

EAI

TR-20

COMPUTER

Maintenance Series

RELATED PUBLICATIONS

The table below lists other publications which may be of interest to the readers of this manual. Unless otherwise indicated by title or footnote, all are maintenance handbooks. Note that maintenance handbooks directly applicable to a particular system are normally supplied with the system.

<u>Title</u>	<u>Publication Number</u>
Handbook of Analog Computation	00 800.0001-3
TR-20 Computer Operators Reference Handbook	00 800.2003-1
Sine-Cosine Diode Function Generators, Models 16.313 and 16.314	00 800.2005-0
TR-20 Maintenance Manual	00 800.2006-0
Transport Delay Simulator, Type 2.448	00 800.2009-0
Reactor Kinetics Group, Type 2.475	00 800.2010-0
Dual DC Amplifier, Model 6.282	00 800.2011-0
Quarter-Square Multiplier 7.045	00 800.2013-0
Dual X ² Diode Function Generator 16.101	00 800.2016-0
Dual Log X Diode Function Generator 16.126	00 800.2017-0
Dual One-Half Log X Diode Function Generator 16.133	00 800.2018-0
Variable Diode Function Generator	00 800.2019-0
Variable Diode Function Generator 16.156	00 800.2020-0
Signal Comparator 6.143	00 800.2023-0
Repetitive Operation Display Unit 34.034 and 34.035	00 800.2024-1
Dual Coefficient Attenuators 42.183, 42.187 and 42.188	00 800.2025-0
Reference Regulator 43.037	00 800.2027-0
Bi-Polar Multiplier, Models 7.117 and 7.137	00 800.2038-0

UNITED STATES AND CANADIAN OPERATIONS

Marketing Division

SALES OFFICE

EASTERN REGION

Eastern Regional Office: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Special System Department: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Customer Services: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Northeastern District Office: 875 Providence Highway, Dedham, Massachusetts 02026, Tel: 617-326-6756

Syracuse District Office: Pickard Building, Room 144-147, 5858 East Malloy Road, Syracuse, New York 13211, Tel: 315-455-5521

SOUTHEASTERN REGION

Southeastern Regional Office: 12260 Wilkins Avenue, Rockville, Maryland 20852, Tel: 301-933-4100

CENTRAL REGION

Central Regional Office: 33166 Des Plaines Ave., Des Plaines, Illinois 60018, Tel: 312-296-8171

Cleveland District Office: 6741 Ridge Road, Parma, Ohio 44129, Tel: 216-842-1840

SOUTHERN REGION

Southern Regional Office: 3514 Cedar Springs Road, Room 211, Dallas, Texas 75219, Tel: 214-528-4920

Houston District Office: 7007 Gulf Freeway, Room 128, Houston, Texas 77017, Tel: 713-MI 4-3678

Huntsville District Office: Holiday Office Center, Suite 2, 3322 South Memorial Parkway, Huntsville, Alabama 35801, Tel: 205-881-7031

WESTERN REGION

Western Regional Office: 1500 East Imperial Highway, El Segundo, California 90245, Tel: 213-322-3124, TWX 910-348-6284

San Francisco District Office: 4151 Middlefield Road, Palo Alto, California 94303, Tel: 415-321-0363, TWX 910-373-1241

Northwestern District Office: 1107 Northeast 45th St., Room 323, Seattle, Washington 98105, Tel: 206-632-7470

CUSTOMER SERVICES OFFICES

EASTERN REGION

Eastern U.S. Headquarters: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Northeastern District Office: 875 Providence Highway, Dedham, Massachusetts 02026, Telephone: 617-326-6756

Princeton, New Jersey: U.S. Route No. 1, P.O. Box 582, Princeton, New Jersey 08541, Telephone: 609-452-2900

Resident Field Engineers: Bedford, Mass./Florham Park, N. J./Washington, D.C./Baltimore, Md./Eatontown, N. J.

SOUTHEASTERN REGION

Southeastern Regional Office: 12260 Wilkins Avenue, Rockville, Maryland 20852, Telephone: 301-933-4100

CENTRAL REGION

Central Regional Office: 3166 Des Plaines Avenue, Des Plaines, Illinois 60018, Telephone: 312-296-8171

Cleveland District Office: 6741 Ridge Road, Parma, Ohio 44129, Telephone: 216-842-1840

Resident Field Engineers: Detroit, Michigan/Pittsburgh, Pennsylvania/Dayton, Ohio/Warren, Michigan

SOUTHERN REGION

Southern Regional Office: 3514 Cedar Springs Road, Room 211, Dallas, Texas 75219, Telephone: 214-528-4920

Houston District Office: 7007 Gulf Freeway, Room 128, Houston, Texas 77017, Tel: 713-MI 4-3678

Huntsville District Office: Holiday Office Center, Suite 2, 3322 South Memorial Parkway, Huntsville, Alabama 35801, Telephone: 205-881-7031

Resident Field Engineers: San Antonio, Texas/Alamogordo, New Mexico/Tulsa, Oklahoma/Houston, Texas

WESTERN REGION

Western U.S. Headquarters: CUSTOMER REPAIR FACILITY, 1500 East Imperial Highway, El Segundo, California 90245, Telephone: 213-322-3220, TWX 910-348-6284

Western U.S. Headquarters: CUSTOMER SERVICES FACILITY, 1500 East Imperial Highway, El Segundo, California 90245, Telephone: 213-322-3220, TWX 910-348-6284

San Francisco District Office: 4151 Middlefield Road, Palo Alto, California 94303, Tel: 415-321-0363, TWX 910-373-1241

Resident Field Engineers: Edwards, California/Pasadena, California/Moffet Field, California/Martin Marietta Corp., Denver, Colorado/Ryan Aeronautical, San Diego, California

CANADA

Toronto Office: Allan Crawford Associates, Ltd., 65 Martin Ross Avenue, Downsview Ontario, Canada, Tel: 416-636-4910

ANALYSIS AND COMPUTATION CENTERS

Princeton Analysis and Computation Center: U.S. Route No. 1, P. O. Box 582, Princeton, New Jersey 08541, Telephone: 609-452-2900

Los Angeles Analysis and Computation Center: 1500 East Imperial Highway, El Segundo, California 90245, Telephone: 213-322-3220, TWX 910-348-6284

San Francisco Analysis and Computation Center: 4151 Middlefield Road, Palo Alto, California 94303, Tel: 415-321-0363, TWX 910-373-1241

Washington, D. C. Analysis and Computation Center: 12260 Wilkins Avenue, Rockville, Maryland 20852, Tel: 301-933-4100

Houston Analysis and Computation Center: 7007 Gulf Freeway, Room 128, Houston, Texas 77017, Tel: 713 MI 4-3678

Engineering and Manufacturing Division

Engineering Department: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Manufacturing Department: West Long Branch, N. J. 07764, Tel: 201-229-1100, TWX 710-722-6597, Telex 01-26655, Cable: PACE West Long Branch, N. J. 07764

Other Departments, Divisions and Subsidiaries

Instrument Division: Long Branch, N. J. 07740, Tel: 201-229-4400, TWX 710-722-6597, Cable: PACE West Long Branch, N. J. 07740

Pacific Data Systems, Inc.: 644 Young Street, Santa Ana, California 92705, Tel: 714-540-3610, TWX 714-546-3049

Scientific Instruments Department: 4151 Middlefield Road, Palo Alto, California 94303, Tel: 415-321-7801, TWX 910-373-1241

INTERNATIONAL SALES & CUSTOMER SERVICES OFFICES

UNITED KINGDOM & SCANDINAVIA

Electronic Associates, Ltd.: Burgess Hill, Sussex, England, Tel: Burgess Hill (Sussex) 5101-10, 5201-5, Telex: 87183, Cable: PACE Burgess Hill

Northern Area Office: Roberts House, Manchester Road, Altrincham, Cheshire, Tel: Altrincham 5426

SWEDEN

EAI-Electronic Associates-AB: Hagavagen 14, Solna 3, Sweden, Tel: Stockholm 82-40-96; 82-40-97, 83-38-60, Telex Stockholm 10064, Cable: PACE STOCKHOLM

EUROPEAN CONTINENT

EAI-European Continental Regional Office: Centre International, 22nd Floor, Place Rogier, Brussels 1, Belgium, Tel: Brussels 18-40-04, Telex: 2.21-106, Cable: PACEBELG Brussels

FRANCE

EAI Electronic Associates SARL: 72-74, rue de la Tombe Issoire, Paris 14e, France, Tel: 535.01.07, Telex 27610

GERMANY

EAI-Electronic Associates GMBH: 5100 Aachen, Bergdriesch 37, West Germany, Tel: Aachen 2 60 42; 2 60 41, Telex 832.676 eai d

AUSTRALIA & NEW ZEALAND

EAI-Electronic Associates, Pty., Ltd.: 26 Albany St., Leonards, N.S.W. Australia, Tel: 43-7522, Cable: PACEAUS, Sydney

Victorian Office: 34 Queens Road, Melbourne S. C. 2, Australia, Tel: 26-1329, Cable: PACEAUS, Melbourne

JAPAN

EAI-Electronic Associates (Japan), Inc.: 9th Mori Building, 1-3 Shiba-Atago-cho, Minato-Ku, Tokyo, Japan, Tel: 433-4671, Telex: 7814285, Cable: EAIJAPACE

ENGINEERING AND MANUFACTURING

Electronic Associates, Ltd.: Burgess Hill, Sussex, England, Tel: Burgess Hill (Sussex) 5101-10, 5201-5, Telex: 87183, Cable: PACE BURGESS HILL

MEXICO

EAI-Electronic Associates, S.A. de C.V.: Darwin #142, Planta Baja, Col. Azures, Mexico 5, D.F., Tel: 28-55-13, Cable: PACEMEX

COMPUTATION CENTERS

European Computation Center: Centre International, 22nd Floor, Place Rogier, Brussels 1, Belgium, Tel: Brussels 18-40-04, Telex: 2.21-106, Cable: PACEBELG Brussels

United Kingdom Computation Center: Electronic Associates, Ltd., Burgess Hill, Sussex, England, Tel: Burgess Hill (Sussex) 5101-10, Telex: 871-183, Cable: PACE BURGESS HILL

Australian Computation Center: 34 Queens Road, Melbourne S. C. 2, Australia, Tel: 26-1329, Cable: PACEAUS, Melbourne

EAI

ELECTRONIC ASSOCIATES, INC. West Long Branch, New Jersey 07764

ADVANCED SYSTEMS ANALYSIS AND COMPUTATION SERVICES/ANALOG COMPUTERS/DIGITAL COMPUTERS/HYBRID ANALOG-DIGITAL COMPUTATION EQUIPMENT/ANALOG AND DIGITAL PLOTTERS/SIMULATION SYSTEMS/SCIENTIFIC AND LABORATORY INSTRUMENTS/INDUSTRIAL PROCESS CONTROL SYSTEMS/PHOTODIAGNOSTIC EQUIPMENT/RANGE INSTRUMENTATION/MILITARY AND INDUSTRIAL RESEARCH AND DEVELOPMENT SERVICES/FIELD ENGINEERING AND EQUIPMENT MAINTENANCE SERVICES.

NOTICE

In order to enable us to process your requests for spare parts and replacement items quickly and efficiently, we request your conformance with the following procedure:

1. Please specify the type number and serial number of the basic unit as well as the EAI part number and description of the part when inquiring about replacement items such as potentiometer assemblies or cups, relays, transformers, precision resistors, etc.
2. When inquiring about items as servo multipliers, resolvers, networks, printed circuit assemblies, etc., please specify the serial numbers of the major equipment with which the units are to be used, such as: Console, Type 8811, Memory Module, Type 4.204, Serial No. 000, etc. If at all possible, please include the purchase order or the EAI project number under which the equipment was originally procured.

Your cooperation in supplying the required information will speed the processing of your requests and aid in assuring that the correct items are supplied.

It is the policy of Electronic Associates, Inc. to supply equipment patterned as closely as possible to the requirements of the individual customer. This is accomplished, without incurring the prohibitive costs of custom design, by substituting new components, modifying standard components, etc., wherever necessary to expedite conformance with requirements. As a result, this instruction manual, which has been written to cover standard equipment, may not entirely concur in its content with the equipment supplied. It is felt, however, that a technically qualified person will find the manual a fully adequate guide in understanding, operating, and maintaining the equipment actually supplied.

Electronic Associates, Inc. reserves the right to make changes in design, or to make additions to or improvements in its product without imposing any obligation upon itself to install them on products previously manufactured.

CONTENTS

	<u>Page</u>
CHAPTER I - THE TR-20 COMPUTER	
1. GENERAL DESCRIPTION.....	1
2. EQUIPMENT COMPLEMENT.....	1
3. OPERATING AND MAINTENANCE ACCESSORIES.....	7
4. PRELIMINARY CHECKOUT.....	7
<u>a.</u> Visual Inspection.....	7
<u>b.</u> Insertion of Pre-Patch Panel.....	9
<u>c.</u> Feedback for the Amplifiers.....	9
<u>d.</u> Application of Primary Power.....	9
<u>e.</u> Operational Check.....	11
5. INSTALLATION OF PATCHING BLOCKS AND CONTACT SPRINGS.....	11
6. CHASSIS AND ETCHED CARD REMOVAL.....	11
7. OUTPUT DEVICES.....	13
CHAPTER II - DUAL DC AMPLIFIER, MODEL 6.712	
1. INTRODUCTION.....	15
2. TECHNICAL DATA.....	15
3. OPERATING CONSIDERATIONS.....	15
<u>a.</u> Patching.....	15
<u>b.</u> Amplifier Balancing.....	17
<u>c.</u> Overloads.....	18
4. CIRCUIT DESCRIPTION.....	18
<u>a.</u> Basic Block Diagram.....	18
<u>b.</u> The DC Amplifier Section.....	20
<u>c.</u> The Stabilizer Section.....	23

CONTENTS (Cont)

	<u>Page</u>
5. TEST PROCEDURES.....	23
<u>a.</u> Frequency Response.....	23
<u>b.</u> Offset Measurement.....	25
<u>c.</u> Noise Measurement.....	25
<u>d.</u> Output Current Capability.....	25
6. TROUBLESHOOTING.....	26
<u>a.</u> Failure to Balance.....	26
<u>b.</u> DC Amplifier Section Check.....	26
<u>c.</u> Stabilizer Check.....	27
<u>d.</u> Some Symptoms and Possible Remedies.....	27
<u>e.</u> Amplifier Voltage and Resistance Checks.....	27
CHAPTER III - DUAL INTEGRATOR NETWORK, MODEL 12.1116	
1. GENERAL DESCRIPTION.....	33
2. TECHNICAL DATA.....	33
3. PATCHING.....	33
4. CIRCUIT DESCRIPTION.....	33
5. TEST PROCEDURES.....	35
<u>a.</u> Operational Check.....	35
<u>b.</u> Initial Condition Resistor Ratio.....	35
<u>c.</u> Integrator Drift Rate.....	35
6. TROUBLESHOOTING.....	37
CHAPTER IV - QUARTER-SQUARE MULTIPLIER, MODEL 7.045	
1. GENERAL DESCRIPTION.....	39
2. TECHNICAL DATA.....	39
3. PATCHING.....	39
4. CIRCUIT DESCRIPTION.....	41

