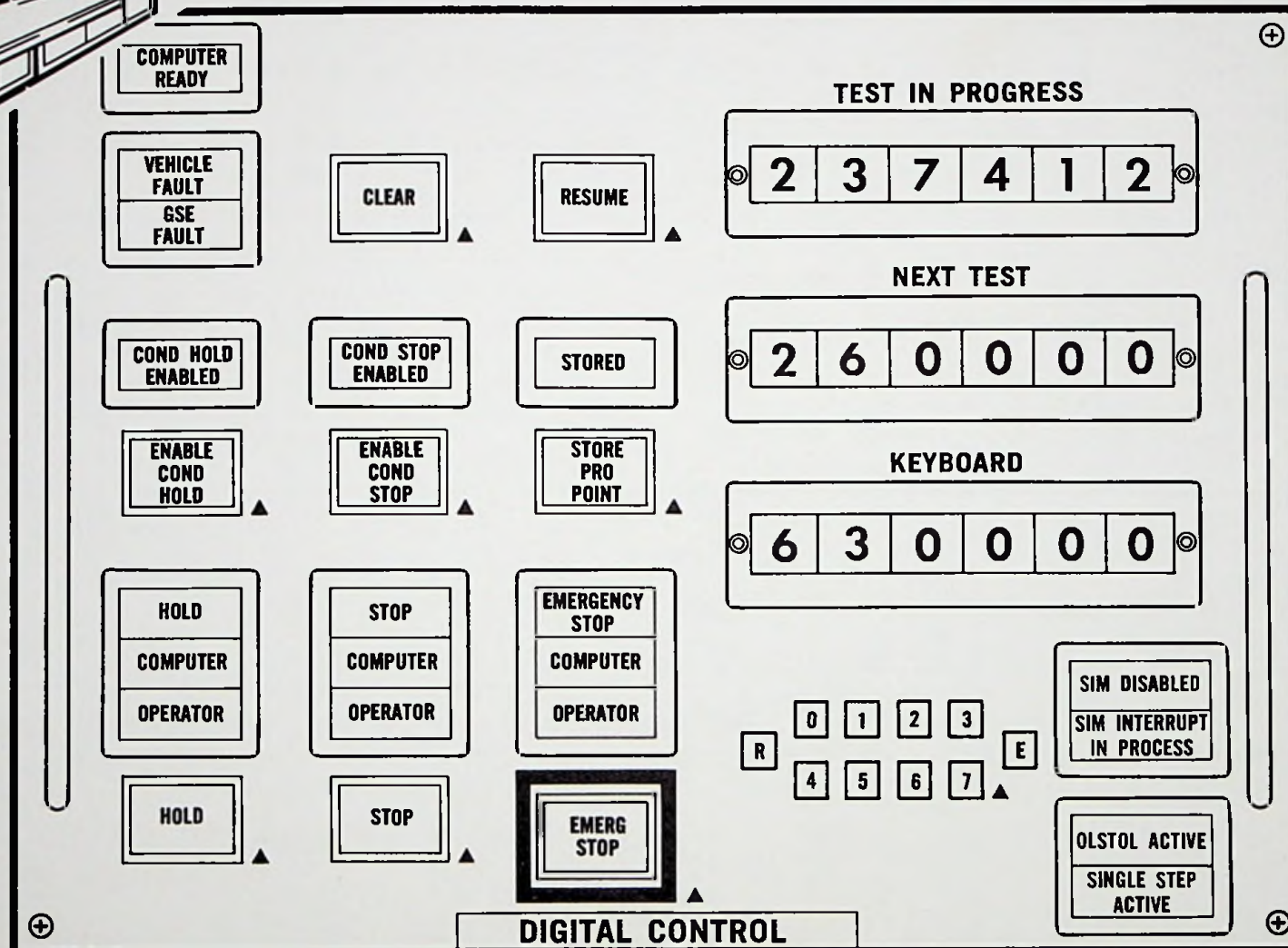
MODEL DSV-4B-121

795-122E



○ MAINTAINED

▲ MOMENTARY



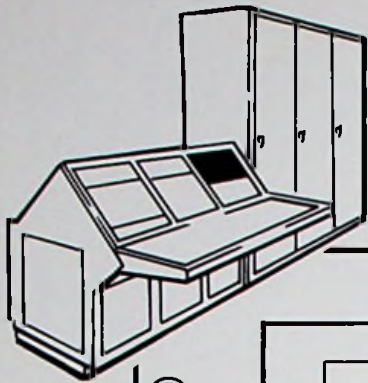
FOR TRAINING USE ONLY

TEST OPERATOR STATION

TEST STATION MONITOR

MODEL DSV-4B-121

795-123D



○ MAINTAINED

▲ MOMENTARY

PROPULSION

○	2	6	0	0	0	0	○
---	---	---	---	---	---	---	---

ENTER

WAIT

TEST
STATION
ENABLE

HOLD

STOP

EMERGENCY
STOPMANUAL CONT
SW ACTIVATEDMANUAL CONT
SWITCH OFF

SPARE

ELECTRICAL NETWORKS

○	3	3	0	0	0	0	○
---	---	---	---	---	---	---	---

ENTER

WAIT

TEST
STATION
ENABLE

HOLD

STOP

EMERGENCY
STOPMANUAL CONT
SW ACTIVATEDMANUAL CONT
SWITCH OFF

SPARE

TELEMETRY

○	4	1	0	0	0	0	○
---	---	---	---	---	---	---	---

ENTER

WAIT

TEST
STATION
ENABLE

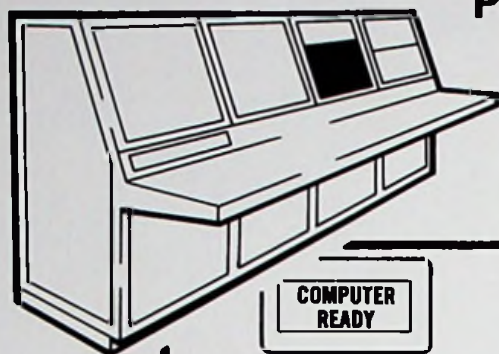
HOLD

STOP

EMERGENCY
STOPMANUAL CONT
SW ACTIVATEDMANUAL CONT
SWITCH OFF

SPARE

TEST STATION MONITOR



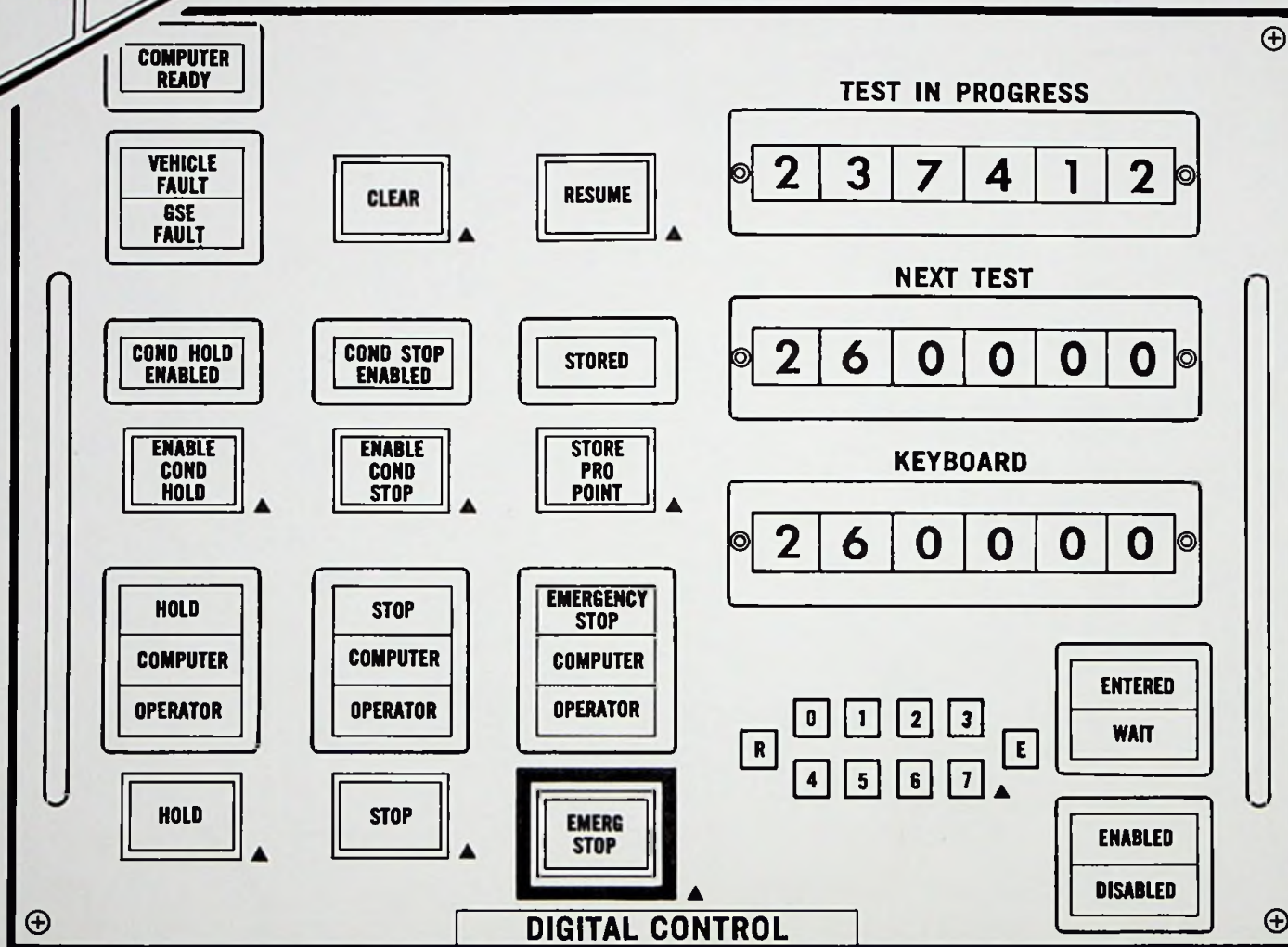
PROPULSION SYSTEM CONTROL CONSOLE

795-121D

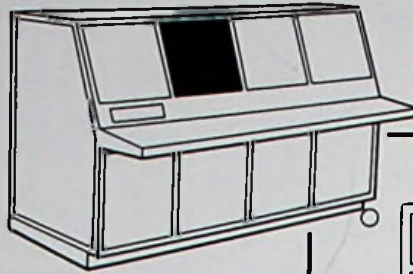
DIGITAL CONTROL
MODEL DSV-4B-234

○ MAINTAINED

▲ MOMENTARY

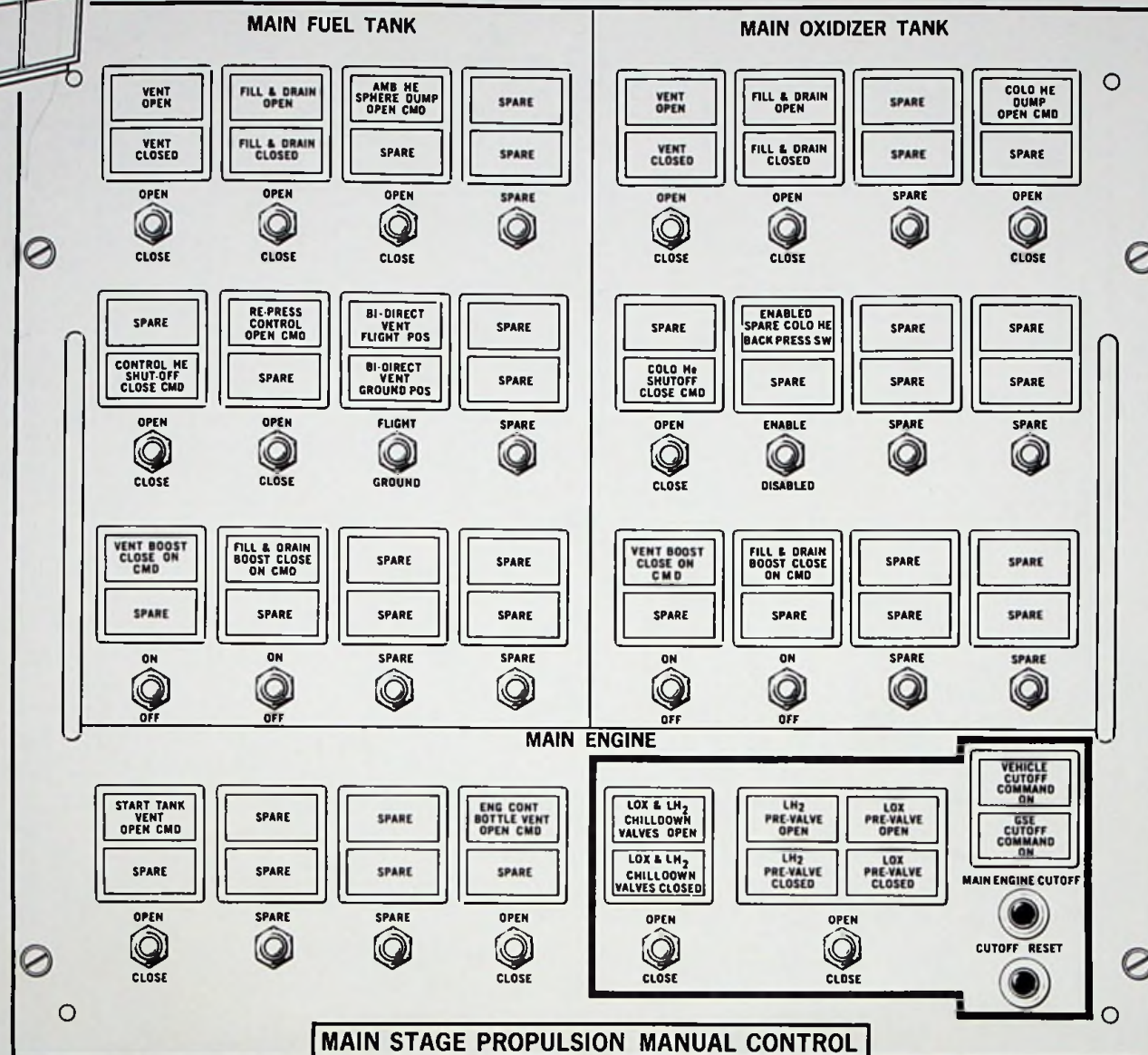


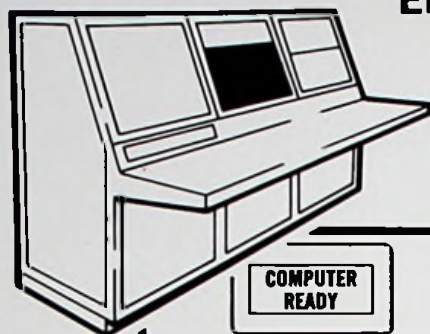
FOR TRAINING USE ONLY



PROPULSION SYSTEM CONTROL CONSOLE

MAIN STAGE PROPULSION MANUAL CONTROL

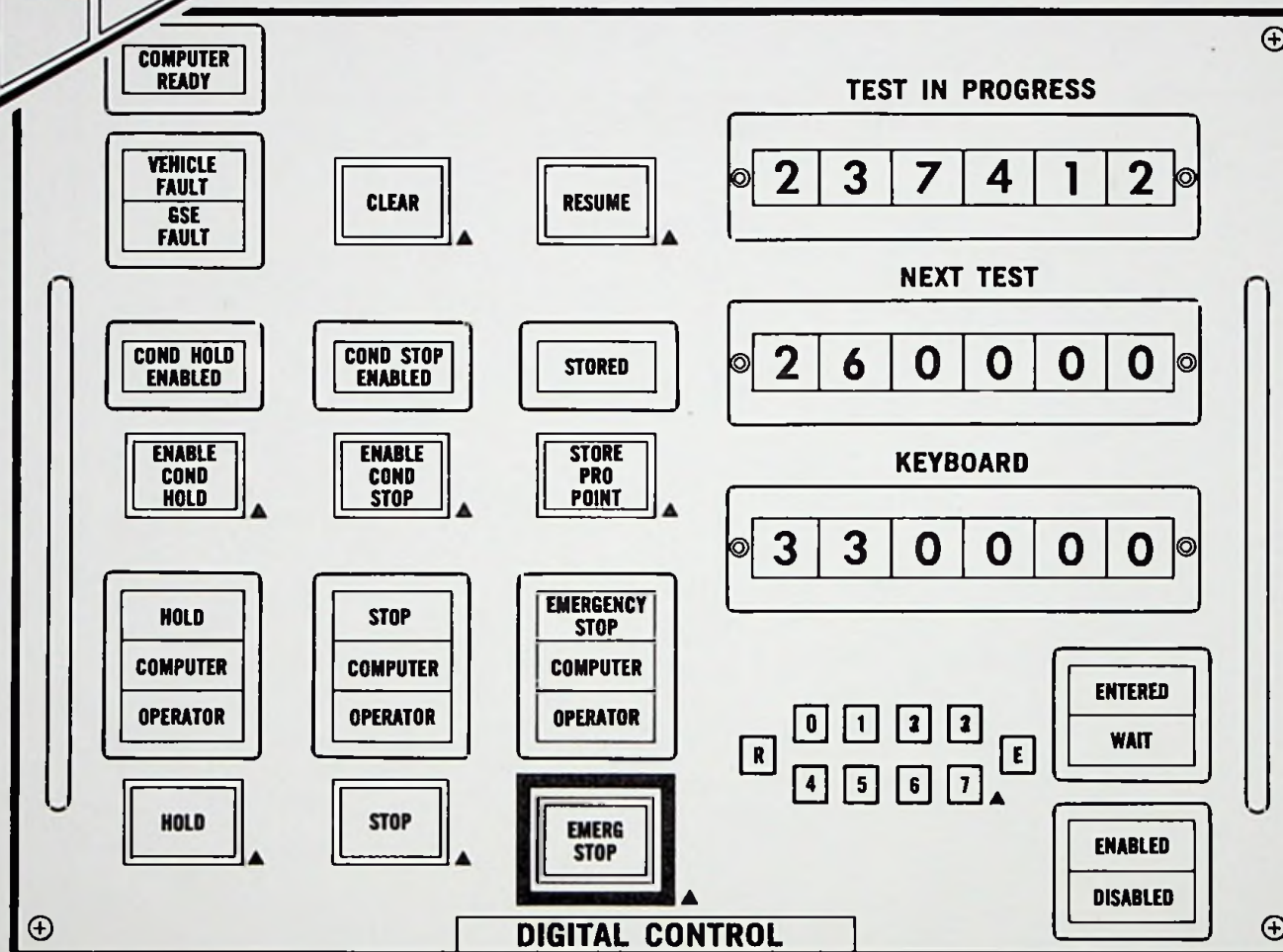




ELECTRICAL NETWORKS CONTROL CONSOLE 795-120B

DIGITAL CONTROL MODEL DSV-4B-236

○ MAINTAINED
▲ MOMENTARY

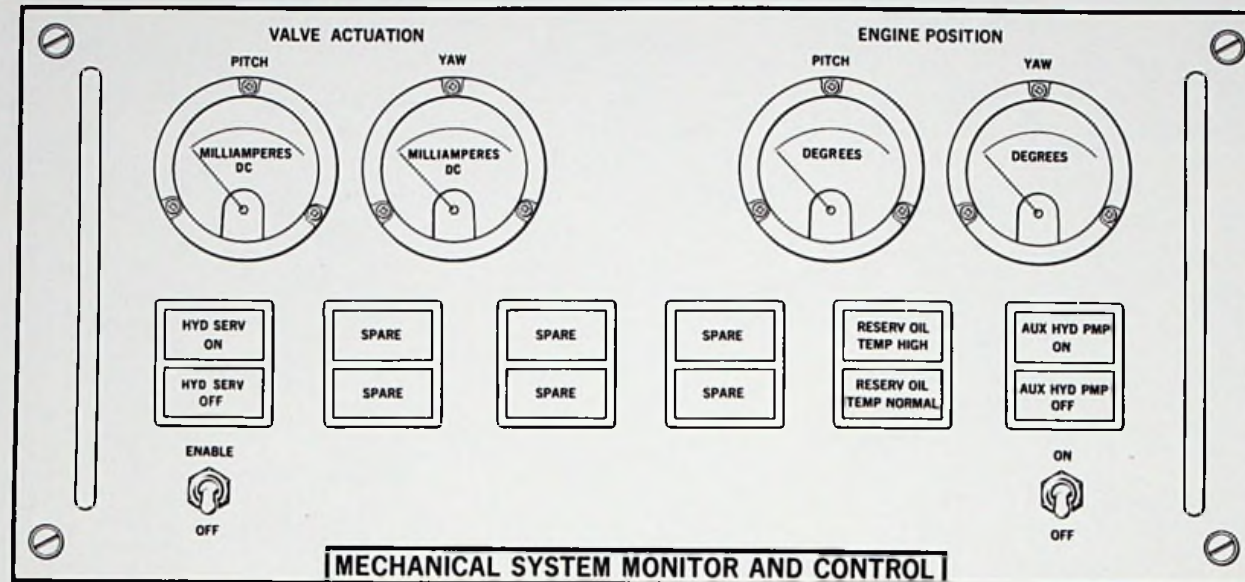
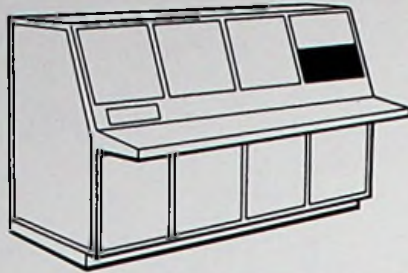


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ELECTRICAL NETWORKS CONTROL CONSOLE

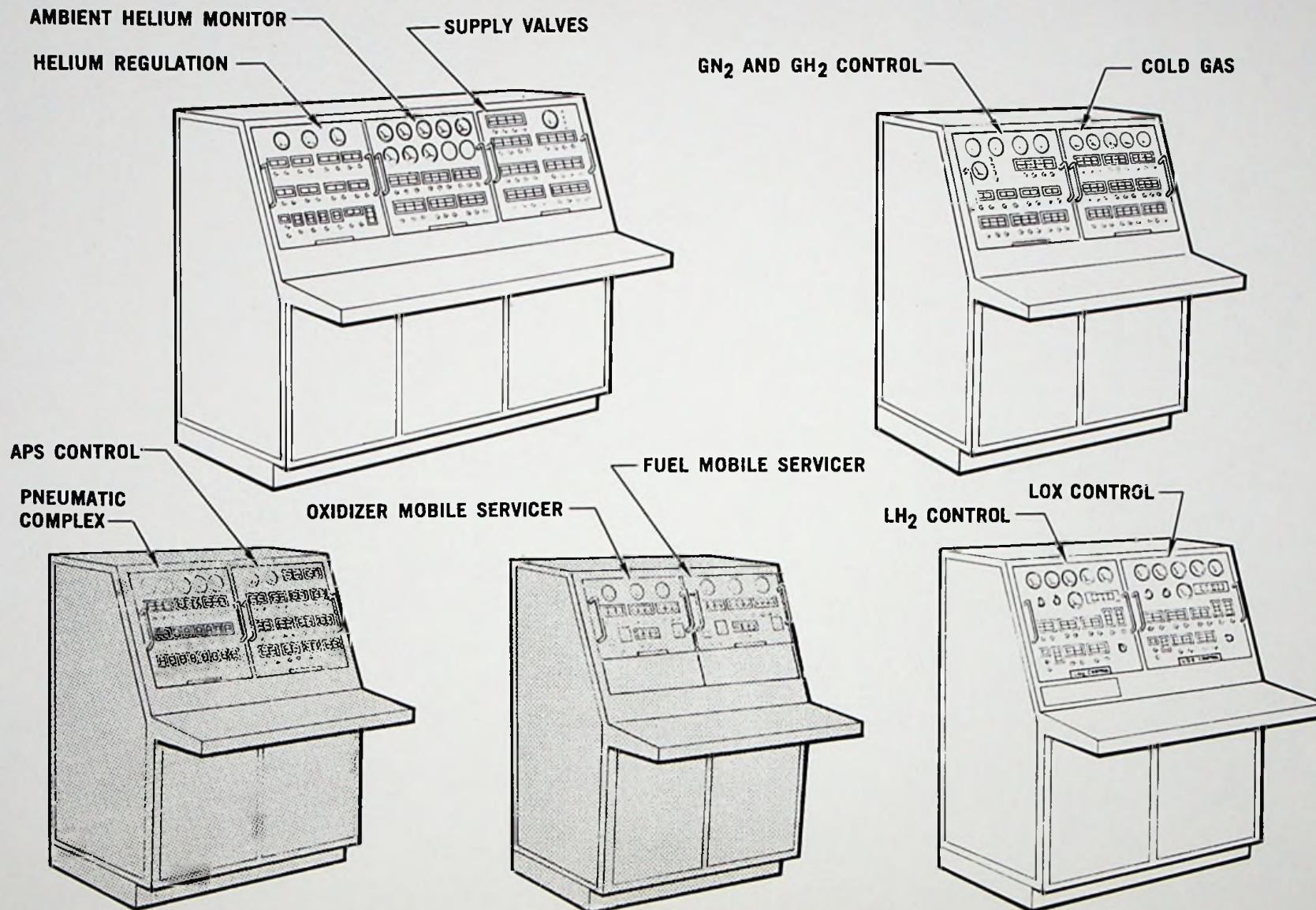
MECHANICAL SYSTEM MONITOR AND CONTROL

795-517B



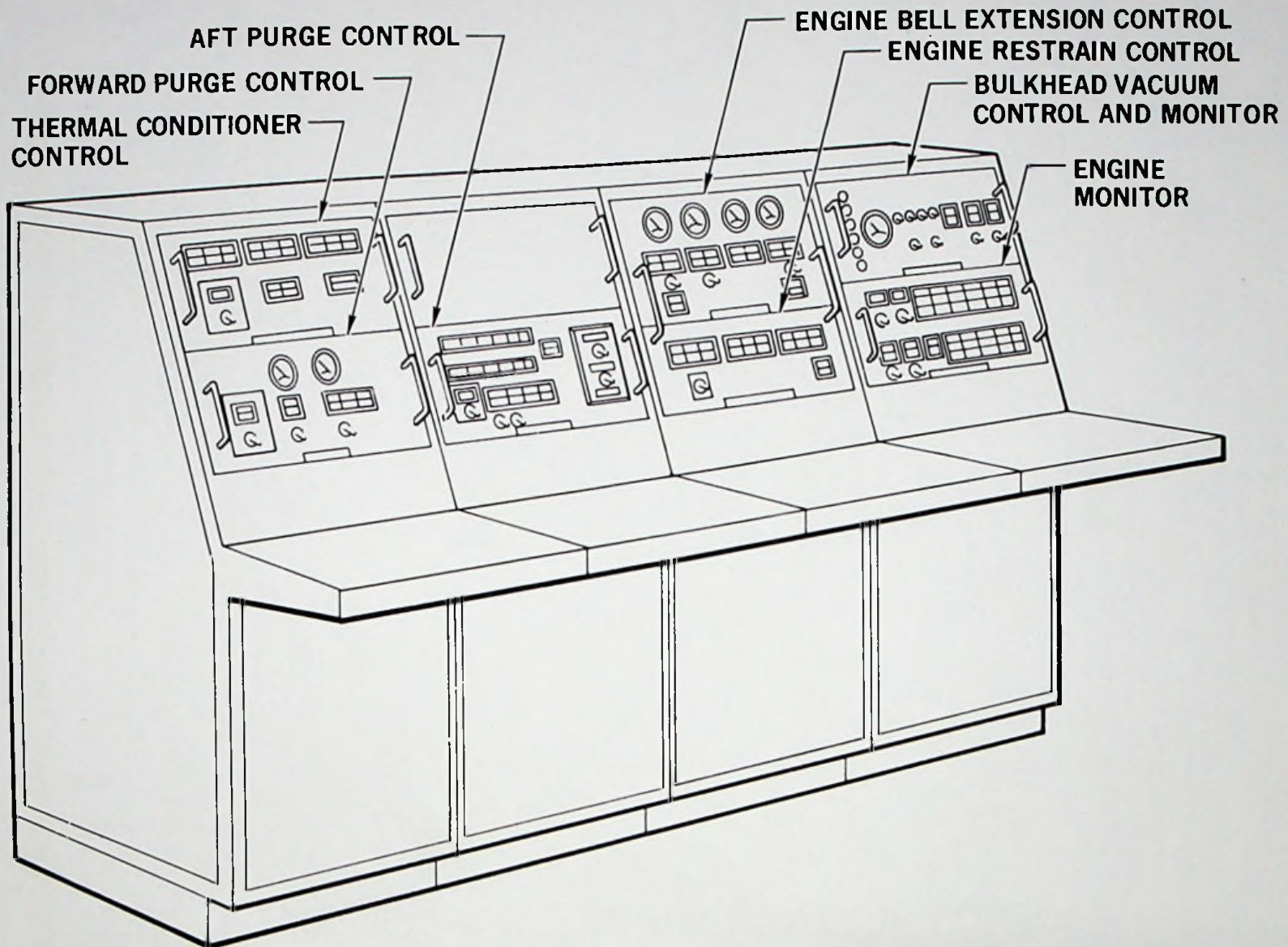
REMOTE PNEUMATIC CHECKOUT CONTROL CONSOLE

795-627B



FOR TRAINING USE ONLY

AUXILIARY CONTROL CONSOLE MODEL NO. DSV-IVB-294

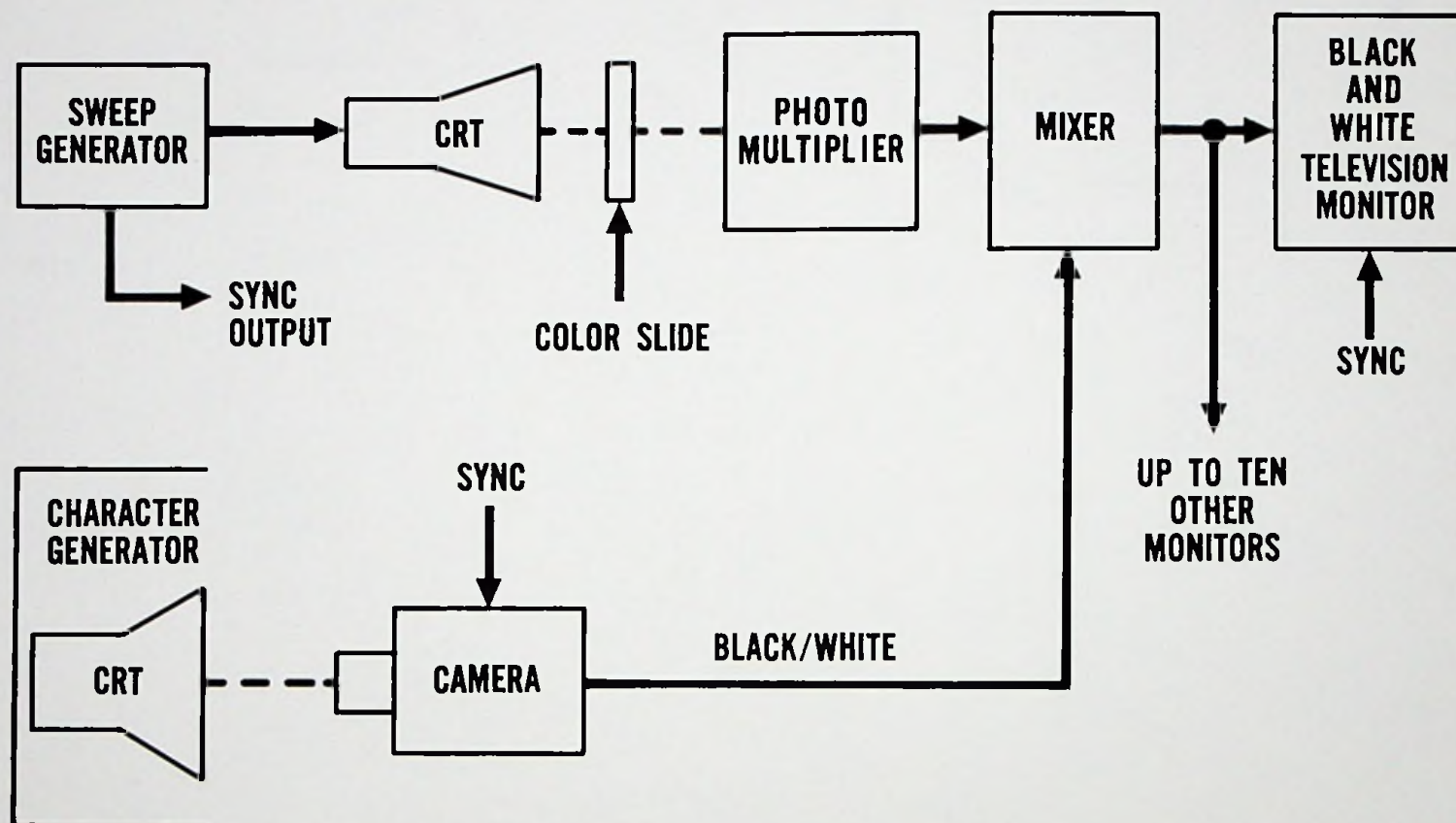


ILLUSTRATIONS

System Status Display

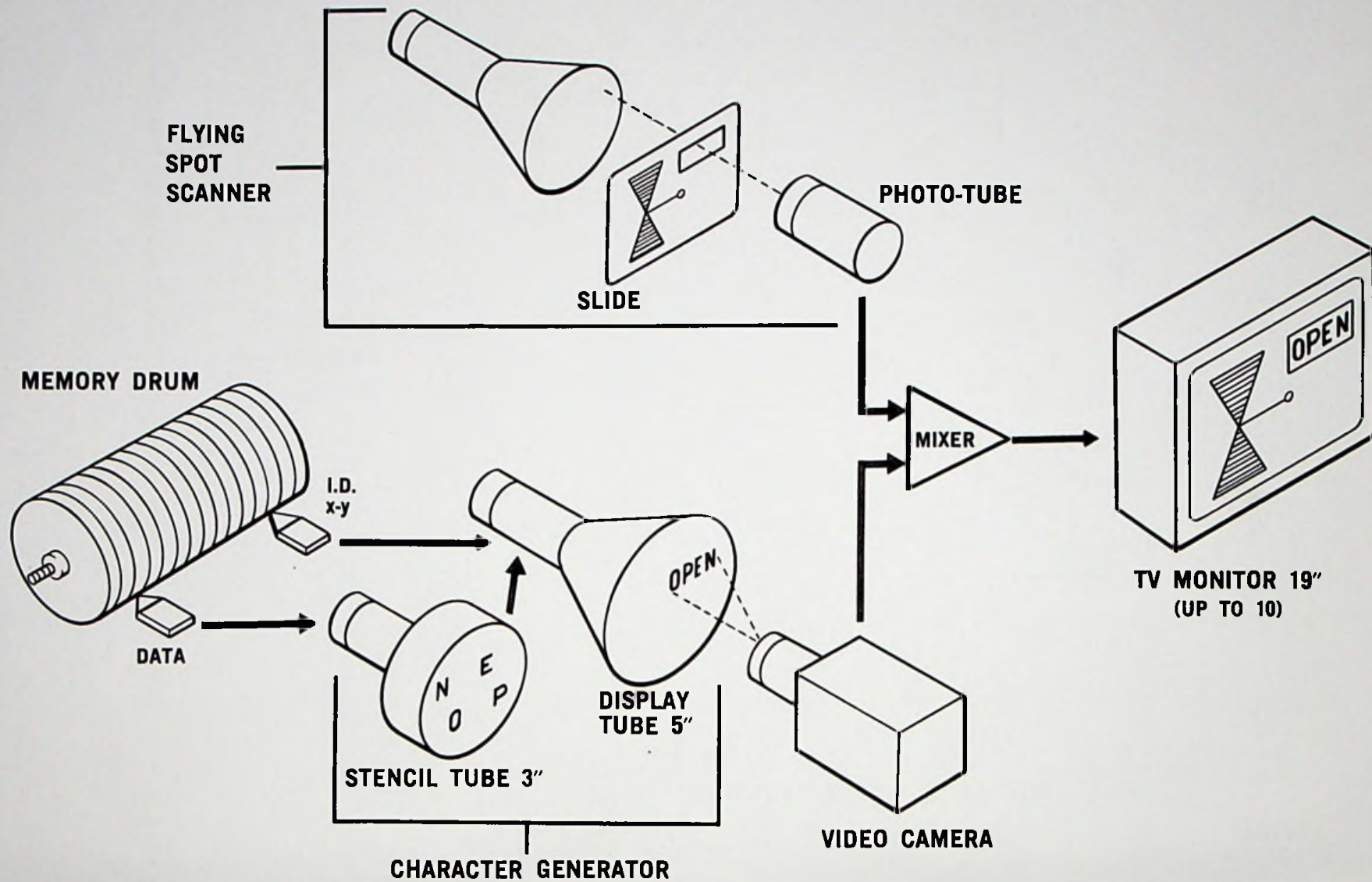
SYSTEM STATUS DISPLAY
(SIMPLIFIED BLOCK DIAGRAM VIDEO SECTION)
(DSV-4B-298)

795-641



SYSTEM STATUS DISPLAY (FUNCTIONAL OPERATION)