CONTENTS (Cont)

	<u>Page</u>
5. MAINTENANCE.....	43
<u>a.</u> Error Test.....	43
<u>b.</u> Adjustment Procedure.....	45
<u>c.</u> Troubleshooting.....	45
CHAPTER V - X^2 DIODE FUNCTION GENERATOR, MODEL 16.101	
1. GENERAL DESCRIPTION.....	47
2. TECHNICAL DATA.....	47
3. PATCHING.....	47
4. CIRCUIT DESCRIPTION.....	49
5. MAINTENANCE.....	49
<u>a.</u> Adjustment Procedure.....	49
<u>b.</u> Troubleshooting.....	52
CHAPTER VI - DUAL LOG X DFG, 16.126 AND DUAL 1/2 LOG X DFG, 16.133	
1. GENERAL DESCRIPTION.....	53
2. TECHNICAL DATA.....	53
3. PATCHING.....	55
4. CIRCUIT DESCRIPTION.....	55
5. MAINTENANCE.....	55
<u>a.</u> Adjustment Procedure.....	55
<u>b.</u> Troubleshooting.....	58
CHAPTER VII - VARIABLE DIODE FUNCTION GENERATOR GROUPS 2.645 AND 2.713	
1. GENERAL DESCRIPTION.....	59
2. TECHNICAL DATA.....	61
3. OPERATING INSTRUCTIONS.....	61
<u>a.</u> Scope.....	61
<u>b.</u> Patching.....	62

CONTENTS (Cont)

	<u>Page</u>
4. CIRCUIT DESCRIPTION.....	62
<u>a.</u> Fixed Breakpoint VDFG.....	62
<u>b.</u> Variable Breakpoint VDFG.....	65
5. MAINTENANCE.....	65
<u>a.</u> Fixed Breakpoint VDFG's.....	65
<u>b.</u> Variable Breakpoint VDFG's.....	67
CHAPTER VIII - COEFFICIENT ATTENUATOR GROUPS	
1. GENERAL DESCRIPTION.....	69
2. CIRCUIT DESCRIPTION.....	69
3. MAINTENANCE.....	71
CHAPTER IX - SIGNAL COMPARATORS AND FUNCTION SWITCHES	
1. RELAY COMPARATOR, MODEL 6.143.....	73
<u>a.</u> General Description.....	73
<u>b.</u> Technical Data.....	73
<u>c.</u> Circuit Description.....	73
<u>d.</u> Adjustment of Voltage Switching Level.....	75
<u>e.</u> Maintenance.....	75
2. ELECTRONIC COMPARATOR, MODEL 40.538.....	77
<u>a.</u> General Description.....	77
<u>b.</u> Technical Data.....	79
<u>c.</u> Block Diagram Analysis.....	79
<u>d.</u> Circuit Description.....	81
<u>e.</u> Maintenance.....	85

CONTENTS (Cont)

	<u>Page</u>
3. DUAL FUNCTION SWITCH GROUP 2.127.....	87
 CHAPTER X - MANUAL MODE CONTROL, REPETITIVE OPERATION, AND MONITORING CIRCUITS	
1. READOUT FACILITIES.....	91
2. MANUAL MODE CONTROL.....	91
3. SLAVING.....	93
4. REPETITIVE OPERATION GROUP 2.715.....	95
<u>a.</u> General Description.....	95
<u>b.</u> Dual Integrator Network 12.1115	95
<u>c.</u> Repetitive Operation Control Panel 20.532.....	96
<u>d.</u> Timing Unit, Model 36.082.....	96
<u>e.</u> Adjustment of Reset and Operate Times.....	97
<u>f.</u> Repetitive Relay Checks.....	99
5. READOUT AND DISPLAY NETWORKS.....	101
<u>a.</u> Model 12.987 Display Network.....	101
<u>b.</u> Model 40.538 Electronic Comparator.....	101
6. OVERLOAD INDICATORS.....	103
<u>a.</u> Visual Overload Indicators.....	103
<u>b.</u> Audio Overload Alarm, Model 13.017.....	103
 CHAPTER XI - POWER AND REFERENCE VOLTAGE SUPPLIES	
1. REGULATED POWER SUPPLY, MODEL 10.179.....	107
<u>a.</u> General Description.....	107
<u>b.</u> Technical Data.....	107
<u>c.</u> Circuit Description.....	109
<u>d.</u> Output Voltage Adjustment.....	110
<u>e.</u> Troubleshooting.....	110

CONTENTS (Cont)

	<u>Page</u>
2. REFERENCE REGULATOR, MODEL 43.037.....	111
<u>a.</u> General Description.....	111
<u>b.</u> Technical Data.....	111
<u>c.</u> Circuit Description.....	111
<u>d.</u> Patching.....	113
<u>e.</u> Adjustments.....	113
<u>f.</u> Troubleshooting.....	114
3. POWER BUS BYPASS NETWORK.....	114
4. APPLICABLE DRAWINGS FOR THE POWER AND REFERENCE CIRCUITS.....	114
APPENDIX I - ELEMENTARY PRINCIPLES OF ANALOG DEVICES.....	AI-1
1. THE DC AMPLIFIER.....	AI-2
2. DIODE FUNCTION GENERATORS AND QUARTER-SQUARE MULTIPLIERS.....	AI-3
APPENDIX II - SERVICING TECHNIQUES.....	AII-1
1. TRANSISTOR SERVICING AND TROUBLESHOOTING TECHNIQUES.....	AII-2
2. ETCHED CIRCUIT BOARD SOLDERING TECHNIQUES.....	AII-3
APPENDIX III - REPLACEABLE PARTS LISTS.....	AIII-1
APPENDIX IV - DRAWINGS.....	AIV-1

ILLUSTRATIONS

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1a.	Typical TR-20 Computer, Front View	xii
1b.	Typical TR-20 Computer, Rear View	xii
2.	Typical TR-20 Computing Components	2
3.	Inserting the Pre-Patch Panel	8
4.	Amplifiers with Bottle Plugs in Place	10
5.	Installation of Patch Blocks in Pre-Patch Panel	12
6.	Dual DC Amplifier, Model 6.712	14
7.	Model 6.712, Patched as an Inverter	16
8.	One Channel of Dual DC Amplifier, Model 6.712, Simplified Block Diagram	19
9.	One Channel of the Model 6.712, Simplified Schematic ...	21
10.	Frequency Response Test Circuit	24
11.	Test Circuit for Measuring Amplifier Offset	24
12.	Test Circuit for Measuring Noise	24
13.	Output Current Test Circuit	24
14.	Amplifier Troubleshooting Guide	28
15.	Stabilizer Section Test Circuit and Test Points	29
16.	Symptoms and Possible Causes of Amplifier Malfunctions .	30
17.	Dual Integrator Network, Model 12.1116	32
18.	Patching an Amplifier to an Integrator, Showing Simpli- fied Schematic of an Integrator Network	34
19.	Block Diagram and Symbol for an Integrator	34

ILLUSTRATIONS (Cont)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
20.	Operational Check Circuit.....	36
21.	Initial Condition Resistor Ratio Check Circuit.....	36
22.	Integrator Drift Rate Check Circuit.....	36
23.	Symptoms and Probable Causes of Some Integrator Mal- functions.....	38
24.	Quarter-Square Multiplier Patching.....	40
25.	Quarter-Square Multiplier, Simplified Schematic.....	42
26.	Error Test.....	44
27.	Quarter-Square Multiplier Adjustment.....	46
28.	X^2 DFG Patching.....	48
29.	X^2 DFG, Simplified Schematic.....	50
30.	X^2 DFG Adjustment Information.....	51
31.	Log X and 1/2 Log X DFG Patching.....	54
32.	+Input Log X DFG, Simplified Diagram.....	56
33.	Adjustment Information Log X DFG's.....	57
33a.	VDFG Mounting Locations	60
34.	+VDFG Patching and Symbol.....	63
35.	+Fixed Breakpoint VDFG Unit, Simplified Schematic.....	64
36.	+Variable Breakpoint VDFG Unit, Simplified Schematic..	66
37.	VDFG Test Circuit.....	68
38.	Attenuator Schematic.....	70
39.	Schematics and Symbols for Attenuators.....	70
40.	Relay Comparator, Simplified Diagram.....	74

ILLUSTRATIONS (Cont)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
41.	Circuit for Setting Voltage Switching Level	74
42.	Sensitivity and Switching Time Test Circuit	76
43.	Test Waveform	76
44.	Model 40.538 Electronic Comparator	78
45.	Comparator Unit, Functional Block Diagram	80
46.	Electronic Switch Unit, Functional Block Diagram	80
47.	Comparator, Simplified Schematic	82
48.	Electronic Switch, Simplified Schematic	84
49.	Gate Output Offset Test Patching	86
50.	Gate Junction Offset Test Patching	86
51.	Control Area of the TR-20	88
52.	Readout Circuits, Simplified Schematics	90
53.	Relay Bus Driver, Simplified Schematics	92
54.	Patching an Amplifier to a Rep-Op Integrator Showing Simplified Schematic of Integrator Network	94
55.	Reset and Operate Time Adjustment	98
56.	Improper Waveforms	98
57.	Locating an Integrator with an Average Start Time	100
58.	Start Time Error Test.....	100
59.	Simplified Diagram of Wiring for Display Networks	102
60.	Overload Indicator, Simplified Schematic	104
61.	Overload Indicators, Simplified Wiring Diagram ..	104
62.	Power and Reference Supplies	108
63.	Reference Regulator, Model 43.037, Simplified Schematic	112
64.	Reference Balance Test Circuit	112

INTRODUCTION

TR-20 MAINTENANCE MANUAL

An Operator's Reference Handbook and a Maintenance Manual are provided with each TR-20. The Operator's Reference Handbook provides programming procedures, and sufficient information on computer operation to enable the user to interconnect computing components and to operate the computer without difficulty. This publication is the maintenance manual for the TR-20 and its contents have been arranged in accordance with that use. The manual is divided into sections that describe a particular computing component or a group of related circuits. A technically qualified person will find the circuit descriptions an adequate guide in understanding the operation of the equipment. Persons who are not familiar with analog devices are referred to Appendix I for a discussion of some elementary principles. (Suggestions and techniques for servicing transistor circuits are included in Appendix II to aid maintenance personnel who are not familiar with transistorized equipment.) Where applicable, recommended test and adjustment procedures are included. The test procedures selected are designed to provide a simple and convenient means for monitoring the equipment on a regular basis. A replaceable parts list and schematic and wiring diagrams for each unit are located in the rear of the manual. A component location diagram has been placed near each schematic diagram to facilitate maintenance.