795-660

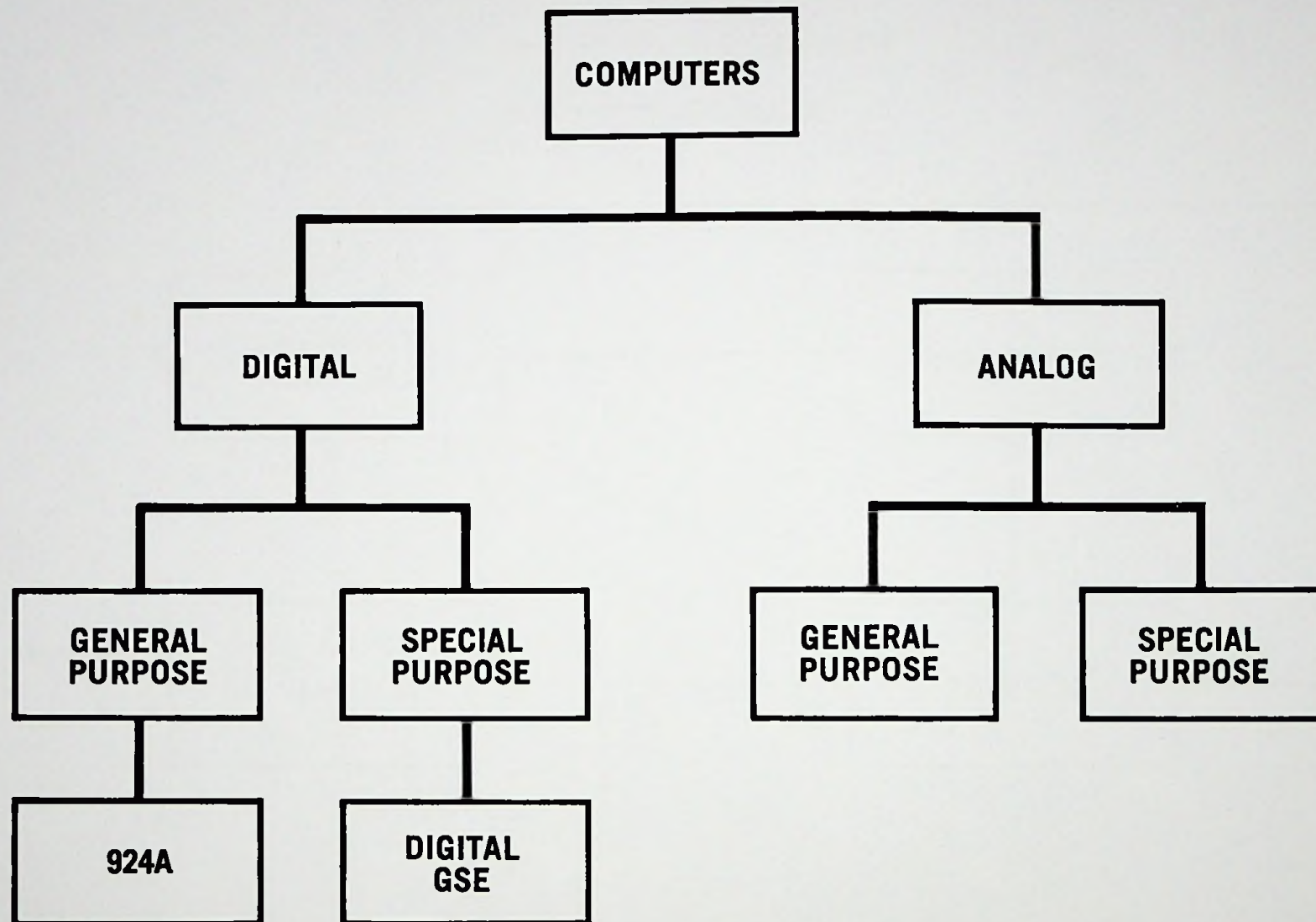


ILLUSTRATIONS

Digital Operation

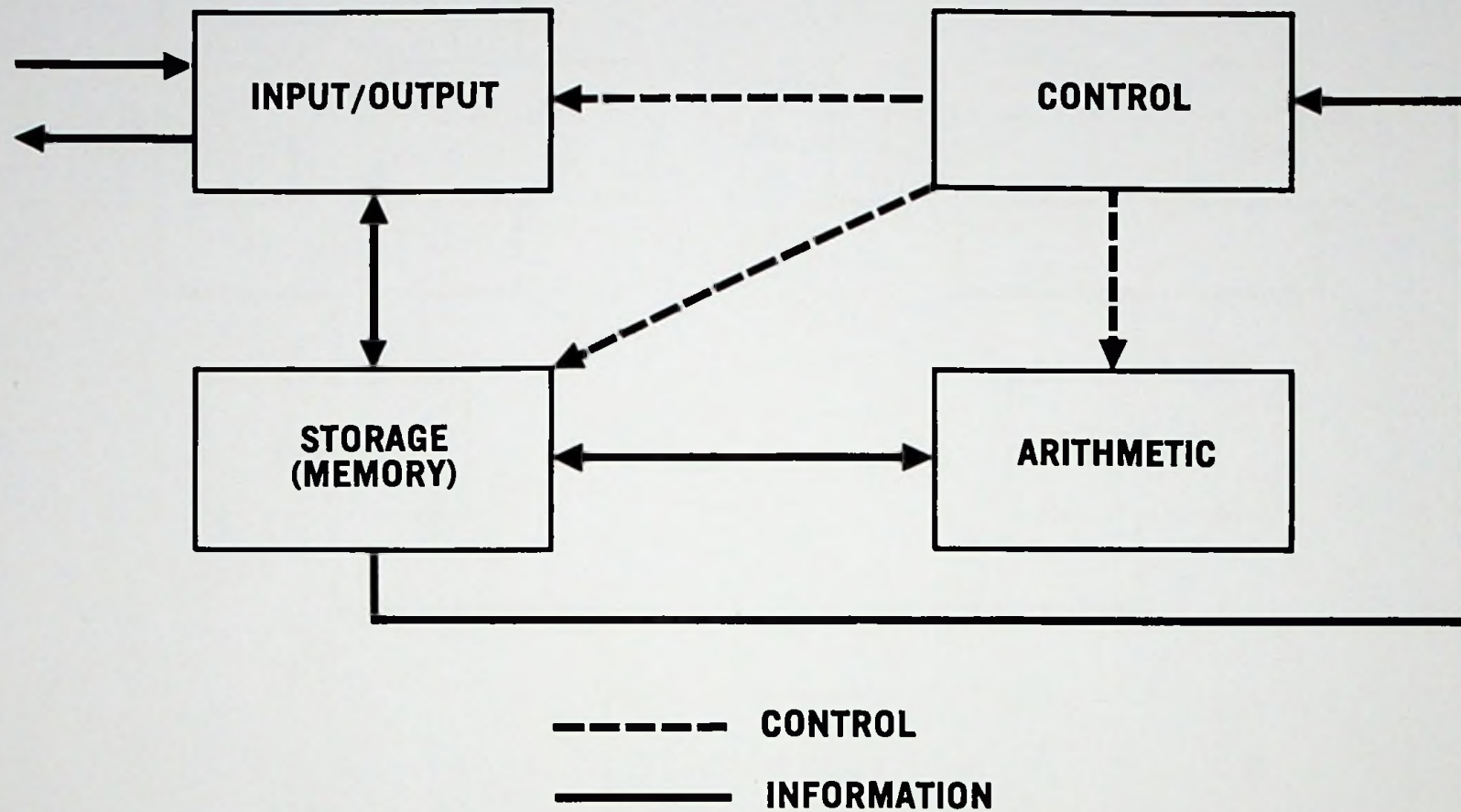
BASIC TYPES OF COMPUTERS

795-15



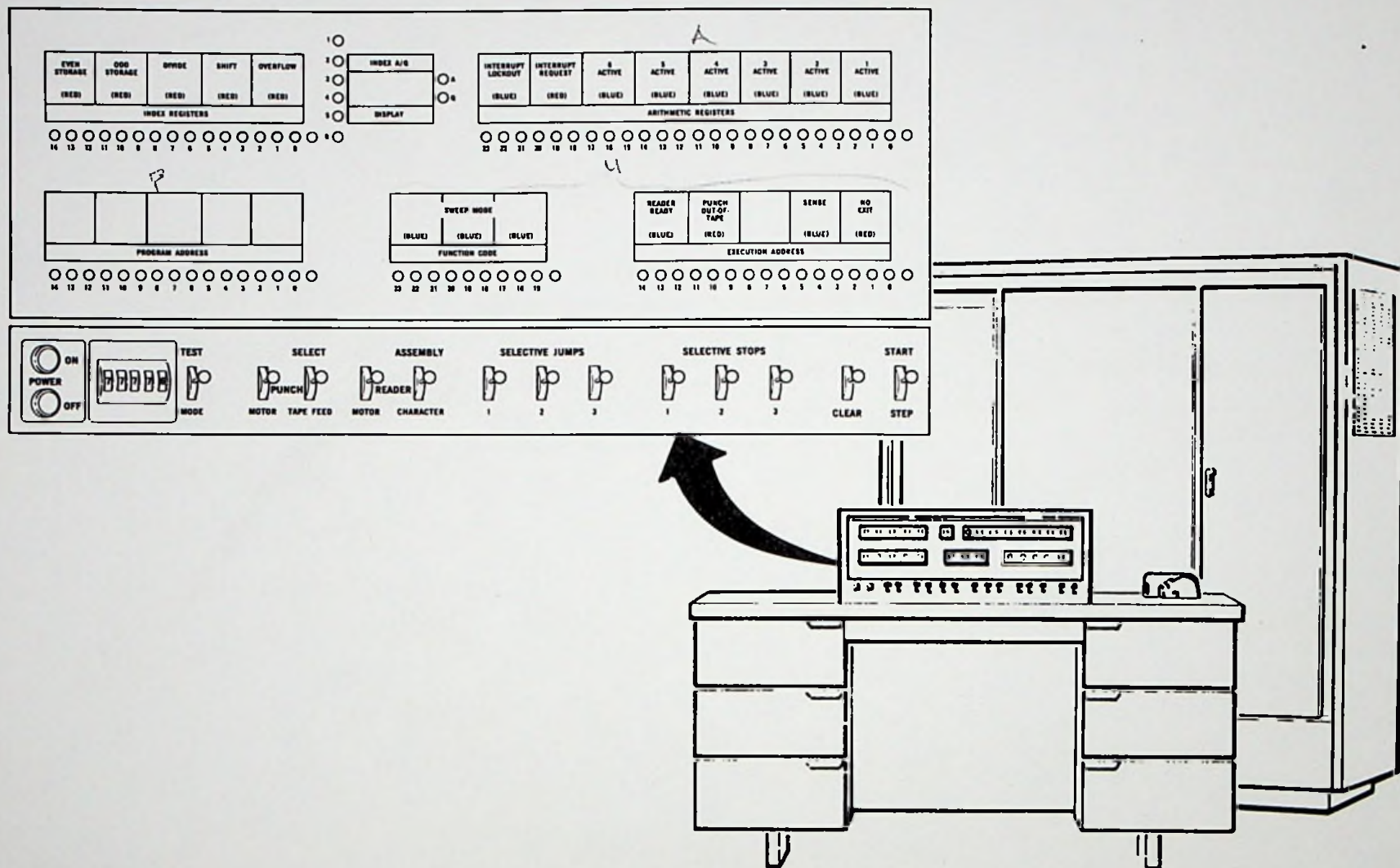
BASIC 924-A COMPUTER ORGANIZATION

795-2



CDC-924A CHECKOUT COMPUTER (WITH CONTROLS)

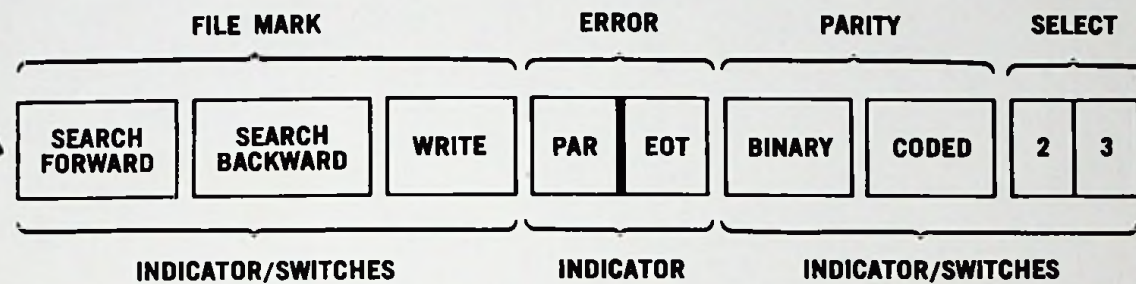
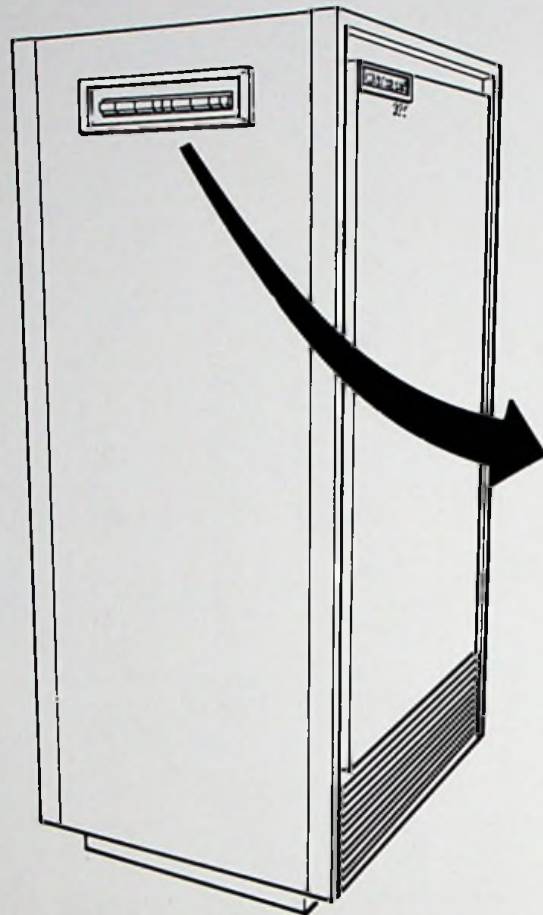
795-650



FOR TRAINING USE ONLY

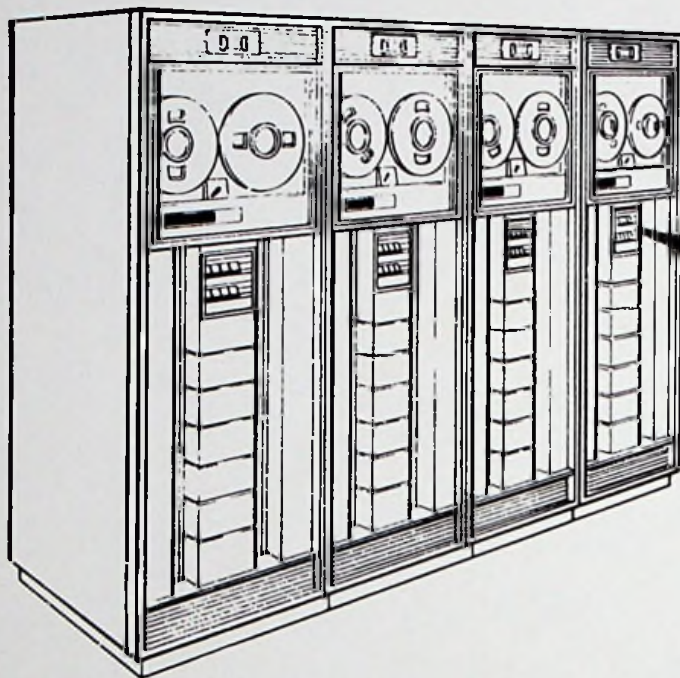
925 TAPE SYNCHRONIZER (WITH CONTROLS)

795-651



603 MAGNETIC TAPE TRANSPORT (WITH CONTROLS)

795-652



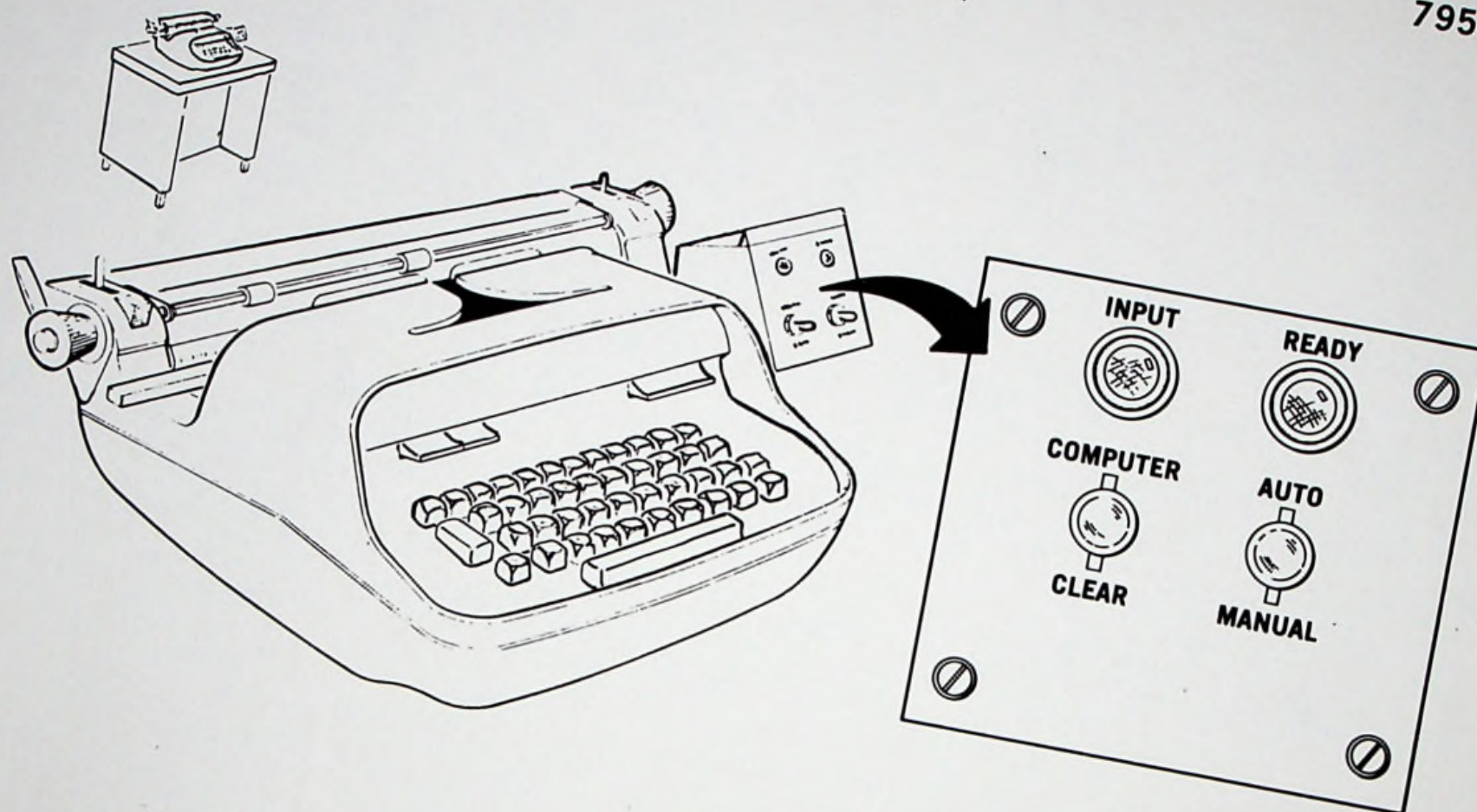
POWER	FORWARD	REVERSE	REWIND
WRITE	READ	DENSITY LO	DENSITY HI
UNLOAD	LOAD	READY	CLEAR