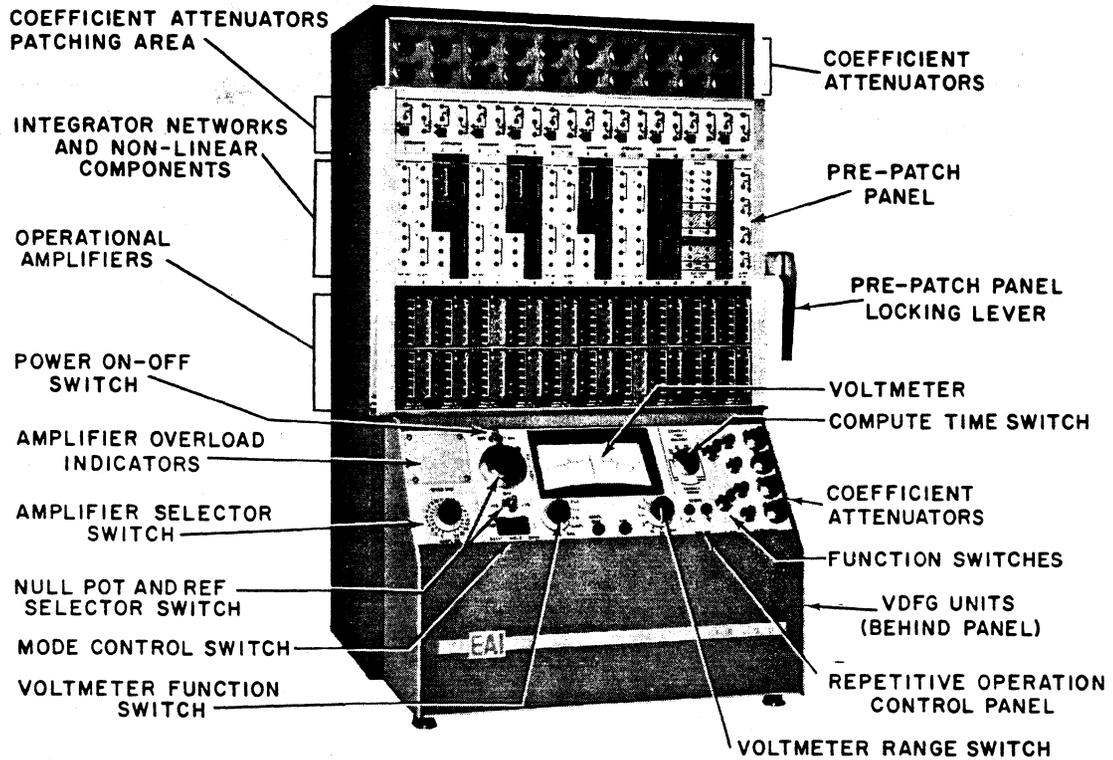


Figure 1a. Typical TR-20 Computer, Front View

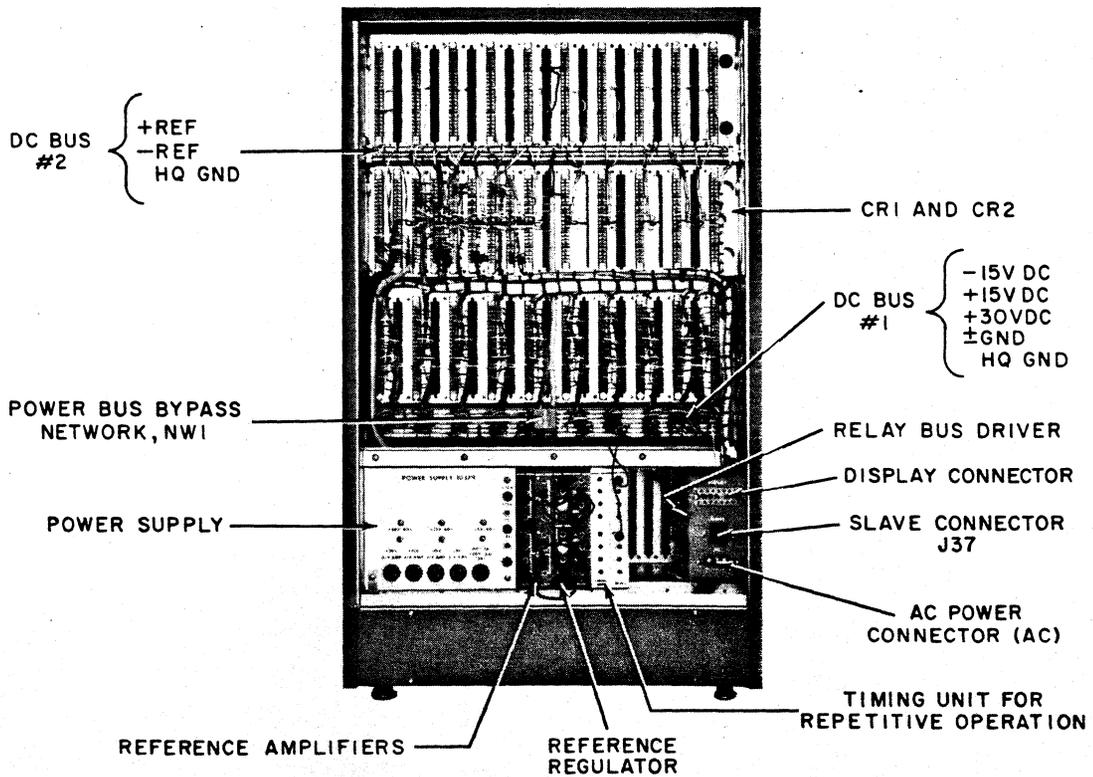


Figure 1b. Typical TR-20 Computer, Rear View

CHAPTER I

THE TR-20 COMPUTER

1. GENERAL DESCRIPTION

The PACE[®] TR-20, Figure 1, is a general purpose analog computer designed and manufactured by Electronic Associates, Inc. Composed of solid-state computing components, the TR-20 is compact in size, has low power requirements, and does not need special cooling equipment in order to operate in normal office or classroom environments. A fully expanded computer consumes less than 60 watts.

The computing components (see Figure 2) in the TR-20 occupy cradles above the slanting control panel area. The cradle area is divided into three rows; the top row contains the coefficient attenuators; the middle row houses the integrator networks, comparators and other non-linear computing components; the bottom row provides space for twenty (10 dual units) operational amplifiers.

The computing components are constructed on plug-in chassis. The front of each computing component consists of a color-coded plastic patching block that contains the input and output terminations for the unit. The computing components are interconnected by placing patch cords between the appropriate input and output terminations. TR-20 Computers may be equipped with a removable pre-patch panel that allows problem patching away from the computer. The pre-patch panel consists of a rigid aluminum frame with individual rows that contain patching blocks identical to the patching blocks that form the front panels of the components. Contact between the pre-patch panel and the computing components is accomplished by means of gold plated contact springs.

2. EQUIPMENT COMPLEMENT

The components contained in and available for the TR-20 Computer are listed in Table I.

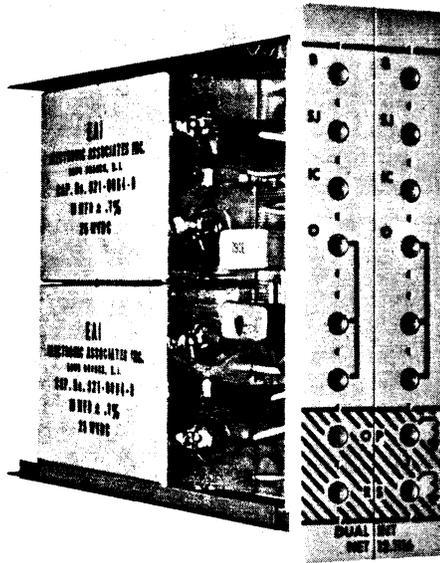
The TR-20 Computer cabinet accepts the plug-in computing components listed in Table I in five areas as follows:

a. Attenuator Row

This is the top row of computing components. It is wired to accept a maximum of 10 dual coefficient setting potentiometer plug-in modules (20 potentiometers).

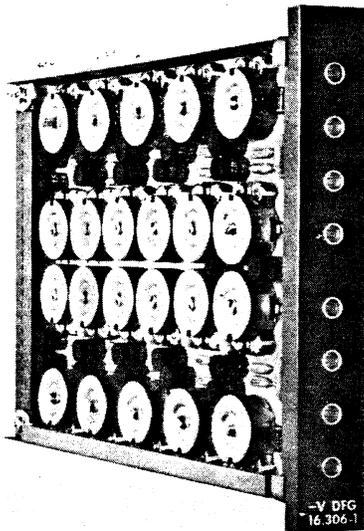
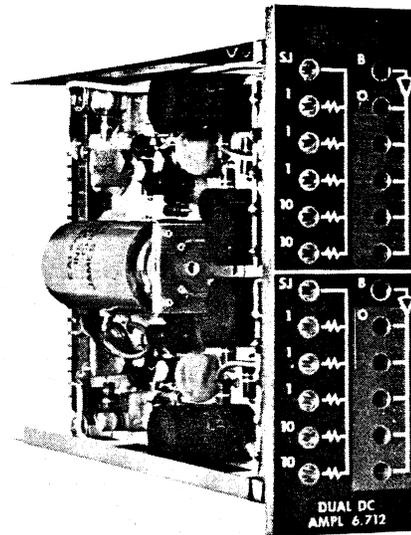
b. Non-Linear Row

This is the middle row of computing components. It is wired to accept a variety of interchangeable linear and non-linear computing components.



(a) 12.1116 Integrator Network

(b) 6.712 Dual DC Amplifier



(c) 16.306 Variable Diode Function Generator

Figure 2. Typical TR-20 Computing Components

c. Amplifier Row

This is the bottom row of computing components. It is wired to accept a maximum of 10 dual amplifier modules (20 amplifiers).

d. Control Panel Area

This is the area on the right side of Control Panel 20.734. Three positions are available (numbered left to right) to accept the following accessory equipment:

- (1) Position CP1. High Speed Repetitive Operation Control Panel, 20.532.
- (2) Position CP2. Type 20.366 Function Switch Assembly.
- (3) Position CP3. Type 42.185 Quad Coefficient Setting Potentiometer Panel.

e. The VDFG Area

This area is located behind the hinged cover below the control panel. Space is provided for housing up to six VDFG units in slide-out trays. The slide-out feature makes the adjustment pots readily accessible for function setup.

Certain TR-20's, such as those that are equipped with a Reactor Kinetics Network or a Transport Delay Simulator, will have different arrangements.

Non-Linear computing components (multiplier; DFG's, etc.) are housed in full-width (1-1/2 inches) or half-width (3/4 inches), plug-in modules that are interchangeable in the non-linear row. This row consists of twenty 3/4-inch positions numbered to correspond to the numbering strip across the top of the row. It has the capacity for mounting twenty half-width modules, or ten full-width modules, or any combination of both which does not exceed the total capacity of the row. Full-width modules occupy adjacent odd and even numbered position pairs, i.e., 1 and 2, 5 and 6, etc.

The non-linear row makes provisions for the following inter-changeable components in any combination (within the limitations described below), providing that the total capacity of the row is not exceeded.

(1) Integrator Networks. Up to nine Type 12.1116 or Type 12.1115 Dual Networks can be accommodated in positions 1 through 18. Each dual network occupies adjacent position pairs.

(2) Multipliers. Up to nine Type 7.045 Quarter-Square Multipliers or 7.117 Bi-Polar Quarter-Square Multipliers can be accommodated in positions 1 through 18. Since the multiplier is housed in a full-width module it also occupies adjacent position pairs.

TABLE I. TR-20 COMPONENTS

GROUP	COMPONENT	MODEL NUMBER
COMPUTING COMPONENTS		
1	Dual DC Amplifier	6.712
2 a	Dual Integrator Network (Non-Rep-Op)	12.1116
2b	Dual Repetitive Operation Integrator Network	12.1115
3a	Quarter-Square Multiplier	7.045
3b	Bi-Polar Quarter-Square Multiplier	7.117*
4a	X ² Diode Function Generator	16.101
4b	Log X Diode Function Generator	16.126
4c	1/2 Log X Diode Function Generator	16.133
4d	Sine/Cosine Diode Function Generator	16.313*
5a	Variable Diode Function Generator Group	2.713-0
	Consists of:	
	-Variable Diode Function Generator	16.154-1
	+Variable Diode Function Generator	16.156-1
	+VDFG Readout Module	16.310
5b	Variable Diode Function Generator Group	2.645
	Consists of:	
	+Variable Diode Function Generator	16.304 -1
	-Variable Diode Function Generator	16.306 -1
	VDFG Readout Module	16.308
5c	Variable Diode Function Generator Group	2.752
	Consists of:	
	+Variable Diode Function Generator	16.165-1
	VDFG Readout Module	16.310

GROUP	COMPONENT	MODEL NUMBER
COMPUTING COMPONENTS (Cont)		
6a	Attenuator Group	42.183
6b	Attenuator Group	42.187
6c	Attenuator Group	42.188
6d	Attenuator Group	2.128
	Consists of:	
	Attenuator Panel	42.185
	Readout Module	12.265
7a	Reference Network	12.266
7b	Tiepoint Network	12.267
7c	Dual Function Switch Group	2.127
	Consists of:	
	Function Switch Assembly	20.366
	Readout Module	12.264
8a	Signal Comparator	6.143
8b	Electronic Comparator	40.538
9	Regulated Power Supply	10.179
10	Reference Regulator	43.037
11	Dual DC Amplifier	6.282
OPTIONAL COMPONENTS AND ACCESSORY EQUIPMENT		
12	Repetitive Operation Expansion Group	2.715
	Consists Of:	
	High Speed Repetitive Operation Control Panel	20.532
	Repetitive Operation Timing Unit	36.082

GROUP	COMPONENT	MODEL NUMBER
OPTIONAL COMPONENTS AND ACCESSORY EQUIPMENT (Cont)		
	Dual Repetitive Operation Integrator Network	12.1115
13	Display Unit**	12.987
14	Reactor Kinetics Group	2.475*
15	Transport Delay Simulator	2.448*
16	Audio Overload Alarm	13.017
17	Slave Cable	510.038
18	Patching Kit	100.007
19	Service Shelf	51.039
20	AC Power Cable	51.040
21	Pre-Patch Panel	5.235
22	Rep-Op Slave Panel	20.567
AUXILIARY EQUIPMENT		
1	VARI PLOTTER [®]	1110
2	Repetitive Operation Display Unit	34.035*

(3) Variable DFG. The available models of the variable DFG can be accommodated in any even numbered position with the exception of position 20.

(4) Fixed Diode Function Generators (Half Width). The Type 16.101 X² Function Generator, the Model 16.126 Log X Diode Function Generator, and the Model 16.133 1/2 Log X DFG are housed in half-width modules, and may be placed in any even numbered position with the exception of position 20.

*These Components described in separate manuals.

**This component not required if the Electronic Comparator, Model 40.538 is provided.

(5) Fixed Diode Function Generators (Full Width). The Model 16.313 Sine/Cosine Diode Function Generator is housed in a full-width module, and may be located in adjacent position pair 17-18 only.

(6) Reference Panel. The Type 12.266 Reference Panel can be positioned in any even numbered position with the exception of position 20.

(7) Dual Tie Point Panel. This unit can be used in any position in the non-linear row.

(8) Comparators. The Type 6.143 Relay Comparator may be used in position 18 only. The Type 40.538 Electronic Comparator may be used in adjacent position pair 17-18 only.

(9) Function Switch Patching Module. The Type 12.264 Patching Module may be mounted in position 19 only.

(10) Quad Potentiometer Patching Module. The Type 12.265 Patching Module may be mounted in position 20 only.

(11) Display Module. This module is required only if the electronic comparator is not supplied. It can be placed in position 17 only.

NOTE

The above assignment of computing components applies to the standard TR-20 Computers. Special computers may be supplied with provisions for mounting DFG's or reference panels in the odd numbered positions (with the exception of position 1) or for accommodating more than one comparator.

3. OPERATING AND MAINTENANCE ACCESSORIES

In addition to the components listed in the preceding paragraph, each TR-20 includes a group of operating and maintenance accessories. These items are listed in Table I.

4. PRELIMINARY CHECKOUT

Each TR-20 is completely tested prior to shipment and should be ready for operation upon receipt. However, as a matter of good practice, it is recommended that the procedures below be followed as a preliminary checkout.

a. Visual Inspection

Make a visual inspection of the computer. Look for signs for shipping damage. Become familiar with the location of all components (refer to Figure 1). Check all plug-in units for proper seating. Verify that the patching blocks on the