FOR TRAINING USE ONLY

FOR TRAINING USE ONLY

161 TYPEWRITER (WITH CONTROLS)

795-653



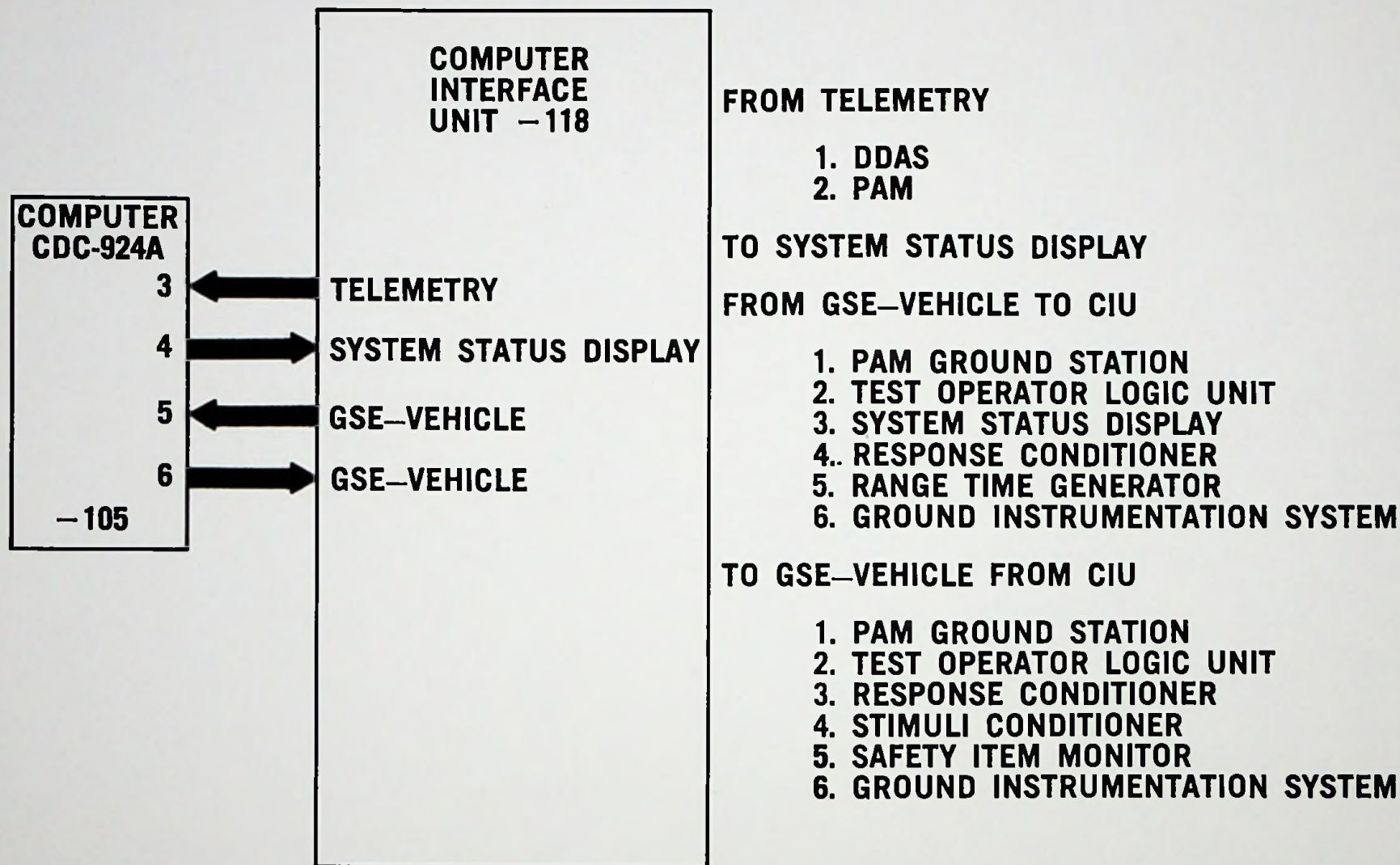
ILLUSTRATIONS

Computer Interface Unit

COMPUTER INTERFACE UNIT

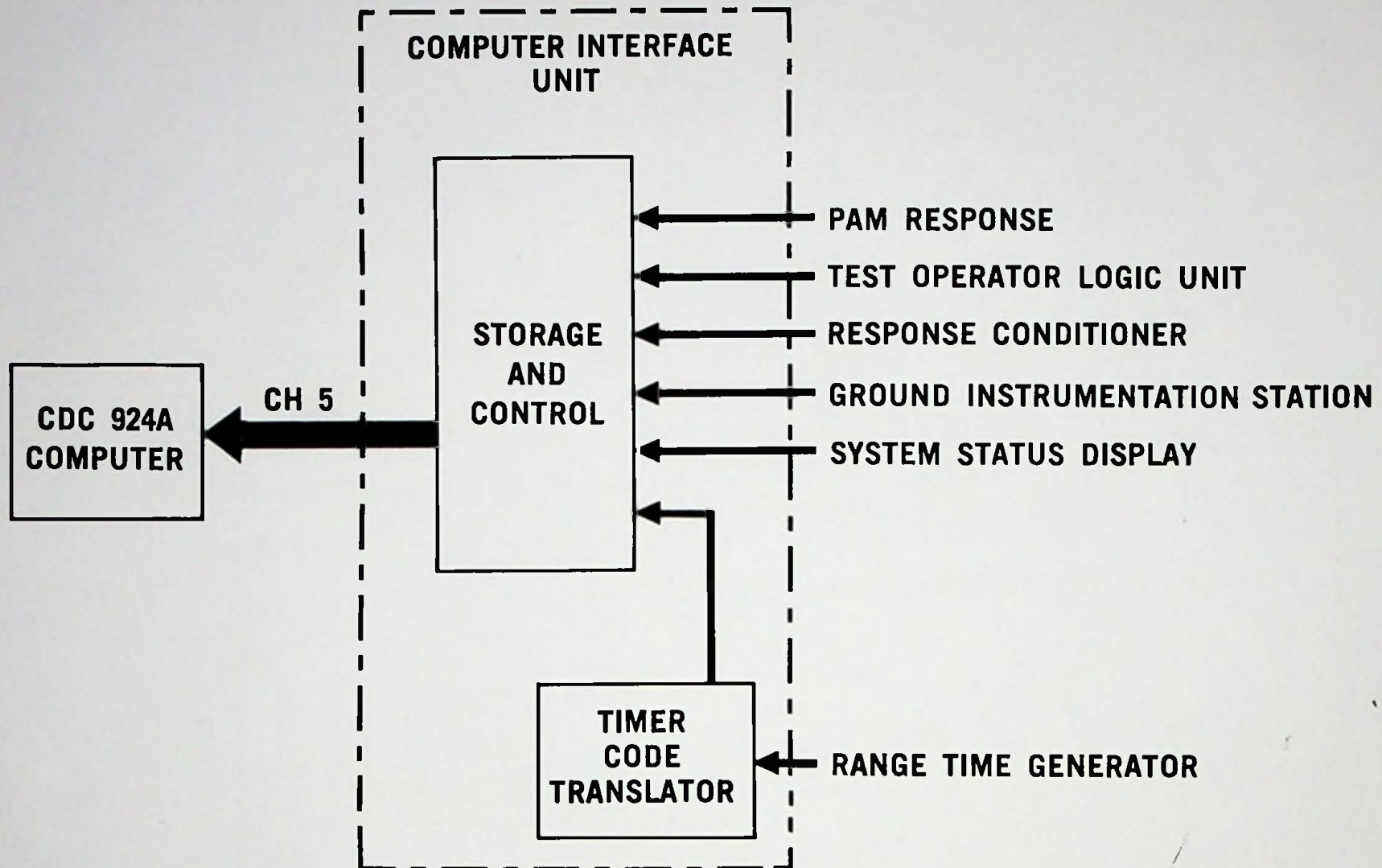
INPUT OUTPUT

795-355



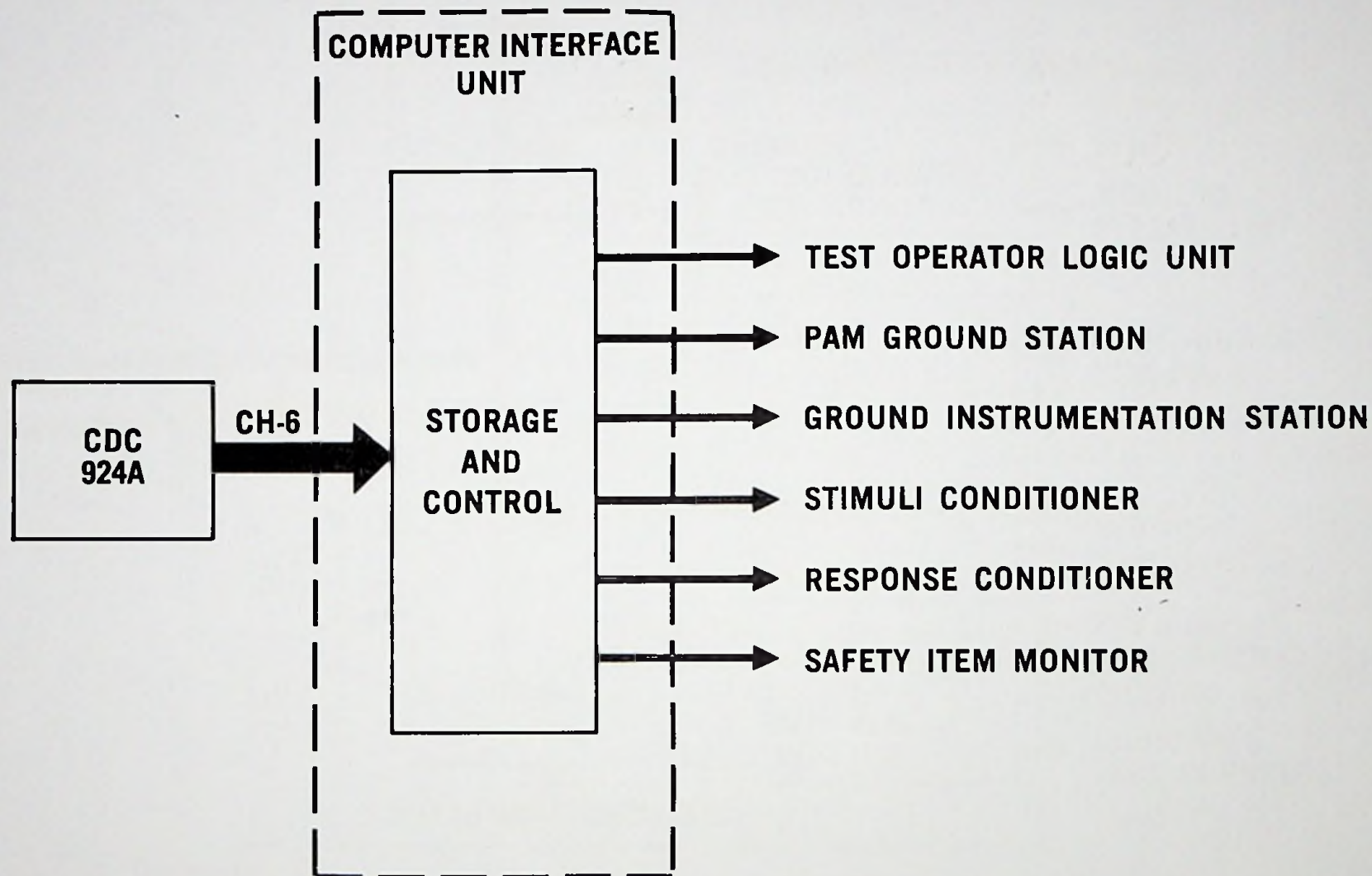
CIU CHANNEL 5 SCANNER INPUT

795-95A



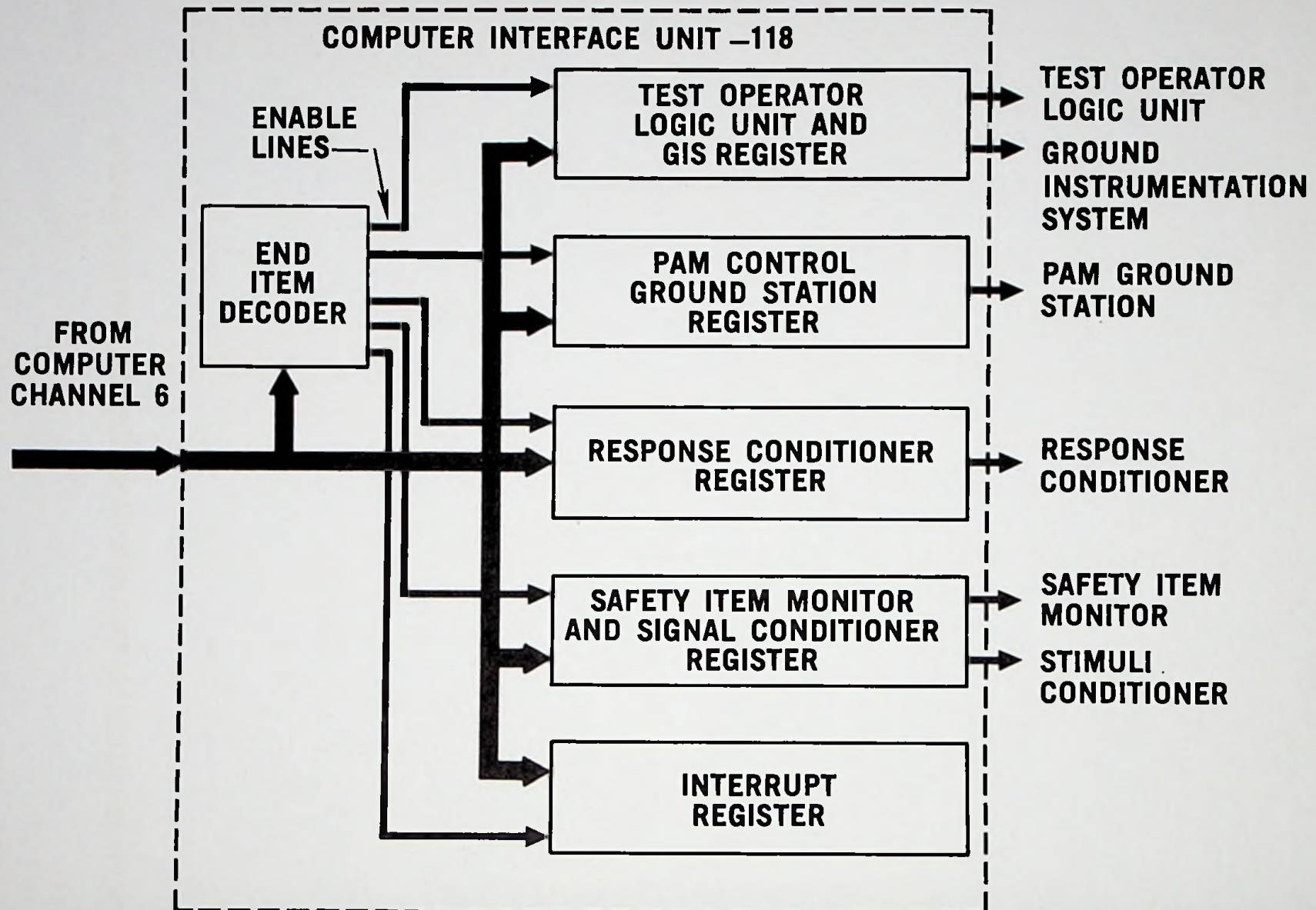
CIU CHANNEL 6 OUTPUT

795-99A



DATA FLOW FROM COMPUTER

795-159

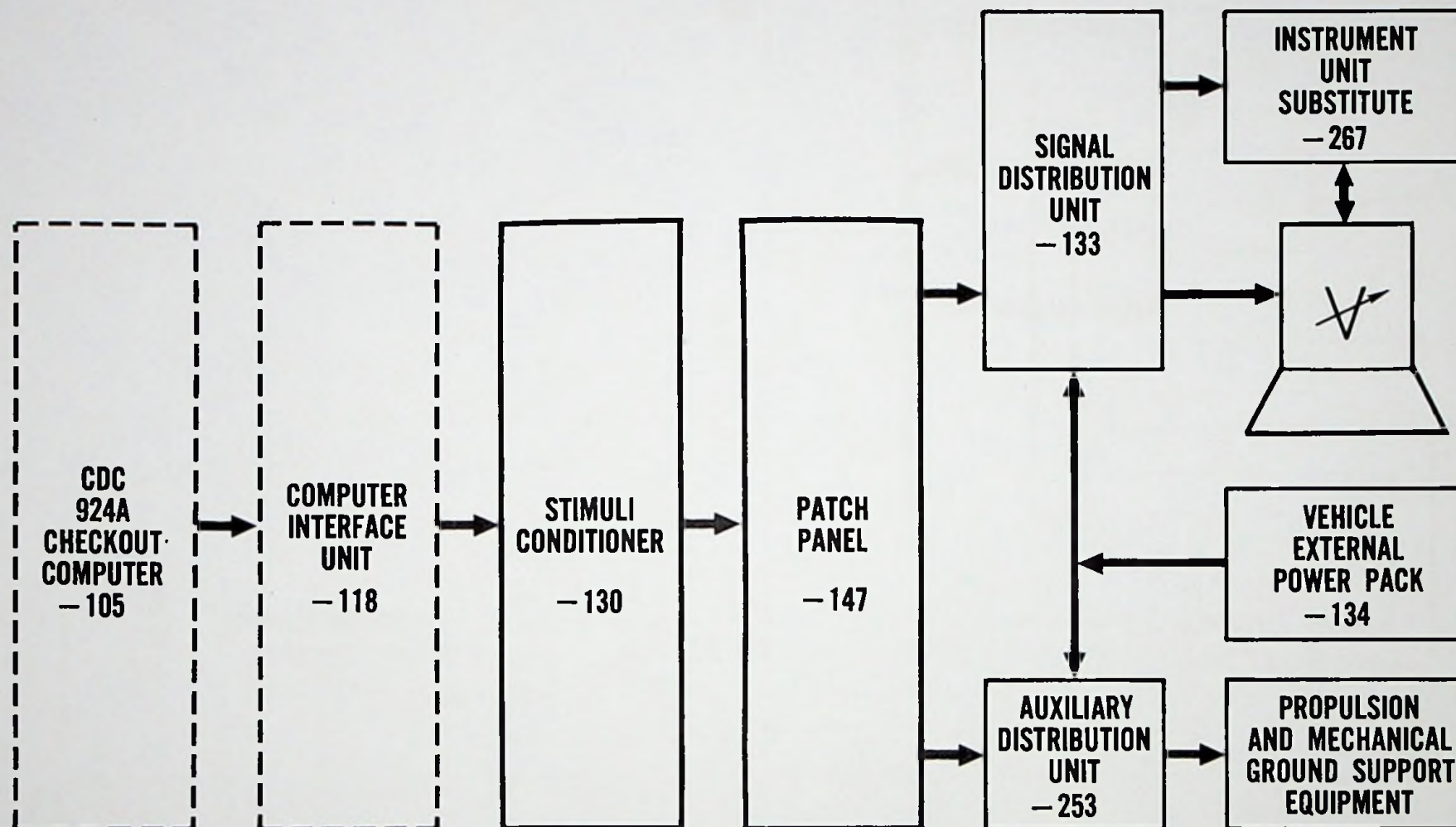


ILLUSTRATIONS

Stimuli

STIMULI DATA FLOW

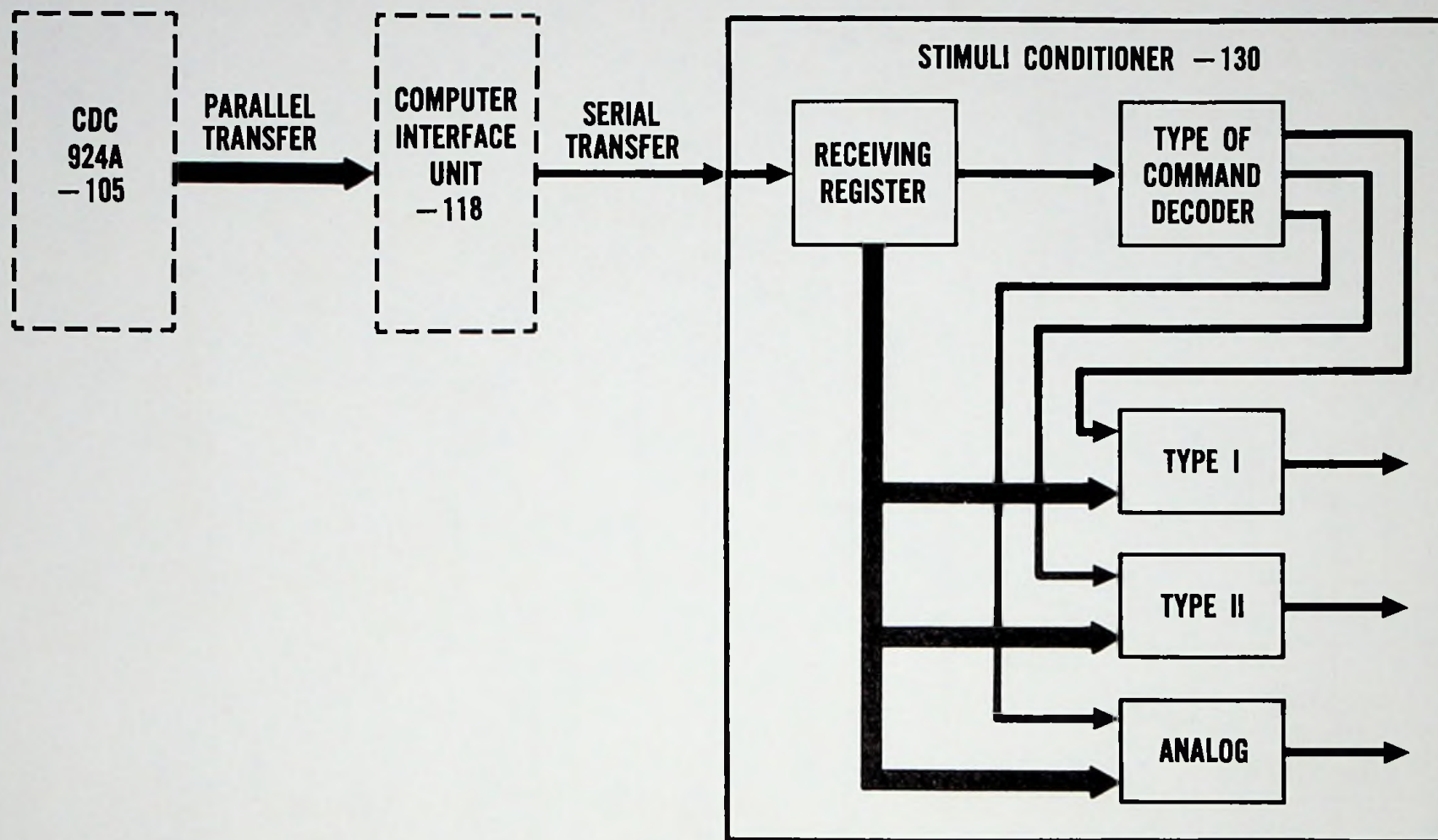
795-158B



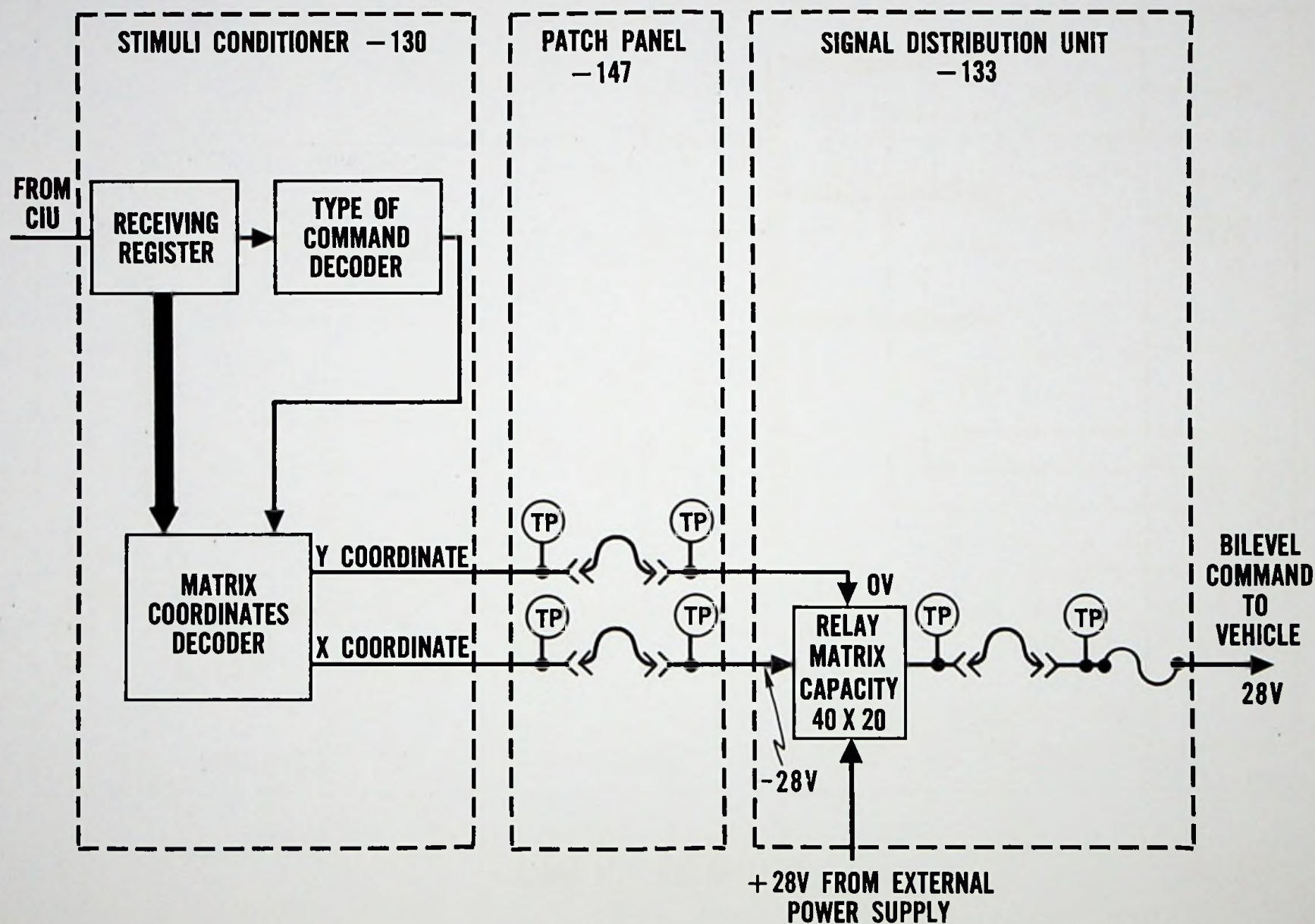
FOR TRAINING USE ONLY

STIMULI DECODE

795-162A

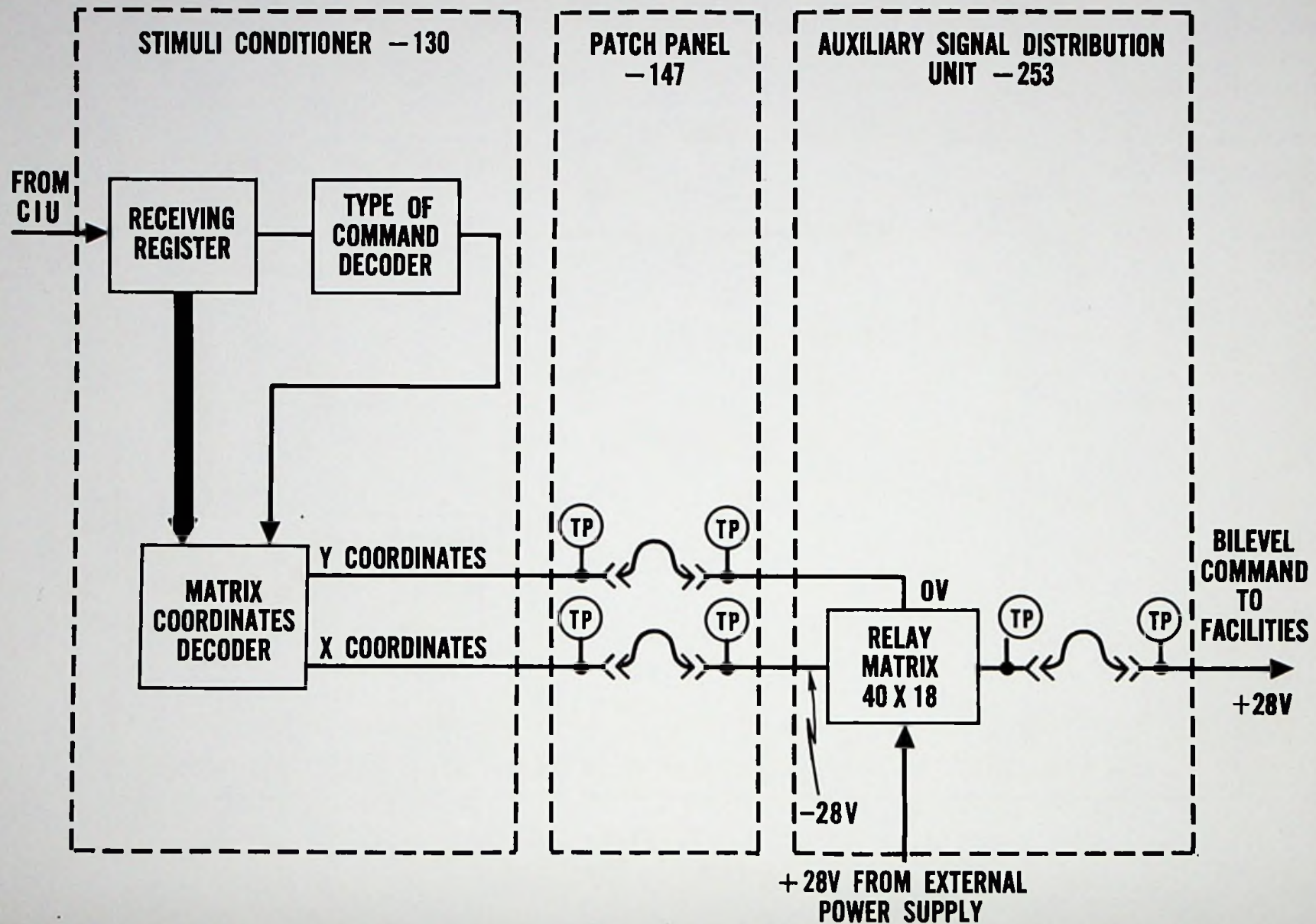


DATA FLOW (TYPE I BILEVEL-VEHICLE)



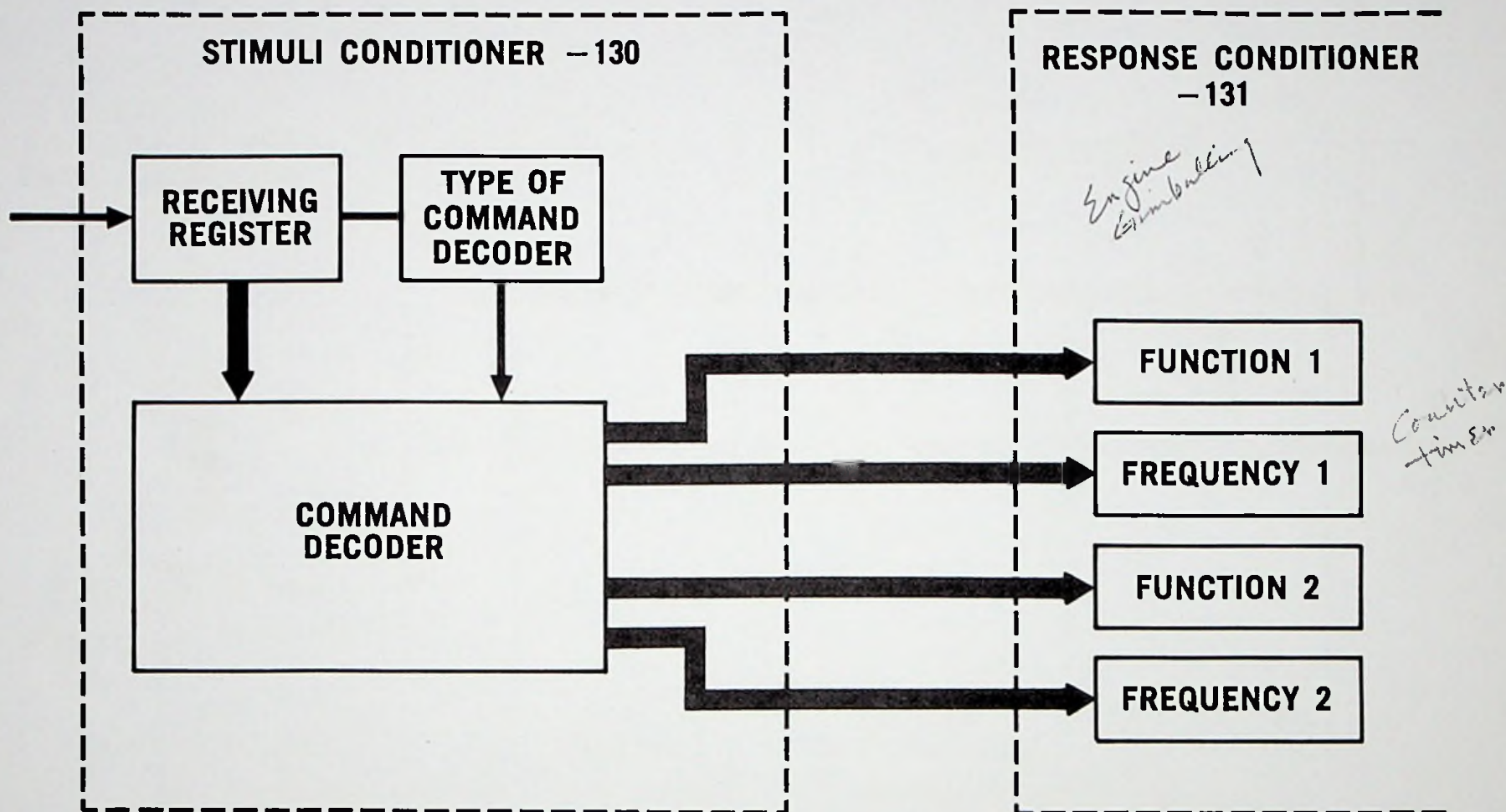
DATA FLOW

(TYPE I BILEVEL-FACILITIES)



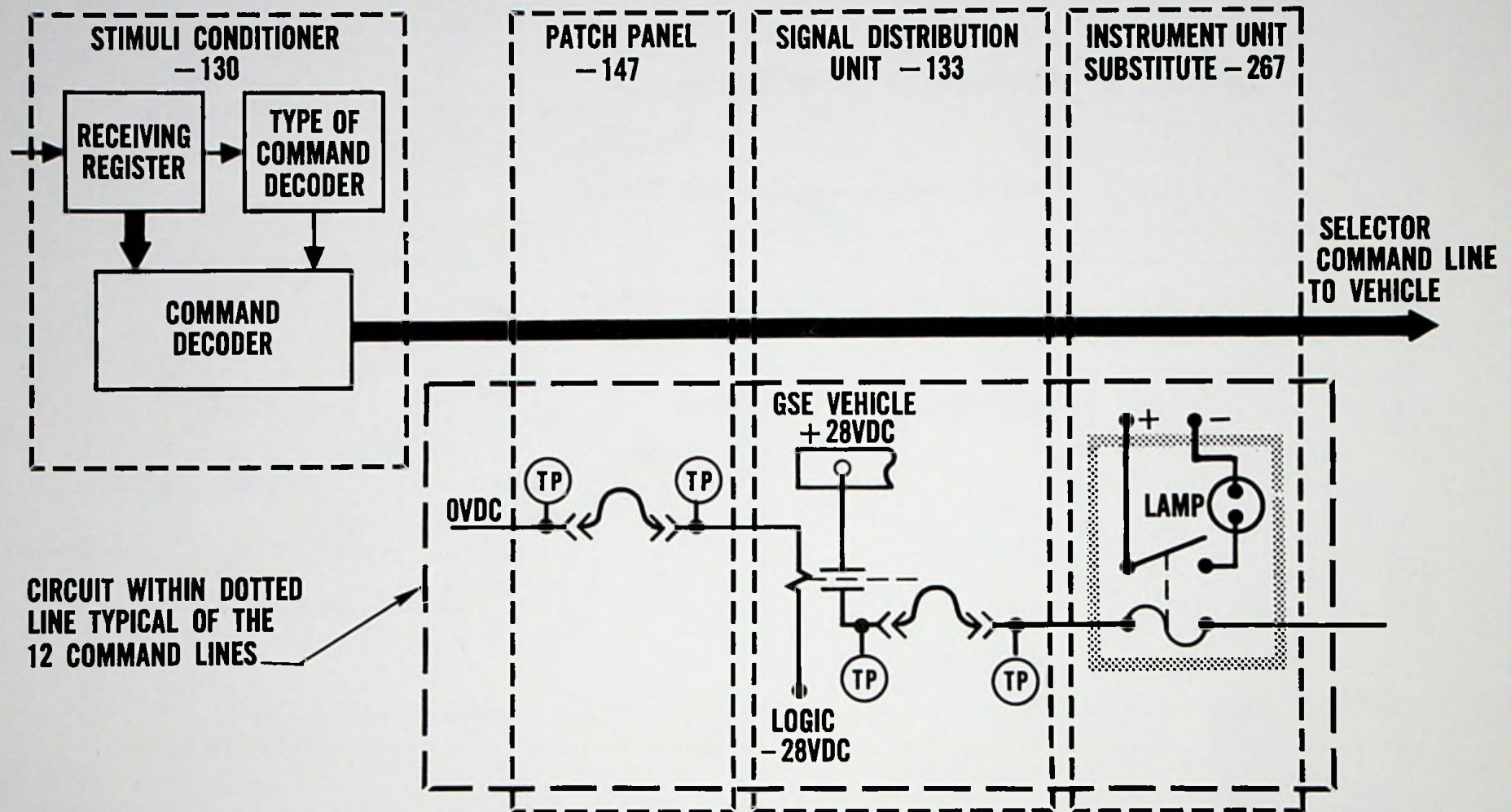
TYPE II-FREQUENCY AND FUNCTION MEASUREMENTS (GROUP 2)

795-173A



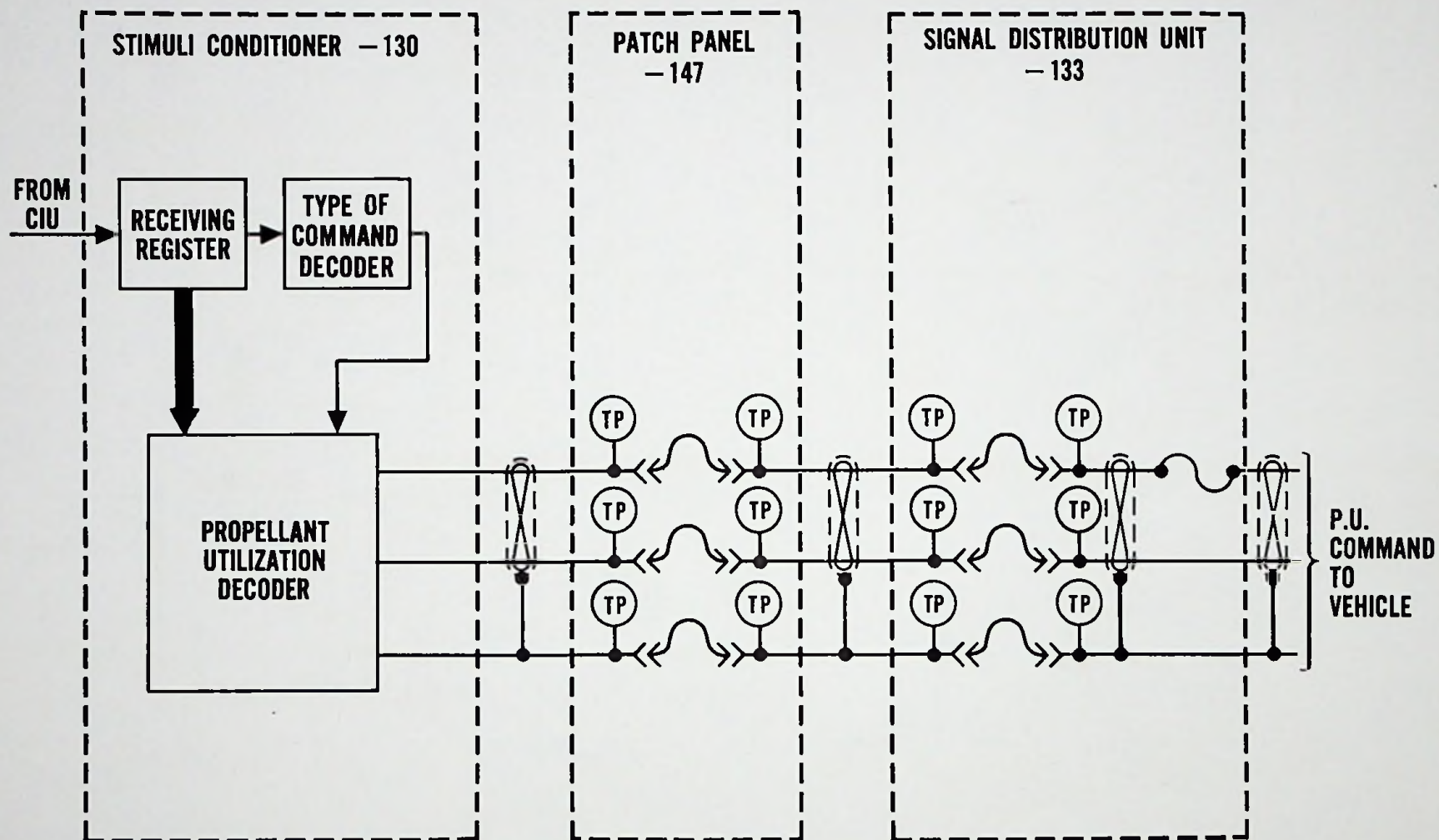
TYPE II-SWITCH SELECTOR (GROUP 3)

795-172A



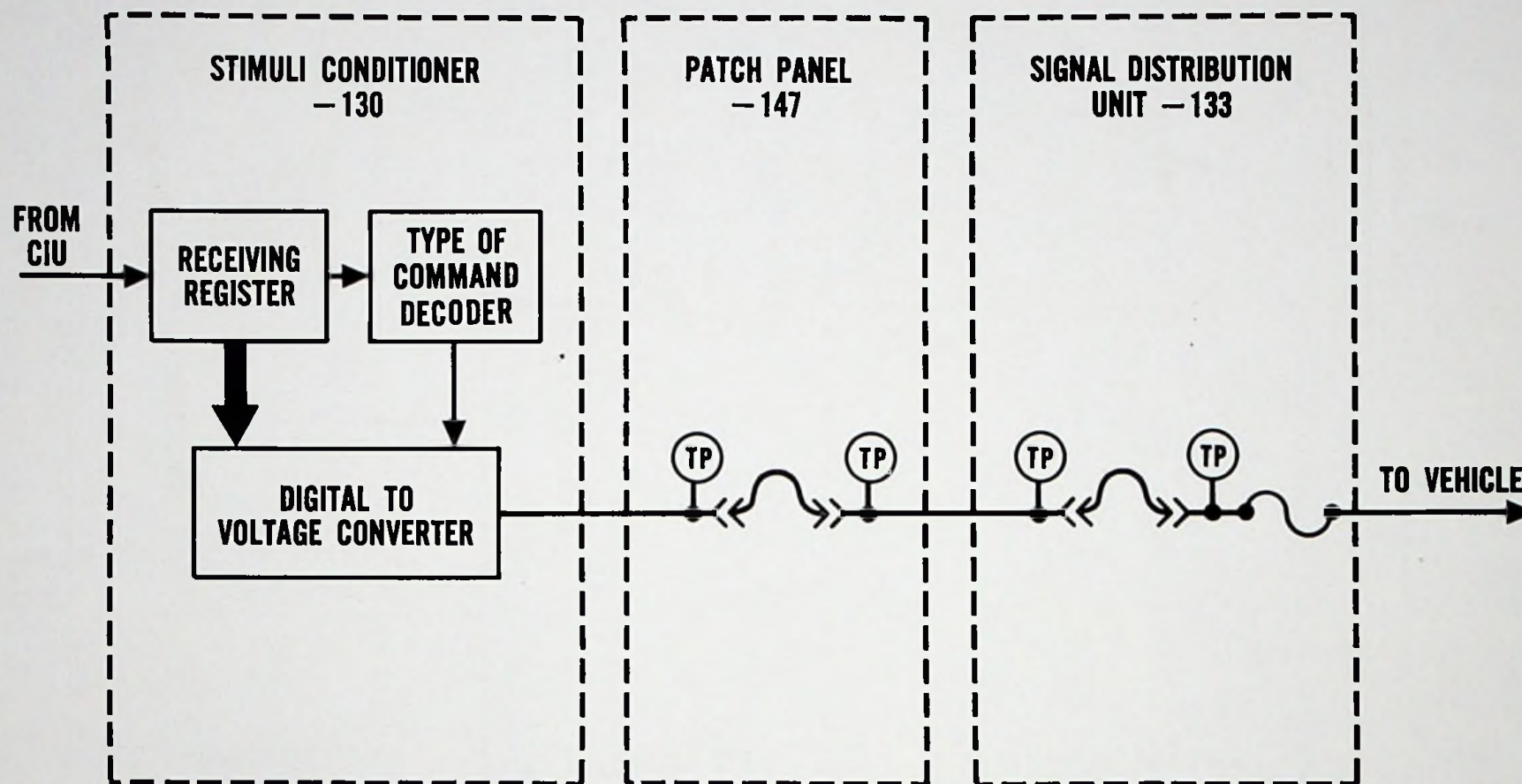
TYPE II-PROPELLANT UTILIZATION (GROUP 4)

795-175A



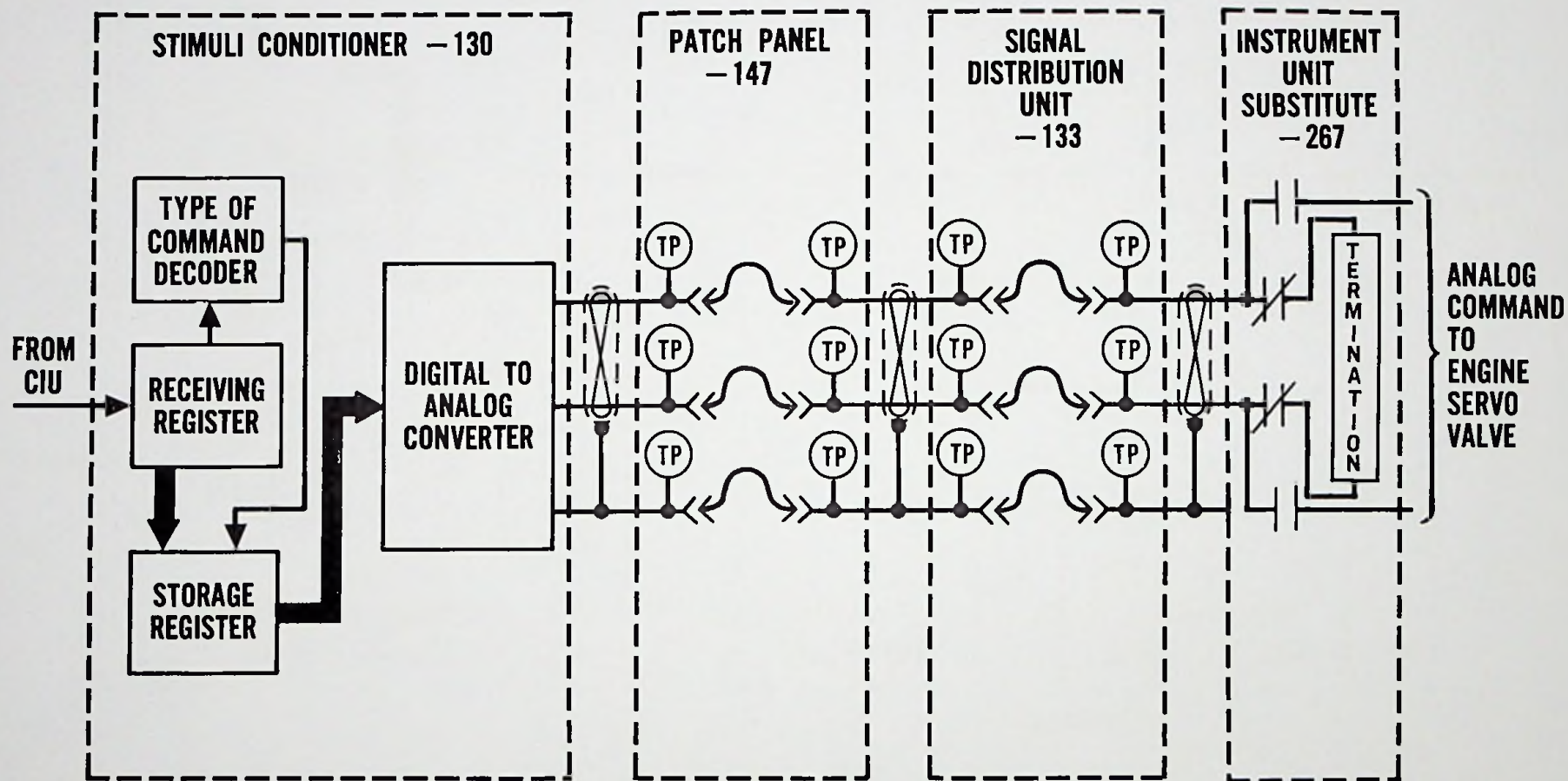
TYPE II-TELEMETRY CALIBRATION VOLTAGE (GROUP 5)

795-176A



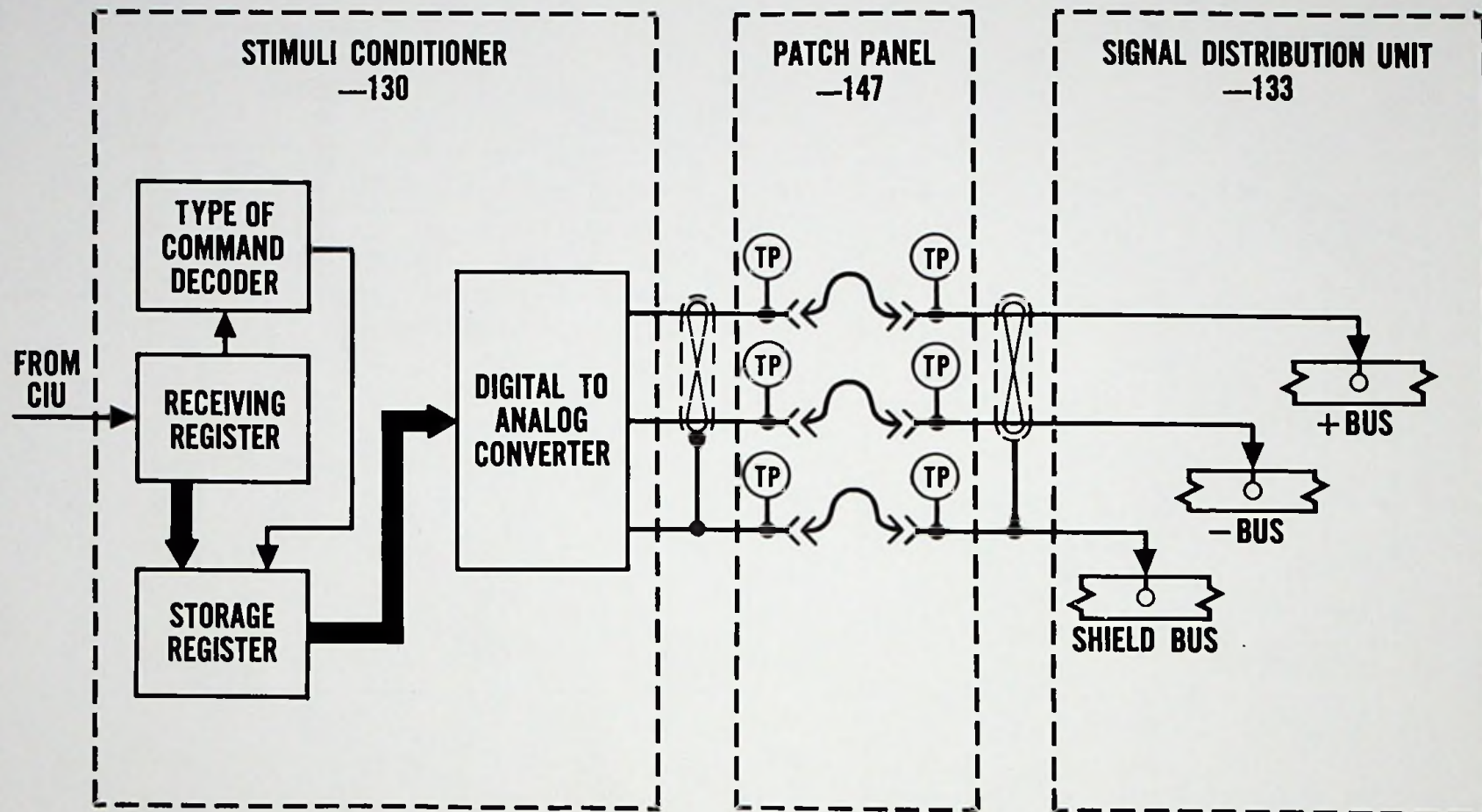
DATA FLOW (ENGINE GIMBALLING SIGNALS)

795-166B



DATA FLOW (ANALOG SELF-TEST)