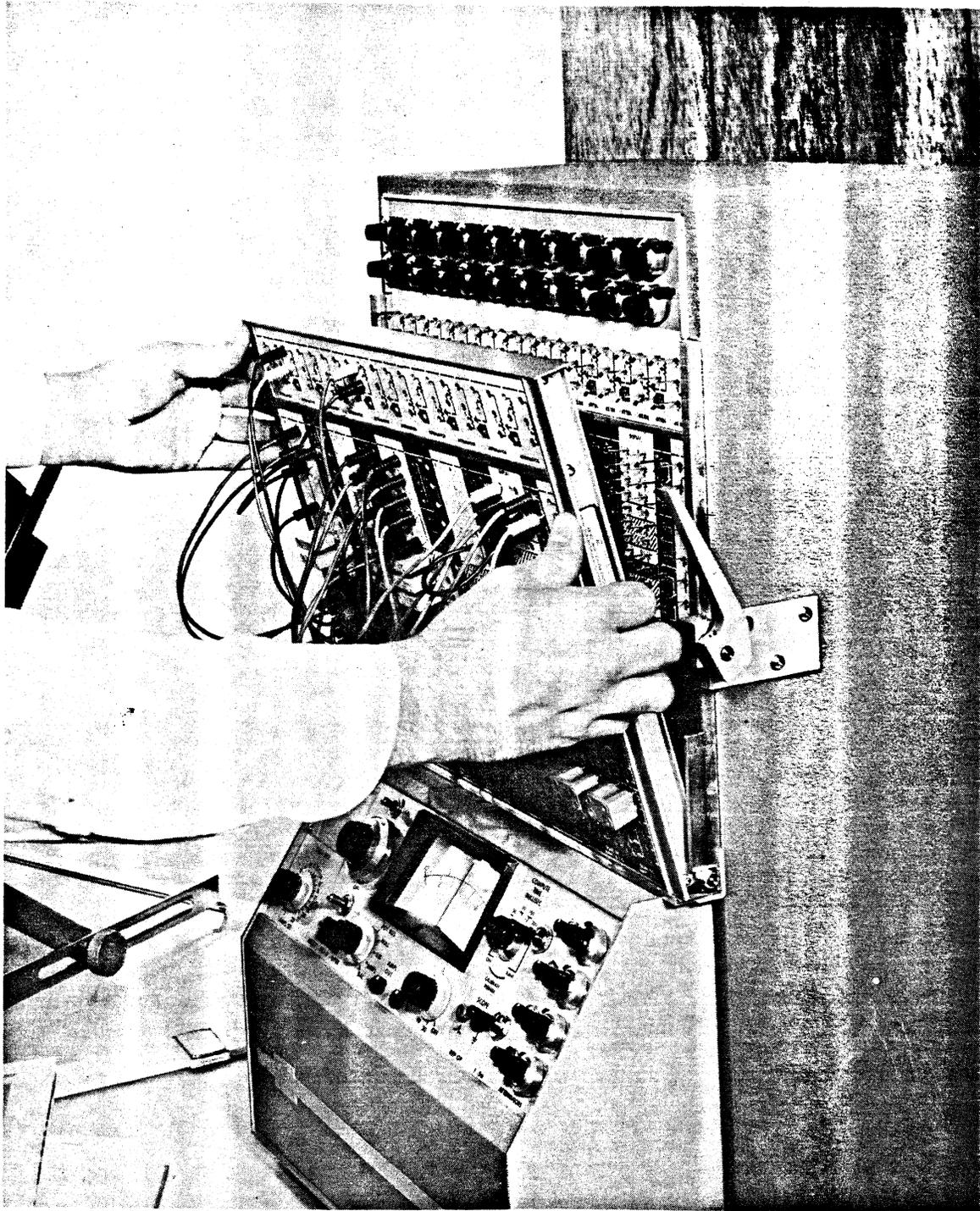


Figure 3. Inserting the Pre-Patch Panel

pre-patch panel are positioned in the same order as the computing components. The switches in the control area should be positioned as follows:

Power ON-OFF Switch OFF
Mode Control Switch RESET
Voltmeter Function Switch..... VM
Voltmeter Range Switch OFF
COMPUTE TIME MILLISEC Switch..... OFF

b. Insertion of Pre-Patch Panel

As shown in Figure 3, hold the pre-patch panel at a slight angle and place it in the patch bay groove. Move the pre-patch panel to the right until it contacts the right-hand side of the patch bay. Gently push the pre-patch panel forward until it is flush with the computer. Turn the locking lever down (the pre-patch panel will slide to the left).

c. Feedback for the Amplifiers

All operational amplifiers should be provided with feedback whenever the computer is turned on. Connect bottle plugs or patch cords as shown in Figure 4.

d. Application of Primary Power

The TR-20 is designed to operate from a 50 to 60 cycle ac supply. The ac circuits are factory-wired for 110 vac or 220 vac as specified in the purchase order for the computer. (Drawings D010 179 0S and D010 179 0W show the required changes for converting from one power level to the other.) A three wire power cable is furnished for connecting primary power to the TR-20. The power cable is terminated in a parallel ground (3-prong, polarized) plug for connection to a parallel ground receptacle. If the primary power line to which the computer is to be connected is not equipped with such a receptacle, a parallel ground adapter (adapts 3 prong appliance plugs for use in standard 2 prong outlets) must be used. In this case, two precautions should be observed:

(1) The power cable should be connected so that the ground side of the ac line is connected to the ac common line of the computer. The ac common line is terminated on pin 1 of the ac power connector; see Drawings D045 078 0W, Sheet 2 and B045 078 0W, Sheet 3.

(2) The ground wire on the adapter must be connected to earth ground.

These precautions should be taken for safety reasons and also to prevent excessive noise in the amplifier outputs.

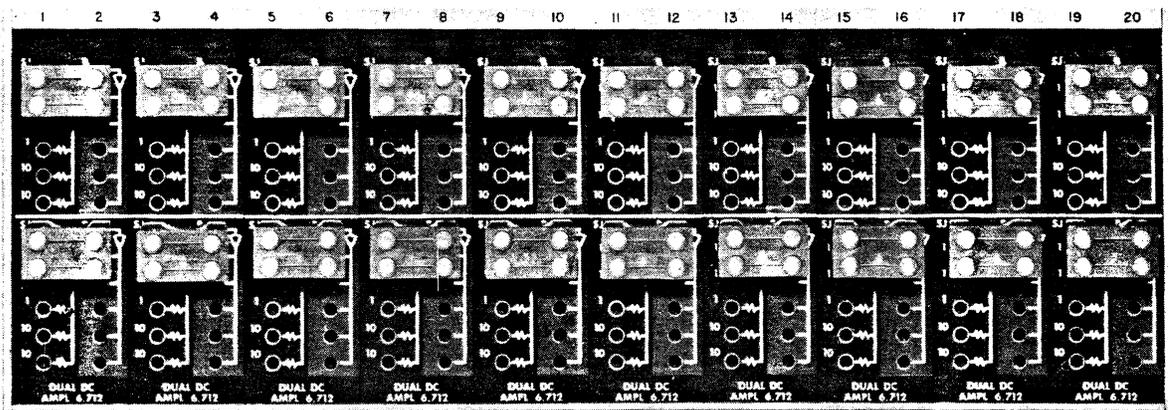


Figure 4. Amplifiers with Bottle Plugs in Place

e. Operational Check

Place the power ON-OFF switch in the ON position. The amplifier overload indicators will flicker briefly, then go out. If an overload indicator remains on, try to balance the amplifier (see Chapter II).

Next, measure the power supply output voltages and adjust them if necessary. Balance the amplifiers and verify that they will perform as inverters. (Place one end of a patch cord into a minus reference voltage termination; connect the other end to a 1 input of each amplifier. Connect a voltmeter to the 0 termination of the amplifier; the output should measure +10 vdc.)

Check out all other computing components in turn by applying selected inputs and observing the proper output. The sections of the manual that describe the patching for a component are helpful here since they show typical patching schemes. If any difficulties arise, reference to the appropriate section of this manual should help to clear them up.

5. INSTALLATION OF PATCHING BLOCKS AND CONTACT SPRINGS

The patching blocks in the pre-patch panel are installed or changed by proceeding as follows:

a. Lay the pre-patch panel on a flat surface. Remove the four hex head screws from the left side. (See Figure 5.)

b. Remove the left side member by sliding it off the four mounting pins. The mounting pins will remain in the cross members when the side member is removed.

c. Slide the blocks out of the row. Position the blocks in the desired order.

d. Replace the left side member. Take care to fit it properly over the mounting pins. Tighten the four side screws quickly. Be sure that the patching blocks on the pre-patch panel are positioned in the same order as the computing components.

The contact springs can be inserted and removed with a pair of long-nose pliers. The patching blocks on the computing components have small orientation holes near each banana receptacle. The projection on the contact spring goes into this hole and the spring is held at the proper angle. Do not install more than one spring for each group of input or output terminations. That is, for the amplifier (as an example), only one spring is required for the 0 terminations.

6. CHASSIS AND ETCHED CARD REMOVAL

The computing components of the TR-20 are packaged as plug-in components so that installation and removal can be accomplished easily. A U-shaped metal chassis provides mechanical strength and affords shielding between the component and adjacent equipment. The components are held in place in the cabinet by two threaded

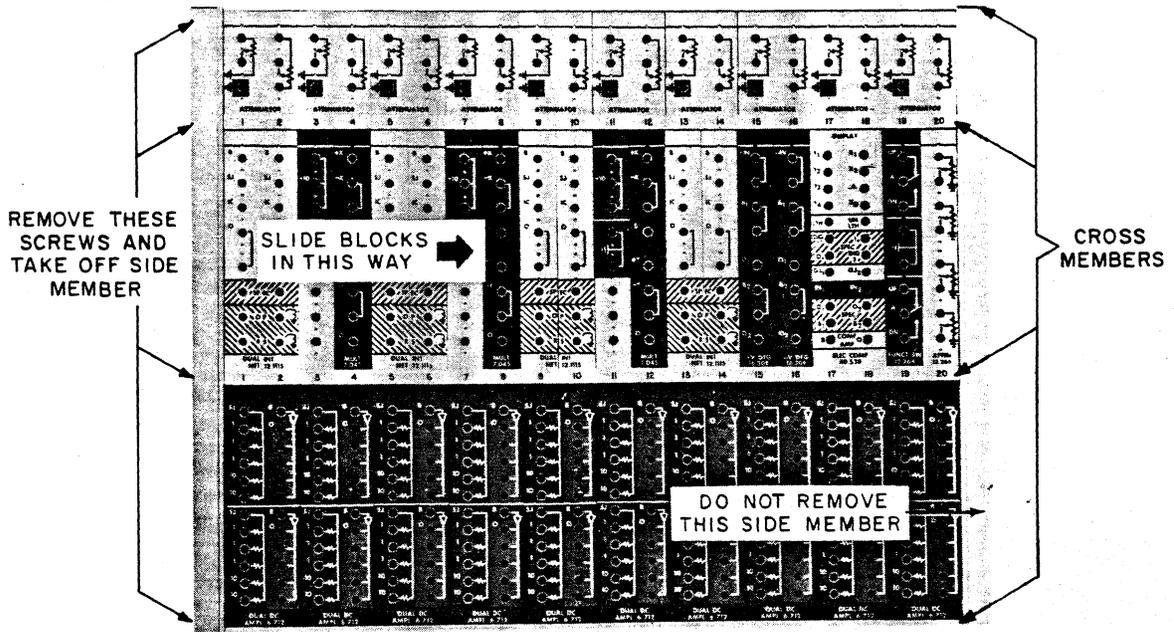


Figure 5. Installation of Patch Blocks in Pre-Patch Panel

studs on the rear of the chassis. The etched-circuit card is positioned in the metal housing by guide slots and held in place by screws that pass through tapped blocks.

The computing components are removed as follows:

- a. At the rear of the TR-20, use a 3/16 inch Spintite to remove one of the hex nuts.
- b. Loosen the second nut approximately 3/8 inches.
- c. Strike the back of the wrench with the palm of the hand to break the mated connectors apart.
- d. Remove the second nut and pull the component from the shelf.

The etched-circuit cards are removed from the metal chassis as follows:

- a. Remove the two screws at the rear of the card.
- b. Flex the metal chassis and slide the rear of the card loose.
- c. To remove the front plastic block, flex the metal chassis and slip the block from its locking tabs.

7. OUTPUT DEVICES

Digital voltmeters, XY plotting boards, strip chart recorders, and oscilloscopes are in general use as output devices for the TR-20. EAI's 5000 and 5001 TDVM's are high quality, transistorized digital voltmeters that can be used to measure dc potentials in the computer. The EAI Model 1110 VARI PLOTTER, equipped with a general purpose module, produces plots of one variable against another. The MARK 200 strip chart recorder contains eight independent channels and is used to obtain qualitative time histories of problem variables. The Model 34.035 Repetitive Operation Display Unit is available as an accessory. This unit provides up to four traces on a rectangular CRT by means of an internal sequential electronic switch. This accessory is very useful for observing the effect of one variable on another in repetitive operation. An oscilloscope, such as the Hewlett-Packard, Model 120 or equivalent, may be used to view problem variables when the computer is used in the repetitive operation mode if the Model 34.035 is not supplied.

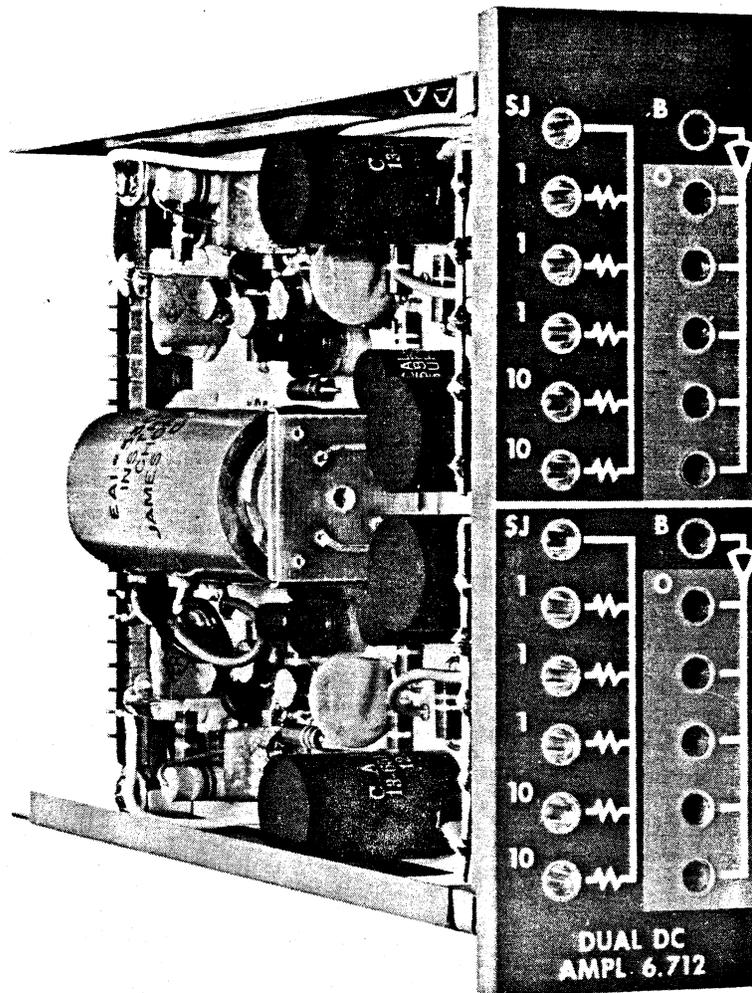


Figure 6. Dual DC Amplifier, Model 6.712

CHAPTER II

DUAL DC AMPLIFIER, MODEL 6.712

1. INTRODUCTION

The Dual DC Amplifier, Model 6.712, Figure 6, consists of two independent high-gain amplifiers packaged in a plug-in module together with two independent precision resistor networks. Each amplifier may be used in conjunction with appropriate networks to perform linear computations such as summation, integration, and multiplication by a constant. Accessory components enable the amplifier to be used for operations such as multiplication and division of variables, and the generation of analytic or arbitrary functions.