795-165A

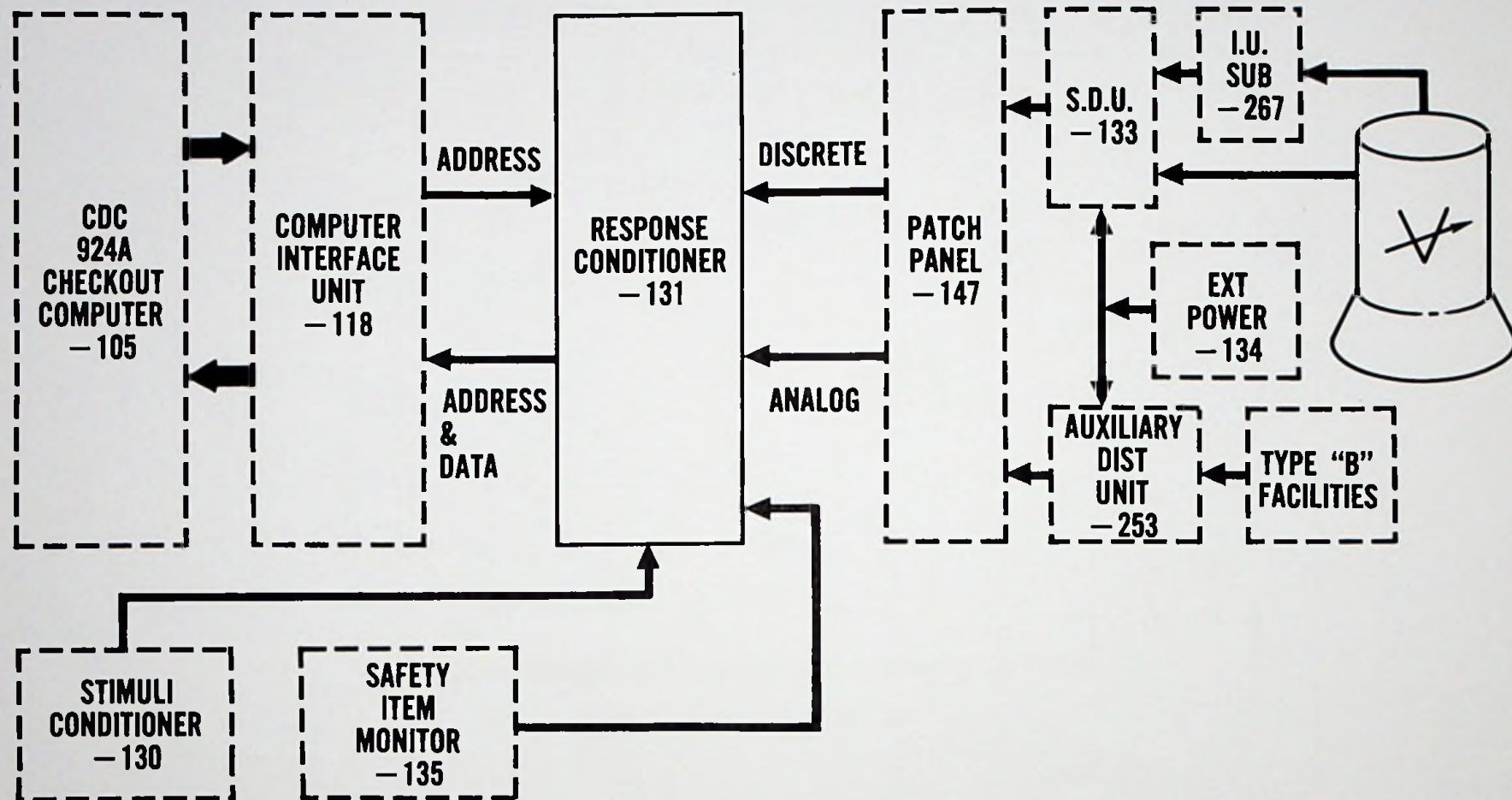


ILLUSTRATIONS

Responses

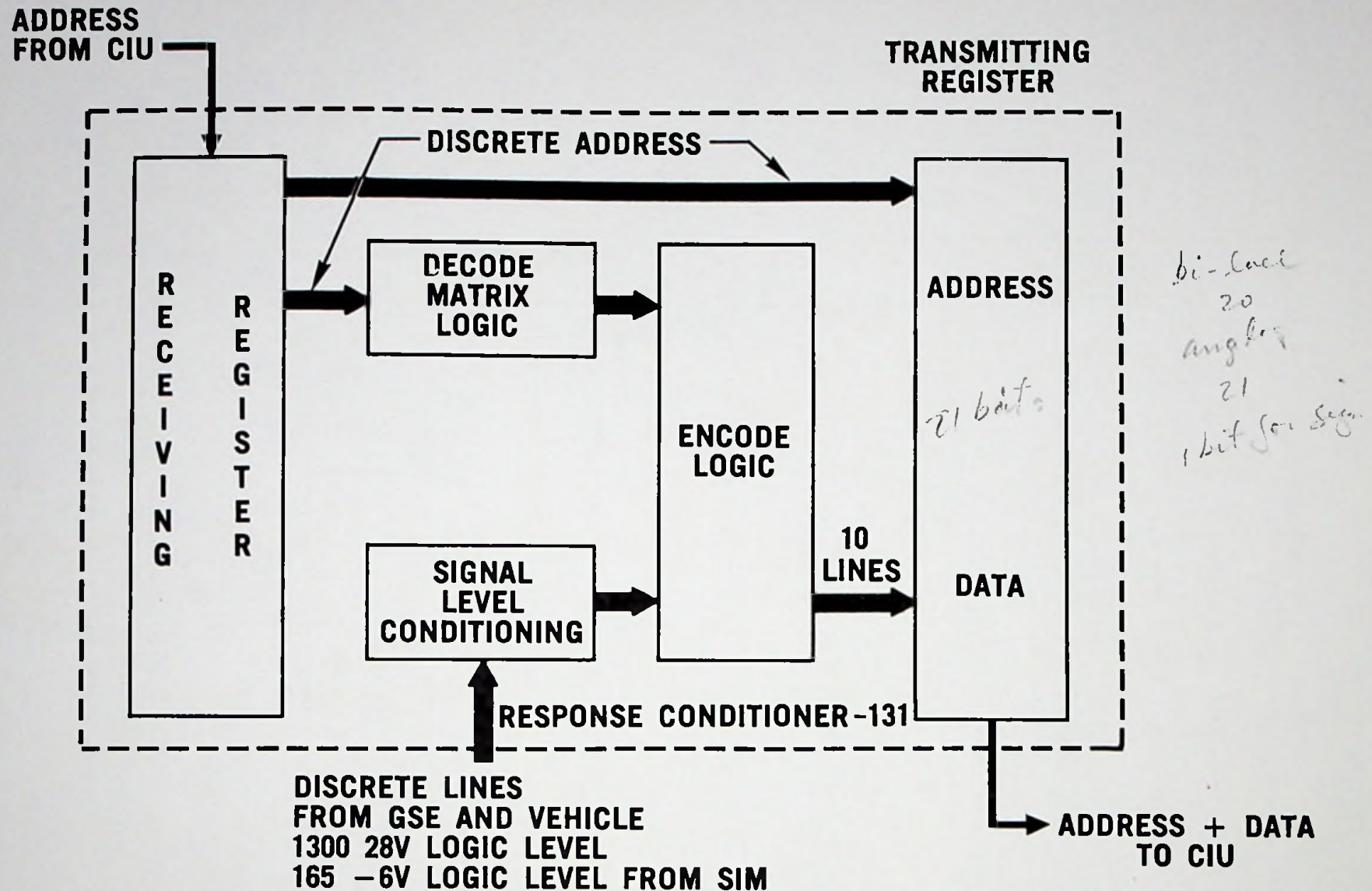
RESPONSE DATA FLOW

795-490



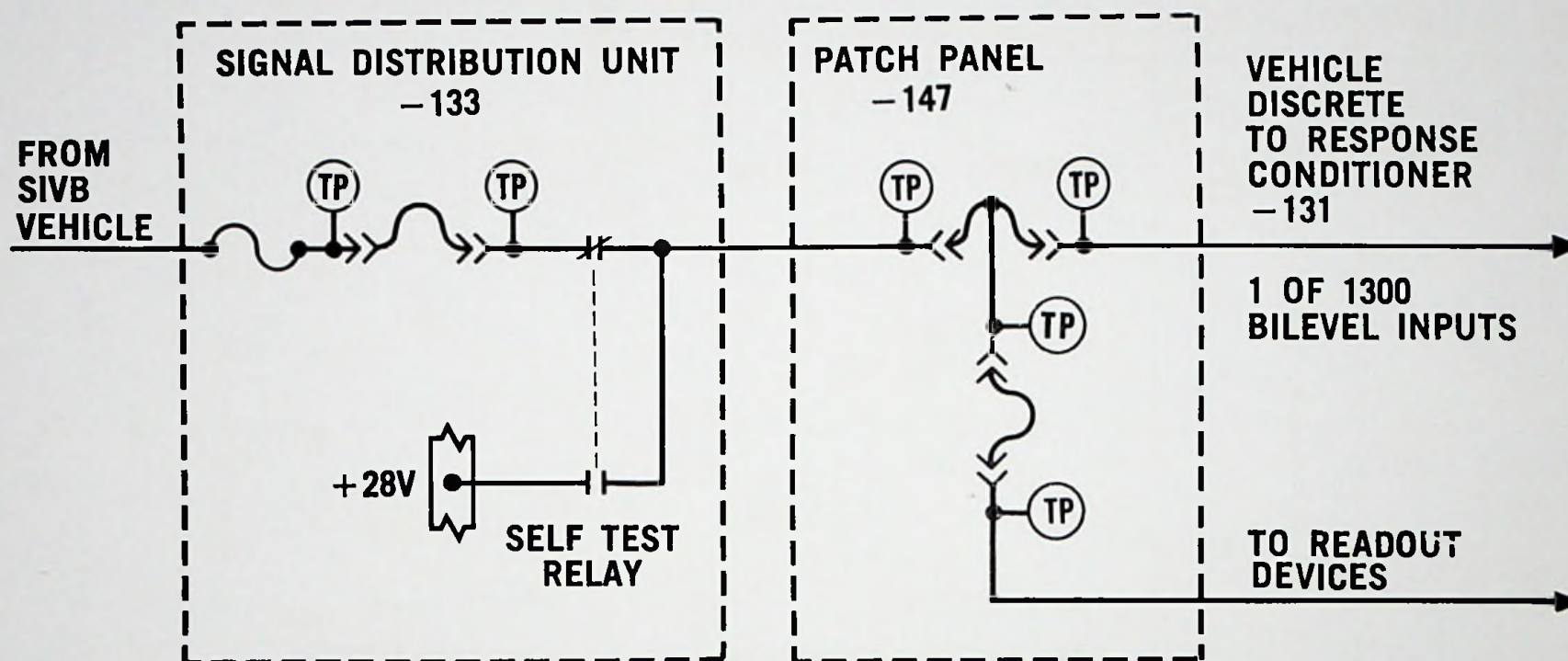
DISCRETE RESPONSE REQUEST AND REPLY

795-183A



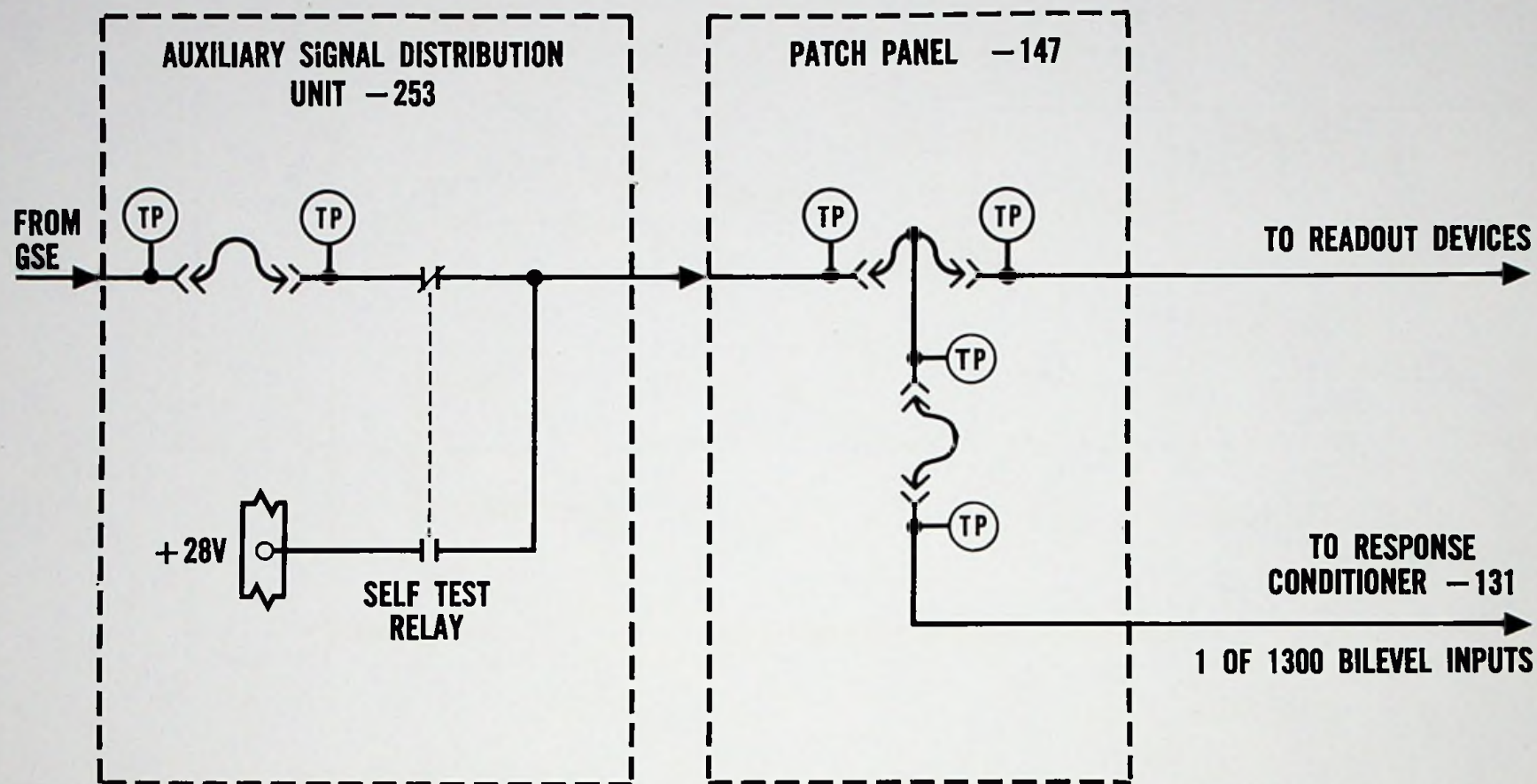
DISCRETE RESPONSE FROM VEHICLE (TYPICAL)

795-181B



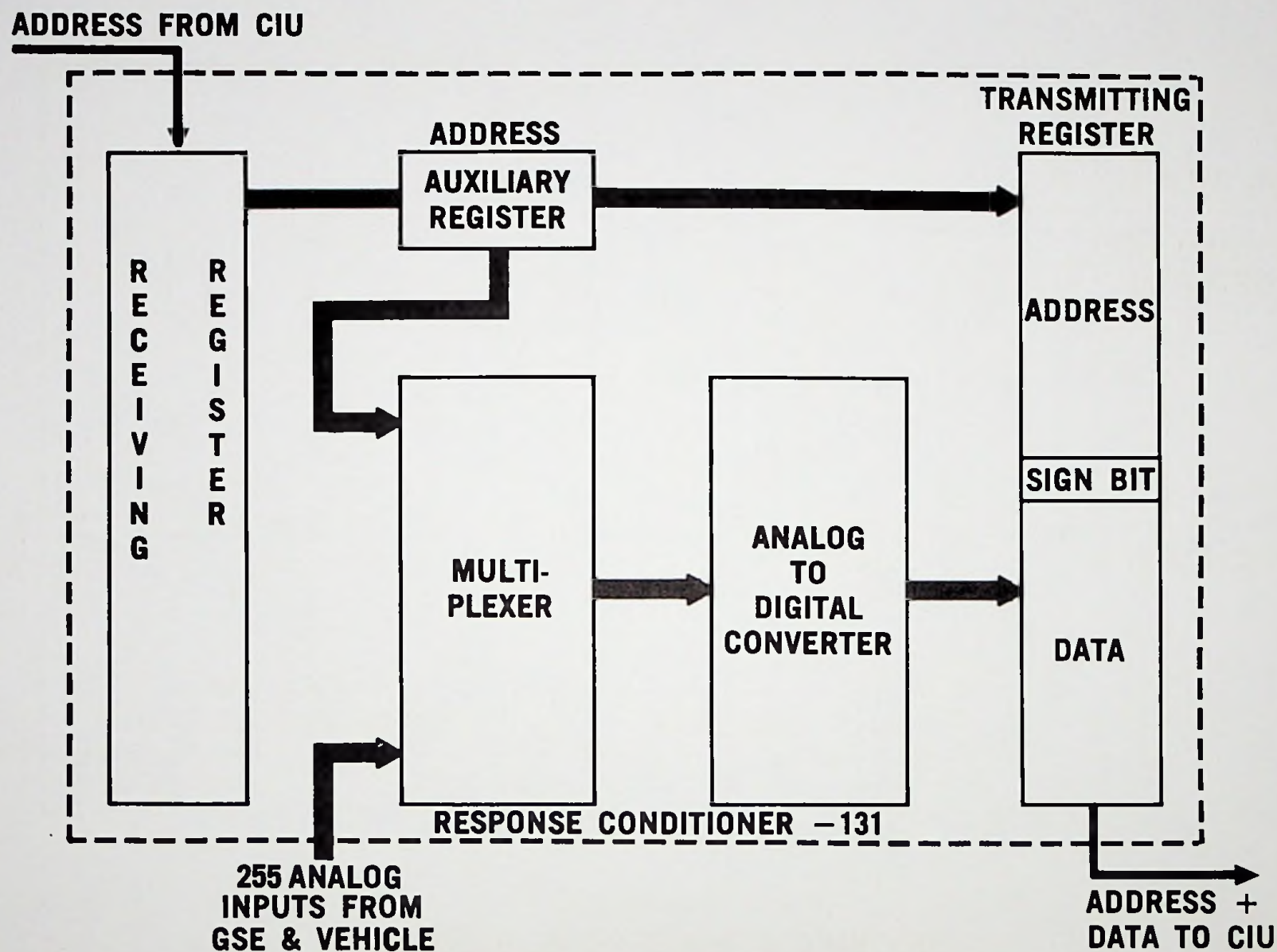
DISCRETE RESPONSE FROM GSE (TYPICAL)

795-182 A



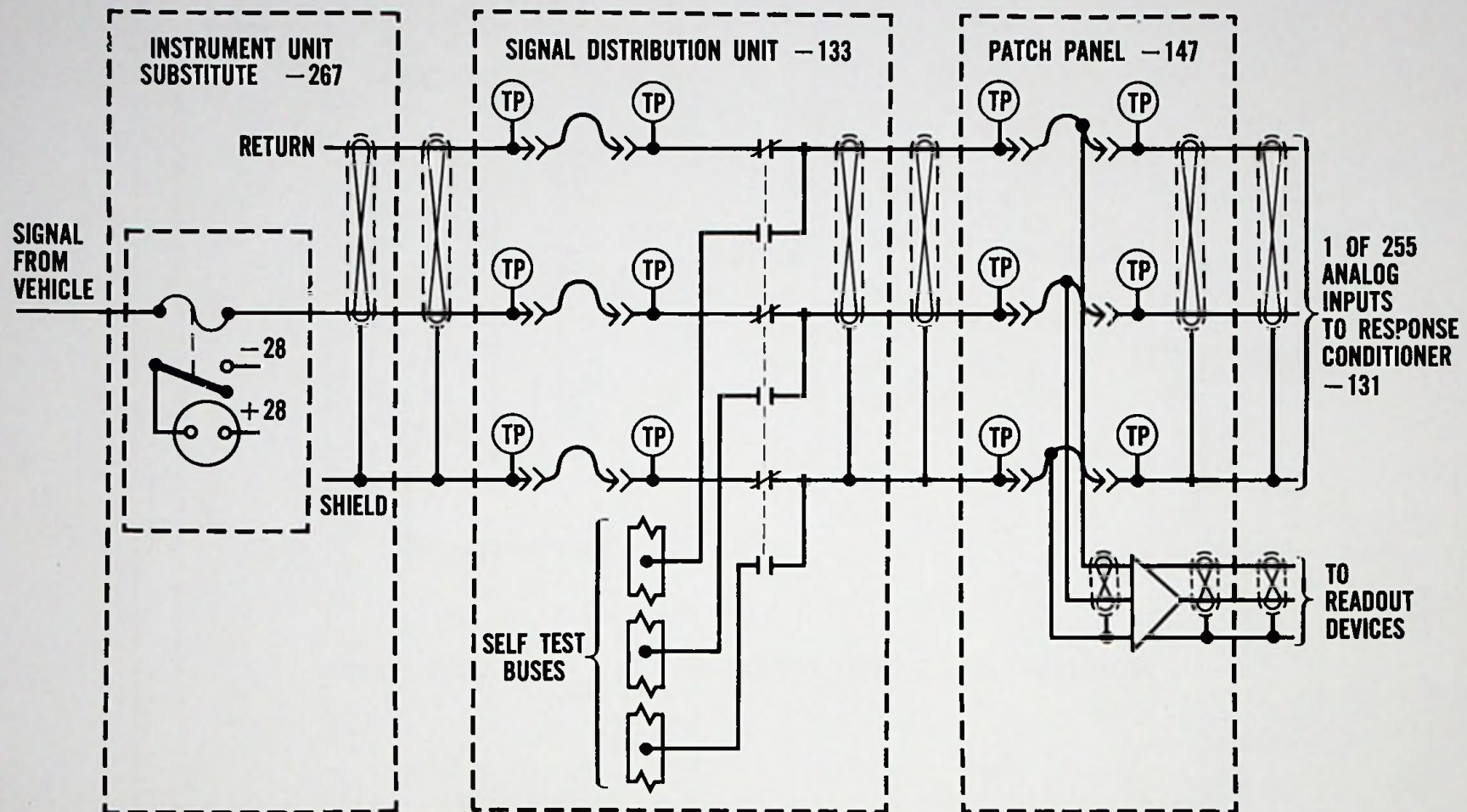
ANALOG RESPONSE REQUEST AND REPLY

795-189



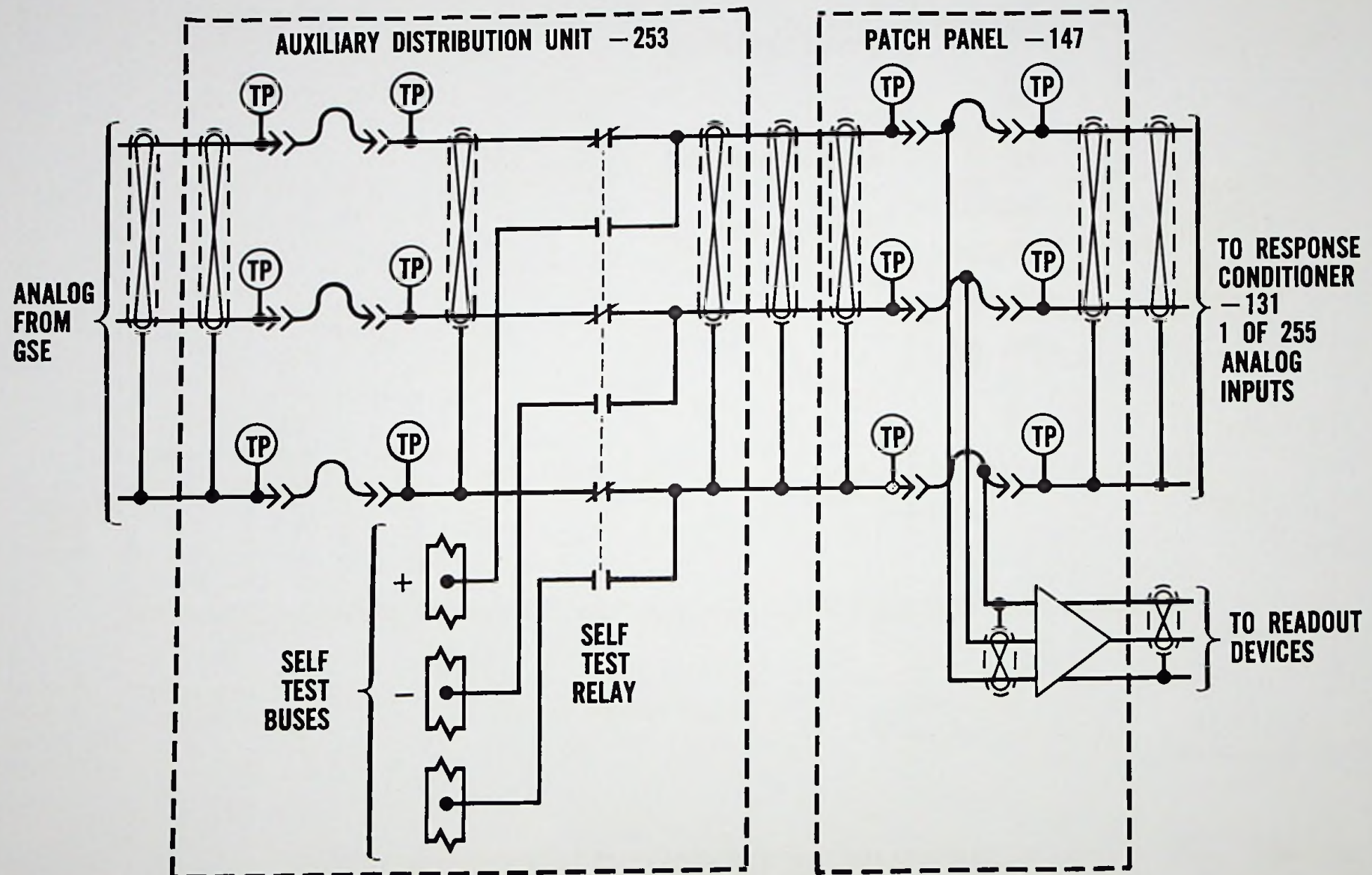
ANALOG RESPONSE FROM VEHICLE

795-184A



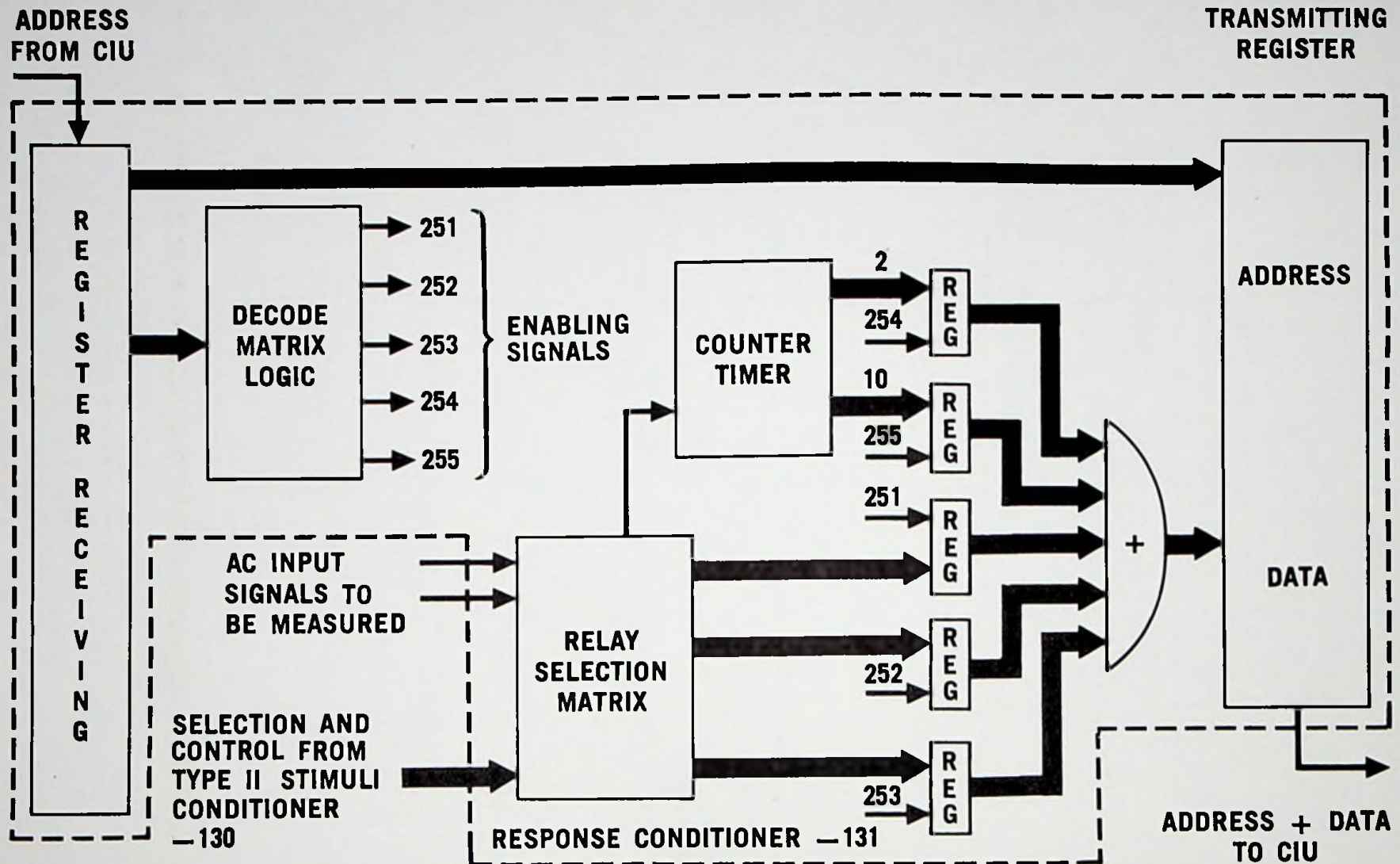
ANALOG RESPONSE FROM GSE

795-185



PERIOD COUNTER REQUEST AND REPLY

795-186 B



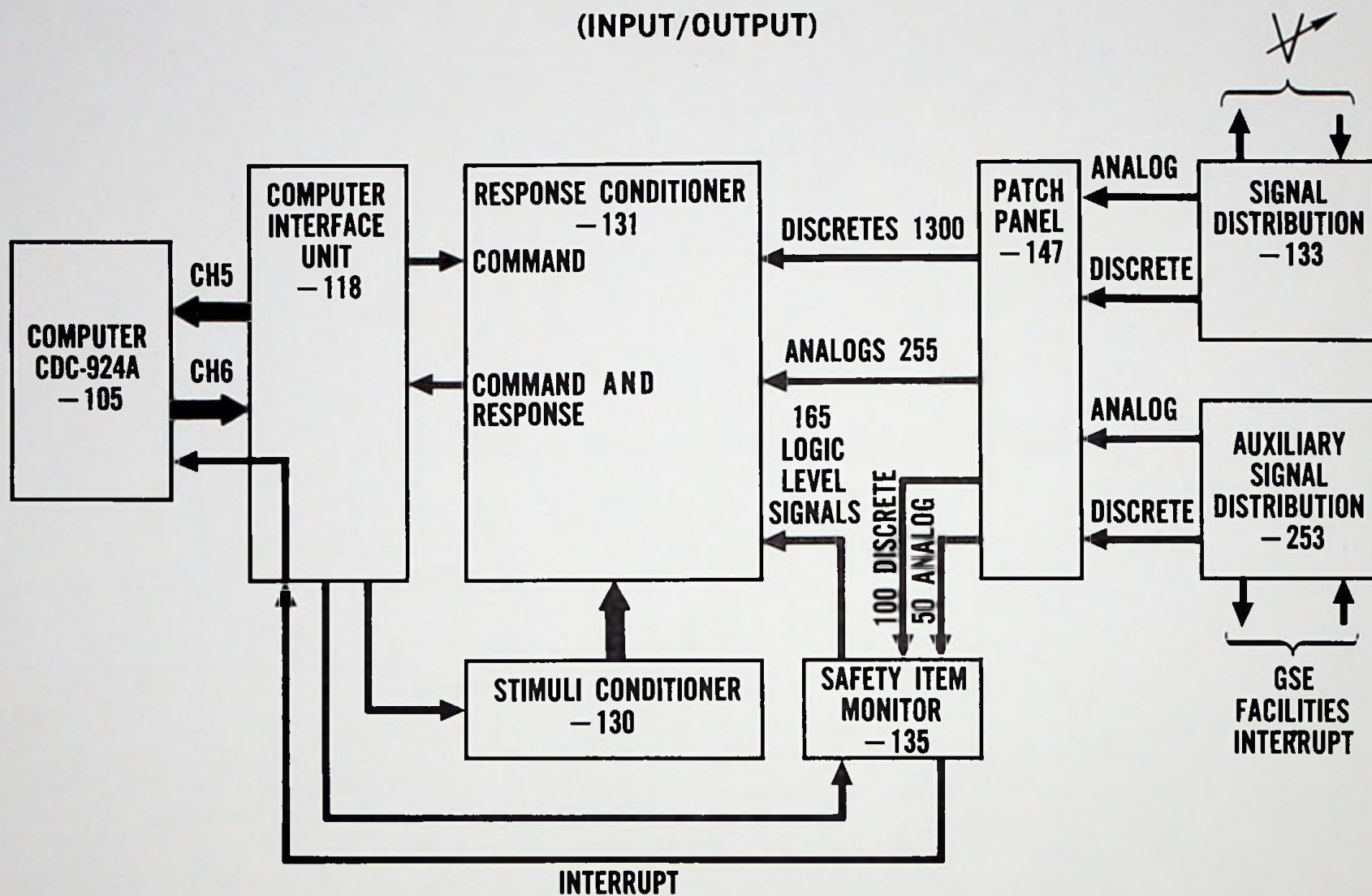
ILLUSTRATIONS

Safety Features

RESPONSE CONDITIONER & SAFETY ITEM MONITOR

795-187

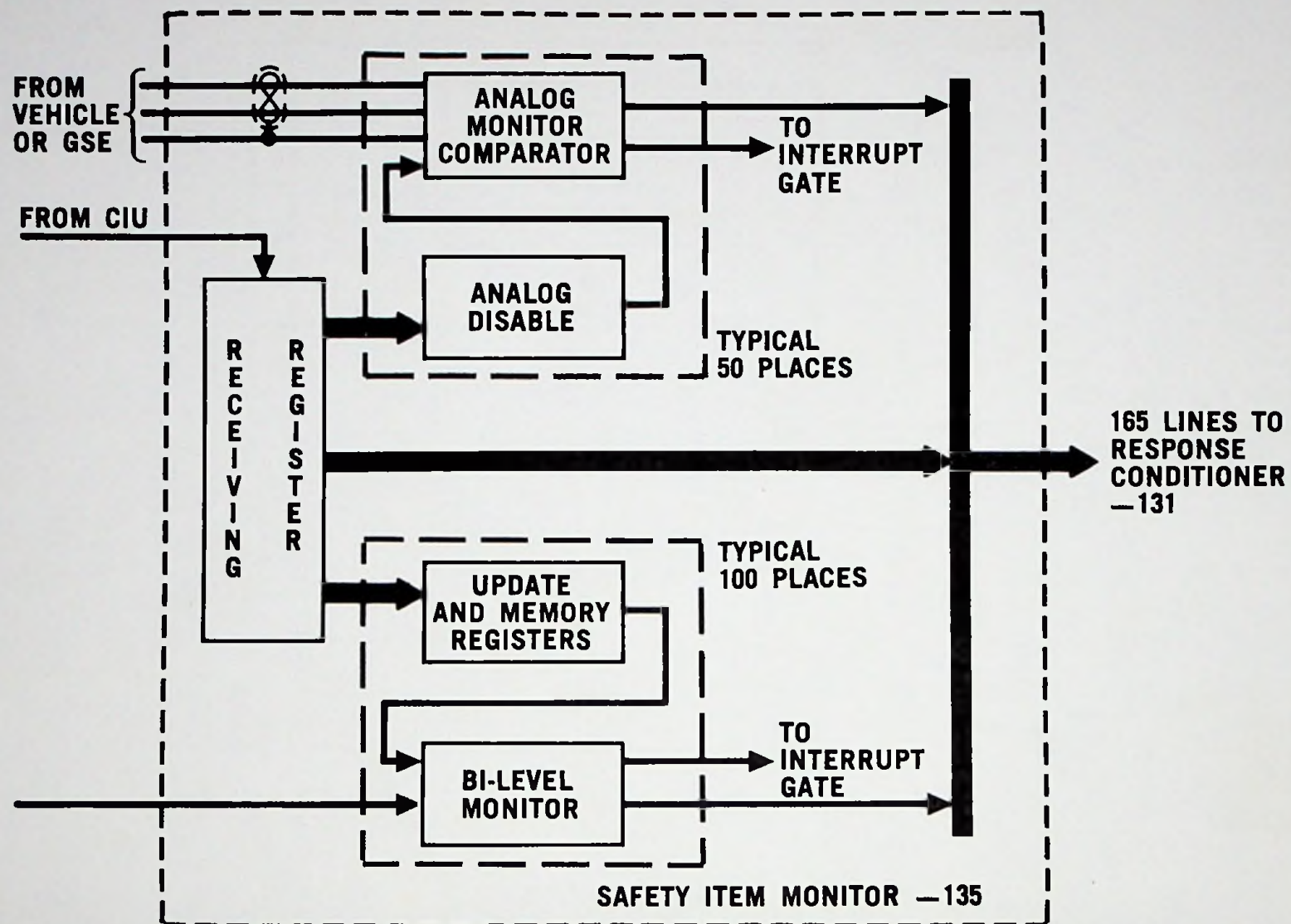
(INPUT/OUTPUT)



SAFETY ITEM MONITOR

(DATA FLOW)

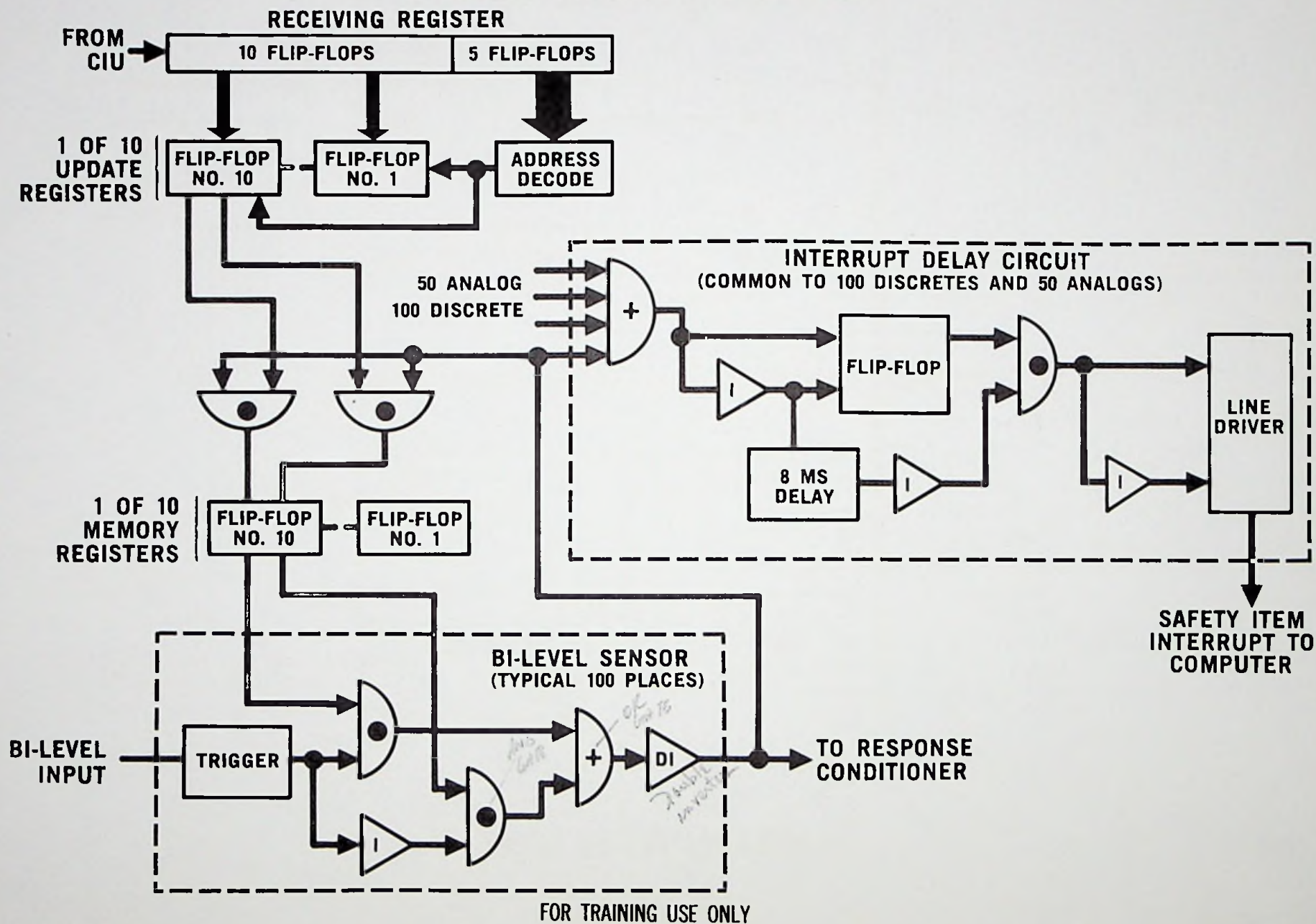
795-191



SAFETY ITEM MONITOR

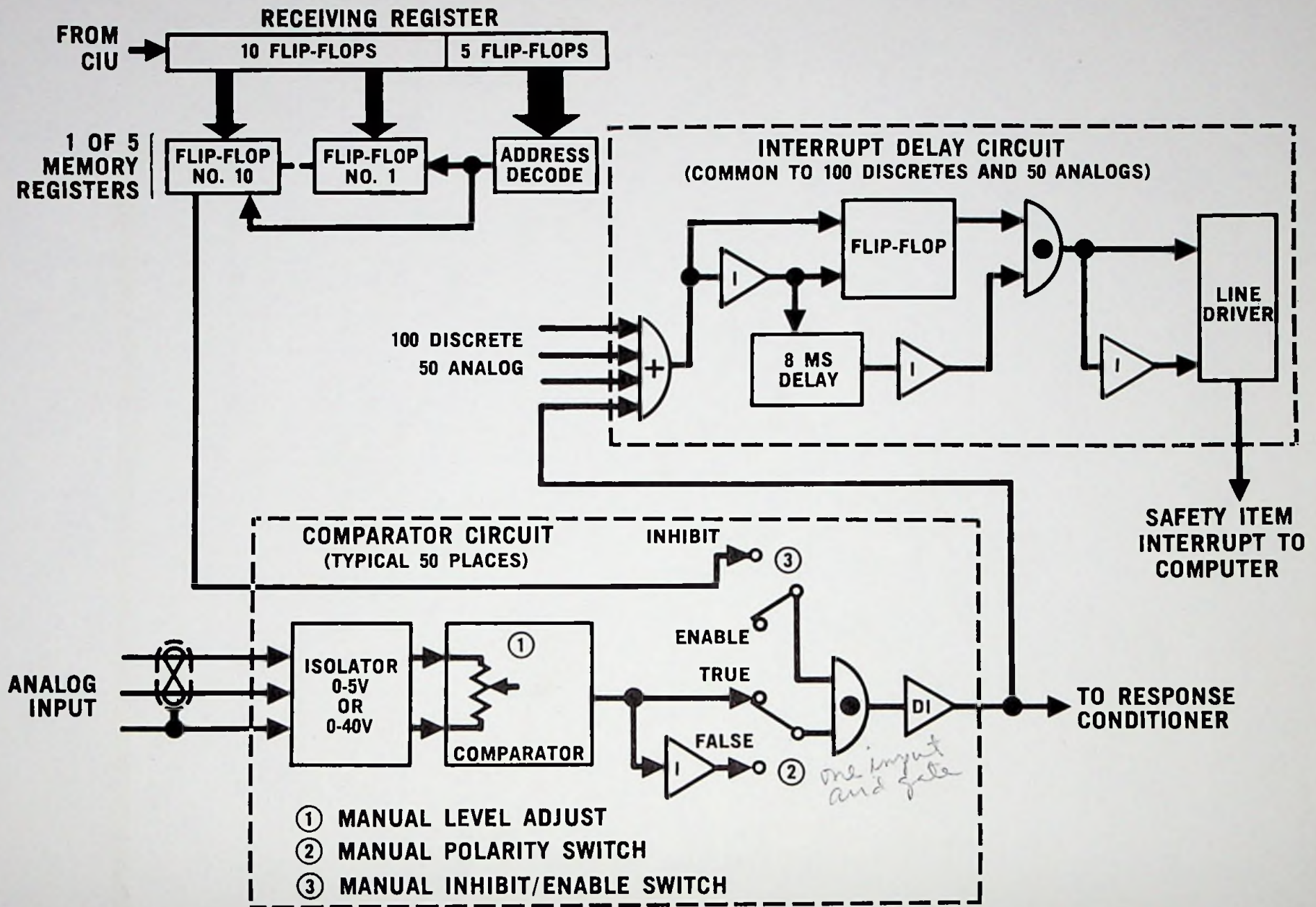
(DISCRETE CONTROL AND UPDATE)

795-193B



ANALOG MONITOR

795-188A

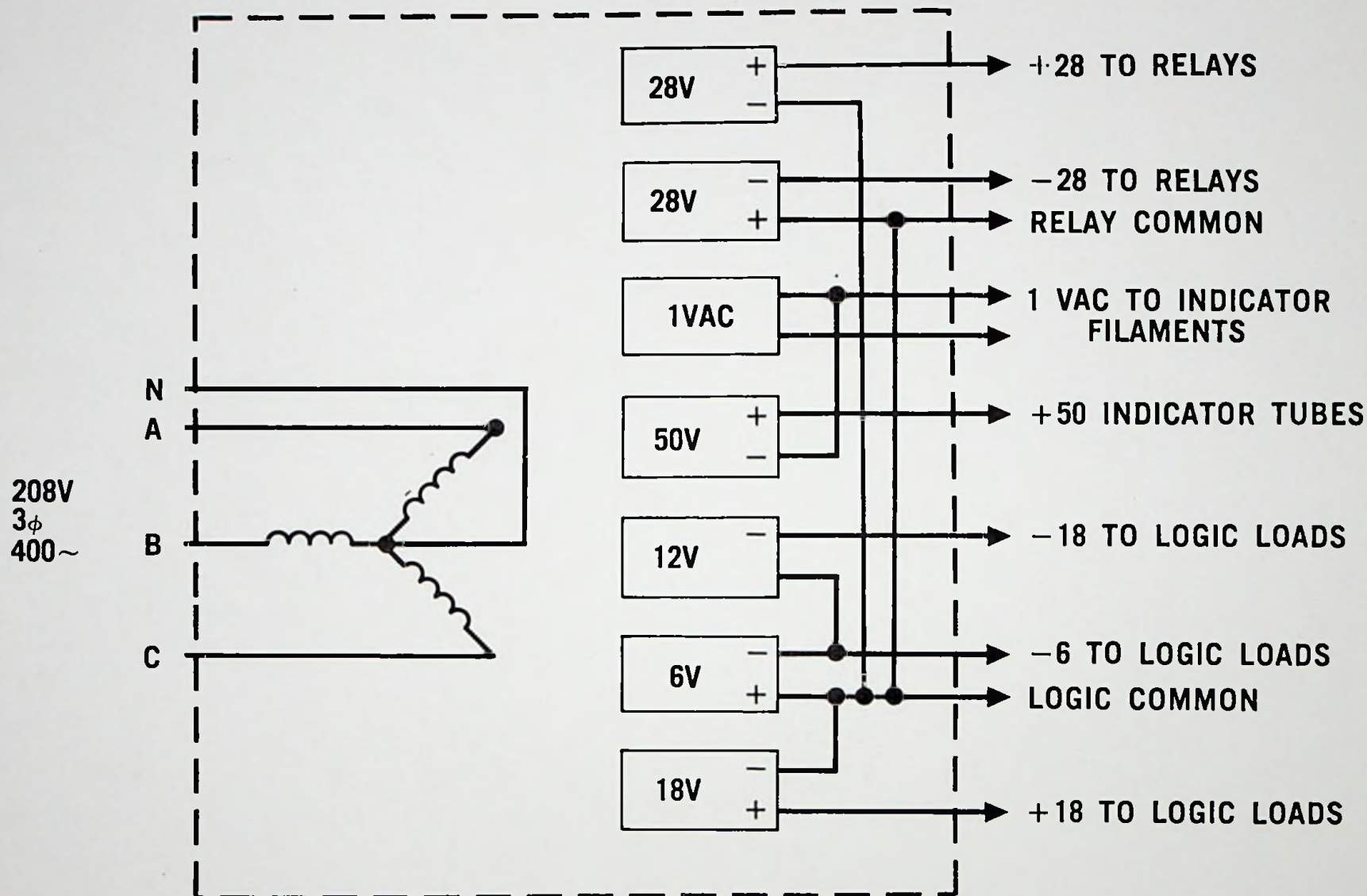


ILLUSTRATIONS

System Power

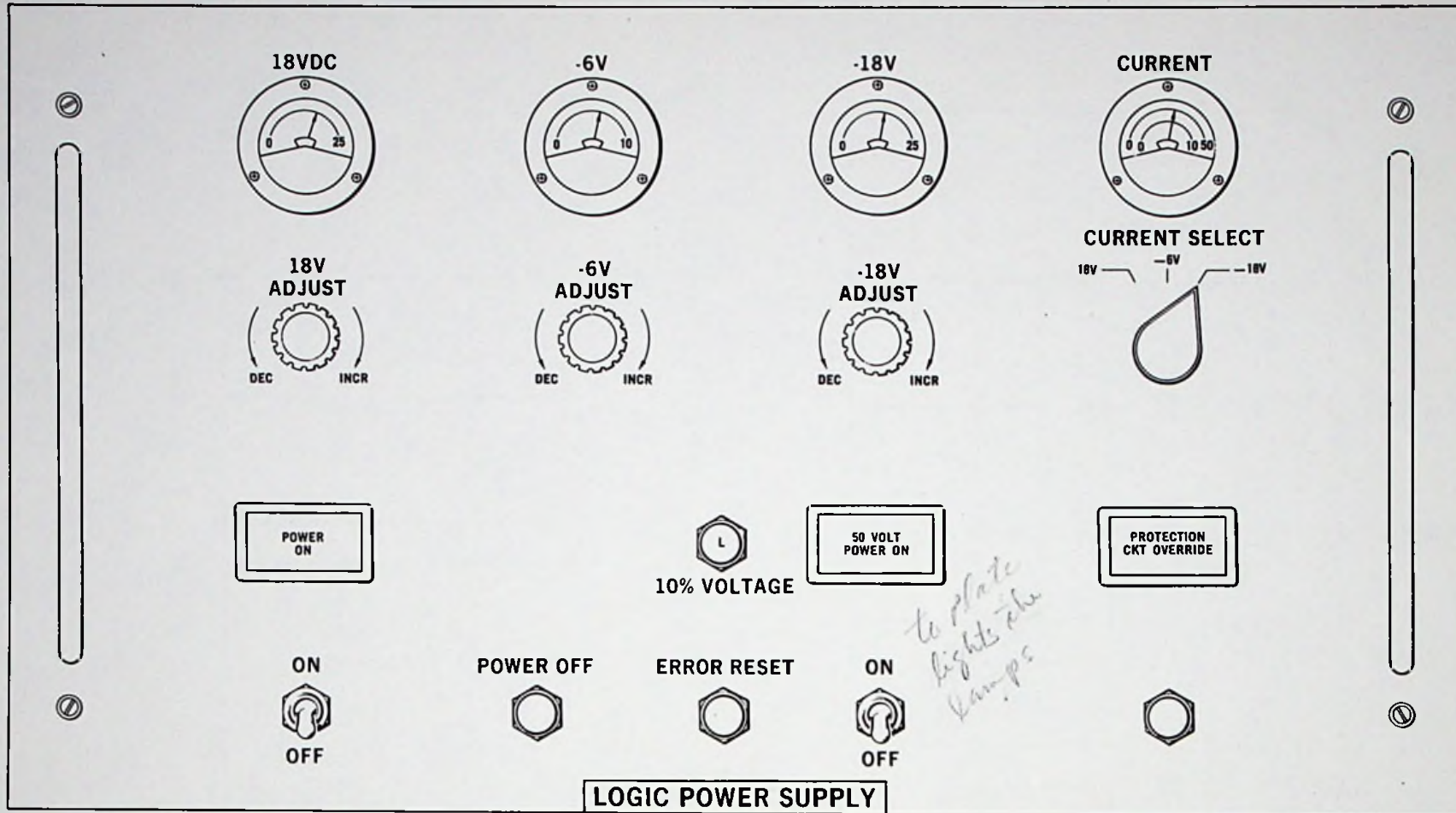
LOGIC POWER SUPPLY

795-260A



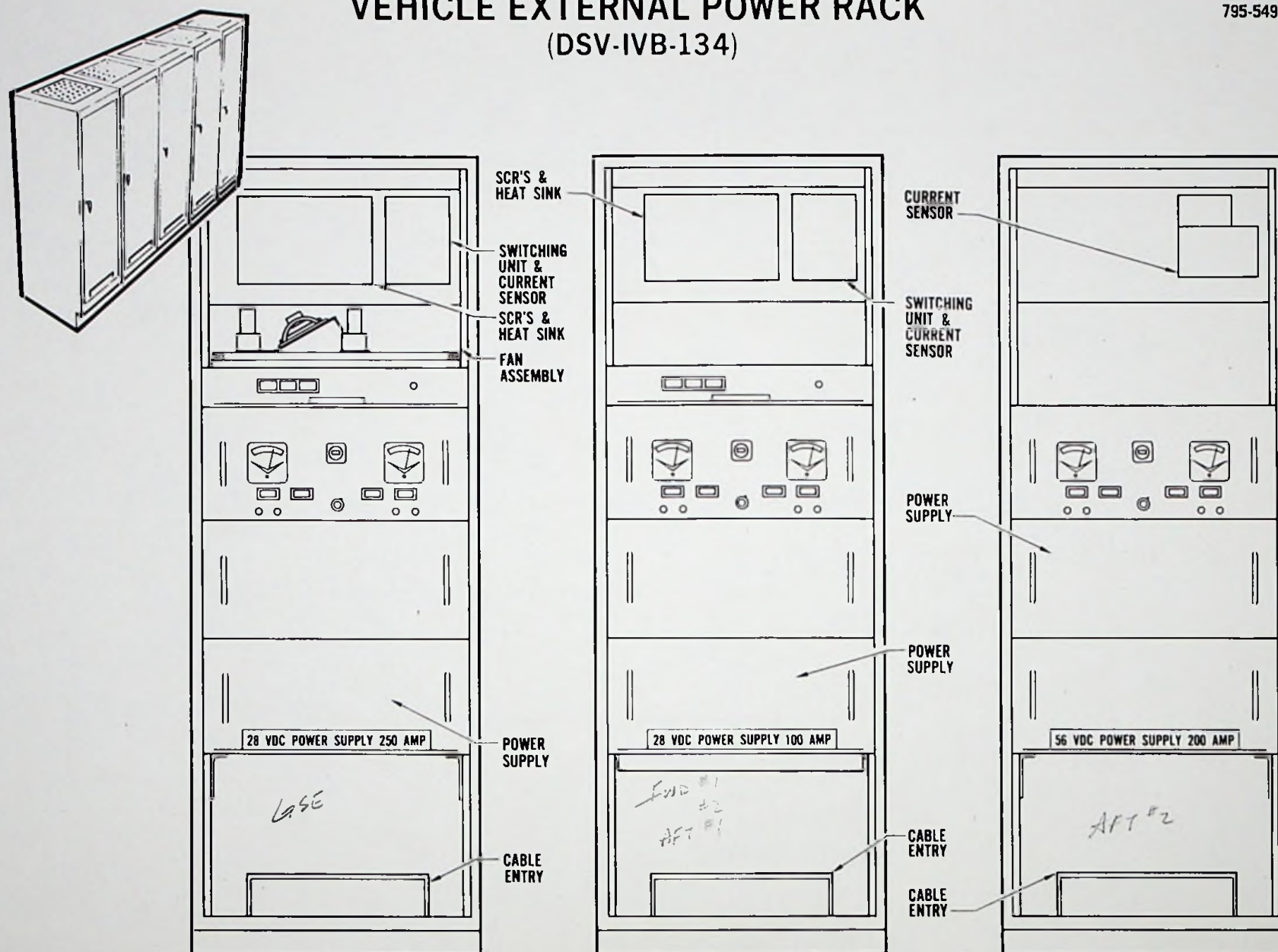
PRINTED CIRCUIT CARDS
(FRONT PANEL LOGIC POWER SUPPLY)

795-475



VEHICLE EXTERNAL POWER RACK (DSV-IVB-134)

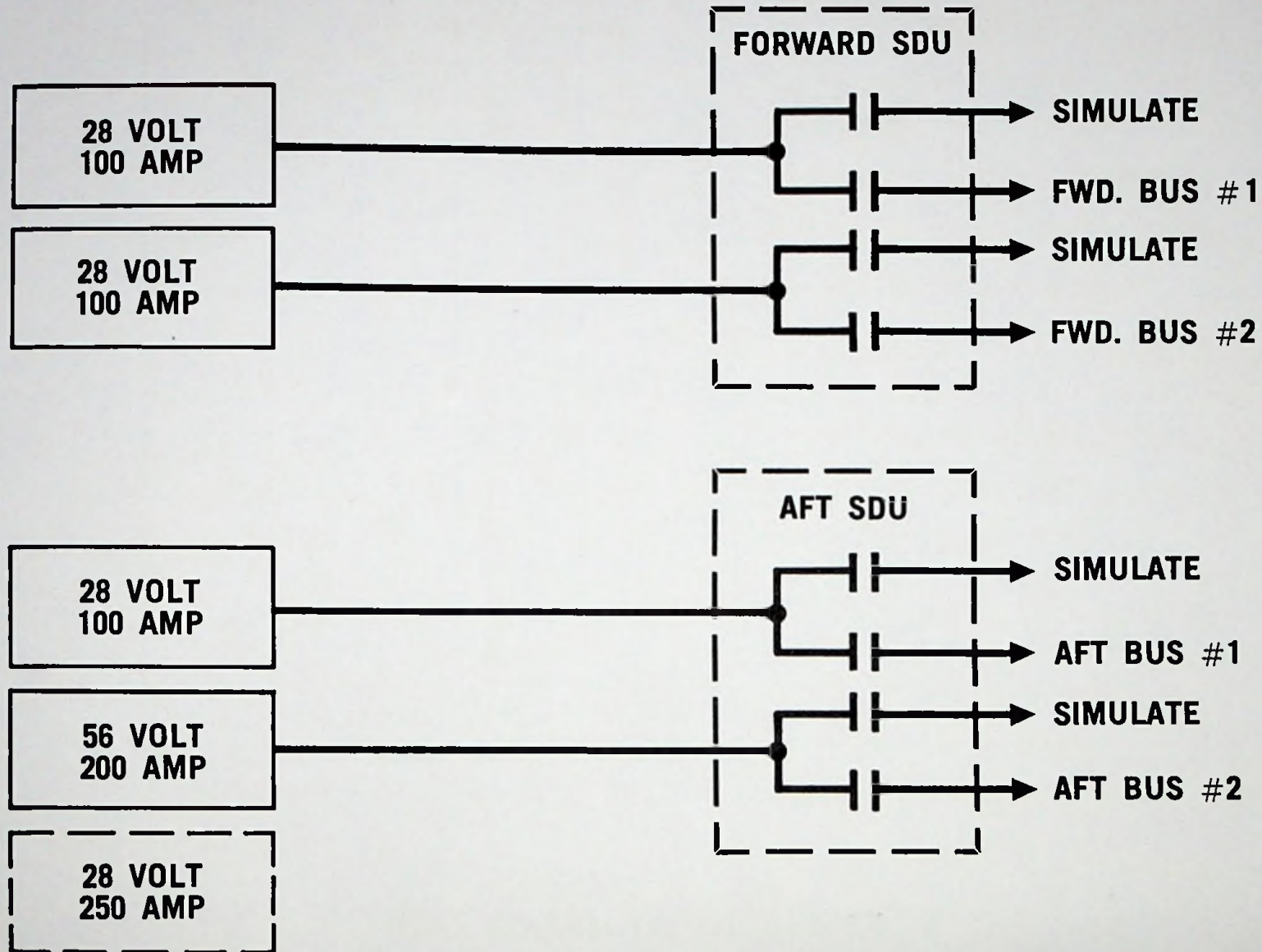
795-549A



FOR TRAINING USE ONLY

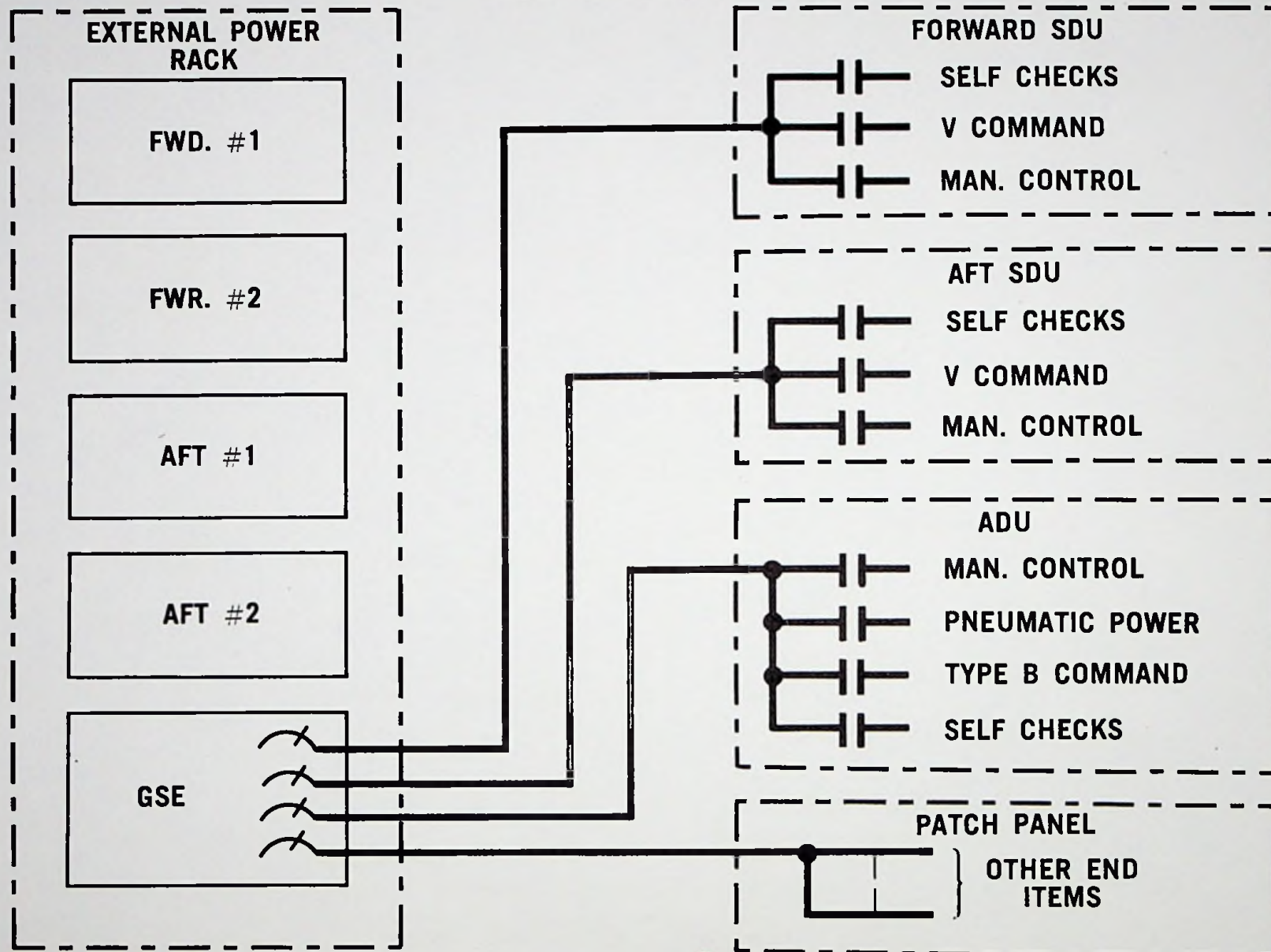
GND POWER DISTRIBUTION (VEHICLE POWER — TYPICAL)

795-223



GND POWER DISTRIBUTION (GSE POWER — TYPICAL)

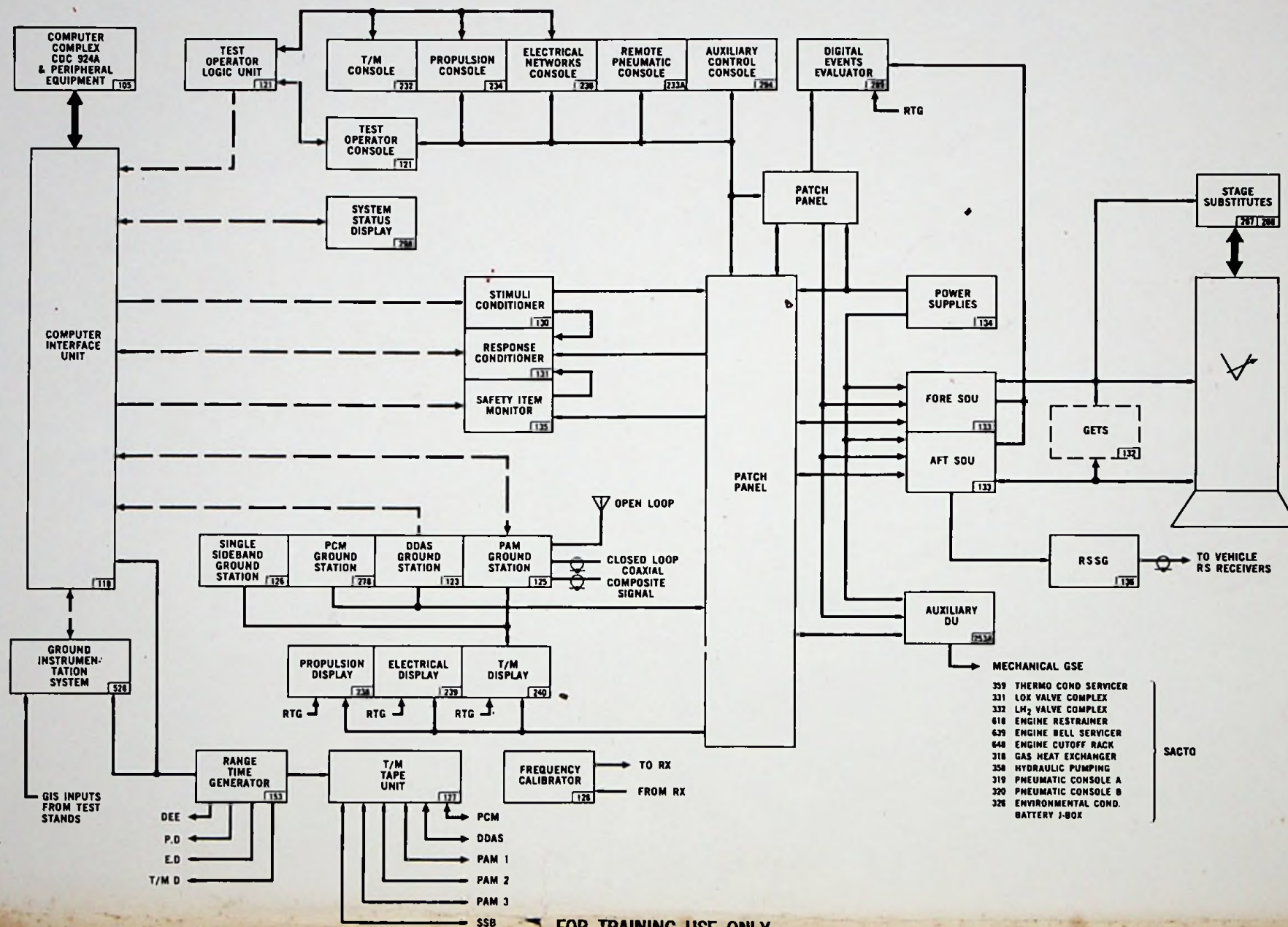
795-222



FOR TRAINING USE ONLY

S-IVB AUTOMATIC CHECKOUT EQUIPMENT

795-494D

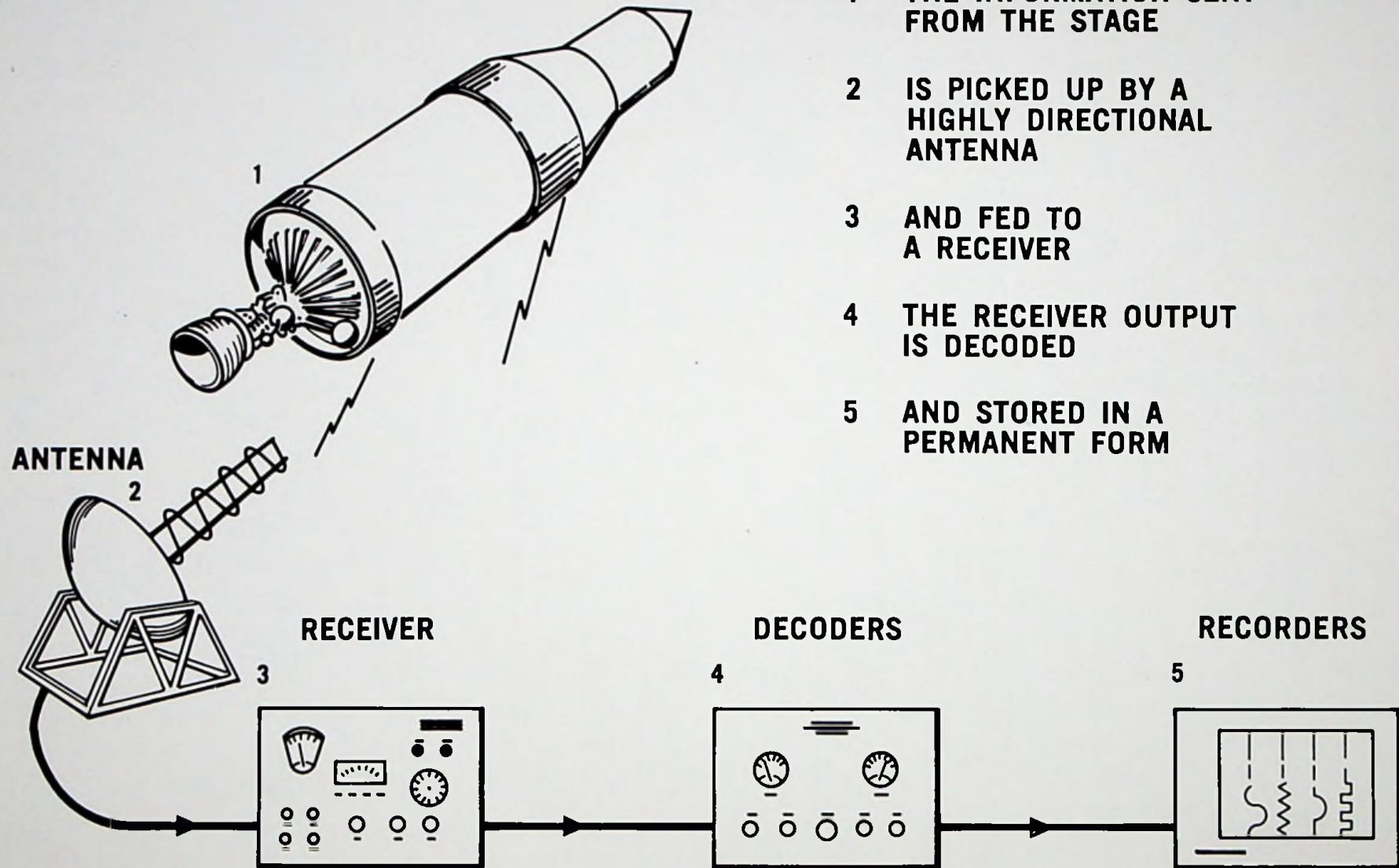


ILLUSTRATIONS

Telemetry Systems

BASIC RADIO-TELEMETRY SYSTEM

794-497



FOR TRAINING USE ONLY

TYPICAL PARAMETERS MONITORED BY T/M

795-718

PROPELLANTS

- UTILIZATION
- LEVEL (LOADING, OFF-LOADING)
- DEPLETION
- TEMPERATURE
- FLOW RATES
- VALVE POSITIONS

AUXILIARY PROPULSION

- IGNITION (ROLL, PITCH or YAW)
- HYPERGOLIC (QUANTITY)
- PRESSURES (HELIUM, HYPERGOLICS)
- VENTING

ORDNANCE

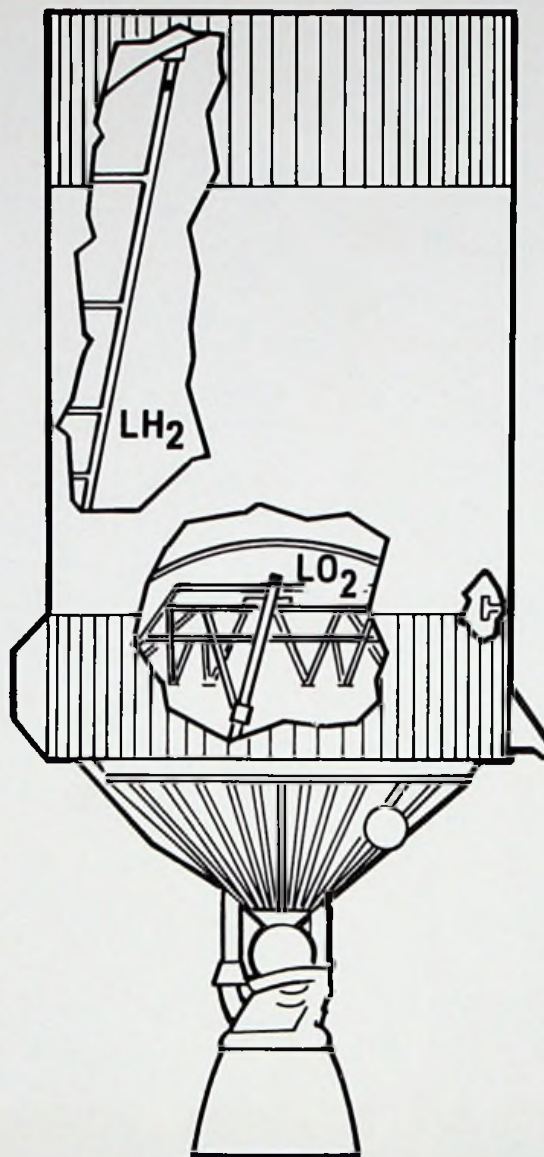
- RANGE SAFETY RECEIVERS
- EBW UNITS
- STAGE SEPARATION
- ULLAGE ROCKET

PNEUMATICS

- TEMPERATURES
- VALVE POSITIONS
- PRESSURES

EXAMPLE:

201 VEHICLE HAS 470 PARAMETERS
MONITORED BY TELEMETRY.



TANK & STRUCTURES

- PRESSURES
- VENTING
- SKIRT ENVIRONMENTS
- STRAIN
- PURGE
- ACOUSTIC — VIBRATION

ELECTRICAL

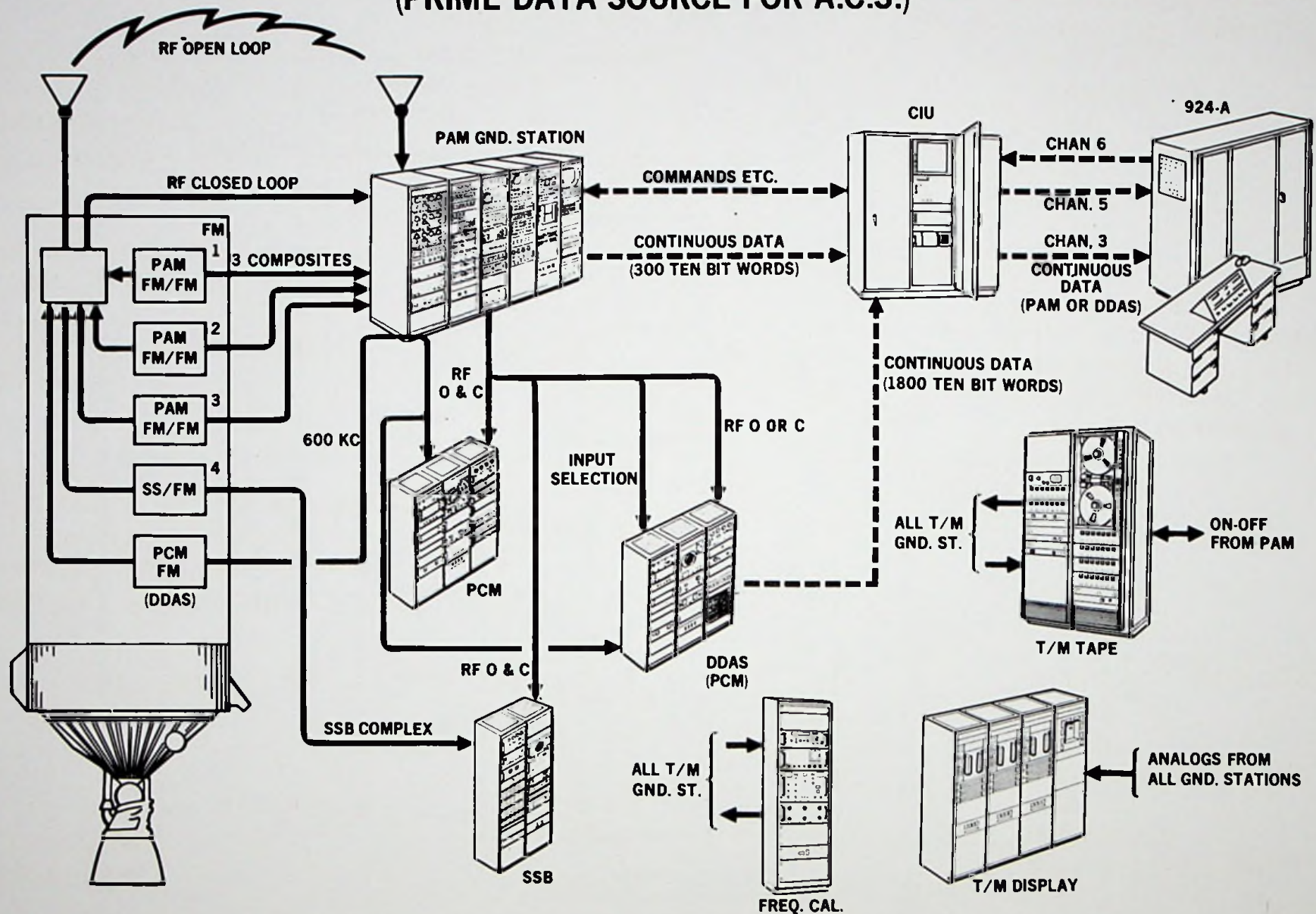
- BATTERY VOLTAGES
- INVERTER-CONVERTER
- POWER DIST. (RELAYS)
- CHILLDOWN INVERTERS
- AUX. HYDRAULIC MOTOR
- ANTENNA VSWR

ENGINE

- TEMPERATURE
- VALVE POSITIONS
- GIMBALLING SIGNALS
- ACTUATOR POSITION
- PUMP SPEEDS
- PRESSURES
- IGNITION

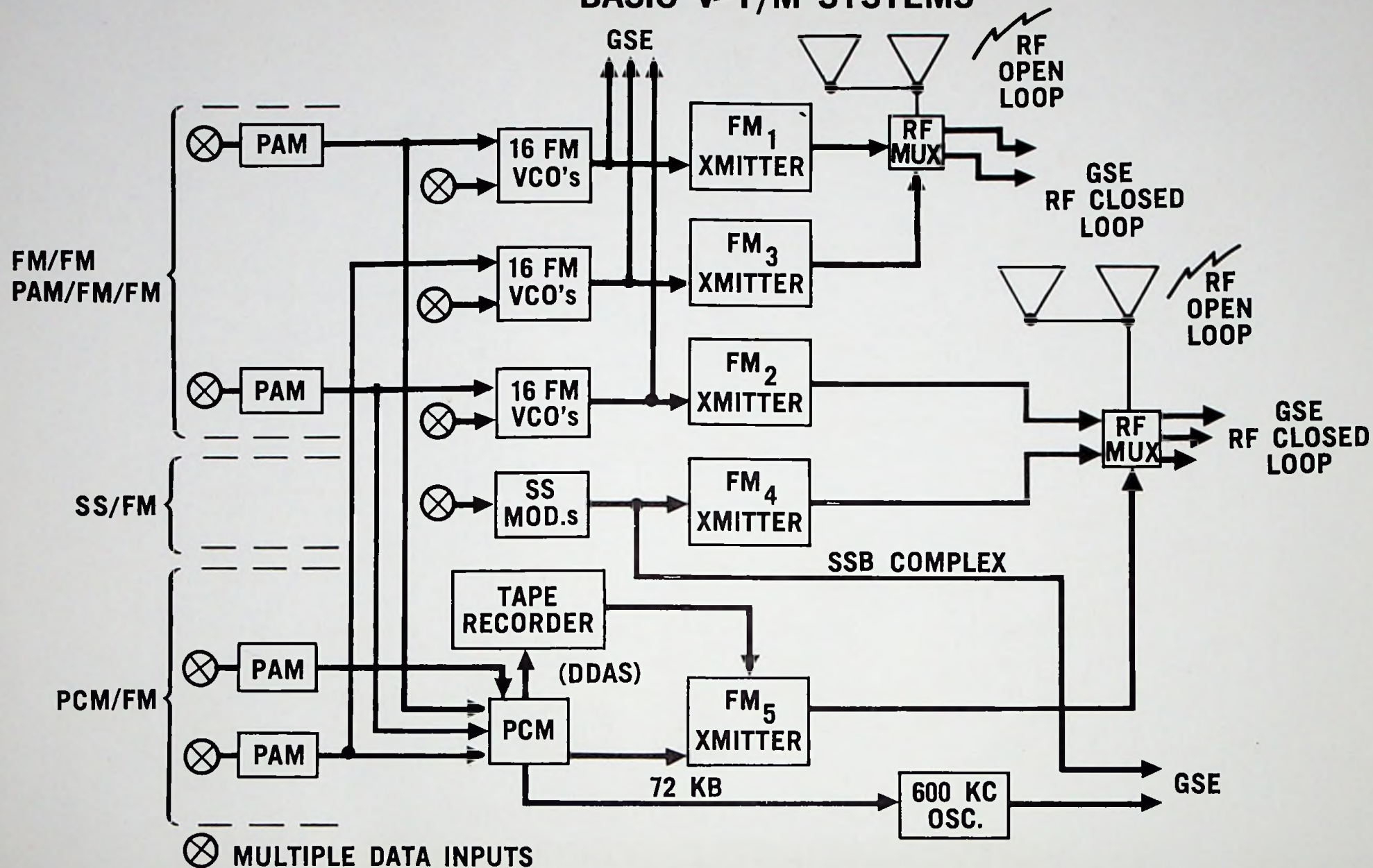
VEHICLE CHECKOUT TELEMETRY SYSTEMS (PRIME DATA SOURCE FOR A.C.S.)