2. TECHNICAL DATA

Output Voltage Range	$\pm 10V$, Minimum
Offset (At the Summing Junction)	
Unity-Gain Inverter with 10K Resistors	20 μV , Maximum 10 μV , Typical
Output Current at ± 10 VDC	± 20 MA, Minimum (Drives 500 Ohms)
Frequency Response (3 db Down), for a Unity-Gain Inverter with 10K Resistors	
20 MV, P-P Input	200 KC, Minimum 300 KC, Typical
Noise (Peak-to-Peak) from DC to 500 KC	200 μV , Maximum 100 μV , Typical

3. OPERATING CONSIDERATIONS

a. Patching

The input (B) and output (O) of each amplifier are terminated on the patching block, together with one end of each of the five input/feedback resistors. The other end of each resistor is connected to a common bus terminated at the summing junction (SJ) terminal. To patch an amplifier as a standard inverter or summer, connect a four-prong bottle plug as shown in Figure 7. A single input applied to a 1 terminal (for example, +X) is inverted and appears as -X at any of the 0 terminals. If two inputs (for example +Y and +Z) are applied to 1 terminals, their sum appears inverted as $-(Y + Z)$ at any of the 0 terminals.

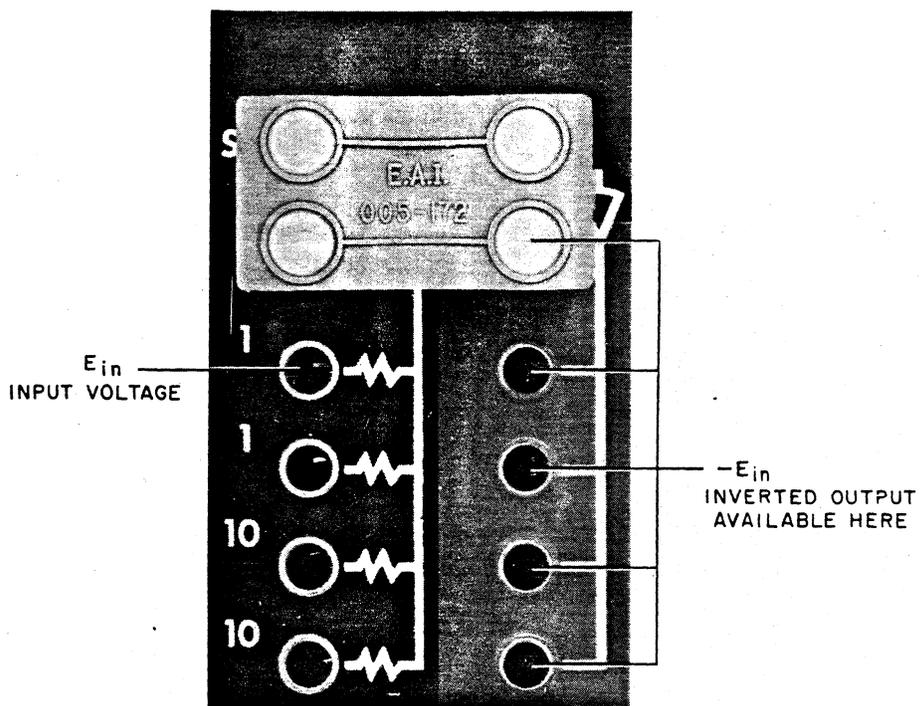


Figure 7. Model 6.712, Patched as an Inverter

The operational amplifiers are rated for a maximum output of ± 10 volts. The amplifier patching arrangement should be such that the output voltage does not exceed this limit. (The amplifiers are capable of producing outputs up to ± 13 volts, depending on load, in order to allow for minor scaling discrepancies.) It is important to note that all amplifiers must be provided with feedback even if they are not being used in a problem. This is most easily accomplished by inserting a four-prong bottle plug as shown in Figure 7. When the amplifier is used in conjunction with an integrator network or one of the non-linear components, its patching requirements are discussed in the chapter pertaining to these units.

b. Amplifier Balancing

Under normal circumstances, the amplifier will remain balanced for periods of weeks. However, at intervals it is desirable to check this condition, and if an amplifier is found to be unbalanced, then an adjustment should be made. The period between balance checks depends to a large extent on the application of the amplifier. For uses which might be unusually sensitive to amplifier unbalance or integrator drift, the amplifier should be balanced at more frequent intervals. In any case, maintenance personnel should recognize the fact that most amplifier and network malfunctions can be detected by checking amplifier balance. Consequently, it is recommended that a check of amplifier balance be made once a week. If the check indicates that the amplifier balance is within two or three divisions of zero (on the voltmeter), no adjustment need be made.

The amplifier must have some sort of feedback in order to be balanced. Normally this requirement is satisfied by the circuit in which the amplifier is connected. The amplifier may be balanced while normal inputs are applied. Each amplifier has a balance potentiometer that is located behind a hinged cover plate below the control panel. The balance potentiometers are labeled with the number of the amplifier they serve. To balance an amplifier, proceed as follows:

- (1) Place the computer in the reset mode. Place the voltmeter function switch in the BAL position. Rotate the AMPL SEL switch to the number of the amplifier to be balanced.

- (2) Vary the appropriate amplifier balance control until the voltmeter reads within two or three divisions of zero. (The amplifier overload indicator may be triggered during the balancing process.)

When the computer is first turned on, a check of amplifier balance may show meter deflections that are slightly high, but they will return to their normal levels after a warm-up period. For unusual problems that might be sensitive to amplifier unbalance or integrator drift, the amplifiers may require balancing at more frequent intervals to keep the meter deflection below one division.

c. Overloads

The computer is equipped with an overload alarm system that indicates the presence of an overloaded amplifier. The visual overload alarm is located to the left of the control panel. The lamps are illuminated whenever their associated amplifier is overloaded. The computer may also be equipped with an audio overload alarm unit located in the rear of the TR-20; this unit provides an audible alarm whenever any amplifier is overloaded.

4. CIRCUIT DESCRIPTION

The elementary principles of the operational amplifier are discussed in Appendix I.

a. Basic Block Diagram

Each channel of the Model 6.712 Dual DC Amplifier consists of a dc amplifier section, a chopper (D1), and a stabilizer amplifier connected as shown in Figure 8. (The dashed components are external to the amplifier chassis.) The circuit is arranged in such a manner that the drift-free characteristics of an ac amplifier and the high frequency response of a dc amplifier are both realized. The resulting circuit also has an extremely high gain at low frequencies.

Inputs to the amplifier are applied through the input impedance Z_{in} . The dc and low frequency components of the signal voltage at the summing junction (SJ) cannot pass directly to the input of the dc amplifier section because of C1. Instead, they are connected through R14 to contact 3 of chopper D1. (A chopper or synchronous vibrator consists of a coil-driven vibrating reed (2) that alternates between the contacts (1, 3) on each half cycle of the coil excitation voltage.) The chopper alternately grounds contact 3 producing a 60 cps square wave input to the stabilizer amplifier. After amplification, the resulting signal is de-modulated (or synchronously rectified) at the second contact (1) of the chopper. The resulting signal at contact 1 is pulsating dc whose polarity is the same as the polarity of the signal at the summing junction. The dc signal is filtered by R15 and C2 and applied through R11 to the input to the dc amplifier section. Thus dc or very low frequency signals are amplified by the stabilizer amplifier and by the dc amplifier.

The circuit from contact 3 of D1 to contact 1 is a modulated carrier-type amplifier that provides high gain dc amplification with very low drift. The stabilizer is phase sensitive; if the polarity of the summing junction signal changes, the phase of the modulated signal changes and the polarity of the pulsating dc output voltage changes.

High frequency components of the input signal are passed by C1 to the dc amplifier, and are amplified by the gain of the dc amplifier only. The open loop gain of the amplifier thus depends on the frequency of the input signal. At very low frequencies, the gain is extremely high because the stabilizer amplifier is placed in cascade with the dc amplifier. At higher frequencies, the gain is decreased but remains high enough to satisfy all expected computer operations.

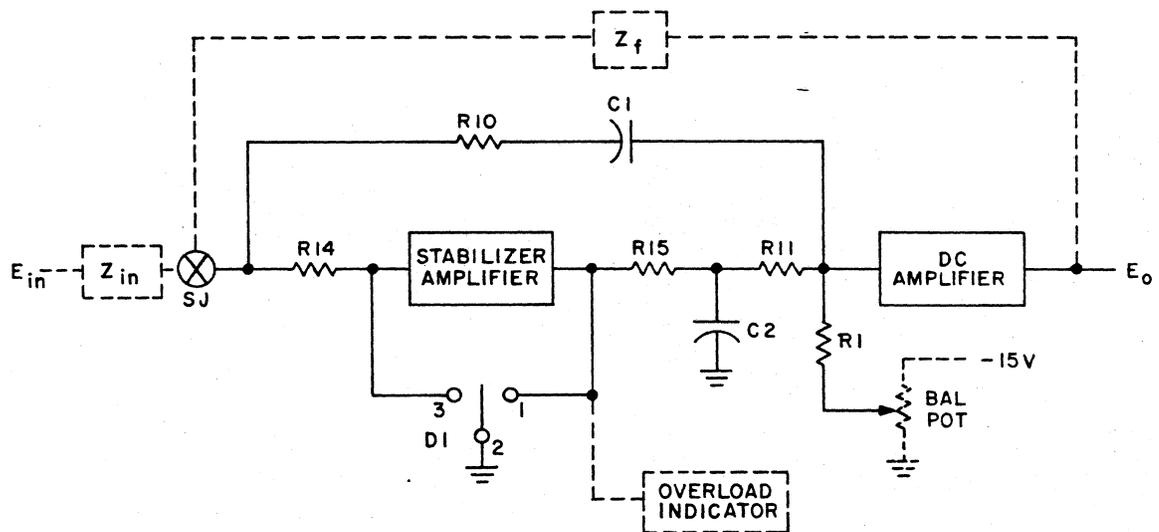


Figure 8. One Channel of Dual DC Amplifier, Model 6.712, Simplified Block Diagram

One of the criteria for a high quality operational amplifier is that the output voltage be zero when the input voltage is zero. This zero corresponding between input and output voltages is called amplifier balance. The manual adjustment process to insure this correspondence is called balancing. As previously described, the balance potentiometer (BAL POT) is adjusted until the amplifier output is zero volts when the input is zero volts. The amplifier would require balancing every few minutes without stabilization. The drift compensation produced by chopper stabilization allows the amplifier to be used for weeks without attention.

Any component of the amplifier output voltage due to drift in the dc amplifier section is fed back through the feedback impedance Z_f to the summing junction of the amplifier. Since any drift-produced voltage has a very low frequency, it will be amplified by the stabilizer section, filtered, then applied as a drift-correction signal to the input of the dc amplifier section. The drift-produced component in the output voltage is reduced by a factor equal to the effective gain of the stabilizer section.

The amplifier in the stabilizer section has a gain of about 1000. Since it is connected to the summing junction, it serves as a monitor of the summing junction voltage. Under normal circumstances, the input current to the operational amplifier is equal to the feedback current, and the summing junction is at virtual ground. If the currents are not equal, the amplifier is not performing properly, and the summing junction departs from virtual ground. This rise in voltage is amplified by the stabilizer and results in a large output signal that is used to trigger an overload indicator which informs the user that the amplifier is not operating properly. Because the stabilizer is a sensitive monitor of the summing junction voltage, the magnitude of its output voltage is an indication of the balance of the amplifier. The amplifier is balanced accurately by connecting the stabilizer output to the voltmeter on the control panel and adjusting the balance potentiometer until the voltmeter reads zero. Note that it is not necessary to remove the inputs to the operational amplifier during the balancing process since all circuit requirements are satisfied if the summing junction is at virtual ground. A feedback resistor must be connected around the amplifier before the balancing procedure can be accomplished.

The schematic diagram of the dual amplifier used in the TR-20 is shown on Drawing D006 282 OS in the rear of this manual. Each amplifier consists of a six-transistor dc amplifier and a three-transistor stabilizer amplifier. Each amplifier uses a set of contacts of chopper D1. The coil excitation voltage (6.3 vac, 60 cps) for D1 is obtained from Regulated Power Supply, Model 10.179, which also provides the other operating voltages for the amplifier. Since each of the dual amplifiers is identical, the following circuit description is confined to the amplifier shown in the upper half of the schematic. A simplified schematic to be used with the following description is shown in Figure 9.

b. The DC Amplifier Section

The summing junction of the operational amplifier is connected to the Input

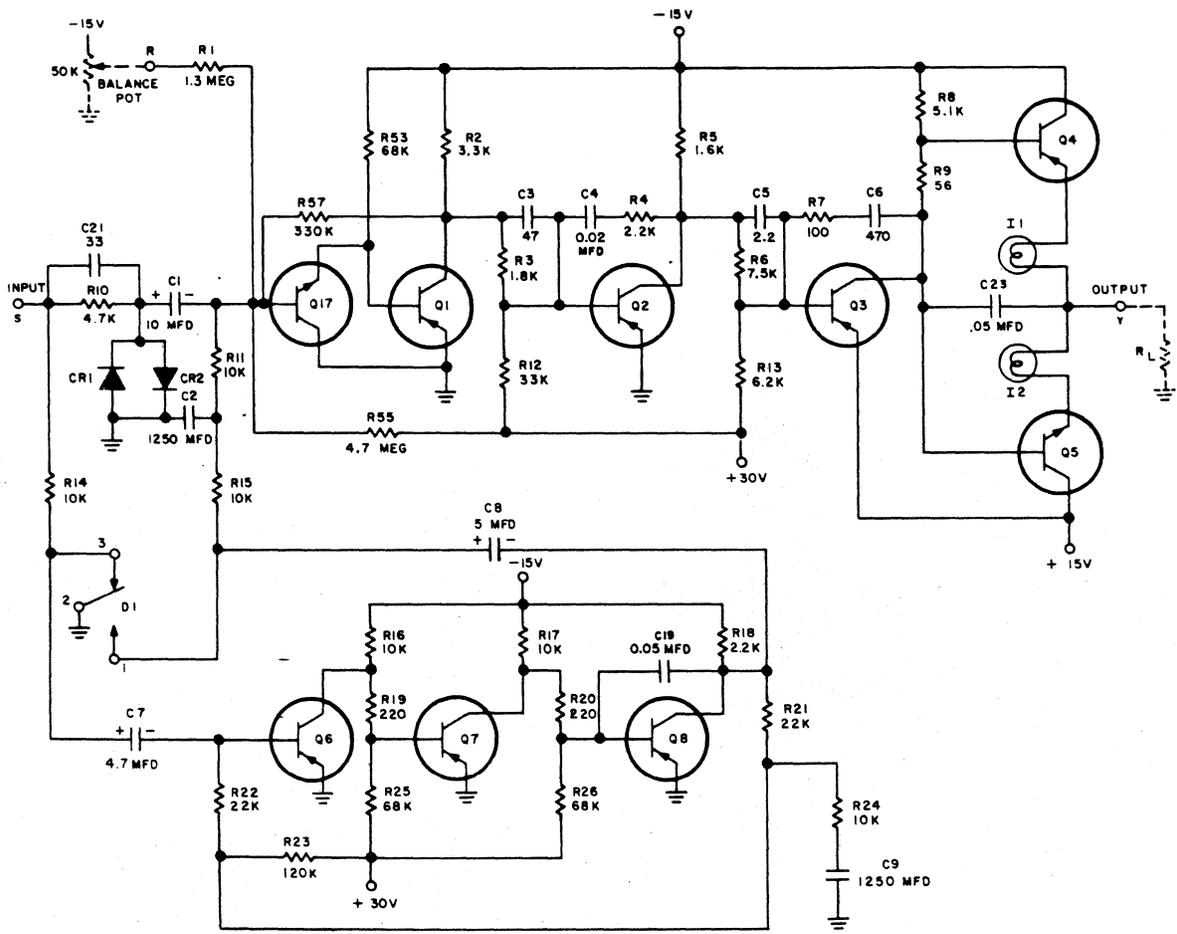


Figure 9. One Channel of the Model 6.712, Simplified Schematic

terminal. The ac components of the input signal are applied to the base of transistors Q17 through R10, C21, and C1. The input signal is also coupled through R14 to the input to the stabilizer section. Two reverse-connected diodes (CR1 and CR2) are connected from the input to ground so that capacitor C1 cannot be charged to a high voltage during overload conditions. This feature allows the amplifier to recover quickly should an overload occur. The normal signal at this point is below the diode conduction point.