795-717



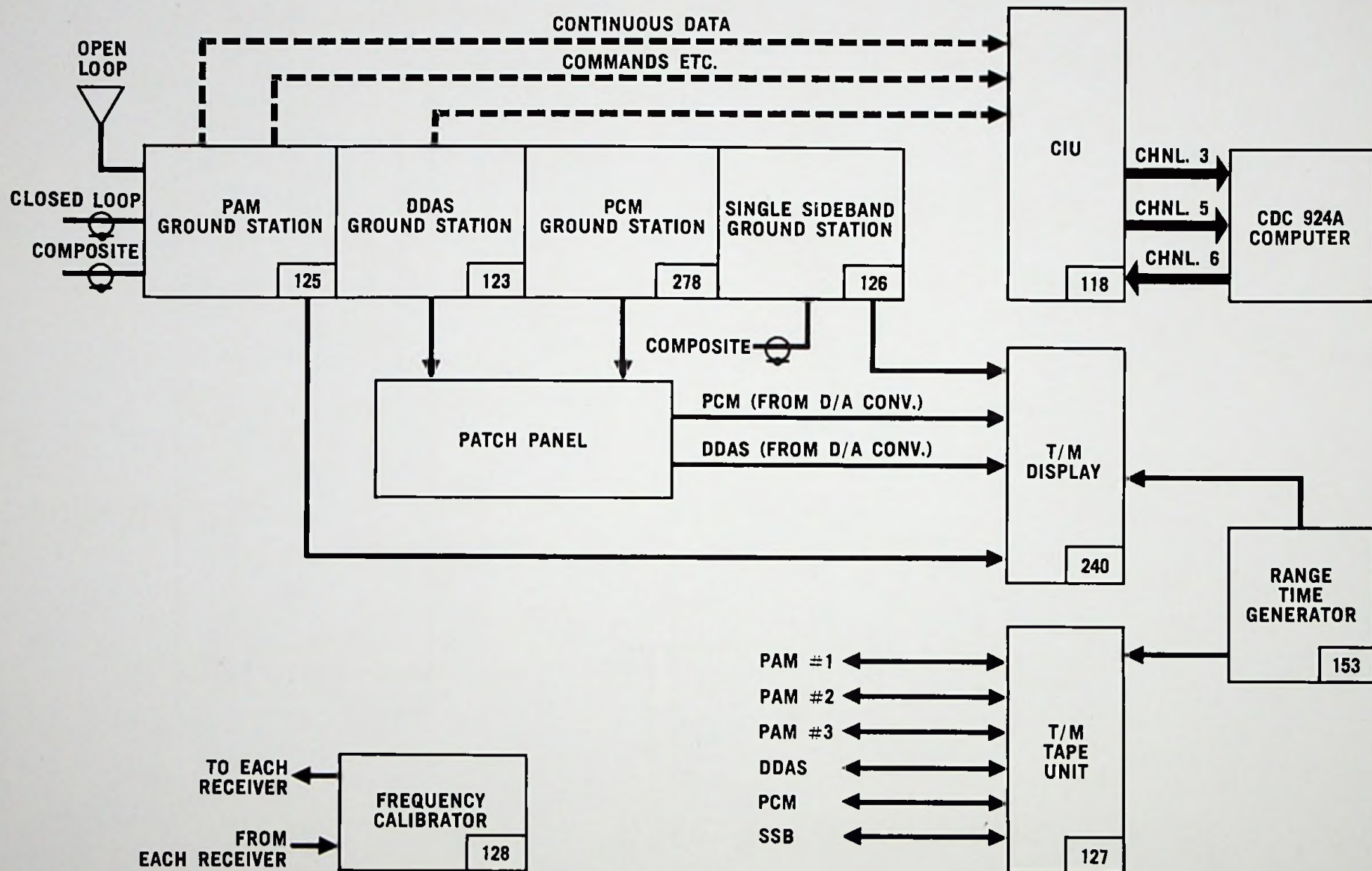
FOR TRAINING USE ONLY

BASIC T/M SYSTEMS



BASIC GROUND STATION T/M SYSTEMS

795-724



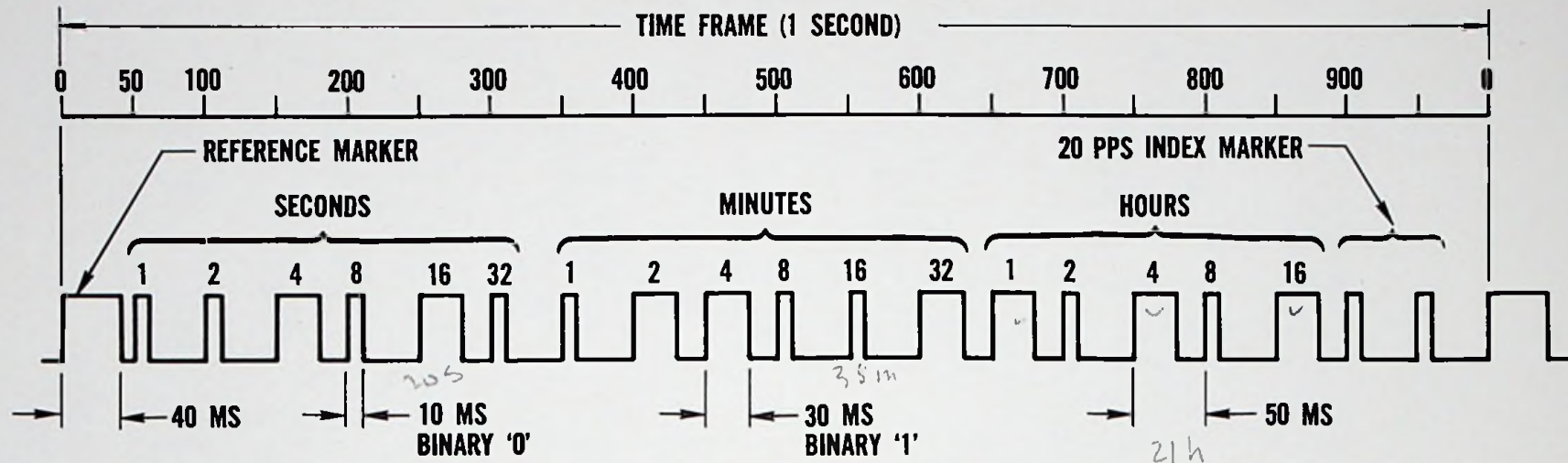
FOR TRAINING USE ONLY

ILLUSTRATIONS

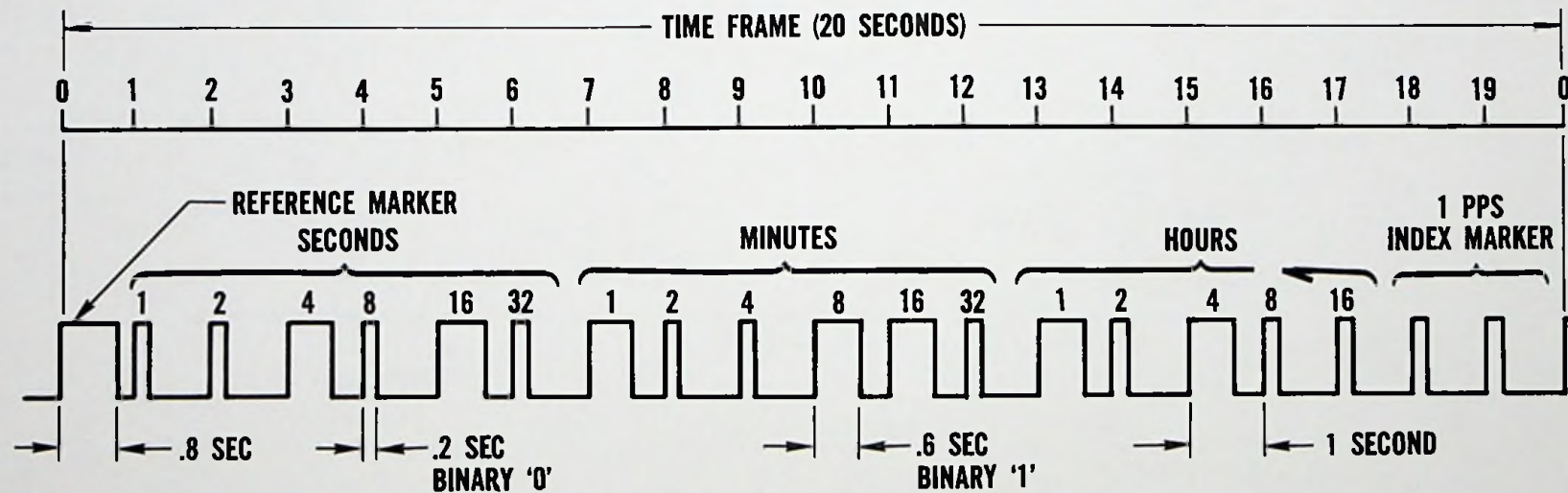
System Timing

RANGE TIME CODES (PULSE WIDTH CODING)

795-229



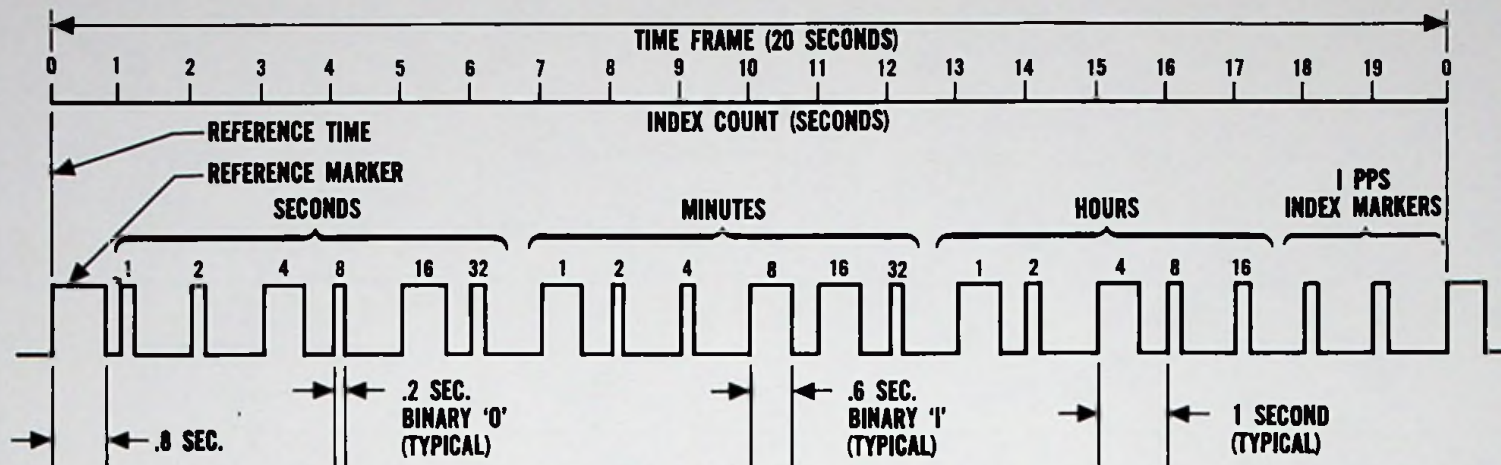
AMR C-1 TIME CODE



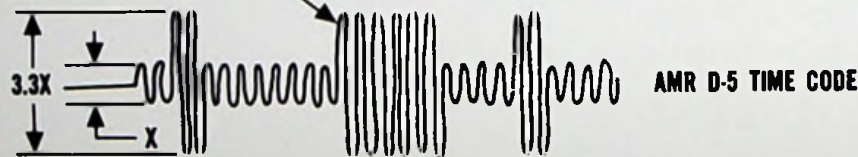
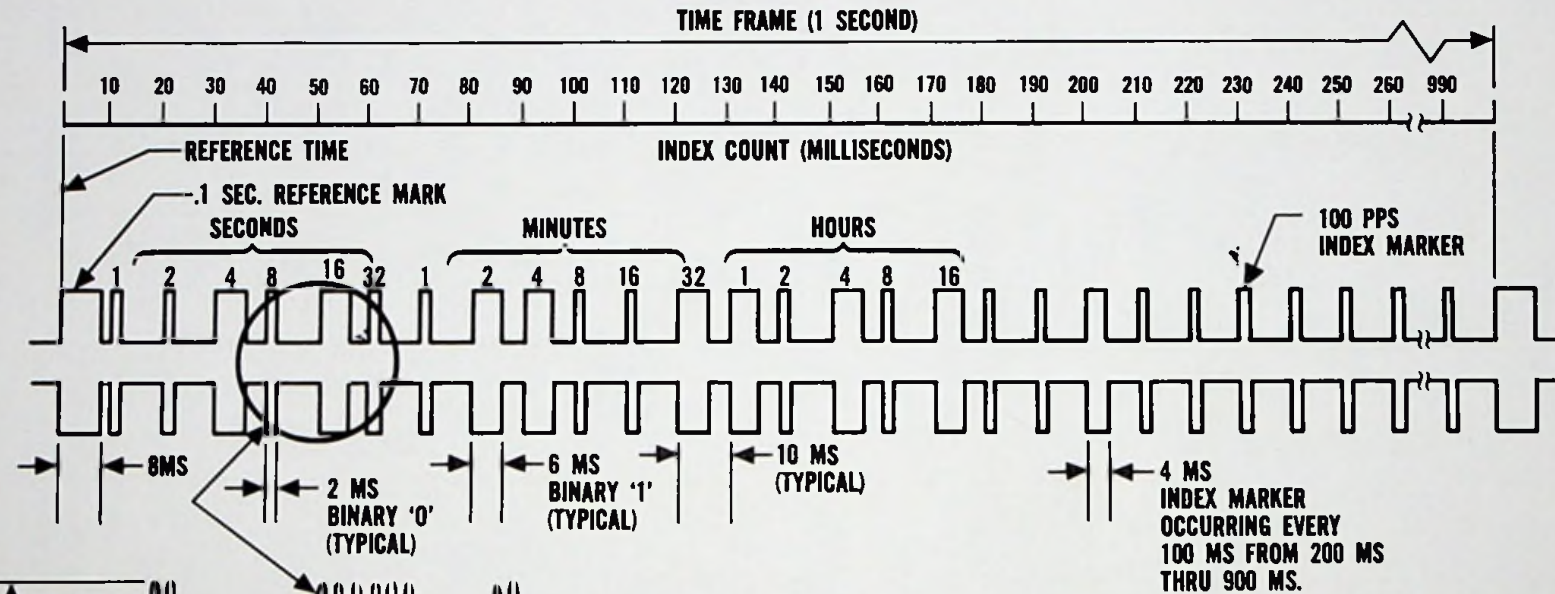
AMR B-1 TIME CODE

TIME CODE FORMAT

795-30

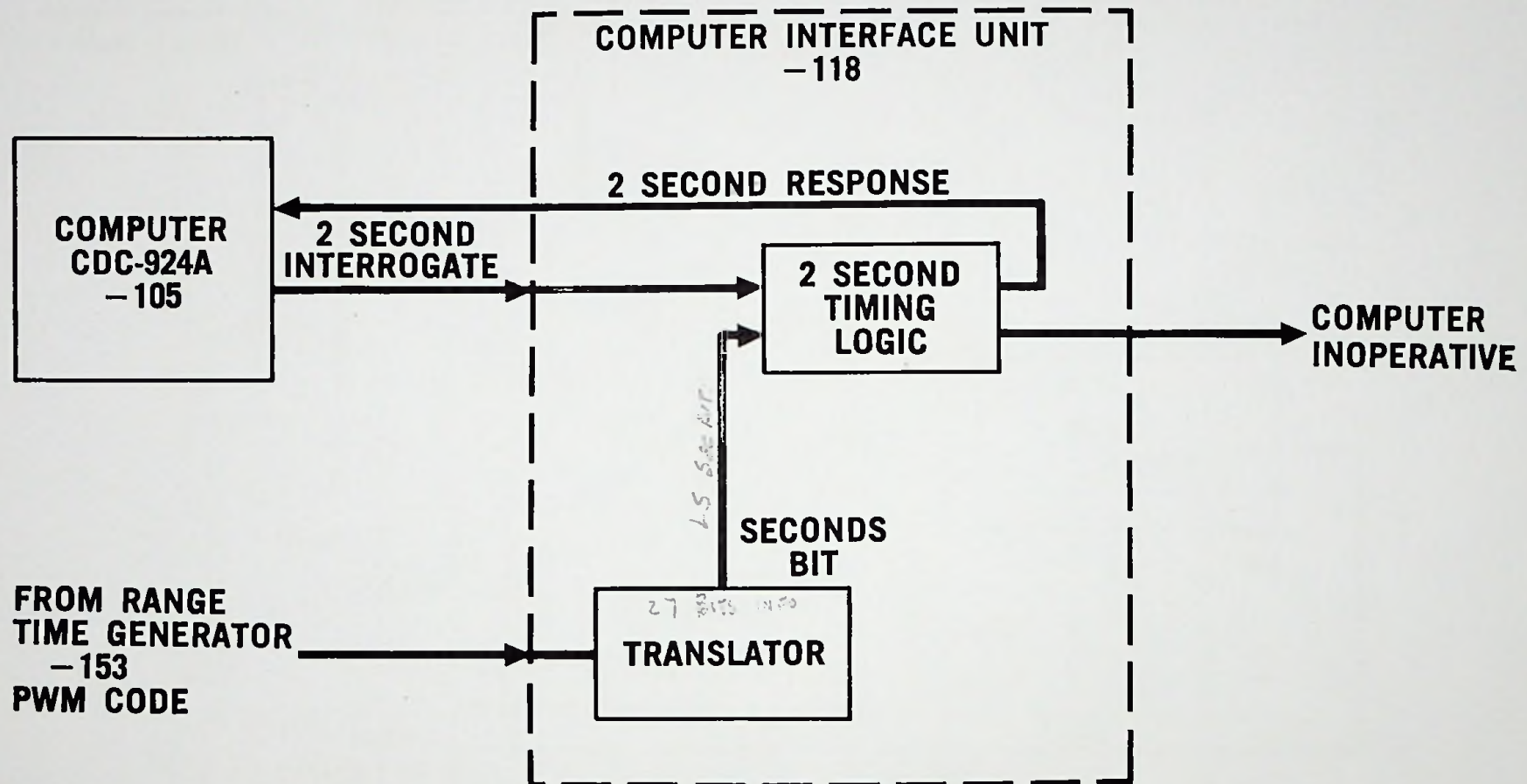


AMR B-1 TIME CODE



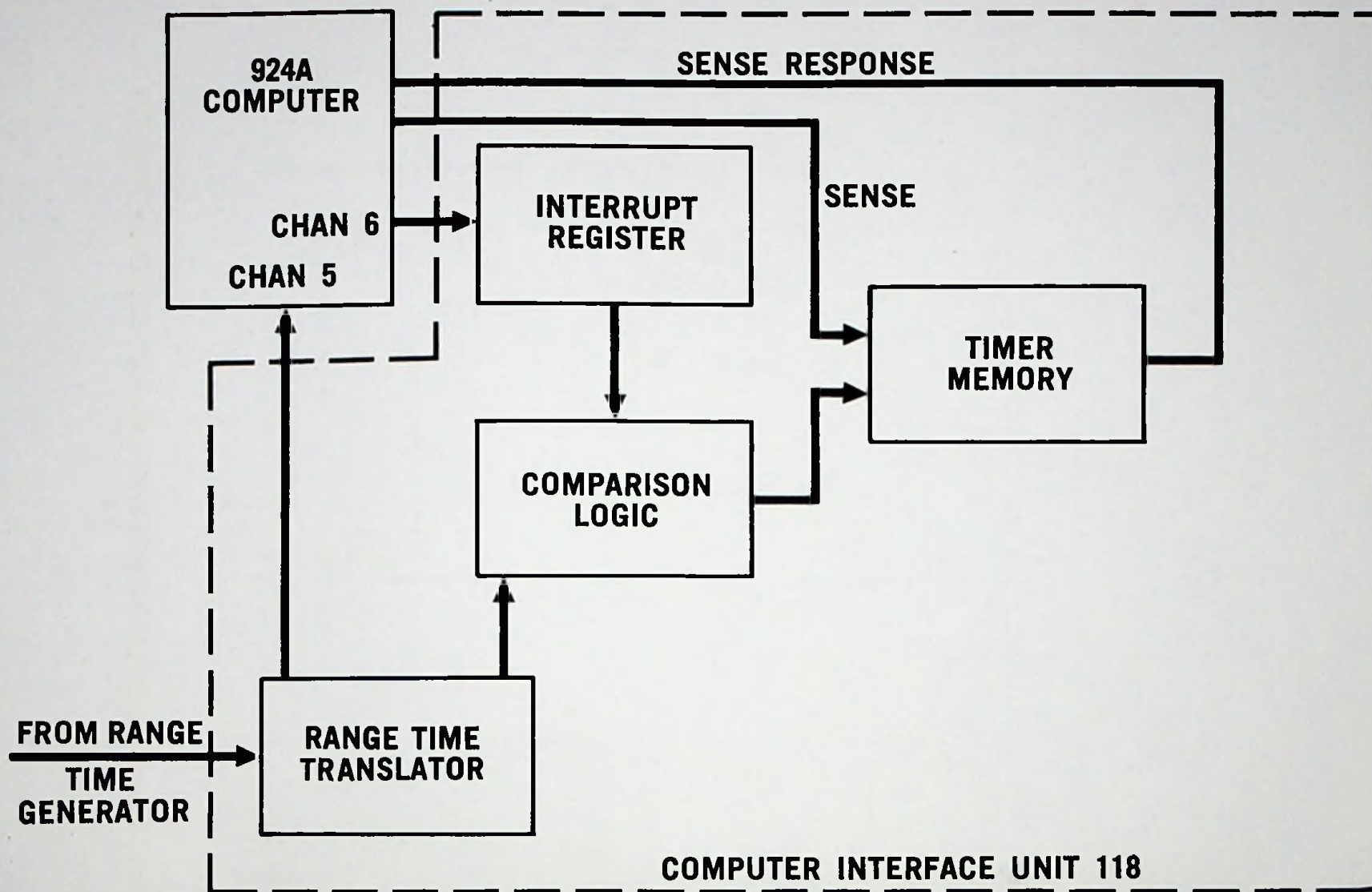
SYSTEM TIMER (2 SECOND INTERRUPT)

795-356



SYSTEM TIMER (INTERRUPT PORTION)

795-237



ILLUSTRATIONS

System Programming

PROGRAMMING

795-495

DEFINITION - ANY PREARRANGED PLAN OF COURSE OF PROCEEDINGS

**REQUIREMENT - EXCHANGES PART OF THE EQUIPMENT HARDWARE
FOR "SOFTWARE" i.e. COMPUTER PROGRAM**

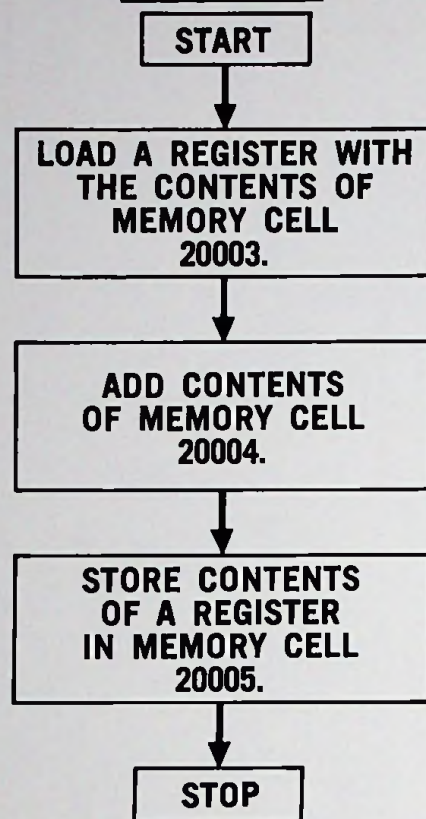
GENERAL CATEGORIES

**MICRO - SMALL OR PETTY. A STEP BY STEP SEQUENCE
OF INSTRUCTIONS**

**MACRO - LONG IN EXTENT OR DURATION. COMPILATION
OF MICRO ROUTINES**

SIMPLIFIED COMPUTER DIAGRAM SEQUENCE

795-6

FLOW CHARTCOMPUTER INSTRUCTION

LDA O 20003

ADD O 20004

STA O 20005

SLS O 00000

A REGISTER

1	2	3	2	1	2	3	2
---	---	---	---	---	---	---	---

3	5	5	3	3	5	5	3
---	---	---	---	---	---	---	---

3	5	5	3	3	5	5	3
---	---	---	---	---	---	---	---

3	5	5	3	3	5	5	3
---	---	---	---	---	---	---	---

MEMORY CELL

20003
20004
20005

CONTENTS

12321232
23212321
35533553

INSTRUCTION

LDA O 20003
ADD O 20004
STA O 20005
SLS O 00000

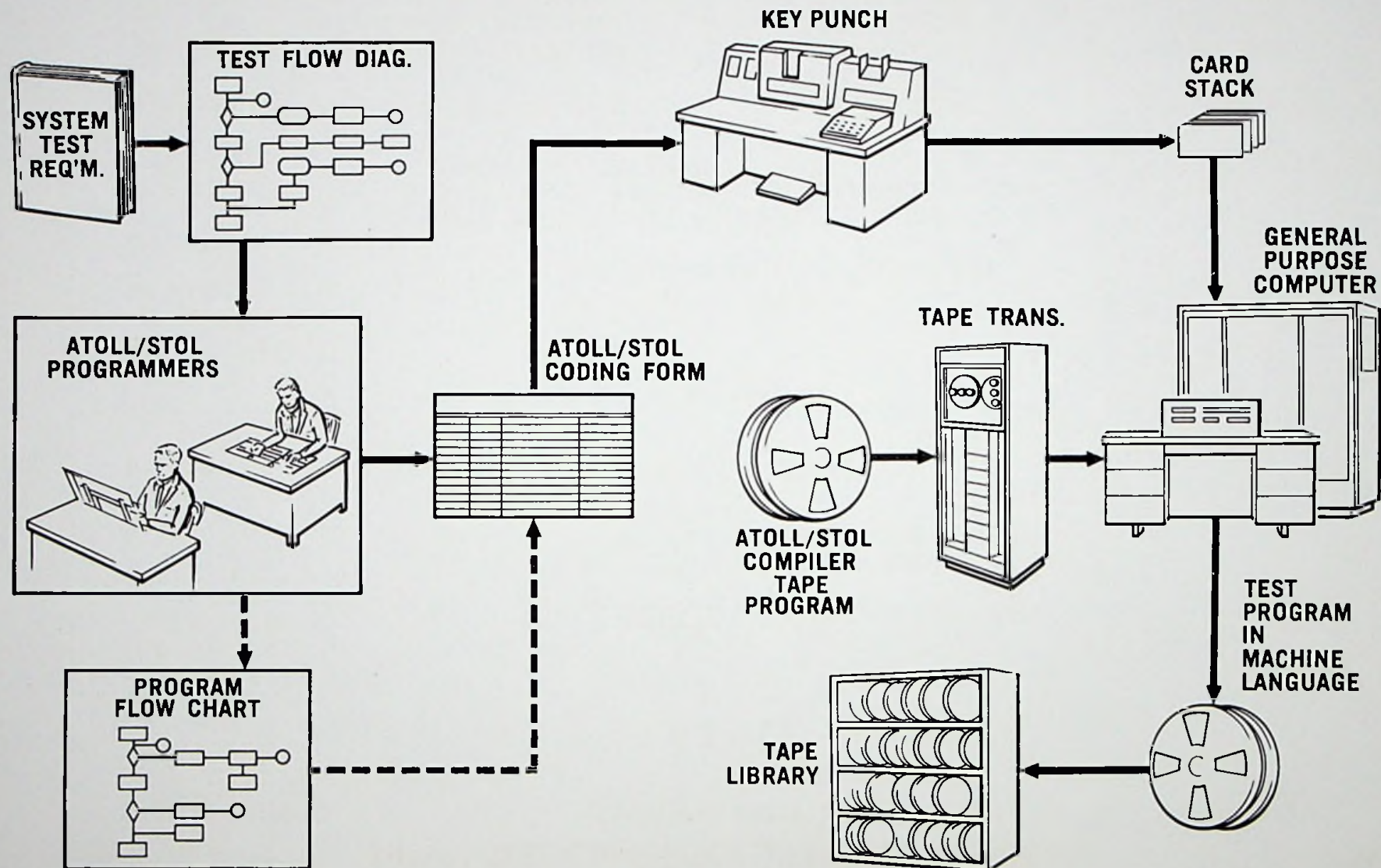
AVERAGE TIME

9.9 μ SEC.
9.9 μ SEC.
9.8 μ SEC.
7.9 μ SEC.

37.5 μ SEC.

TEST PROGRAM PREPARATION SEQUENCE

795-125A



ATOLL/STOL DEFINITION

ATOLL

ACCEPTANCE TEST OR LAUNCH LANGUAGE

ATOLL ALLOWS TEST PROCEDURES TO BE
SPECIFIED IN PRECISE, BUT READABLE SYMBOLIC
LANGUAGE STATEMENTS.

STOL

SATURN TEST ORIENTED LANGUAGE

STOL ALLOWS TEST PROCEDURES TO BE
SPECIFIED IN PRECISE, BUT READABLE, ENGLISH
LANGUAGE STATEMENTS.

ADVANTAGES OF STOL/ATOLL

795-141A

**STOL/ATOLL IS DESIGNED
TO ALLOW THE
FOLLOWING ADVANTAGES:**

- **EASE OF PROGRAM PREPARATION AND CHECKOUT**
- **EASE IN CHANGING A PROGRAM WHICH HAS PREVIOUSLY BEEN CHECKED OUT**
- **EASE OF COMMUNICATION BETWEEN THE TEST ENGINEER AND PROGRAMMER**

TYPICAL STOL/ATOLL TEST STATEMENTS (OPERATORS)

795-144B

THE ACTION TO BE PERFORMED BY A TEST PROCEDURE STATEMENT IS INDICATED BY AN OPERATOR. EACH STATEMENT STARTS WITH AN OPERATOR.

<u>NON ACTION</u>		<u>BI-LEVEL</u>		<u>ANALOG</u>	
<u>STOL</u>	<u>ATOLL</u>	<u>STOL</u>	<u>ATOLL</u>	<u>STOL</u>	<u>ATOLL</u>
BEGIN	BEGN	SET	DISO 1	APPLY	APLY
DEFINE	DEFN	RESET	DISO 0	MEASURE	TEST
RESERVE	RESV	TURN ON	DISO 1		
END	END	TURN OFF	DISO 0		
		OPEN	DISO 1		
		CLOSE	DISO 0		

<u>CONTROL</u>		<u>OUTPUT</u>		<u>TIME</u>	
<u>STOL</u>	<u>ATOLL</u>	<u>STOL</u>	<u>ATOLL</u>	<u>STOL</u>	<u>ATOLL</u>
IF	TEST	DISPLAY	RECD	DELAY	GATE
GO TO	GO TO	TYPE	RECD		
EXECUTE	EXEC	PRINT	RECD		
HALT	SENI				
RETURN	RETN				

A. TYPICAL SYSTEM OPERATION

Prior to the use of the Automatic System with the stage to be tested, several preliminary operations are required. These are both automatic (computer controlled) and manual in nature. Some of these operations are:

1. Turn on and verify ground power supplies (manual)
2. Verify proper patch panel installation (visual)
3. Self-check GSE (automatic/manual)
4. Turn on and verify facility pneumatics (manual)
5. Input and verify computer executive and utility routines (automatic)
6. Install test program, stage history (if available) and test results tape on tape handlers

Testing is initiated by the test operator by inserting a test request from the digital control console. This test request is a six digit number which is inserted by use of the keyboard on that panel. In general, this number would take the form XX0000, with the first two digits varying from 10 to 77 octal.

The actual entry of the test request into the computer via the Computer Interface Unit will cause the computer to find the requested test and read it into memory if it is not already there. The computer will also execute the first phase of the test requested at this time. This phase is an initial condition search.

The initial condition search consists of a series of measurements and comparisons to determine if the state of the system, including the stage and facilities, is such that the test may be processed. No overt action is taken during this phase, but all discrepancies are noted. At the end of the search the information relating, whether the initial conditions are met or not, and if not, what conditions are not met, is displayed to the operator on the Systems Status Display and the typewriter.

If the initial conditions are met, the test may be caused to proceed by the activation of the "Resume" switch on the Digital Control Panel (DCP). If the initial conditions are not met, several alternatives are open to the operator, depending upon the circumstances.

If the condition or conditions which are not met are not controlled by the automatic system (e.g., facilities functions, power supplies, etc.) the condition can be corrected by operation

of the necessary controls at the proper control panels. These control panels would generally be either facility-type panels or local control panels on the GSE.

If the condition or conditions which are not met are controlled by the automatic system, several approaches to the problem exist, depending on the nature of the functions involved. In some cases, parts of test programs may exist which can be called upon to establish the necessary conditions. The test operator must comply with the following procedure to call up the necessary test programs:

Operate the "Store Program Point" switch on the DCP. This will cause the computer to store the present test number (the hold state the system is in at the end of the initial condition search in this case) and stand by for another test request from the test operator. The new test request is entered in the same manner as the original request (i.e., through the keyboard) and the computer will react to it in the same manner (i.e., call in the test and perform an initial condition search). It should be noted that the new initial conditions must also be met in order to proceed. If conditions are met, the test is caused to proceed as before using the "Resume" input. If they are not met and are not controlled by the automatic system, they should be established manually and the test conducted. If the condition or conditions which are not met are controlled by the automatic system, there are again several alternatives open to the operator. One of these, as it was with the original test, is that another test program may be used to establish the necessary conditions. However, in this case the procedure to call up this new program is to "Clear" the existing program and call up the new program. Assuming the initial conditions for this new program are met, it is then processed to establish the necessary conditions. Upon completion of this operation, the new program is cleared as before by operating the "Clear" switch on the DCP. The old test is then requested through the keyboard as before. It should be noted at this point that the original test program point is still stored. The operation of requesting or clearing tests when a program point is stored only affects the new tests requested, and does not affect the original test. When all the tests are processed that are required to establish the necessary conditions for the original test, or when some other method is decided upon, the original program point is restored by pushing the "Store Program Point" switch again.

A second alternative is to make use of the capabilities provided through the CDC 161 Typewriter. A portion of the STOL (Saturn Test Oriented Language) compiler will be modified as necessary and kept in memory (or on tape from which it may be read into memory). This program will allow the test operator to enter

certain STOL statements into the computer through the typewriter. Such statements might be "Open LOX Vent Valve," "Measure LH₂ Tank Pressure," etc. The special program, designated the OLSTOL (On-Line STOL) compiler, will translate the typewriter input into the necessary machine language instructions. When the necessary translation has taken place and the computer is ready to execute the statement, a word will be typed out on the typewriter to inform the operator of the fact. The statement is actually executed either by operating the "Resume" switch on the DCP, or typing in an appropriate word on the typewriter. Test statements input on the typewriter are executed in the same manner as normal test statements. However, no initial condition search is done, nor would the Safety Item Monitor be updated if the function were a safety item. However, a problem caused by the latter fact would be very rare.

A third alternative is to put the automatic system in its manual mode and establish the conditions manually. This capability only exists for certain functions, since manual control is provided to safe and shut-down the system, not to checkout the stage. Since none of the safety and self check features of the automatic system inherently programmed into the computer operation would be used during this type of operation, use of the system in this manner must be done exercising extreme caution, and should not be done if one of the first two alternatives is available.

A fourth alternative is to modify the test program such that the condition or conditions which are not met are ignored (effectively deleted from initial conditions requirements), such that the initial conditions are met, i. e., those that remain are met. It must be realized that there will almost certainly be at least one, if not many, holds during the test which result from the ignoring of an initial condition. Hence, the operator must be prepared to work his way around that situation when it occurs. Since initial conditions are established for many different reasons, the operator must exercise good judgment and extreme caution when choosing this alternative, and hence, it should not be chosen unless other alternatives, including not running the test, are unacceptable.

Once initial conditions are met, the test is then processed by operating the "Resume" switch on the DCP. Four modes of operation are available to the operator. These are:

1. Normal
2. Conditional Stops Enabled
3. Conditional Holds Enabled
4. Single Statement Operation

The normal mode of operation is per the test program with operator control from the DCP in the event of some unusual event. That is, the test is processed as it has been preprogrammed, with the

operator monitoring the operation, and exercising his "Hold," "Stop," or "Emergency Stop" capability in the event it is necessary. If the system under test meets the test requirements, the test would be processed and completed without further operator action. If the system does not meet the test requirements, the fault or faults would be identified and further action would then be a function of how the test program and the circumstances are at the time.

"Hold - Operation of the "Hold" switch causes the computer to continue to the next hold point in the test program and halt there. A hold point is generally defined as a point in the program where the stage is in a quiescent state; (i.e., functions are not being performed that result in a changing state such as pressurization, loading, gimbaling, etc.) It is implied that a hold is not necessarily a state in which the stage may be kept for long periods of time, nor is it necessarily a state in which personnel may be in the vicinity of or do work on the stage. It is further implied that a hold point does not appear in the middle of a logical sequence of operations; (i.e., a hold point would not appear between a command and a measurement used to verify the result of that command or between a measurement and a conditional statement - comparison - that determines the validity of the measurement).

"Stop" - Operation of the "Stop" switch causes the computer to continue to the next hold point in the test program and then to reset to the last stop point. If the routine is not posted in the program, the computer will proceed forward to the next stop point. A stop point is defined as a point at which the stage may be left for an extended period of time. It is implied that the stage is in a condition such that personnel may work on the stage in order to repair, replace or install parts thereof.

"Emergency Stop" - Operation of the "Emergency Stop" switch causes the computer to immediately jump to an emergency shut-down routine designed to put the stage in a safe condition. It is further defined that a test program may not be "resumed" after an emergency stop, but must be "cleared and restarted."

The "Conditional Stops Enabled" mode of operation allows the operator to process a test in relatively large sequences, but still causes the test to stop at discrete, definable places in the test. Each stop point, as defined previously, is also considered a conditional stop. When the "Enable Conditional Stops" switch is operated, it causes the computer to operate in such a mode that the test program will halt each time it reaches a stop point in the test program. Depending upon the test program being processed,

this may result in the test being halted one or two times during the run, or in other cases, hundreds of times. The computer will continue to process tests in this manner until the switch is operated a second time, at which time it will return to the normal mode of operation.

The "Conditional Holds Enabled" mode of operation allows the operator to process a test in a much smaller increment than that defined above for the "Conditional Stops Enabled" mode. When the operator establishes a "Conditional Holds Enabled" mode by pushing the equivalent switch on the DCP, the computer executes the test program. As in the case of conditional stops, each hold point, as previously defined, is also treated as a conditional hold. Since, as was also noted above, hold points tend to fall in between functional operations, this mode of operation allows the operator to effectively step the test program in functional groups. The test engineer who prepares the test program can then control the manner in which he would like to operate when in this mode by the appropriate selection of hold points, as long as it is consistent with other requirements with respect to the establishment of hold points in the test program.

The "Single Statement Operation" mode is primarily designed for the checkout and debugging of computer programs, principally the executive and the test programs themselves, after compilation. This mode is established by first storing the program point as previously described and then calling up a special test request number which will be recognized by the computer as establishing this mode of operation. The computer will then actually process the test program test statement by test statement. The computer is caused to execute the next step upon the activation of the "Resume" switch on the DCP. Since this mode of operation almost certainly will result in a series of fault indications, based upon the time dependent statements within the test program, it should be used with caution, and only by personnel who are thoroughly familiar with the programming aspects of the computer itself.

In addition to all of the alternatives open to the test operator during the operation of a test, another alternative is available which bypasses the computer. This is the "Computer Word Simulator Panel" located as a part of the Test Operator Console. This panel consists of twenty-four (24) toggle switches and twenty-four (24) indicators along with several other control toggle switches. When this panel is activated, the twenty-four (24) bit word input into the Computer Interface Unit from channel six of the computer is replaced by a twenty-four (24) bit word which is created by placing the toggle switches in appropriate positions. Therefore, any output that can be sent from the computer on this channel, which is the main output channel of the computer for system

operation, can be output from this panel. This capability is primarily intended for troubleshooting the automatic system, but can be used by the test operator to cause a function to be controlled when other alternatives are not feasible. As in the case of switching to manual control with the automatic system, this mode of operation must be accomplished with caution since none of the self-checking and safety circuits programmed into the computer are available when the computer is bypassed. The computer itself must be prohibited from outputting on channel six during this operation.

The twenty-four (24) bit word that normally is input to the computer from the Computer Interface Unit can be switched such that it appears on the twenty-four (24) indicators supplied on this same panel. Again, the inputs to the computer on channel five are disabled during this type of operation.

As can be seen from the above description, a great many alternatives are available to the test operator. He has considerable versatility with which to meet unforeseen problems. Experience with the equipment in the Systems Integration Laboratory will cause some changes to the presently held theory of operation and will no doubt uncover further capabilities not heretofore recognized. During normal operation when everything, including the system under test is working normally, the operator has very little to do except monitor the operation and call up the next test. However, when things do not go normally, and problems are encountered which were not foreseen, and therefore not accounted for in the test program, he must make full use of the capabilities built into the system and programs, to successfully locate and identify to the extent made possible by stage and checkout system design, those faults encountered.

During normal operation, the computer causes the automatic system to control the stage under test by sending outputs through the Computer Interface Unit to the Stimuli Conditioner. For all bi-level commands this output takes the form of a twenty-four bit word. The format for this word is:

Stimuli	Bi-Level	Group	Relay	1/10
Conditioner	Type 1	Select	Select	
End Item	Command	1/63		
Address	Desig.			

0 0 0 0 1 1 G G G G G G K K R R R R R R R R R R

The Computer Interface decodes the end item address, 00001, and shifts the remaining nineteen bits into the appropriate register for transmission to the Stimuli Conditioner. In addition, the Computer Interface Unit causes a one to appear before the Bi-Level Type 1 Command Designation Bit which acts as the control bit for

the transmission. The format of the digital information that appears in the register in the Computer Interface Unit for transmission to the Stimuli Conditioner is then:

Control	Bi-Level	Group	1/4	Relay
Bit	Type 1	Select		Select
	Command	1/63		1/10
	Desig.			

1 1 G G G G G G K K R R R R R R R R R R R

When the Stimuli Conditioner senses the lead one in the first flip flop of the output register, it clears its input register and starts shifting in, in series, the information. It also sends a command to the Computer Interface Unit causing the CIU to start shifting out this information synchronously with the Stimuli Conditioner. This synchronism is obtained by keying both shifting operations off of a "clock" line which is supplied by the Computer Interface Unit to the Stimuli Conditioner.

When the lead one, which has been shifting through the Stimuli Conditioner input register followed by the rest of the word shown, reaches the last flip flop in the Stimuli Conditioner input register, the shifting is stopped in both the Stimuli Conditioner and Computer Interface Unit.

Upon completion of the shifting operation, the Stimuli Conditioner starts decoding the data word. The first bit is interpreted to determine if the word should be decoded as a bi-level command or an analog/bi-level Type II command. Once interpreted as a bi-level Type 1 command, the group select bits are decoded and the appropriate line is energized. The relay select bits are decoded simultaneously, and the appropriate one of forty lines is energized. The one of sixty-three lines are connected to drivers which drive zero volts with respect to minus twenty-eight volts dc. The one of forty lines are connected to drivers which drive minus twenty-eight volts with respect to zero volts dc. Therefore, as a result of the input digital word, two lines going to the selected relay matrix are driven on, one on each side of the matrix, and the relay selected begins to operate.

Upon completion of the output to the Stimuli Conditioner, the computer immediately goes into an echo checking routine to determine that the correct two lines out of the Stimuli Conditioner have been selected. Each of the one-hundred and three lines which go to the matrices are brought back to the Response Conditioner for checking. The computer sends out data requests to the Response Conditioner through the Computer Interface Unit for each group of ten echo checking lines it must measure. Special circuitry in the Response Conditioner converts the zero and minus twenty-eight volt signals appearing on the two lines

selected, plus the off signals appearing on the non-selected lines, into the standard system logical levels which can be transmitted to the computer.

In order to gather bi-level response data from the system, the computer outputs a twenty-four bit word to the Computer Interface Unit. The format for this word is:

Response	Bi-Level	Bi-Level	Not Used
Conditioner	Response	Group	
End Item	Designa-	Selected	
Address	tion	1/255	

1 0 1 1	1	A A A A A A A A	0 0 0 0 0 0 0 0 0 0
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The Computer Interface Unit treats this output from the computer in the same manner it did the initial output for the Stimuli Conditioner. The end item address is decoded and the information shifted into the appropriate register for the Response Conditioner. Again, the end item address is dropped and the leading one added for control purposes. In this case, the eleven not used bits are also dropped such that only those bits containing information are shifted. The information is then shifted serially to the Response Conditioner using the same technique described before for the Stimuli Conditioner.

Upon completion of the shifting operation, the information is decoded by the Response Conditioner. The Bi-Level Response Designator is decoded to indicate which of the two multiplexers within the Response Conditioner are to be controlled by the eight bit select. The eight bits are then shifted into a register which controls the multiplexer, in this case the bi-level multiplexer, which has as its inputs all of the bi-levels into the Response Conditioner. The proper group of ten bi-levels is selected by the multiplexer and shifted into the Response Conditioner output register. In addition, the ten bit digital word which was shifted into the Response Conditioner is also put in the output register. When both the above noted shifting operations are completed, the lead one, which now appears in the output register of the Response Conditioner, causes the Computer Interface unit to start shifting in the information from the Response Conditioner. The information, which is now made up of the original data request and the bi-level group consisting of ten bits of bi-level information, is shifted into the Computer Interface Unit into a register which corresponds to the Response Conditioner outputs. The shifting is completed in the same manner as information going out of the Computer Interface Unit.

Upon completion of the shifting operation, the Computer Interface Unit drops the lead one, and adds on the end item address for the Response Conditioner. The resulting twenty-four bit word is then shifted into the computer. Upon receipt of this word, the

computer first checks the address to insure that the same address that was sent out appears on the returned data. This checking operation assures the computer that there was no transmission error in this part of the data either going to or coming from the Response Conditioner.

The operation described above for gathering bi-level data is repeated for each bi-level group until all of the information required to check the bi-level output of the Stimuli Conditioner is in the computer. The computer then checks the state of each of the one hundred and three lines coming back from the addressed matrix to assure that the correct two, and only the correct two, driver lines are on. This entire operation takes approximately 1.7 milliseconds, which is less than the lower limit of operating time for the relays in the distribution units which make up the matrix being driven by these signals. Therefore, if a wrong line has been driven due to an error anywhere in the bi-level command generating system, the signals can be turned off prior to any damage being done, and in most cases, prior to the relay ever operating. In this manner, damage to equipment or personnel that might result from an erroneous command being generated due to a transmission or decoding failure in the bi-level generation equipment is avoided without adding any additional hardware in series with that generation equipment that would degrade the operation thereof.

When an appropriate period of time has passed after the echo checking of the bi-level command generation for the electromechanical device being operated to have operated, another bi-level response request would normally be sent out to check whatever talkback was expected from the operation of the device. This talkback is gathered by the computer in exactly the same manner that the echo checking information was gathered. In fact, the response conditioner, except for design considerations with respect to the level and polarity of the signal being processed, makes no distinction between any bi-level routed to it. The requesting, multiplexing, and returning operations are identical, with only the contents of the eight bit bi-level response group address being changed.

Certain parameters within the system are classified as critical and are routed to a Safety Item Monitor for continuous monitoring. In the case of the bi-level responses, which are classified as critical items, the computer establishes the required states of the bi-levels by transmitting a series of twenty-four bit words to the Computer Interface Unit for re-transmission to the Safety Item Monitor. In the case of analog responses a level sensor is used which may be set up to give an output when the value is out of tolerance. This tolerance limit is preset in the level sensor and is established as an upper or lower limit, depending upon a

switch position on the level sensor. Therefore, instead of establishing required states, the computer enables or disables the output of the level sensors. In the case of both bi-level and analogs, the format used by the computer to control the operation of the Safety Item Monitor is the same. The format for this word as it appears in the output register of the Safety Item Monitor:

Control Bit	Safety Item Group Select	Required State
1	G G G G	D D D D D D D D D D

The digital information is transmitted to the Safety Item Monitor in the same manner as described above for other end items. As noted above for data requests, the un-used bits in the computer-generated twenty-four bit word are discarded within the Computer Interface Unit prior to transmission to the Safety Item Monitor. When the shift operation is complete, the Safety Item Monitor decodes the four group select bits and shifts the ten bits designating the required state into 1 of 15 ten bit registers as indicated by the group select. When either a bi-level response is opposite from the computer required state or an analog value exceeds or is less than the pre-established limit, whichever the case may be, the Safety Item Monitor will generate an interrupt signal to the computer. Upon receipt of this signal the computer will stop whatever it is doing and jump to a sub-routine designed to process safety item interrupts. The outputs of the one hundred bi-level comparison circuits and the fifty analog comparison circuits are sent to the Response Conditioner as bi-level signals. The computer may then send the appropriate data requests to the Response Conditioner in order to ascertain which one or more critical items caused the interrupt. The action taken by the computer as a result of the interrupt will be controlled by parts of the test program and is dependent upon which item caused the interrupt and the status of the system at that particular point in the test program.

Information gathered by the computer during the test program may be displayed in various forms and in various places. In general, all information can be displayed on the System Status Display in engineering units. This display takes the form of a slide background with computer-generated dynamic data overlaid. In the case of a bi-level parameter, the computer will request the information from the Response Conditioner as before and through a look-up process in tables internal to the computer will convert the resulting 1 or 0 into the engineering term which describes that stage. This term is limited to four characters, which results in abbreviations used to describe some of the possible states. For example, a valve may be "OPEN" or "CLSD"; a power bus may be "ON" or "OFF", etc. For analog parameters the information is again acquired from its source and converted into engineering units

through appropriate conversions factors stored within the computer. The value of the analog is displayed in four decimal digits on the status display.

In addition to the status display numbers, Numerical Readout Panels exist at the test stations which allow individual parameters to be displayed in engineering units. The process of gathering these values for display is the same as for the System Status Display except that the required values are gathered individually and do not appear as overlays on a slide. Also provided in the system are strip charts and sequence recorders which allow display and recording of both analog display and recording of both analog and bi-level values independent of the automatic system. For those parameters which have manual control, additional readouts are provided on the manual control panels in order to allow intelligent operation of the manual controls provided thereon.

In the event of a failure of the automatic system, a manual backup system is provided to allow safing and shut-down of the stage and GSE. Two phases are used in the establishment of this manual control mode of operation. The first is "Manual Control Enabled." This state means that manual control may be activated (established) only by the test operator in the event that it is necessary to assume manual control of the checkout system. Because of the intricate interface between the automatic and manual control systems, it is necessary to define that the system must be in one state or another, and cannot be partly in each. Hence, when the system is put into the manual control mode, all systems are in manual control and all manual control panels must be manned to control those systems. The computer continues to service the displays and input DDAS data as before, but it cannot control any of those functions for which manual backup control exists.

The manual control enabled state is established in one of two ways. Whenever an emergency stop is caused, either by the test operator, test station operators, or the computer as a result of a safety item interrupt, the state is automatically established by circuitry external to the computer. Secondly, the test operator himself may establish this state by the operation of a switch on the Checkout System Monitor and Control Panel that is part of the Test Operator's Console.

The "Manual Control Activated" state, which is the second phase of establishing manual control, is effected when any of the test station operators, including the test operator, operates a switch on their manual control panel. Establishing this state causes a series of manual control relays in the distribution units to switch the coils of the command magnetic latch and crystal can relays from those lines which control them in the matrix to

separate lines which are connected to switches located on manual control panels located at the individual test stations. In this way, manual control of those systems necessary to safe and shut-down (including unloading) the stage is established.

Because the computer has no control over what is done during a period of time when the system has been switched to manual control, it is not thought advisable to return to automatic control once the switch to manual control has been made. It is possible that a return to automatic control could be accomplished if the system were returned to the precise state that it was in when manual control was established. It is expected, however, that the system will not be switched to the manual mode during the processing of a test unless there is a failure in the automatic system or a major inadequacy in the test program. In either event, considerable work is probably necessary before tests may be processed by the automatic system again, and therefore, it is probably advisable in all cases to shut-down the stage and start over again once the problem has been eliminated.

B. TEST OPERATOR CONSOLE

The Test Operator Console consists of five main control and/or monitor panels. These are:

1. Digital Control Panel
2. Numerical Readout Panel
3. Test Station Monitor Panel
4. Checkout System Monitor and Control Panel
5. Computer Word Simulator Panel

1. Digital Control Panel

The functions associated with the switches and indicators on the Digital Control Panel are as follows:

Hold Switch

Each test station digital control panel has a Hold Switch which, when activated, will cause the computer to hold at the next hold point in the test program. During detailed sub-systems tests, when one or more test stations are enabled for quasi-independent operation, the computer will only recognize as valid a "Hold" input from the test station that has cognizance over the test being processed or the Test Operator Station. During integrated tests the computer will accept inputs from all test stations. The Hold switch is intended to be used in order to provide brief interruptions in the test program which do not require that the stage be necessarily in a safe condition. In conjunction with the Hold switch on each panel is a Hold indicator and two associated

indicators to indicate whether the system is in a hold state and whether the hold was operator or computer initiated.

Stop Switch

Located on each test station digital control panel is a Stop switch which will cause the computer to go to the next hold point in the test program, and then reset to the last stop point in the test program. Stop points are by definition, conditions of vehicle and personal safety which can be maintained for long periods of time, during which time a certain amount of activity may take place in the vicinity of the stage.

During both sub-systems and integrated testing this input will be considered valid by the computer from any test station. In conjunction with the stop switch a stop indicator and two associated indicators are located on the control panel to indicate when the system is in a stop condition and whether that condition was operator or computer initiated.

Emergency Stop Switch

Located on each test station digital control panel is an Emergency Stop Switch. This switch will cause the computer to stop immediately and reset to some predetermined point in the program. This input will be considered valid by the computer from all test stations for all types of tests. Whereas the "Hold" and "Stop" switches activation result in digital words being input into the computer, the Emergency Stop Switch will provide a contact closure for a Computer Interface Unit supplied ground level to be returned to the Computer Interface Unit as a hardline signal. The five hardline signals (1 from each test station) plus a sixth line from the Ground Instrumentation System at Sacramento only, will be connected in parallel and a single input presented to the computer as a high-priority interrupt on channel 6.

This switch will provide the main source of engine cut-off during static firing at Sacramento. In conjunction with this switch will be an emergency stop indicator and 2 associated indicators located on the control panel to indicate that the computer has received the emergency stop command and whether such command was computer or operator initiated. In addition, this switch will cause enabling of the manual control system as described later in this document.

Resume Switch

Located on each test station digital control panel is a Resume Switch. This switch will cause the computer to continue the test

program from either a hold or stop point. It will not be recognized as a valid input by the computer in an emergency stop condition. During sub-system testing, the computer will only recognize as valid "resume" inputs from the test station having cognizance over the test, or the Test Operator Station. During integrated tests it will only recognize as valid a resume input from the Test Operator Station. Actuation of this switch will result in a digital word being sent to the computer to cause the requested computer action.

Clear Switch

Located on each test station digital control panel is a Clear switch. This switch will cause the computer to reset the system to the initial conditions of the test in progress. This switch input will only be recognized as valid when the computer is in a hold, stop, or emergency stop condition. During sub-system testing, a clear input will only be recognized as valid from the test station having cognizance over the test or the Test Operator Station.

During integrated systems tests this input will only be recognized as valid by the computer from the Test Operator Station. In addition, this switch will remove the manual enable condition established by the Emergency Stop switch.

Computer Ready Indicator

Located on each test station digital control panel is a Computer Ready Indicator. This light will be controlled by the computer to indicate when the executive routines have been loaded into the computer, and the computer is capable of processing test requests.

Fault Indicators

A GSE Fault and Vehicle Fault indicator will be located on each test station digital control panel. These will be controlled by the computer to indicate when a malfunction has occurred and whether such malfunction is determined to be in the vehicle or checkout system.

Store Program Point Switch

At present, the capability exists in the system which allows access to the computer by any of 4 Digital Control Panels during sub-systems testing. Some ground rules must be established with respect to how many tests may be entered into the computer by any given test station at one time. In order not to complicate the programming and storage requirements for this capability, the

decision has been made to limit this capability to one test request per test station at any given time. This decision creates certain operational problems, in that during a requested test a "Hold" or "Stop" condition may appear which requires the use of some other test or sub-test.

If the rule of one test per test station is applied here, the result is that the operator has the option of requesting the required sub-test or continuing the test in progress, but cannot do both. In order to obviate this condition a "Store Program Point Switch" is on each of the 4 Digital Control Panels. The operation of this switch causes the computer to store the step number of the test in progress and to look for a test request input from that test station. During sub-system testing, the Store Program Point Switch will only be recognized as valid by the computer if it comes from the test station having cognizance over the test in progress or from the Test Operator Station. The computer will then accept a test request input from the test station having cognizance or the Test Operator Station, and will process the requested sub-test in a normal fashion. At the completion of the requested sub-test another sub-test may be entered by the test stations noted above, or the Store Program Point switch may be turned off. Removal of this input will cause the computer to return to the step in the original test in progress and await further instructions. Since the test in progress was in a hold or stop condition the computer will return to a hold or stop position, whichever the case may be.

Enable Conditional Holds

The test program will be such that a conditional hold will be inserted at each hold point in the program. During the early phases of the operation with the Saturn checkout equipment it is desirable to have the capability of operating the system in a step by step mode in order to work out any problems that may arise in operating with the automatic system. This capability is significant from the point of view of verifying vehicle checkout concepts and operational procedures as well as to verify the actual test program as prepared by the compiler program. An "Enable Conditional Hold" switch has been incorporated on each Digital Control Panel which will cause the test program to hold at each hold point. By definition then, the conditional holds inserted in the test program are conditional upon this Operator Station. The computer will not recognize as valid this input from any other test station. During Integrated Tests, this input will only be recognized as valid if it comes from the Test Operator Station.

Enable Conditional Stops

For the same reasons that the Enable Conditional Hold capability is desirable, a further capability of causing the computer to

hold at the end of somewhat larger increments of testing is being incorporated in the system design. In the creation of the test programs, certain stop points will be defined. These points will also be hold points although all hold points will not be stop points. A stop point is defined as a point where the vehicle is in a safe condition and personnel may be in the vicinity of the vehicle. In general, for sub-systems tests, a stop point will appear at the end of each test with various hold points appearing throughout the test. The Enable Conditional Stop input will cause the computer to hold at each stop point and await further instructions. This input will be recognized as valid only when it comes from the test station having cognizance over the test or the Test Operator Station. During Integrated Tests, this input will only be considered valid if it comes from the Test Operator Station.

Program Point Stored Indication

The computer will cause an output to the Test Operator Station which will light an indicator to denote that the program point of the test in progress has been stored and it is awaiting instructions or processing some other sub-routine. This same indicator will appear on all test station Digital Control Panels directly in parallel with the indicator on the Test Operator Station.

Conditional Holds Enabled Indication

The computer will cause an output to the Test Operator Station whenever conditional holds are enabled in the test in progress. This input to the test operator station will result in the lighting of an indicator to denote this state. The same indicator will appear on each of the test stations Digital Control Panel directly in parallel with the indicator of the Test Operator Station.

Enable Conditional Stop Indication

The computer will cause an output to the Test Operator Station whenever conditional stops are enabled in the test in progress. This input to the Test Operator Station will result in the lighting of an indicator to denote this state. The same indicator will appear on each of the test station Digital Control Panels directly in parallel with the indicator of the Test Operator Station.

Test Numbering

The primary link of communication between the operator and the computer to control the automatic system takes the form of test requests. A test request consists of a 6 digit octal number which

is inserted into the computer from the octal keyboard on the Digital Control Panel. In order to define the control capability which may be exercised by the operator over the automatic system it is necessary to define the numerical designation of tests.

The first digit defines the classification of tests and indicates which test station has cognizance over that test. The number assignment is as follows:

- 0 Not allowed
- 1 GSE Self Test
- 2 Propulsion System Test
- 3 Electrical Networks Test
- 4 Telemetry Systems Test
- 5 Not used (Spare for Propulsion System)
- 6 All Systems Test
- 7 Sacramento Peculiar Test

The breakdown within each category is as follows:

- 1. GSE Self Test
 - 1.0 Miscellaneous
 - 1.1 End Items Test
 - 1.2 Pre-Operation Test
 - 1.3 Display Device Test
 - 1.4 Telemetry Systems Test
 - 1.5 Spare
 - 1.6 Spare
 - 1.7 Spare
- 2. Propulsion Systems Test
 - 2.0 Miscellaneous
 - 2.1 J2 Engine
 - 2.2 Control Pneumatic
 - 2.3 APS
 - 2.4 Ambient Helium
 - 2.5 LH₂ Tank
 - 2.6 Cold Helium
 - 2.7 LOX Tank
- 3. Electrical Networks Test
 - 3.0 Miscellaneous
 - 3.1 Power
 - 3.2 Propellant Utilization
 - 3.3 EBW
 - 3.4 Engine Gimbaling
 - 3.5 Environmental
 - 3.6 Spare
 - 3.7 Spare

- 4. Telemetry Systems Test
 - 4.0 Miscellaneous
 - 4.1 DDAS
 - 4.2 SSB/FM
 - 4.3 PAM/FM/FM
 - 4.4 Measuring (RACS)
 - 4.5 Range Safety
 - 4.6 Spare
 - 4.7 Spare
- 5. Spare
- 6. All Systems Test
 - 6.0 Miscellaneous
 - 6.1 Overall Test, Umbilical In
 - 6.2 Overall Test, Umbilical Out
 - 6.3 Spare
 - 6.4 Spare
 - 6.5 Spare
 - 6.6 Spare
 - 6.7 Spare
- 7. Sacramento Peculiar Test
 - 7.0 Miscellaneous
 - 7.1 Static Firing
 - 7.2 Propellant Loading
 - 7.3 Tank Pressurization
 - 7.4 PU Calibration (Weigh System)
 - 7.5 Overall Test (Simulate Static Firing)
 - 7.6 Overall Test, Umbilical In
 - 7.7 Overall Test, Umbilical Out

The second digit represents a major test number. In general, a major test is defined as any operation which may be processed independently from other tests and which normally be considered as a unit of testing.

The remaining 4 digits represent sub-tests or incremental parts of the main tests. In general, the smallest controllable increment in this category would be from "Hold Point" to "Hold Point" within a main test. This is not, however, the only restriction on this number assignment. A further restriction exists with respect to the capability of inserting requests for particular sub-tests or increments based on initial conditions required. This restriction will be described under keyboard operation. It is apparent that a numerical breakdown may not be accomplished until such time as the actual tests to be performed are concretely defined. However, to define the system capability and the hardware and programs required, certain ground rules with respect to this assignment must be established.

Keyboard Operation

A test station operator is somewhat limited as to which test numbers he may request from the computer. Except for the Test Operator, the first digit on any test which may be inserted from a test station is inherent to that test station. That is, the Propulsion test station operator cannot enter a test starting with any digit except 2 since, by definition, the tests over which the propulsion test station has cognizance begin with that digit. The first digit entered by the Test Operator will be the most significant digit of the test number but the first digit entered by any other test station operator will be stored as the second most significant digit of the test number. In addition, the least significant digit of requested numbers will always be zero.

The operator will cause a test number to appear in his keyboard readout by punching consecutively the number of the test request he wishes to insert in the computer. If the test station is enabled, that is, has direct access to the computer, he then causes this test request to be transmitted to the computer by pressing the "Enter" button which is part of his keyboard. If the computer is not in the process of doing another test, it will accept this request, call in that numbered test from the test program tape and begin to process the requested tape. The first step the computer must do in processing the test is an Initial Condition Search. This Initial Condition Search does not cause any operations to be performed on the vehicle or facilities, but does cause the computer to gather information about the present status of the system and compare this against conditions established as part of the test program. At the end of this Initial Condition Search the computer will go into an unconditional hold and will display the status of the initial conditions. This would consist of a statement as to whether those conditions were met, and if not, would indicate which conditions are not met. Before any sub-test can be processed that does not immediately follow another sub-test in the same main test, this Initial Condition Search must be accomplished in order to insure that some step or operation in a previous part of this main test is not necessary in order to accomplish that sub-test or incremental part. If the capability exists for the operator to call up any sub-test or any incremental part without going through the steps previous to it in the main test, then an Initial Condition Search peculiar to that sub-test would have to be programmed for each sub-test or incremental part of a main test. The magnitude of the programming efforts required and resulting test program make such an undertaking unfeasible. Therefore, only one Initial Condition Search routine will be inserted for each main test. This then restricts those sub-tests or increments of the main test which may be called up independently

to those which have the same initial conditions as the main test as a whole.

All test requests must have a zero in the sixth digit since any increment designated by a non-zero digit cannot be called up from the test station. In general, once a main test has been entered at a given starting point as represented by the first 5 digits of the increment number it will continue until a hold or stop exists, whether computer or operator initiated. Since the requestable starting points are at least 1 stop point apart and may in fact be more, by "Enabling Conditional Stops" the operator can insure he does not go beyond the sub-test or increment he has requested. In fact, by initiating "Enable Conditional Holds," he may operate the sub-test or increments in even smaller increments as designated by the pre-programmed hold points.

In accordance with the above restrictions, the inserting of a test request by any test station other than the Test Operator Station would consist of entering 4 digits since the first and last digits of any request from that test station are fixed. The computer would accept this input, look at the first two digits, and call up the beginning of that main test from the test program tape. It would then complete the Initial Condition Search and go into an unconditional hold state. Upon receiving a resume command, and assuming the initial conditions are met, it would look at the 4th and 5th digit and jump to that place in the test program to begin processing the test request.

Test in Progress and Next Test Indicators

Located on all Digital Control Panels are a "Test in Progress" and a "Next Test" indicator. These are 6 digit, octal, numeric readouts. In general, the intent of this readout is to allow the test operator to maintain cognizance over the state of testing being performed by the computer. In most cases, the test steps will be operated with sufficient speed to cause the last three or four digits of the test number to be continually changing and, therefore, probably not readable. In this case, a zero would be displayed in these positions and the computer would only control the first two digits. However, when conditional holds are enabled all of the digits including the 6th digit would only advance at the operator's discretion since he would resume from each conditional hold.

2. Numerical Readout Panel

The Numerical Readout Panel provides the controls and numerical readouts which allow the operator to request information from the Automatic Checkout System independent of the test program.

Data Request Select Switches

These four switches (with positions numbered 0 through 7) allow the console operator to set up a four octal digit data request which can be transferred to the Automatic Checkout System. The octal digits 4 through 7 on the "MSD" switch are not presently expected to be used so only 11 binary bits are transmitted to the Automatic Checkout System when the request is initiated; that is, octal 3777 is the maximum number which may be legitimately entered.

Data Request Initiate Switch

This switch allows the selected data request to be transferred to the Automatic Checkout System. Hard wire outputs from the switch will be gated into the Test Operator Logic Unit transmitting register along with an address associated with the requesting panel. The resultant word will be transmitted to the Computer Interface Unit when enabled by that unit.

Enable Continuous Request Switch

When this switch is "on", prior to energizing the "Data Request Initiate" Switch a logical one will be included in a reserved position in the transmitted word to indicate that this data request should be updated periodically until a new request is initiated.

Test Station Monitor Panel

During subsystem tests, the Test Station Monitor Panel displays information to the test operator as to which test stations are actually requesting tests from the computer, and contains control switches to enable independent test station operation. During integrated tests, the panel provides a monitor point for the test operator as a supplement to voice communication.

Numeric Indicators

Three numeric indicators are provided to display the same test number as the individual test station keyboard displays. This provides the capability of transferring recommended test numbers from the test station operator in a more reliable manner than trying to transmit a 6 digit number by phone. With this mode of communication, the test station operator can be assured that the test operator has received the correct test number since the same number appears on the keyboard display at the test station.

Enter and Wait Switches

In conjunction with each numerical readout are an "Enter" and a "Wait" switch. By use of these switches the Test Operator can either cause the recommended test number to be entered into the computer or indicate to the test station operator that the test number request has been recognized, but will not be entered at this time. In the normal case, test numbers would only be recommended by the test station operators in the event of some failure during an integrated test. Under these conditions, there would no doubt be some voice communication between test operator and the test station operators. The use of the numeric readouts and switches noted are not intended to eliminate the need for voice communication, but merely to supplement that communication.

Hold, Stop and Emergency Stop Instructions

During integrated tests, the "Hold", "Stop", and "Emergency Stop" switches at the test stations are active and will affect the computer program. Lights are incorporated on the test station monitor panel to indicate to the test operator when a test station has initiated any of these conditions. This will immediately tell the test operator in which area the problem exists and which test station operator has information relative to the problem.

Manual Control Switch Indicators

In addition, "Manual Control Switch Activated" and "Manual Control Switch Off" indicators are incorporated. The "Off" indicator will be used by the test operator to assure that all test station "Manual Activate" switches are off during normal operation. If, for some reason, it became necessary for an "Emergency Stop" to be initiated by any of the test stations, the system would immediately go into a manual mode of operation and the computer would not be able to perform the Programmed Shutdown routine.

If it is necessary to manually initiate an "Emergency Stop" from a test station, the possibility also exists that the computer will not be able to perform the necessary shutdown; however, if this is the case, the determination to switch to the manual mode shall be made after confirming the automatic system is unable to perform the Emergency Shutdown routine. During the period of time when the manual control switches are enabled, either through the initiation of an Emergency Stop or from the Test Operator Station, the "Manual Control Switch Activated" indications will inform the test operator which test station has caused the system to go into the manual mode and provide information of a similar nature to the "Hold", "Stop", and "Emergency Stop" lights.

4. Checkout System Monitor and Control Panel

The Checkout System Monitor and Control Panel contains switches and indicators which allow the Test Operator to: (1) monitor the operational status of various end-items in the Automatic Checkout System, (2) control the turn on of the vehicle external power supplies and the GSE power supply, and the related back-up power supplies and, (3) control the capability of transferring to the manual control mode of operation.

End Item Operative Indicators

"End Item Operative" indicators exist for every end-item in the Automatic Checkout System which has a switch which will allow the end-item to be placed in a local manual control mode. The fact that the end-item is in the automatic mode is one of the common requirements for all of the "End Item Operative" circuits. In addition, end-items using DACO Logic Power Supply No. 1A82853-1 will include the available contact closure in the power supply which indicates that the outputs are within their operating limits. Any of these indicators being extinguished prior to a checkout will indicate to the Test Operator that a completely automatic checkout cannot be performed. An indicator extinguishing during a test would require an immediate shut-down in most instances, but, depending on the end-item and the type of test being performed, it would be left to the discretion of the Test Operator as to the type of action which should be taken.

Power Control Switches

The five "Power Supply Input" switches allow the Test Operator to turn the four vehicle external power supplies and the GSE Power Supply "on" or "off" whether the Automatic Checkout System is in the automatic or manual mode of operation. These switches control the application of the 3-phase, 60 cps input to the power supplies. An auxiliary 28 VDC power supply at the input of the GSE Power Supply is routed through the "momentary on - off - momentary on" switch to control the application of power to this power supply. The output of the GSE Power Supply is routed to the on - off control switches for the vehicle power supplies and controls the application of the 3-phase, 60 cps input to these power supplies. The power supply output lights the "on" indicator for the selected power supply.

Two "Back Up Power" enable switches which also are not restricted to operation during the manual mode of operation are available to the Test Operator. These switches allow the Back Up Power source to be disabled when there will definitely be no requirement for it, and will increase the useful life of the batteries.

Vehicle Command Power Switch

The GSE Power Supply output bus is routed into several different branches such as "Talkback Power," "Sequencer Power," "Vehicle Command Power," etc. This switch which is operable only during the manual mode of operation, is one of several in the Automatic Checkout System which provides manual control of matrix relays which are controlled by the Stimuli Conditioner in the automatic checkout mode. The primary function of this switch is to remove the command power if the Automatic Checkout System fails in a manner which would not allow this to be done automatically during an emergency shutdown. Its "turn on" capability might be used during calibration or fault isolation routines performed in the manual mode of operation.

Manual Control

A limited number of manual control switches are provided on each test station console. These switches will control the same matrix relays normally controlled by the computer during the automatic checkout mode of operation. The primary purpose of these switches is to provide those controls required to save the vehicle in the event of a failure in the automatic system. The operation of these switches is controlled by a "Manual Control Activate" switch located on each console. This switch must be in the "Activate" position before the operational capabilities of the manual switches on that console are enabled. In addition to the requirement that the "Manual Control Activate" switch must be in the "Active" position, one other condition must be met before the manual control switches are enabled. This second condition is generated in two different ways, with the method dependent upon the circumstances which dictate the requirements for manual control. The two methods for generating this second condition are described below.