Transistors Q17 and Q1 comprise the amplifier input stage. Transistor Q1 (PNP) is connected in a common-emitter configuration with R53 providing self-bias. Transistor Q17 (NPN) is used in a common-collector configuration and uses the voltage drop (0.3 volt) across the base-emitter diode of Q1 as its operating voltage. The base-emitter resistance of Q1 serves as the load for Q17. This configuration gives the amplifier a relatively high input impedance. The base circuit of Q17 is completed through R55, R1, and the balance potentiometer. These components form a voltage divider between -15 volts and +30 volts; adjusting the balance potentiometer sets the optimum operating point for Q17. In practice, the balance potentiometer is adjusted for zero output from the stabilizer.

The output at the collector of Q1 is directly-coupled to the base of Q2, which is also connected in the common-emitter configuration. Bias is supplied from voltage divider R3 and R12, connected between the collector of Q1 and the +30 volt supply. This high-frequency roll-off of the Q2 stage is controlled by the series combination of R4 and C4 which provides an increasing amount of negative feedback at higher frequencies. Capacitors C3, C5, and C23 provide correct phasing for higher input frequencies.

Transistor Q3 is the driver for the output stage. The circuit arrangement of this stage is similar to that of Q2, except that the emitter is returned to +15 volts instead of ground in order to establish the correct operating point for Q3, Q4, and Q5. The output stage of the dc amplifier consists of Q4 and Q5, each connected in a common-collector (emitter-follower) arrangement. Transistor Q4 is a PNP type transistor and Q5 is an NPN type with similar characteristics. The circuit employs the advantages of the complementary-symmetry of the two types to provide push-pull operation with single ended input. A phase inverter is not required to drive a stage of this type. The NPN transistor (Q5) conducts when the output of Q3 goes positive and the PNP transistor (Q4) conducts when the output of Q3 goes negative.

With no signal, the forward bias across resistor R9 causes a small current flow from the negative supply through Q4, I1, I2, and Q5 to the positive supply. Because the transistors are similar, the voltage drop is the same across each and the circuit is similar to a balanced bridge; no current flow through the load. An input to the amplifier causes one of the output transistors to conduct more heavily than the other (unbalancing the bridge) and current flows through the external load on the amplifier. The output voltage appears between terminal Y (the common-emitter point) and ground. Incandescent lamps (I1 and I2) are connected in series with each emitter. Since the resistance of these lamps increases with increasing current (higher temperature), the lamps serve to stabi-

lize and protect the output stage by limiting the maximum current flow through each transistor.

c. The Stabilizer Section

The stabilizer section consists of a three-stage amplifier (Q6, Q7, and Q8) and a 60 cps chopper (D1). The stabilizer pre-amplifies the dc and low frequency components of the input signal and applies the resulting signal to the input of the dc amplifier section. Any dc or low frequency voltage appearing at the summing junction is modulated by contacts 2 and 3 of D1. The resulting 60 cycle square wave is applied to the base of Q6 and is amplified by Q6, Q7, and Q8. The ac signal from the amplifier at the collector of Q8 is coupled through C8 to contact 1 of D1. Contacts 1 and 2 of D1 function as a phase-sensitive demodulator or rectifier and produce a pulsating dc signal which is applied to a filter (R15-C2). The filter removes the carrier frequency generated by the chopper action. The filter output is a smooth dc which is applied to the base of Q17.

5. TEST PROCEDURES

The test procedures outlined below are designed to provide the maintenance technician with simple and convenient procedures for monitoring amplifier performance on a regular basis.

a. Frequency Response

A check of the frequency response of the operational amplifier is accomplished by applying a fixed amplitude, variable frequency input to the amplifier and observing the output amplitude with an oscilloscope. Proceed as follows:

(1) Patch the amplifier for unity gain using 10K ohm resistors (Figure 10).

(2) Connect the output of a well-regulated audio oscillator to the amplifier input. Connect an oscilloscope to the oscillator output and adjust the oscillator and oscilloscope controls until a 20 millivolt peak-to-peak deflection appears on the oscilloscope screen. Vary the oscillator frequency from a few cycles to about 200 kilocycles. Be certain that the amplitude of the oscillator output remains constant over the frequency range. If it does not stay constant, the oscillator amplitude control must be adjusted for each frequency check point.

(3) Connect the oscilloscope to the amplifier output. Observe the amplitude of the amplifier output voltage as the generator frequency is varied. No pronounced peaks or dips (greater than ten percent) should occur below 100 kilocycles. At 200 kilocycles, the amplifier output should be decreased by less than 3 db. (That is, the output voltage should be greater than 70.7 percent of the input voltage up to 200 kc.)

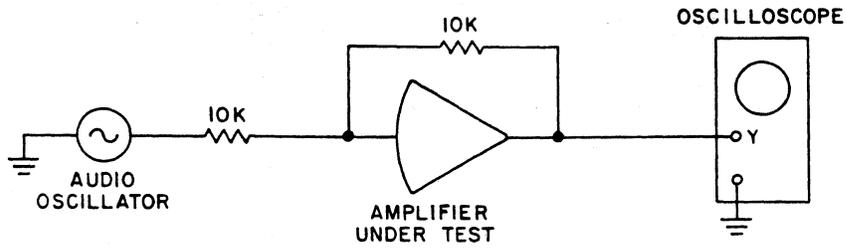


Figure 10. Frequency Response Test Circuit

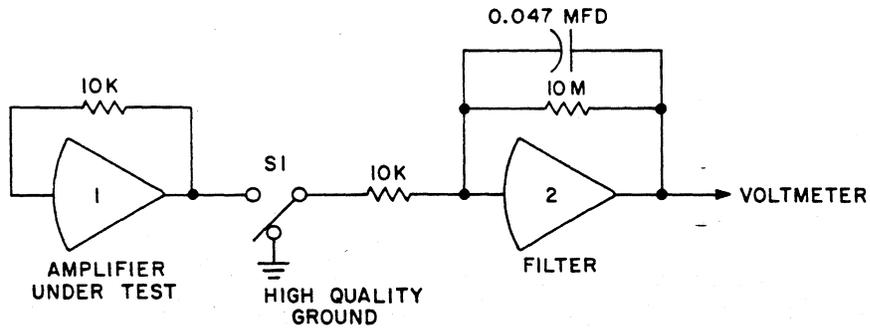


Figure 11. Test Circuit for Measuring Amplifier Offset

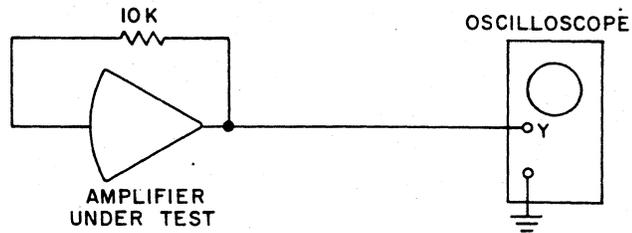


Figure 12. Test Circuit for Measuring Noise

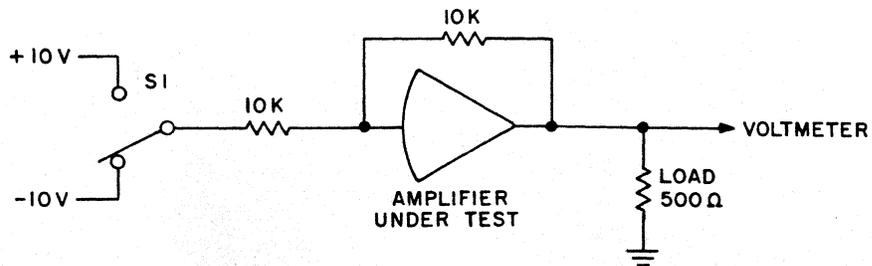


Figure 13. Output Current Test Circuit

(4) If the operational amplifier fails this test, it is probably due to a malfunction in the dc amplifier section.

b. Offset Measurement

Periodic checks for excessive amplifier offset are performed by monitoring the amplifier output with the circuit shown in Figure 11. Amplifier 2 in the measuring circuit amplifies any offset by a factor of 1000 and also acts as a filter or smoothing device. Switch S1 is used so that any offset of amplifier 2 can be compensated for. High quality ground is available at the ground terminations in the middle row of the patch panel. If possible, remove all other patch cords connected to these terminations. Do not use chassis ground or the ground terminations in the coefficient potentiometer row. Proceed as follows:

(1) After a warm-up period of one hour, carefully balance the amplifier under test using the standard procedure.

(2) Place S1 in the down position. Adjust the balance potentiometer of amplifier two until the meter reads zero volts.

(3) Place S2 in the up position, place the voltmeter on the 0.1 volt scale. Since the voltmeter is preceded by a gain of 1000, the equivalent meter range is 100 microvolts full scale.

(4) Record the voltmeter reading. The offset should be less than 20 microvolts.

c. Noise Measurement

The noise content of the amplifier can be observed with the circuit shown in Figure 12. Balance the amplifier and observe the output noise on the oscilloscope. The peak-to-peak noise should be less than 400 microvolts from dc to 500 kc.

d. Output Current Capability

The amplifier's ability to deliver rated current is checked with the circuit in Figure 13. The load resistor need not be a precision resistor.

(1) Place switch S1 in the down position and measure the amplifier output voltage. The output should measure +10 volts.

(2) Place S1 in the up position. The output should measure -10 volts.

(3) If the amplifier is not supplying approximately 20 ma of current, the output voltage will be less than ± 10 volts. (Also, the amplifier will be out of balance, i.e., the balance test will indicate a malfunction.)

6. TROUBLESHOOTING

The amplifier is used with several different types of networks depending on the operation it must perform. Unsatisfactory performance by an operational amplifier could be due to a network malfunction. The malfunction can usually be isolated to a particular chassis by interchanging suspected modules with ones that are known to be good. Unlike most types of electronic equipment, a faulty operational amplifier usually identifies itself immediately. If a component in the amplifier fails, the output voltage of the amplifier characteristically flops to its plus or minus limit (up to ± 13 volts, depending on load).

a. Failure to Balance

The most common indication of unsatisfactory amplifier operation is failure to balance properly. If an amplifier will not balance, the malfunction can be localized to either the dc or stabilizer section with the following procedure.

(1) Mount the amplifier on a service shelf and plug the assembly into the amplifier's rack position. Patch a feedback resistor around the amplifier and remove all inputs.

(2) Disable the stabilizer section by grounding the stabilizer output at pin P or L (depending on which amplifier is malfunctioning).

(3) Monitor the output of the amplifier with an oscilloscope or voltmeter and slowly rotate the balance potentiometer.

(4) The amplifier output should flop between its plus and minus limits (about ± 13 volts) as the balance control is turned from one end to the other. A slight delay in response is normal. If the amplifier fails to do this, the malfunction is probably in the dc section of the amplifier.

(5) Remove the ground from pin P or L. Connect an oscilloscope to the output of the stabilizer (pin P or L) and observe the stabilizer output as the balance potentiometer is slowly rotated.

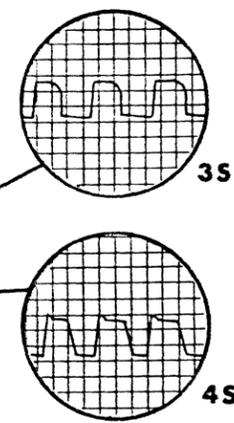
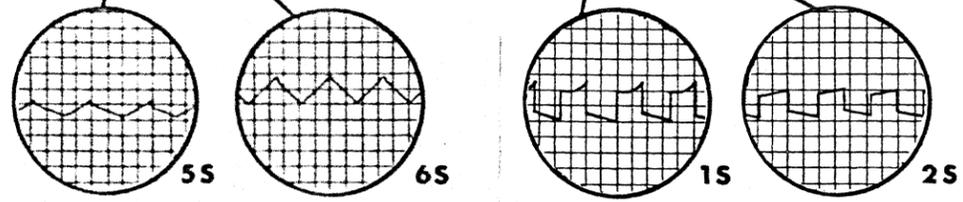
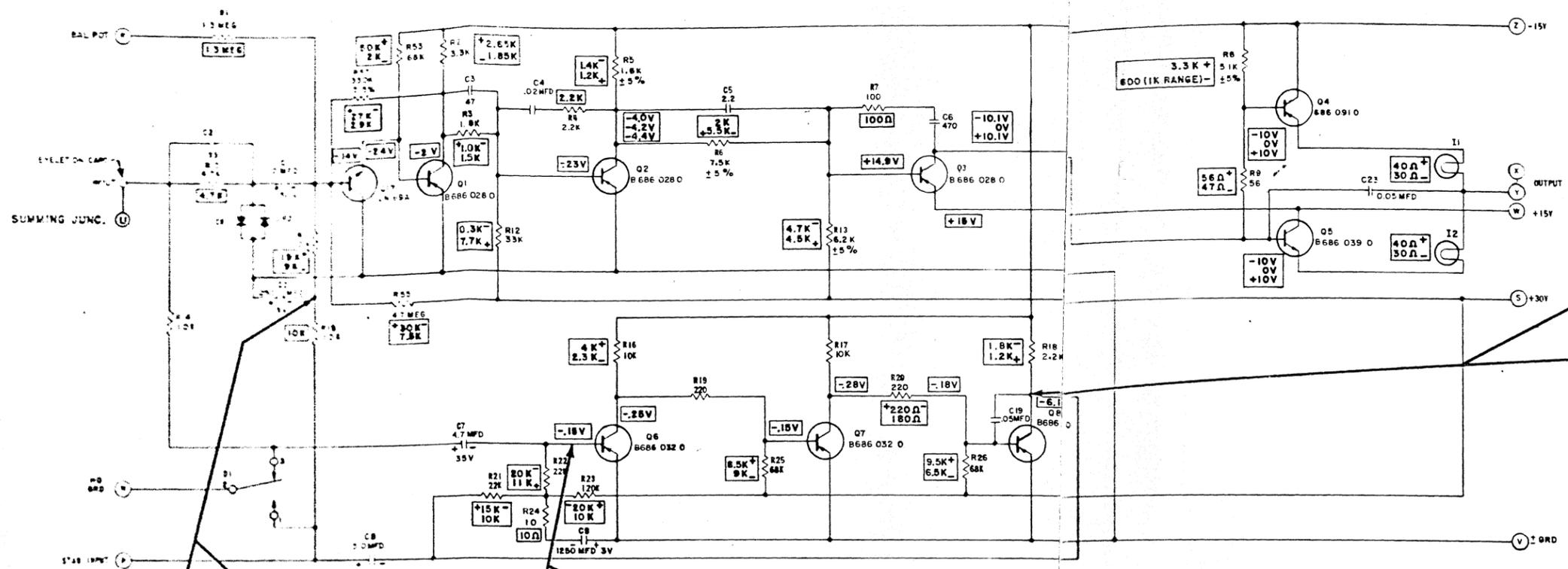
(6) The square wave output should change polarity, from negative-going to positive-going, as the balance control is turned from one end to the other. Failure to do so indicates that the malfunction is probably in the stabilizer section.

b. DC Amplifier Section Check

The dc amplifier section can be checked according to the following procedure.