1. Manual control capability may be required during tests if a failure or malfunction in the Automatic Checkout System prevents automatic detection and subsequent correction of some unsafe condition. If the unsafe condition requires immediate action, it shall be a requirement that the first corrective action taken by operating personnel shall be actuation of the "Emergency Stop" switch located on each test station console. Actuation of this switch at any console shall generate a hardline signal to the computer which will command the Automatic System to immediately proceed through a pre-programmed emergency shutdown routine. Actuation of the Emergency Stop switch shall also enable the function of the "Manual Control Activate" switch located on each test station console. This will allow the test station to immediately assume manual control in the event the

nature of the failure in the system is such that the automatic system is unable to perform the emergency shutdown routine. The manual control capability will be disabled upon receipt of a "Clear" command from the Test Operator Console.

2. It is expected that during performance of certain tests, manual control capability will be desired for conditions which are not of an emergency nature. For example, if a hold condition occurs which has not been anticipated in the program, it may be necessary to turn off the vehicle telemetry transmitters to prevent overheating during this hold period. To permit manual control under other than emergency conditions, the Test Operator Console shall be provided with a master "Manual Control Enable-Disable" switch which may enable the function of the individual "Manual Control Activate" switch provided on each test station console. This will permit manual operation under the cognizance of the Test Operator for those conditions which do not require immediate emergency shutdown. This master switch shall have a neutral position which neither enables nor disables manual control. When in this neutral position, or the "Disable" position, it shall not affect the function of the "Emergency Stop" as described in Item 1.

The only exception to this philosophy will be on the Test Operator's Console. The Manual Control "Activate-Off" switch on this console will not be dependent on the "Enable-Disable" switch. The Test Operator has the capability of initiating manual control regardless of what position the "Enable-Disable" switch is placed in.

5. Computer Word Simulator Panel

The Computer Word Simulator Panel is to be used only during maintenance or troubleshooting operations. When this panel is turned on, the Computer/Computer Interface Unit communications on channels 5 and 6 are inhibited and the operator has the capability of simulating an output from the computer on channel 6 (via toggle switches) and monitoring the response from the Computer Interface Unit on channel 5 (via indicator lamps).

On-Off Switch

When this switch is turned "on", (1) the computer channel 6 input to the Computer Interface Unit is disabled, (2) the "Enter" and "Input Resume" pushbuttons and the 24 channel 6 toggle switches are enabled, and (3) the "Input Ready" signal from the Computer Interface Unit to the computer is disabled.

Channel 6 Control Switches

Twenty-four toggle switches, representing bits 0 through 23 from the computer, allow the operator to set the word which is to be transmitted to the Computer Interface Unit. When the "Enter" switch is energized, this word is made available to the Computer Interface Unit which then decodes it and sends the command or data request to the addressed end item.

Channel 5 Monitoring and Control

Twenty-four indicating lamps, representing bits 0 through 23 from the Computer Interface Unit, will indicate the input to computer channel 5 after the "Input Resume" switch has been energized. A lit indicator will represent a logical one.

C. ELECTRICAL NETWORKS CONTROL CONSOLE

The Electrical Networks Control Console consists of four main monitoring and/or control panels. These are:

1. Digital Control Panel
2. Numerical Readout Panel
3. Electrical Networks Monitor and Control Panel
4. Mechanical Systems Monitor and Control Panel

1. Digital Control Panel

See Section B1 for a description of the operation of this panel.

2. Numerical Readout Panel

See Section B2 for a description of the operation of this panel.

3. Electrical Networks Monitor and Control Panel

The Electrical Networks Monitor and Control Panel will provide meters for monitoring the voltage and current outputs of the power supplies which make up the DSV-4B-134 power rack, potentiometer for adjusting the output voltage of the above-mentioned power supplies, and switches which all provide a manual control capability for maintenance, calibration or emergency shutdown operations.

Meters

There is a voltmeter and an ammeter associated with each of the five power supplies, that is, the GSE Power Supply and the four vehicle power supplies. The GSE voltmeter, and the vehicle power supply voltmeters, when selector is in "External Power" position, will be indicating either the power supply output or

the "Back-up Battery" output. The operator of this console will have to check with the Test Operator to determine which is being indicated, since the indicators and switches on the Test Operator's "Checkout System Monitor and Control Panel" will provide this information. When the selector switch is in the "Vehicle" position, the voltmeter will be monitoring the voltage on the vehicle buss. There will be no indication in the "Battery" position unless a battery test is being performed. During a battery test, this meter will allow the operator to observe the voltage drop-off with respect to time while the load is being applied. A potentiometer for each power supply will allow remote adjustment of the power supply output. The ammeters are 5VDC (full scale) voltmeters which are reading an amplified series shunt output internal to the power supply; the 5VDC signal will indicate the nominal rated output current of the power supply.

Switches

The remaining switches on the panel are used only during the manual control operating mode. None of the momentary switches performs a function until the "Manual Control Active" indicator shows that the manual control operating mode has been selected. The "On" and "Off" positions of the momentary switches provide outputs to the "Set" and "Reset" inputs, respectively, of magnetic latching relays which are normally controlled by the Automatic Checkout System during the automatic mode of operation.

Vehicle Power Control Switches

There are six switches which provide the operator with manual control of the power to the vehicle.

Four of these switches are associated with the Fwd No. 1, Fwd No. 2, Aft No. 1, and Aft No. 2 vehicle power busses. These switches control the application or removal of the power supply outputs to the respective vehicle busses.

The Battery Simulator switch controls the application or removal of the power supply outputs to the respective battery simulator cables. All four battery simulator cables are powered simultaneously via contactors which are in parallel with the contactors associated with the four switches mentioned above.

After the Battery Simulator cables have been energized or if batteries are installed in the vehicle, all four busses may be transferred simultaneously to internal power by switching the Power Transfer switch to "Internal". After the completion of this operation, the switches which control the application of power to the external power input cables do not have to be switched "Off", since they will now be dead-faced internally in the vehicle.

Vehicle System Control Switches

Three of these switches apply power to the sequencer, the Talkback lines and the DDAS translator. The "RF Silence" switch results in the telemetry transmitters being turned off.

4. Mechanical Systems Monitor and Control Panel

Indicators

The Mechanical Systems Monitor and Control Panel provides indicators for observing the actuator commands and the resultant engine movement, the hydraulic oil temperature in the reservoir in the vehicle and the "On" or "Off" state of the Hydraulic Servicer and the Auxiliary Hydraulic Pump on the vehicle.

Switches

Two switches are provided for manual control of the Hydraulic Servicer and the Auxiliary Hydraulic Pump in the vehicle. The Auxiliary Hydraulic Pump can be turned on or off from this panel. The Hydraulic Servicer can be turned off from this panel but the "Enable" position just enables the local "On" switch at the servicer.

D. PROPULSION SYSTEMS CONTROL CONSOLE

The Propulsion System Control Console consists of four main monitor and/or control panels. These are:

1. Digital Control Panel
2. Numerical Readout Panel
3. APS Manual Control Panel
4. Mainstage Manual Control Panel

1. Digital Control Panel

See Section B1 for a description of the operation of this panel.

2. Numerical Readout Panel

See Section B2 for a description of the operation of this panel.

3. APS Manual Control Panel

The APS Manual Control Panel provides the operator with switches which will control valves in the APS Modules No. 1 and No. 2 during the manual control operating mode. The indicators are lit by talkbacks from the magnetic latching relays and indicate only that the command was given.

4. Mainstage Manual Control Panel

The Mainstage Propulsion Manual Control Panel provides the operator with switches which will control valves in the mainstage fuel and oxidizer loading and pressurization systems. The "Fill and Drain" indicators and the "Vent" indicators are powered by talkbacks from the valves, but the remainder of the valve indicators show only that the command was given.

E. TELEMETRY SYSTEMS CONTROL CONSOLE

The Telemetry Systems Control Console consists of two main monitor and/or control panels. These are:

1. Digital Control Panel
2. Numerical Readout Panel

1. Digital Control Panel

See Section B1 for a description of the operation of this panel.

2. Numerical Readout Panel

See Section B2 for a description of the operation of this panel.

F. REMOTE PNEUMATIC CONTROL CONSOLE - BETA

The Remote Pneumatic Control Console - Beta provides the operator with complete manual control over the mechanical propulsion ground support equipment at the Beta facility during "All-Systems" checkout. Mechanical propulsion ground support equipment is defined as: LH₂ loading skid, LO₂ loading skid, Heat Exchanger, Pneumatic Stage Servicing Console, and all APS pneumatic regulation and distribution complexes. This control console consists of eight main monitor and/or control panels. These are:

1. Helium Regulation Panel
2. Ambient Helium Monitor Panel
3. Ambient Helium Distribution Panel
4. GN₂ and GH₂ Control Panel
5. Cold Gas Panel
6. Mainstage Propellant Loading Panel
7. APS Regulation Panel
8. APS Distribution Panel

1. Helium Regulation Panel

The Helium Regulation Panel provides the operator with remote control of all the dome loaders and solenoid regulator loading valves in the Pneumatic Stage Servicing Console - A (DSV-4B-319). It also provides the operator with meters which allow him to monitor all regulator dome pressures and the helium console supply pressures. Switches are also provided to control Mainstage Pneumatic Power and the 5 VDC transducer excitation power.

2. Ambient Helium Monitor Panel

The Ambient Helium Monitor Panel provides the operator with remote control of the bleed valves and supply valves associated with the pressure stages in the DSV-4B-319. Meters are also available which allow the monitoring of the line pressures of the outputs of these stages.

3. Ambient Helium Distribution Panel

The Ambient Helium Distribution Panel provides the operator with remote control of the distribution of ambient helium pressure stages to the vehicle.

4. GN₂ and GH₂ Control Panel

The GN₂ and GH₂ Control Panel provides the operator with switches which allow him to bleed the GN₂ and GH₂ lines and to distribute the GN₂ and GH₂ to the vehicle.

5. Cold Gas Panel

The Cold Gas Panel provides the operator with switches which allow him to control the distribution of cold gases to the vehicle and meters which allow him to monitor the pressures of these gases. Indicators and switches are also provided which allow the operator to control and monitor the Heat Exchanger (DSV-4B-318).

6. Mainstage Propellant Loading Panel

The Mainstage Propellant Loading Panel provides the operator with switches and meters which allow him to monitor and control the LOX and LH₂ skids and their outputs to the vehicle.

7. APS Regulation Panel

The APS Regulation Panel provides the operator with switches which allow him to control the APS Pneumatic Distribution Complex and indicators which will allow him to monitor the supply pressures. Control is also provided for the distribution of ambient helium for vehicle checkout.

8. APS Distribution Panel

The APS Distribution Panel provides the operator with switches and meters which allow him to monitor and control the APS module supply pressures.

G. REMOTE PNEUMATIC CHECKOUT CONTROL CONSOLE

The Remote Pneumatic Checkout Control Console will be used for "dry" checkouts of the S-IVB and will be used at all locations where LH₂ and LO₂ will not be loaded. This console will provide the operator with complete manual control of the Pneumatic Stage Checkout Console, Model DSV-4B-321 and associated power. The console is made up of three control panels:

1. Regulation Control Panel
2. APS Checkout Panel
3. Mainstage Checkout Panel

1. Regulation Control Panel

The Regulation Control Panel provides the operator with remote manual control of all regulation in the Pneumatic Stage Checkout Console. Three switchable meters are provided to monitor all of the dome pressures and the console supply pressures. A test stand selection switch allows the operator to supply the pneumatics to either test stand. The operator may also select whether GN₂ or Helium should be used for the checkout. Pneumatic power cannot be turned on automatically or manually unless the Enable-Disable switch has been enabled.

2. APS Checkout Panel

The APS Checkout Panel provides the operator with manual control over all APS supply valves in the Pneumatic Stage Checkout Console. Meters are also provided to allow monitoring of line pressures associated primarily with the Auxiliary Propulsion System.

3. Mainstage Checkout Panel

The Mainstage Checkout Panel provides the operator with complete manual control of all mainstage checkout supply valves. Meters are provided to allow monitoring of line pressures associated primarily with mainstage checkout.

H. STIMULI CONDITIONER

The Stimuli Conditioner receives digital inputs in a serial form from the Computer Interface Unit which are converted to hard line outputs after the appropriate decoding, gating or digital-to-analog

conversion operations have been performed. The stimuli conditioner supplies three different types of outputs. These are:

1. All analog outputs required for stage checkout or automatic checkout system self checks.
2. Bi-Level Type I outputs which operate relays in the matrices of the Signal Distribution Unit and the Auxiliary Distribution Unit.
3. Bi-Level Type II outputs which allow one to fourteen simultaneous, parallel outputs to be supplied to relays in the addressed end item.

1. Analog Generation

The analog signals which must be generated to satisfy the system checkout requirements are:

1. Pitch and yaw actuator control commands;
2. Error signals for checkout of the valves in the Propellant Utilization System;
3. Analog voltages required for self-test of the Automatic Checkout System; and
4. Analog voltages required for calibration of telemetry channels.

The actuator control commands are sinusoidal currents varying from two milliamperes peak current to fifty milliamperes peak current. Twenty-Five incremental steps of two milliamperes from zero to the maximum of fifty milliamperes can be selected; the frequency can be varied from 0 to 12.5 cps in 255 incremental steps of 0.2 cps.

During the self-test programs, the Stimuli Conditioner stimulates the outputs of the vehicle's analog sensors as well as the voltages which exist on various power busses. Since the timing requirements are not severe, relay operated decoders (D/A converters) are used. Two converters are used for self-test outputs. One converter will supply a maximum output of 40 VDC. A six bit code is used as the input and decoded for 64 outputs varying from 0 VDC (000000) to 40 VDC (111111). The other converter supplies -5 VDC to +5 VDC. A six bit code is also used here but the first bit is a polarity bit. This code is decoded to provide -5 VDC (000000) through 0 VDC (011111 or 100000) to +5 VDC (111111). Since the incremental values per bit are 0.165 volts, the maximum value is actually 5.08 VDC.

The remaining analog capability is a zero to 10 VDC signal which is used to initiate the calibration of the telemetry ground stations. The outputs are 0, 1.25, 2.5, 3.75, 5.0, and 10 VDC; these outputs must be within 200 millivolts of the specified values in order that they may be sensed by the Calibration unit in the vehicle which will generate the same output, but with better than 1 per cent accuracy.

A twenty bit word is used to request the above mentioned analog stimuli. The first three bits are 111 to indicate that an analog stimulus is required. Bits four through seven define the specific analog which is to be generated and the remaining bits determine the amplitude, polarity and/or frequency of the stimulus.

2. Bi-Level Type I Commands

The twenty bit word which generates this command is made up as follows: Bits 1 and 2 are 1 and 0 respectively. Bits 3 through 8 represent a requirement to place an energize signal on one of 63 output lines. Bits 9 and 10 designate which of the four groups of ten output lines is to be selected and the remaining 10 bits designate positionally which of the ten lines in the selected group are to be chosen.

The 63 output lines are divided as follows: Ten lines to the Forward Signal Distribution Unit, ten lines to the Aft Signal Distribution Unit, eighteen lines to the Auxiliary Distribution Unit and 25 spare lines. The four groups of ten output lines (forty output lines) are common to each of the three matrices mentioned above. The energized condition of the common forty lines is -28 VDC from transistor drivers; the other 63 control lines will be 0 VDC from transistor drivers when they are energized.

After these instructions have been sent to the Stimuli Conditioner and while the addressed relays are still in the process of operating, the computer will initiate data requests to the Response Conditioner for bi-level responses which will indicate which relays in the matrix have been energized. All 78 input lines to the 38 X 40 matrix will be examined to verify that the proper relays, and no others, have been commanded. It is conservatively estimated that the total "worst case" time involved to request 8 bi-level measurements and receive them in the computer would be approximately 1.7 milliseconds which is less than the minimum relay pull-in time. Therefore, any corrective action which must be taken can be accomplished prior to an erroneous output being sent to the vehicle.

3. Bi-Level Type II Commands

The steps involved in the generation of a bi-level Type II command are very similar to those involved in a bi-level Type I command except for the self-check operation which uses talkbacks from the relay contacts rather than the inputs to the coils.

The twenty bit word which results in a bi-level Type II output is made up as follows: Bits one and two are always logical ones and bit three is a logical zero. Bits 4, 5 and 6 are decoded in the Stimuli Conditioner to indicate which of the possible seven groups

are to be commanded. Six of the seven groups provide a capability of simultaneously energizing up to fourteen external relays. For these groups, a logical one in any or all of the remaining fourteen positions will result in an output from an associated relay driver in the addressed group. The remaining group, which is used to program the counter-timer in the Response Conditioner and control the selection of signals input to the counter-timer has the remaining fourteen bits reserved as follows: Bits 9, 10 and 11 indicate one of seven types of functions which can be programmed such as the period of a signal, the frequency of a signal, the time interval between two signals, the ratio of the frequencies of two signals, etc. Bits 12, 13 and 14 indicate the frequency range which is to be selected; seven ranges from 1 cps through 1 Mcps in power-of-ten steps are possible. The three-bit groups of bits 15, 16 and 17 and bits 18, 19 and 20 are used to control the switching of signals to the two signal inputs of the counter-timer. Bits 18, 19 and 20 control the input to channel A and would be used for all measurements. That is, the frequency and period measurements are always "period of A", "frequency of A", etc. Bits 15, 16 and 17 will be required to switch the signals into channel B when more than one signal is required, such as "ratio A/B" or "interval: A to B". Bit position 7 will be logical zero when the above described programming is to be performed. It is the "Master Reset" bit and will reset all 28 magnetic latching relays when it is a logical one; there are four groups of seven magnetic latching relays associated with the four three-bit groups described above. The remaining bit position, the eighth bit, is a spare bit in this bi-level Type II word.

As previously mentioned, the self-check of Type II outputs uses talk-backs from relays in the addressed end item. There is no requirement for a self-check of bi-level Type II outputs prior to the relays energizing since no dangerous condition can arise from an erroneous output.

Except for commands to the Switch Selector in the vehicle, the Type II outputs are programming the counter-timer or are providing calibration signals for Telemetry Systems or the Propellant Utilization System. If an erroneous output has been commanded, the response can be ignored and the command attempted again. Another faulty self-check would indicate an Automatic Checkout System fault which would have to be corrected. In the case of an erroneous input to the Switch Selector, the programming will not allow the "Read" command until verification of the word stored in the Switch Selector so the resultant Switch Selector output would not be commanded until the proper word had been stored.

I. RESPONSE CONDITIONER

The Response Conditioner, when commanded by the computer via the Computer Interface Unit, will respond with a digital word (or words) which indicate the value of an analog function or the state of a bi-level function.

The Response Conditioner contains an analog multiplexer and an analog-to-digital converter which select and digitize analog signals; bi-level sensors and a bi-level multiplexer which select and convert bi-level signals to digital data; a remote programmable counter-timer which measures frequency or time interval and provides a digital output; and logic and control circuitry for decoding requests, selecting the proper signals and communicating with the Computer Interface Unit.

1. Analog Measurements

The analog data request word is received serially by the Response Conditioner. The first bit is a logical one and is used for decoding and register shift control. A logical one in bit position two indicates that the remaining 8 bits of the ten bit word are the address of the desired analog function. The capability of requesting any one of 255 analog values is provided. These 8 bits are used to control the analog multiplexer. The selected signal is input to the analog-to-digital converter which is capable of converting signals ranging from 0 to ± 5 VDC; any signals not suitable by form or magnitude are preconditioned in the Response Conditioner. The data response will be a 21 bit word constructed as follows. The ten bit data request is also the first ten bits of the data response; this "tags" the response for the computer. The eleventh bit is the polarity of the analog value and the last ten bits are the ten digital bits which represent the value of the measurement. The multiplexer-converter combination has a minimum accuracy of 0.2 per cent of full scale.

The analog signals are routed to the Response Conditioner via normally closed contacts on relays in the Signal Distribution Unit. When an analog signal is found to be out of tolerance, the associated relay is energized by means of a Type I bi-level command to the Stimuli Conditioner. The "self-check" analog signal connected to the normally open contacts of the relay will then be input to the Response Conditioner over the same wires traversed by the questionable analog signal. If this known self-check value indicates correctly, a vehicle fault is indicated; otherwise, a fault in the Automatic Checkout System is indicated.

2. Bi-Level Response

The bi-level data request word is also ten bits in length. The first bit, as in the analog data request, is used for control purposes in the Response Conditioner. A logical zero in bit position two indicates that bi-level data is being requested. The remaining 8 bits are decoded to determine which groups of 10 bi-levels of a possible 250 groups is to be output to the computer. This grouping is performed to cause the bi-level responses to be in the same format as the DDAS bi-level received by the computer from the DDAS Ground Station.

In order to determine the state of a specific bi-level, the computer must request the group that contains that bi-level. The last 8 bits of the data request control the bi-level multiplexer. The first ten bits of the bi-level response are the same ten bits which requested the bi-level group. Since no polarity is involved, the eleventh bit of the bi-level response is a spare bit. The last ten bits of the 21 bit response are the states of the bi-levels of the requested group. Upon receiving the group, the computer examines the position in the group which corresponds to the requested bi-level.

Self-check of bi-level responses is performed in a fashion similar to that used on analog response self-checks. The bi-level signal is wired through the normally closed contact of a relay in the Signal Distribution Unit and +28 VDC from GSE Power Supply is connected to the normally open contact. When the bi-level response is questioned, a Type I bi-level command to the Stimuli Conditioner causes the relay to energize and indicate whether the bi-level source or the Automatic Checkout System is at fault.

3. Counter-Timer Responses

Counter-timer responses require a combination of two of the previously mentioned operations. First, a bi-level Type II command must be generated to set up the counter-timer and connect the signal (or signals) to the proper channel input. Then five separate bi-level data requests are required to obtain the required information.

These requests are identical to the bi-level data requests but specific binary codes have been reserved for counter-timer information. These codes are eight bits in length and are the binary equivalents of decimal numbers 251 through 255. The codes for 251, 252 and 253 result in the states of the 28 programming relays being returned to the computer to verify that the counter-timer has been programmed correctly relative to its function and the range scale. This is followed by codes 254 and 255; the response

to "254" will be the two most significant bits of counter-timer's twelve bit output and the response to "255" will be the remaining ten bits.

Self-check of counter-timer responses does not involve the application of test signals. A self-check of the counter-timer is all that is possible. The Type II bi-level command which programs the counter-timer would program "test" as the function and any of the possible seven frequency ranges that is questioned. No vehicle or Automatic Checkout System signals would be connected to channels A or B. Instead, depending on the range selected, the counter-timer would measure its own reference frequency and output this value to the computer when requested.

J. SAFETY ITEM MONITOR

The purpose of the Safety Item Monitor is to provide continuous monitoring of all parameters in the vehicle or Automatic Checkout System which are classified as safety items. A safety item shall be generally defined as an item which could result in damage to equipment or in injury to personnel, if the item malfunctions or fails to operate within specified limits.

The computer communicates with the Safety Item Monitor by means of the same procedure described for the transfer of data to the Response Conditioner and the Stimuli Conditioner. In fact, the Stimuli Conditioner and the Safety Item Monitor share the same output register in the Computer Interface Unit. The word received in the Safety Item Monitor will include four bits which indicate which of the ten bi-level update registers or which of the five groups of ten analog comparators is to receive the ten bits of digital data. If the data is for the bi-level comparators, a logical one indicates the bi-level signal should be on and a logical zero indicates the signal should be off. If the data is for the analog comparators, a logical one will result in the associated analog comparator being inhibited. The types of signals examined and the operating procedures are as follows:

The Safety Item Monitor monitors three types of signals from the external equipment. These types are classified as: 0 to 40 VDC analog, 0 to 5 VDC analog and bi-level.

In order to monitor an analog signal, the Safety Item Monitor contains an isolation circuit, a voltage comparison circuit and an inhibiting circuit. The isolation circuit electronically isolates the Safety Item Monitor from the external equipment. The voltage comparison circuit compares the incoming analog signal voltage with a manually adjustable reference voltage. The inhibiting circuit is capable of inhibiting the output of the voltage comparison circuit by remote control. A switch is

provided to disable this capability for cases where it is not desirable for the computer to inhibit a comparison. If an incoming analog signal does not compare favorably with the pre-determined reference voltage, and if the inhibiting circuit is not enabled, the Safety Item Monitor outputs a signal to the Computer Interface Unit indicating that a potential safety hazard exists. If an analog signal has different acceptable limits for different periods of time, each limit is considered as an individual signal, and the digital data updates the Safety Item Monitor by inhibiting the comparison circuits for those levels that are not applicable during that period of time.

In order to monitor a bi-level signal, the Safety Item Monitor contains an isolation circuit, a signal conditioning circuit and memory circuits. The isolation circuit electronically isolates the Safety Item Monitor from the external equipment. The signal conditioning circuit transforms the bi-level signal into a form compatible with the internal digital signals. The memory circuits store information received from the external equipment concerning the expected state of the bi-level signal. If an incoming bi-level signal does not compare favorable with the expected stored value, the Safety Item Monitor outputs a signal to the Computer Interface Unit indicating that a potential safety hazard exists. Whenever it is expected that the state of an incoming bi-level signal will change, the Computer Interface Unit inputs the new expected state to an auxiliary memory unit so that when the incoming bi-level changes state, the output to the Computer Interface Unit indicating an unfavorable comparison is inhibited until the new bi-level state is transferred from the auxiliary memory unit to the comparison memory unit.

The signal that indicates an unfavorable comparison, the "Safety Item Interrupt", initiates a search by the computer to determine which function caused the interrupt. The results of the outputs of the 150 comparator circuits are hard wired to the Response Conditioner. The computer will sequentially request and examine 15 bi-level data replies from the Response Conditioner until the incorrect function or functions are identified. Then the computer will output the latest predicted state information associated with the questionable function; if this doesn't remove the interrupt signal, the computer will perform a sub-system shutdown or complete shutdown depending on the function and the pre-programmed corrective action associated with that function.

K. STAGE SUBSTITUTES

Two stage substitutes are also included in the Automatic Checkout System. These units will provide the S-IVB with any electrical signals, loads or talkbacks normally supplied by the Instrument Unit or the S-II Stage. This includes both pre-launch and in-flight signals in order that all operational phases of the S-IVB Stage may be evaluated.

1. Aft Interface Substitute

During flight, the S-IVB Stage receives an indication from the S-II Stage that it has completed separation. The S-IVB +28V is routed through the S-II to a relay in the S-IVB; at separation, this circuit is opened and the relay drops out enabling the S-IVB "Engine Start" circuit. A relay which is part of the Aft Interface Substitute completes this circuit and, when energized by the Automatic Checkout System, simulates S-II separation to the S-IVB.

2. Instrument Unit Substitute

The commands received by the S-IVB Stage from the Instrument Unit will be supplied by the Instrument Unit Substitute. These commands are either generated in the ACS and routed through the Instrument Unit Substitute or generated in the substitute as a result of a command received from the ACS. The majority of the signals or talkbacks normally received by the Instrument Unit are routed through the Instrument Unit Substitute to the ACS for measurement or monitoring.

NUMBER SYSTEMS

Any number system may be defined by two characteristics, the radix or base and the modulus. The radix or base is the number of unique symbols used in the system. The decimal system has ten symbols, 0 through 9. Modulus is the number of unique quantities or magnitudes a given system can distinguish. For example, an adding machine with ten digits, or counting wheels, would have a modulus of $10^{10}-1$. The decimal system has no modulus because an infinite number of digits can be written, but the adding machine has a modulus because the highest number which can be expressed is 9,999,999,999.

Most number systems are positional, that is, the relative position of a symbol determines its magnitude. In the decimal system, a 5 in the units column represents a different quantity than a 5 in the tens column. Quantities equal to or greater than 1 may be represented by using the 10 symbols as coefficients of ascending powers of the base 10. The number 984_{10} is:

$$\begin{array}{rcl} 9 \times 10^2 & = & 9 \times 100 = 900 \\ + 8 \times 10^1 & = & 8 \times 10 = 80 \\ + 4 \times 10^0 & = & 4 \times 1 = 4 \\ & & \hline & & 984_{10} \end{array}$$

Quantities less than 1 may be represented by using the 10 symbols as coefficients of ascending negative powers of the base 10. The number 0.593_{10} may be represented as:

$$\begin{array}{rcl} 5 \times 10^{-1} & = & 5 \times .1 = .5 \\ + 9 \times 10^{-2} & = & 9 \times .01 = .09 \\ + 3 \times 10^{-3} & = & 3 \times .001 = .003 \\ & & \hline & & 0.593_{10} \end{array}$$

BINARY NUMBER SYSTEM

Computers operate faster and more efficiently by using the binary number system. There are only two symbols, 0 and 1; the base = 2. The following shows the positional value.

$$\begin{array}{cccccc} \dots & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 & \\ & =32 & =16 & =8 & =4 & =2 & =1 & \text{Binary point} \end{array}$$

The binary number 011010 represents:

$$\begin{array}{rcl} 0 \times 2^5 & = & 0 \times 32 = 0 \\ +1 \times 2^4 & = & 1 \times 16 = 16 \\ +1 \times 2^3 & = & 1 \times 8 = 8 \\ +0 \times 2^2 & = & 0 \times 4 = 0 \\ +1 \times 2^1 & = & 1 \times 2 = 2 \\ +0 \times 2^0 & = & 0 \times 1 = 0 \\ & & \hline & & 26_{10} \end{array}$$

Fractional binary numbers may be represented by using the symbols as coefficients of ascending negative powers of the base.

$$\begin{array}{cccccc} & 2^{-1} & 2^{-2} & 2^{-3} & 2^{-4} & 2^{-5} & \dots \\ \text{Binary Point} & . & =1/2 & =1/4 & =1/8 & =1/16 & =1/32 \end{array}$$

The binary number 0.10110 may be represented as:

$$\begin{array}{rcl} 1 \times 2^{-1} & = & 1 \times 1/2 = 1/2 = 8/16 \\ +0 \times 2^{-2} & = & 0 \times 1/4 = 0 = 0 \\ +1 \times 2^{-3} & = & 1 \times 1/8 = 1/8 = 2/16 \\ +1 \times 2^{-4} & = & 1 \times 1/16 = 1/16 = 1/16 \\ +0 \times 2^{-5} & = & 0 \times 1/32 = 0 = 0 \\ & & \hline & & 11/16_{10} \end{array}$$

OCTAL NUMBER SYSTEM

The octal number system uses eight discrete symbols, 0 through 7. With the base eight the positional value is:

	8^5	8^4	8^3	8^2	8^1	8^0
. . .	32,768	4,096	512	64	8	1

The octal number 513_8 represents:

$$\begin{aligned} 5 \times 8^2 &= 5 \times 64 = 320 \\ +1 \times 8^1 &= 1 \times 8 = 8 \\ +3 \times 8^0 &= 3 \times 1 = 3 \\ \hline &331_{10} \end{aligned}$$

Fractional binary numbers may be represented by using the symbols as coefficients of ascending negative powers of the base.

8^{-1}	8^{-2}	8^{-3}	8^{-4}	. . .
1/8	1/64	1/512	1/4096	

The octal number 0.4520 represents:

$$\begin{aligned} 4 \times 8^{-1} &= 4 \times 1/8 = 4/8 = 256/512 \\ +5 \times 8^{-2} &= 5 \times 1/64 = 5/64 = 40/512 \\ +2 \times 8^{-3} &= 2 \times 1/512 = 2/512 = \frac{2}{512} \\ &\hline &298/512 = 149/256_{10} \end{aligned}$$

ARITHMETIC

ADDITION AND SUBTRACTION

Binary numbers are added according to the following rules:

$$0 + 0 = 0$$

$$0 + 1 = 1$$

$$1 + 0 = 1$$

$$1 + 1 = 0 \text{ with a carry of } 1$$

The addition of two binary numbers proceeds as follows (the decimal equivalents verify the result):

Augend	0111	(7)
Addend	<u>+0100</u>	+(4)
Partial Sum	0011	
Carry	<u>1</u>	
Sum	1011	(11)

Subtraction may be performed as an addition:

8 (minuend)	8 (minuend)
<u>-6</u> (subtrahend)	<u>+4</u> (10's complement or subtrahend)
2 (difference)	2 (difference - omit carry)

MULTIPLICATION

Binary multiplication proceeds according to the following rules:

$$0 \times 0 = 0$$

$$0 \times 1 = 0$$

$$1 \times 0 = 0$$

$$1 \times 1 = 1$$

Multiplication is always performed on a bit-by-bit basis. Carries do not result from multiplication, since the product of any two bits is always a single bit.

Decimal example:

multiplicand	14
multiplier	<u>12</u>
partial products	28
	<u>14</u> (shifted one place left)
product	168 ₁₀

The shift of the second partial product is a shorthand method for writing the true value 140.

Binary example:

multiplicand	(14)	1110	
multiplier	(12)	<u>1100</u>	
		0000	
partial products		0000	shift to place digits in proper columns
		1110	
		<u>1110</u>	
product	(168 ₁₀)	10101000 ₂	

DIVISION

The following example shows the familiar method of decimal division:

	14	quotient
divisor	13 <u>185</u>	dividend
	<u>13</u>	
	55	partial dividend
	<u>52</u>	
	3	remainder

Binary example:

		1110	quotient (14)
divisor	1101	<u>10111001</u>	dividend
		<u>1101</u>	
		10100	
		<u>1101</u>	
		1110	partial dividends
		<u>1101</u>	
		11	remainder (3)

CONVERSIONS

The procedures that may be used when converting from one number system to another are power addition, double dabble, and substitution.

RECOMMENDED CONVERSION PROCEDURES (INTEGER AND FRACTIONAL)

CONVERSION	RECOMMENDED METHOD
Binary to Decimal	Power Addition
Octal to Decimal	Power Addition
Decimal to Binary	Double Dabble
Decimal to Octal	Double Dabble
Binary to Octal	Substitution
Octal to Binary	Substitution
General Rules	
$r_i > r_f$: Use Double Dabble, Substitution $r_i < r_f$: Use Power Addition, Substitution r_i = Radix of initial system r_f = Radix of final system	

POWER ADDITION

To convert a number from r_i to r_f ($r_i < r_f$) write the number in its expanded r_i poly-nominal form and simplify using r_f arithmetic.

EXAMPLE 1 Binary to Decimal (Integer)

$$\begin{aligned} 010111_2 &= 1(2^4) + 0(2^3) + 1(2^2) + 1(2^1) + 1(2^0) \\ &= 1(16) + 0(8) + 1(4) + 1(2) + 1(1) \\ &= 16 + 0 + 4 + 2 + 1 \\ &= 23_{10} \end{aligned}$$

EXAMPLE 2 Binary to Decimal (Fractional)

$$\begin{aligned} .0101_2 &= 0(2^{-1}) + 1(2^{-2}) + 0(2^{-3}) + 1(2^{-4}) \\ &= 0 + 1/4 + 0 + 1/16 \\ &= 5/16_{10} \end{aligned}$$

EXAMPLE 3 Octal to Decimal (Integer)

$$\begin{aligned} 324_8 &= 3(8^2) + 2(8^1) + 4(8^0) \\ &= 3(64) + 2(8) + 4(1) \\ &= 192 + 16 + 4 \\ &= 212_{10} \end{aligned}$$

EXAMPLE 4 Octal to Decimal (Fractional)

$$\begin{aligned} .44_8 &= 4(8^{-1}) + 4(8^{-2}) \\ &= 4/8 + 4/64 \\ &= 36/64_{10} \end{aligned}$$

DOUBLE DABBLE

To convert a whole number from r_i to r_f ($r_i > r_f$):

- 1) Divide r_i by r_f using r_i arithmetic
- 2) The remainder is the lowest order bit in the new expression
- 3) Divide the integral part from the previous operation by r_f
- 4) The remainder is the next higher order bit in the new expression
- 5) The process continues until the division produces only a remainder which will be the highest order bit in the r_f expression.

To convert a fractional number from r_i to r_f :

- 1) Multiply r_i by r_f using r_i arithmetic
- 2) The integral part is the highest order bit in the new expression
- 3) Multiply the fractional part from the previous operation by r_f
- 4) The integral part is the next lower order bit in the new expression
- 5) The process continues until sufficient precision is achieved or the process terminates.

EXAMPLE 1 Decimal to Binary (Integer)

$45 \div 2 = 22$ remainder 1; record	1
$22 \div 2 = 11$ remainder 0; record	0
$11 \div 2 = 5$ remainder 1; record	1
$5 \div 2 = 2$ remainder 1; record	1
$2 \div 2 = 1$ remainder 0; record	0
$1 \div 2 = 0$ remainder 1; record	1
	<hr/>
	101101

Thus: $45_{10} = 101101_2$

EXAMPLE 2**Decimal to Binary (Fractional)**

$$\begin{array}{rcl}
 .25 \times 2 & = & 0.5; \text{ record } 0 \\
 .5 \times 2 & = & 1.0; \text{ record } 1 \\
 .0 \times 2 & = & 0.0; \text{ record } 0 \\
 & & \underline{0} \\
 & & .010
 \end{array}$$

$$\text{Thus: } .25_{10} = .010_2$$

EXAMPLE 3**Decimal to Octal (Integer)**

$$\begin{array}{rcl}
 273 \div 8 & = & 34 \text{ remainder } 1; \text{ record } 1 \\
 34 \div 8 & = & 4 \text{ remainder } 2; \text{ record } 2 \\
 4 \div 8 & = & 0 \text{ remainder } 4; \text{ record } 4 \\
 & & \underline{4} \\
 & & 421
 \end{array}$$

$$\text{Thus: } 273_{10} = 421_8$$

EXAMPLE 4**Decimal to Octal (Fractional)**

$$\begin{array}{rcl}
 .55 \times 8 & = & 4.4; \text{ record } 4 \\
 .4 \times 8 & = & 3.2; \text{ record } 3 \\
 .2 \times 8 & = & 1.6; \text{ record } 1 \\
 \text{--} & \text{--} & \text{--} \\
 \text{--} & \text{--} & \text{--} \\
 & & \underline{4} \\
 & & .431...
 \end{array}$$

$$\text{Thus: } .55_{10} = .431..._8$$

SUBSTITUTION

This method permits easy conversion between octal and binary representations of a number. If a number in binary notation is partitioned into triplets to the right and left of the binary point, each triplet may be converted into an octal digit. Similarly each octal digit may be converted into a triplet of binary digits.

EXAMPLE 1

Binary to Octal

Binary = 110 000 . 001 010

Octal = 6 0 . 1 2

EXAMPLE 2

Octal to Binary

Octal = 6 5 0 . 2 2 7

Binary = 110 101 000 . 010 010 111



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