(1) Repeat Steps (1) to (3) above.

(2) Check interstage voltages in the dc amplifier section. Begin with the output stage and work towards the input stage. Slowly rotate the balance

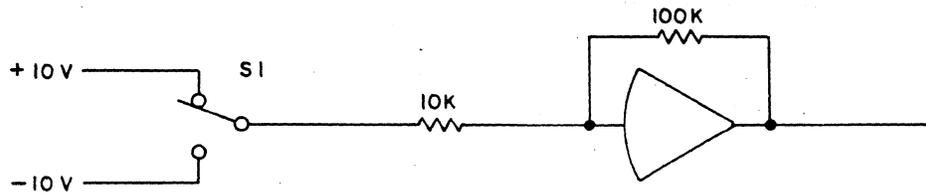


- NOTES:
1. ALL BOXED READINGS TAKEN WITH TRIP-LETT MODEL 630A VOM.
 2. HIGHEST RESISTANCE VALUES CORRESPOND TO PROBE POLARITY WITHIN BOX.
 3. STABILIZER WAVEFORMS TAKEN WITH AMPLIFIER PATCHED AS SHOWN IN FIGURE 15. WAVEFORMS FOR BOTH SWITCH POSITIONS ARE GIVEN.
 4. INFORMATION ON THIS GUIDE REPRESENTS A COMPILATION OF AMPLIFIER MEASUREMENTS. THEREFORE, THESE READINGS SHOULD NOT BE CONSIDERED A SPECIFICATION BUT RATHER A GUIDE TO AMPLIFIER TROUBLESHOOTING.

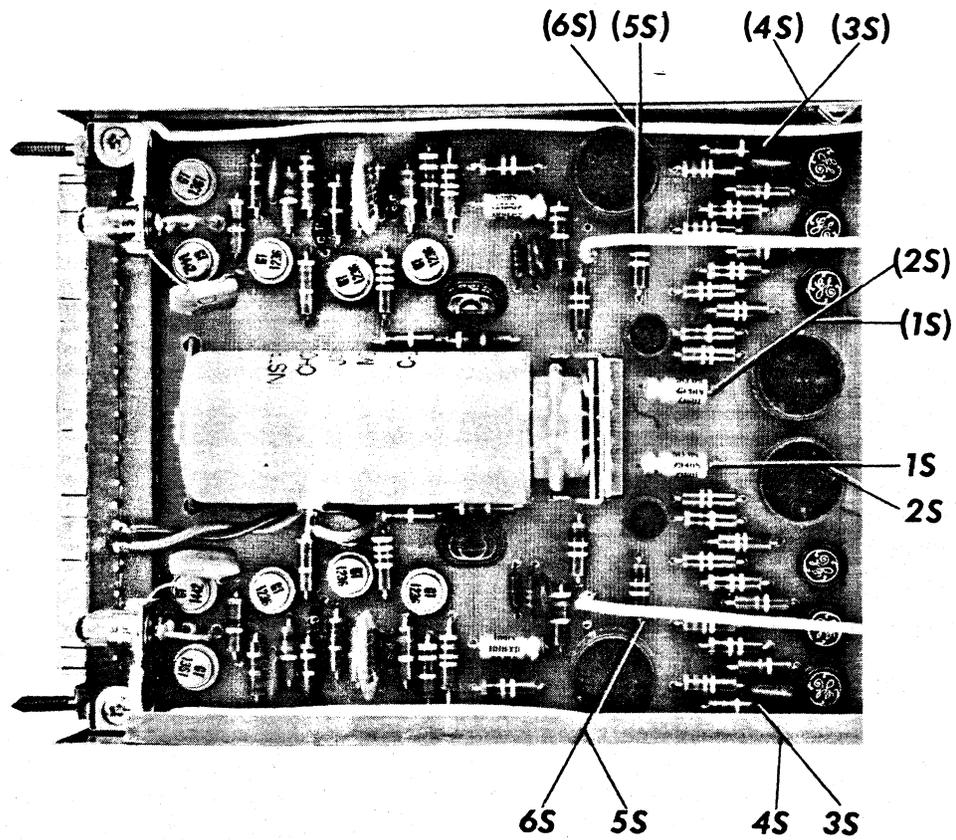
OSCILLOSCOPE CONTROL SETTINGS
(Hewlett-Packard 130B or Equivalent)

WAVEFORM NUMBER	VERTICAL SENSITIVITY	SWEEP SPEED
1S	1V/CM	5 MSEC
2S	1V/CM	5 MSEC
3S	5V/CM	5 MSEC
4S	5V/CM	5 MSEC
5S	5 MV/CM	5 MSEC
6S	2 MV/CM	5 MSEC

Figure 14.
Amplifier Troubleshooting Guide



(a) Test Circuit



(b) Test Points

Figure 15. Stabilizer Section Test Circuit and Test Points

reading is for an input of +10 volts, the center reading is zero input, and the lower reading for -10 volts.

NOTE

A Triplet Model 630A Multimeter or an equivalent 20,000 ohms/volt meter should be used to ensure readings that correspond with those in the guide.

SYMPTOM	SUGGESTED REMEDY
Excessive High-Frequency Noise	Replace Q1 or Q17 or Both
Excessive Low-Frequency Noise	Replace Q6
Poor Frequency Response	Replace Q1. Check Interstage Coupling Networks
Amplifier Oscillates with Negative Output, Positive Output Satisfactory	Replace Q4
Amplifier Oscillates with Negative Output, Negative Output Satisfactory	Replace Q3 or Q5 or Both
Excessive Offset	Replace C1 or C7 or Both
Extremely High Offset	Replace Q1
Negative Output Only	Replace I1
Positive Output Only	Replace I2

Figure 16. Symptoms and Possible Causes of Amplifier Malfunctions

(2) Internal Resistance Measurements

- (a) Remove all connections to the amplifier under test.
- (b) Connect an ohmmeter across the resistors in the circuit and compare the resistance measured with the values given in Figure 14.

- (c) If the polarity of the ohmmeter test probes affects the resistance measurement, the readings for both connections are listed. The plus and minus signs associated with the reading indicates the probe polarity for the highest resistance reading.

NOTE

A Triplet Model 630A Multimeter should be used to ensure readings that correspond with those in Figure 14.

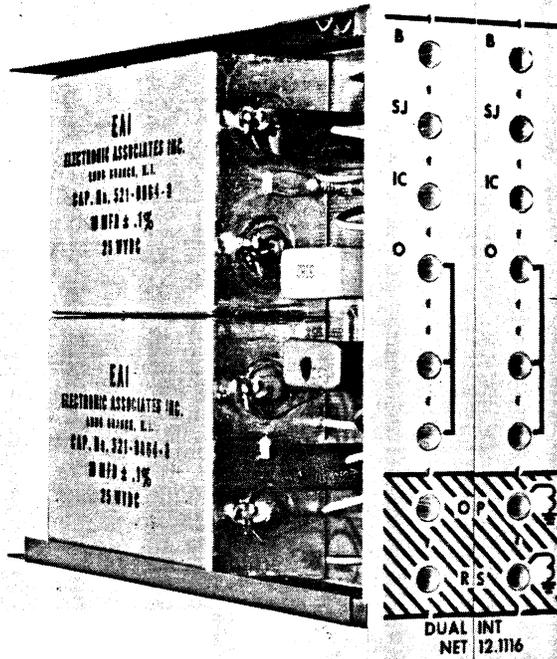


Figure 17. Dual Integrator Network, Model 12.1116

CHAPTER III

DUAL INTEGRATOR NETWORK, MODEL 12.1116

1. GENERAL DESCRIPTION

The Model 12.1116 Dual Integrator Network, shown in Figure 17, is used with an external operational amplifier to perform the mathematical operation of integration with respect to time. The network contains the passive elements and control circuits necessary to form two integrators. The Model 12.1116 is supplied with computers that are not equipped for repetitive operation. The Model 12.1115 is supplied with computers that are equipped for repetitive operation; this network is described in the Repetitive Operation Section of Chapter X.

2. TECHNICAL DATA

Capacitor Value	10 MFD $\pm 0.1\%$
IC Accuracy	100% $\pm 0.2\%$, Minimum 100% $\pm 0.1\%$, Typical
Drift Rate (Using a Model 6.712 Amplifier with a Grounded 100K Ohm Input Resistor)	50 $\mu\text{V}/\text{Sec}$, Maximum 25 $\mu\text{V}/\text{Sec}$, Typical

3. PATCHING

An integrator is formed by connecting the SJ, 0, and B terminations of the integrator network to the SJ, 0, and B terminals, respectively, of an amplifier. Figure 18 shows typical patching and a simplified schematic for a 12.1116 Network; the patching for a 12.1115 Network is similar (see Chapter X). An initial condition voltage may be applied to the IC terminal if required. For normal operation, two-prong bottle plugs (or patch cords) should be inserted to cover the OP and RS designations on the lower cross-hatched areas of the patch block. These bottle plugs connect the operate and reset relays to the operate bus and reset bus respectively. For special applications, other patching arrangements may be used. These applications are described in the Appendix of the Operator's Reference Handbook. Figure 19 shows a typical block diagram and computer symbol for an integrator.

4. CIRCUIT DESCRIPTION

One channel of the dual integrator network is shown connected to an external amplifier in Figure 18. The operate relay (K1) and the reset relay (K2) control the mode of operation of the integrator. The relays are energized by the relay bus driver which is controlled by the mode control switch on the control panel.

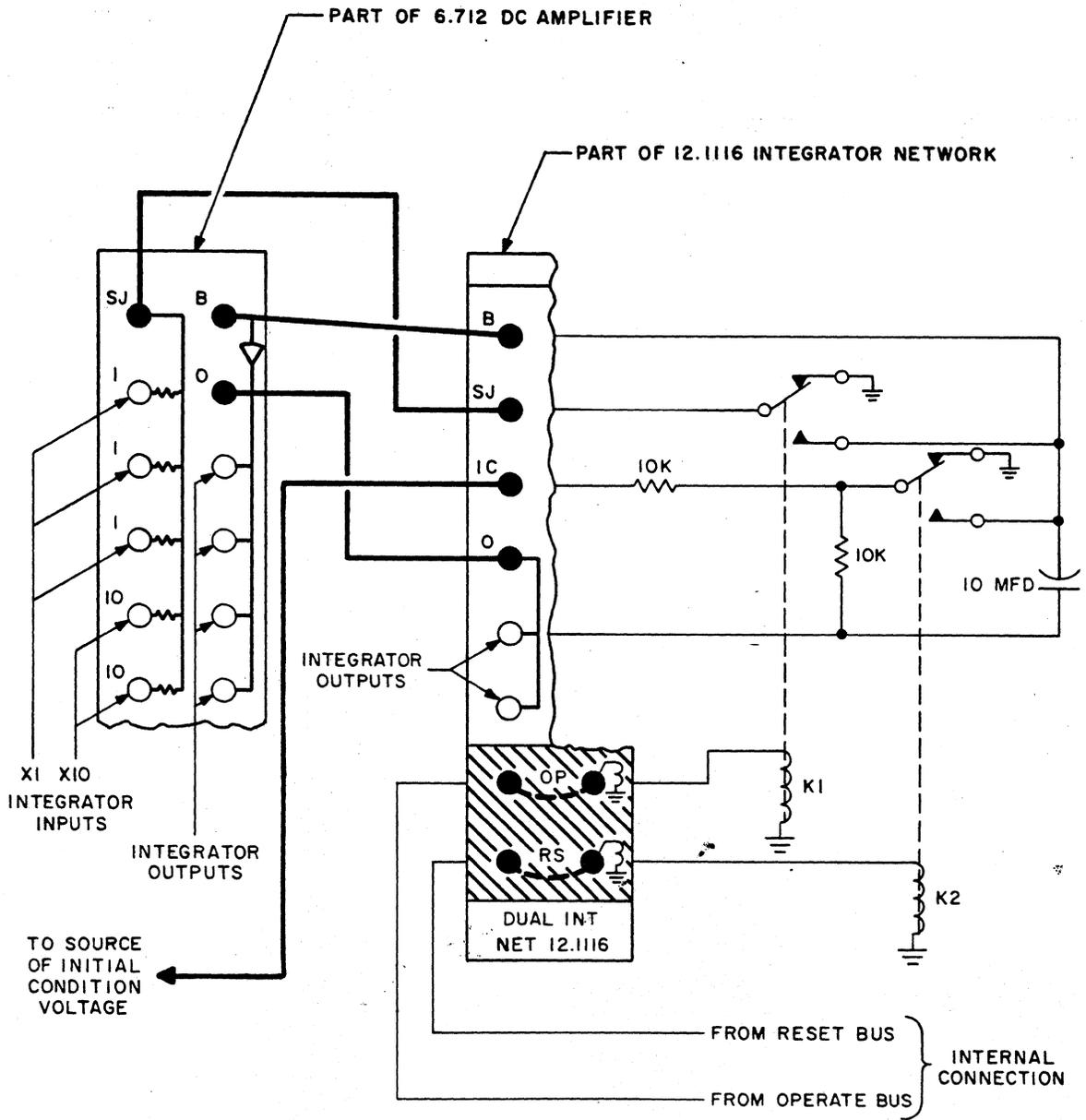


Figure 18. Patching an Amplifier to an Integrator, Showing Simplified Schematic of an Integrator Network

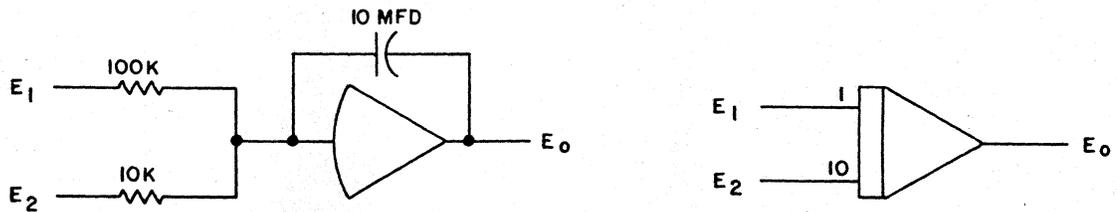


Figure 19. Block Diagram and Symbol for an Integrator

When the mode control switch is placed in the reset position, relay K1 is de-energized and the inputs to the integrators (E_i) are grounded through the input resistors. None of these inputs can affect the amplifier. Relay K2 is energized and its contacts connect the junction point of R1 and R2 to the summing junction of the amplifier. The feedback network for the amplifier consists of R2 and C1 in parallel; R1 is the input resistor. A voltage E_{ic} applied to the IC termination charges the feedback capacitor and establishes a voltage E_o at the output of the amplifier. The time constant of the charging process is determined by values of R2 and C1; with the given values the time constant is 0.1 second and the capacitor charges to the magnitude of the initial condition voltage in about 0.5 second. In the steady-state, the amplifier behaves like an inverter and has an output of $-E_{ic}$. With +5 volts patched into the IC terminal, the steady-state amplifier output is -5 volts. If a voltage is not connected to the IC terminal the amplifier output is zero.

In the hold mode, both K1 and K2 are de-energized. The summing junction of the input resistors is grounded; the initial condition input is removed. If an initial condition voltage has been applied (in the reset mode), the feedback capacitor remains charged. Alternately, the capacitor remains charged to the voltage attained in the operate mode.

In the operate mode, relay K1 is energized and connects the summing junction of the input resistors to the base of the amplifier. The integrator is operational. In summary, an initial condition voltage is applied to the integrator in the reset mode. The output voltage is equal in magnitude and opposite in polarity to the IC input. In the hold mode, all inputs to the integrator are removed and the feedback capacitor remains charged to the voltage applied as an initial condition, or holds the voltage reached during the operate mode. In the operate mode, the inputs are applied and integration with respect to time takes place.

5. TEST PROCEDURES

a. Operational Checks

A single operational check that indicates the qualitative performance of the integrator is outlined below.

(1) Connect the circuit shown in Figure 20. Open both switches. Switch the computer to RESET. Close switch 1; the amplifier output should measure zero volts. Close switch 2; the amplifier output should measure +10 volts.

(2) Switch the computer to HOLD. The amplifier output should measure +10 volts.

(3) Switch the computer to OPERATE. The output of the integrator should change linearly from +10 volts to -10 volts at the rate of minus one volt-per-second. (If a stopwatch is available, this rate can be checked with sufficient accuracy for maintenance purposes. If qualitative measurements are to be made, more elaborate time measuring equipment if required.) After

NOTE:
AN ATTENUATOR
CAN BE USED TO PRO-
VIDE THE 1.0 VOLT
INPUT.

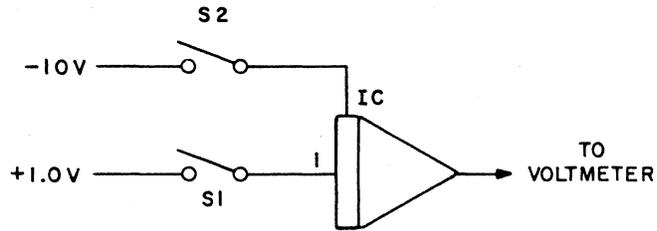


Figure 20. Operational Check Circuit

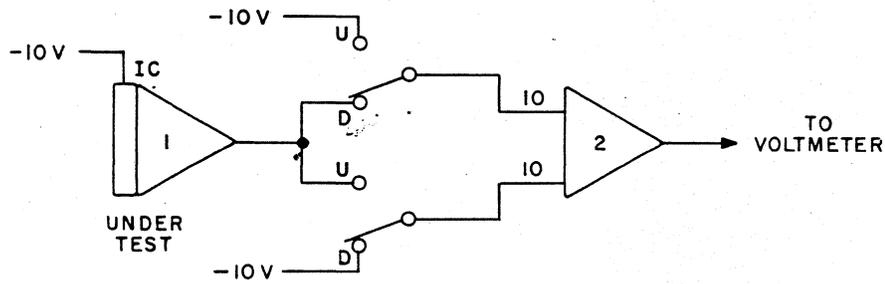


Figure 21. Initial Condition Resistor Ratio Check Circuit

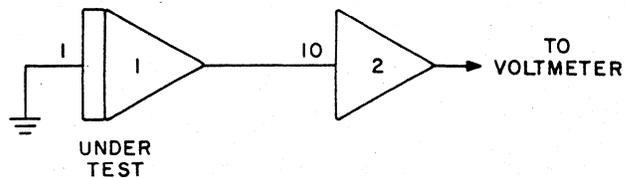


Figure 22. Integrator Drift Rate Check Circuit

operating for 20 seconds, place the computer in HOLD. The amplifier output should measure -10 volts.

(4) Switch the computer to RESET. The amplifier output should measure +10 volts.

b. Initial Condition Resistor Ratio

(1) Connect the circuit shown in Figure 21. Place the computer in the reset mode.

(2) Place both switches in the down position; measure and record the output voltage of amplifier 2. Place both switches in the up position; measure and record the output voltage of amplifier 2.

(3) The algebraic average of the two readings, divided by 10, should be less than 20 millivolts. (The algebraic average is the algebraic sum divided by two.)

(4) If the results of this test are unsatisfactory, the initial condition resistors are mis-matched or out of tolerance.

c. Integrator Drift Rate

(1) Connect the circuit shown in Figure 22. Place the computer in the reset mode, and balance the amplifier. Monitor the output of amplifier 2 with the voltmeter.

(2) Switch the computer to OPERATE; after 100 seconds, record the meter readings.

(3) The meter reading should be less than 0.05 volt. This corresponds to a drift rate of 50 microvolts per second. (If the integrator fails this test, the amplifier should be checked for high offset.)

6. TROUBLESHOOTING

A point-to-point resistance check is the quickest way to troubleshoot the network. Refer to Drawing C012 1116 OS for resistance values. Figure 23 lists symptoms and probable causes for several malfunctions. In each case, it is assumed that a good amplifier is being used.

MODE	SYMPTOM OF MALFUNCTION	PROBABLE CAUSE
RESET	A. Amplifier output is zero for all initial condition inputs.	1. Open initial condition input resistor (R1 - R3). 2. Reset relay not operating. 3. Shorted feedback capacitor.
	B. Amplifier goes into overload if inputs are connected.	1. Operate relay is energized.
	C. Amplifier goes into overload when initial condition inputs are applied. The amplifier holds the voltage reached while in operation with no initial condition inputs.	1. Open initial condition feedback resistor (R2 - R4).
	D. The amplifier output is not equal in magnitude to the initial condition input.	1. Mismatched initial condition resistors. Measure resistance of R1 and R2 (R3 - R4). 2. Amplifier has a feedback resistor patched around it.
HOLD	A. Amplifier will not hold voltage reached during operation but resets to the initial condition input.	1. Reset relay energized.
	B. Amplifier will not hold voltage reached during operation nor will it hold the initial condition input.	1. Leaky or open feedback capacitor.
OPERATE	A. Integrator does not have the proper integration rate.	1. Check circuit time constants. Wrong value of input resistors or feedback capacitor being used.

Figure 23. Symptoms and Probable Causes of some Integrator Malfunctions

CHAPTER IV

QUARTER-SQUARE MULTIPLIER, MODEL 7.045

1. GENERAL DESCRIPTION

The Quarter-Square Multiplier, Model 7.045, is used in conjunction with a dc amplifier to produce a four quadrant product of $-XY/10$ from inputs of $+X$, $-X$, $+Y$, and $-Y$. In addition to multiplication, the Model 7.045 is capable of performing the mathematical operations of division, squaring, and square root extraction.

The operation of the Model 7.045 Multiplier is based on the identity:

$$XY = \frac{1}{4} \left[(X + Y)^2 - (X - Y)^2 \right]$$

which reduces multiplication to the operations of summation and squaring. The squaring operations are performed by diode function generators which produce a seven segment straight line approximation to a square law curve. The complete multiplier assembly contains four squaring circuits whose outputs are summed by an external amplifier.

2. TECHNICAL DATA

Input Voltage Range..... -10V to +10V

Output Voltage Range.....,.... -10V to +10V

Static Error

Typical..... ± 40 MV

Maximum..... ± 80 MV

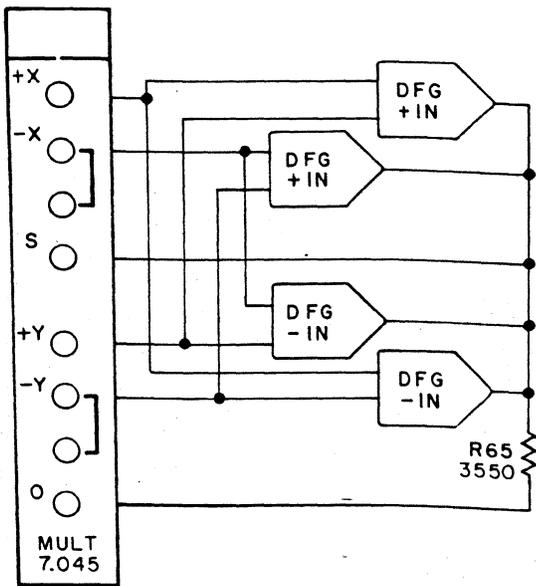
Phase Shift (when multiplying ± 10 VDC by 20V, peak-to-peak)

at 1.0 KC..... 0.26° , Maximum

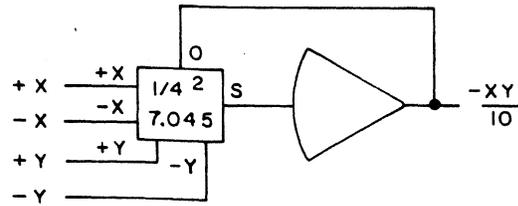
Frequency Response..... Compatible with
Associated Amplifier

3. PATCHING

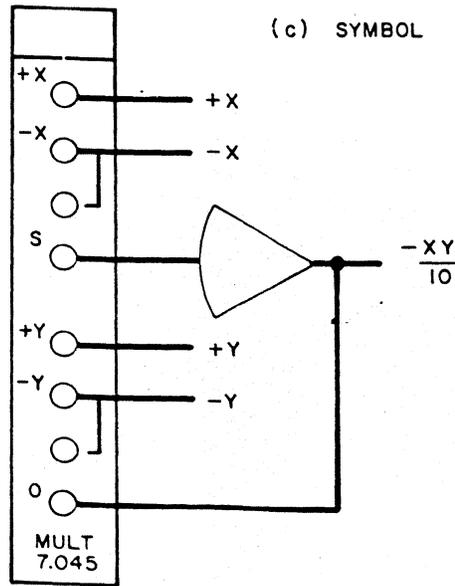
The patching for the Quarter-Square Multiplier is shown in Figure 24. The input voltages, $+X$, $-X$, $+Y$, and $-Y$ are connected to the appropriately labeled terminations on the multiplier; the S and O terminations on the multiplier are connected to the S and O terminations of a dc amplifier. All four inputs ($+X$, $+Y$) must be patched in. The output can be changed to $+XY/10$ by interchanging the $+X$ and $-X$



(a) SIMPLIFIED DIAGRAM OF UNIT



(c) SYMBOL



(b) MULTIPLIER PATCHING

Figure 24. Quarter-Square Multiplier Patching

inputs or the +Y and -Y inputs. Note that the amplifier does not have any feedback resistor except the one (R65) in the multiplier. An appropriate symbol for the multiplier is also shown.

4. CIRCUIT DESCRIPTION

A simplified schematic of the Model 7.045 Quarter-Square Multiplier is shown in Figure 25. (See Appendix I for a discussion of the elementary principles of a quarter-square multiplier.) For simplicity, only one segment in each X^2 diode function generator is shown. The inputs to the multiplier are applied to the terminals designated +X, +Y, -X, and -Y. The outputs of the squaring cards (S1 to S4) are connected to the summing junction of an external amplifier. The feedback resistor (R65) for the amplifier is located on the multiplier chassis. The upper two X^2 DFG's accept net positive inputs and produce a current at S1 or

S2 that is proportional to $\frac{1}{10} \left(\frac{X + Y}{2} \right)^2$. The scale factor of 1/10 is obtained by the choice of circuit resistance values; this scaling is introduced so that the output voltage from the amplifier does not exceed 10 volts. The two lower DFG's accept net negative inputs and produce an output current at S3 or S4 that is proportional to $-\frac{1}{10} \left(\frac{X - Y}{2} \right)^2$. The total summing junction current is proportional to

$$\frac{1}{10} \left(\frac{X + Y}{2} \right)^2 - \frac{1}{10} \left(\frac{X - Y}{2} \right)^2$$

and produces an amplifier output voltage of $-XY/10$. Assume that +5 volts is applied to the +X terminal and -8 volts is applied to the +Y terminal. (Then -5 volts is at -X and +8 volts is at -Y.) With these inputs applied to the DFG's as shown in Figure 25, DFG No. 1 is not conducting because the net input voltage is negative and increases the negative bias on the diode. The net input voltage to DFG No. 2 is positive and the diode conducts permitting the sum of the inputs to be squared. The contribution of the DFG to the output voltage of the amplifier is

$$-\frac{1}{10} \left(\frac{X + Y}{2} \right)^2 = -\frac{1}{10} \left(\frac{5 - 8}{2} \right)^2 = -\frac{9}{40}$$

(The minus sign is due to inversion in the amplifier.) The third DFG is cut off; the fourth conducts. The contribution of this DFG to the output voltage of the amplifier is

$$+\frac{1}{10} \left(\frac{X - Y}{2} \right)^2 = \frac{1}{10} \left(\frac{5 + 8}{2} \right)^2 = +\frac{169}{40}$$

The net output from the amplifier is

$$+\frac{169}{40} - \frac{9}{40} = +\frac{160}{40} = +4 \text{ volts}$$

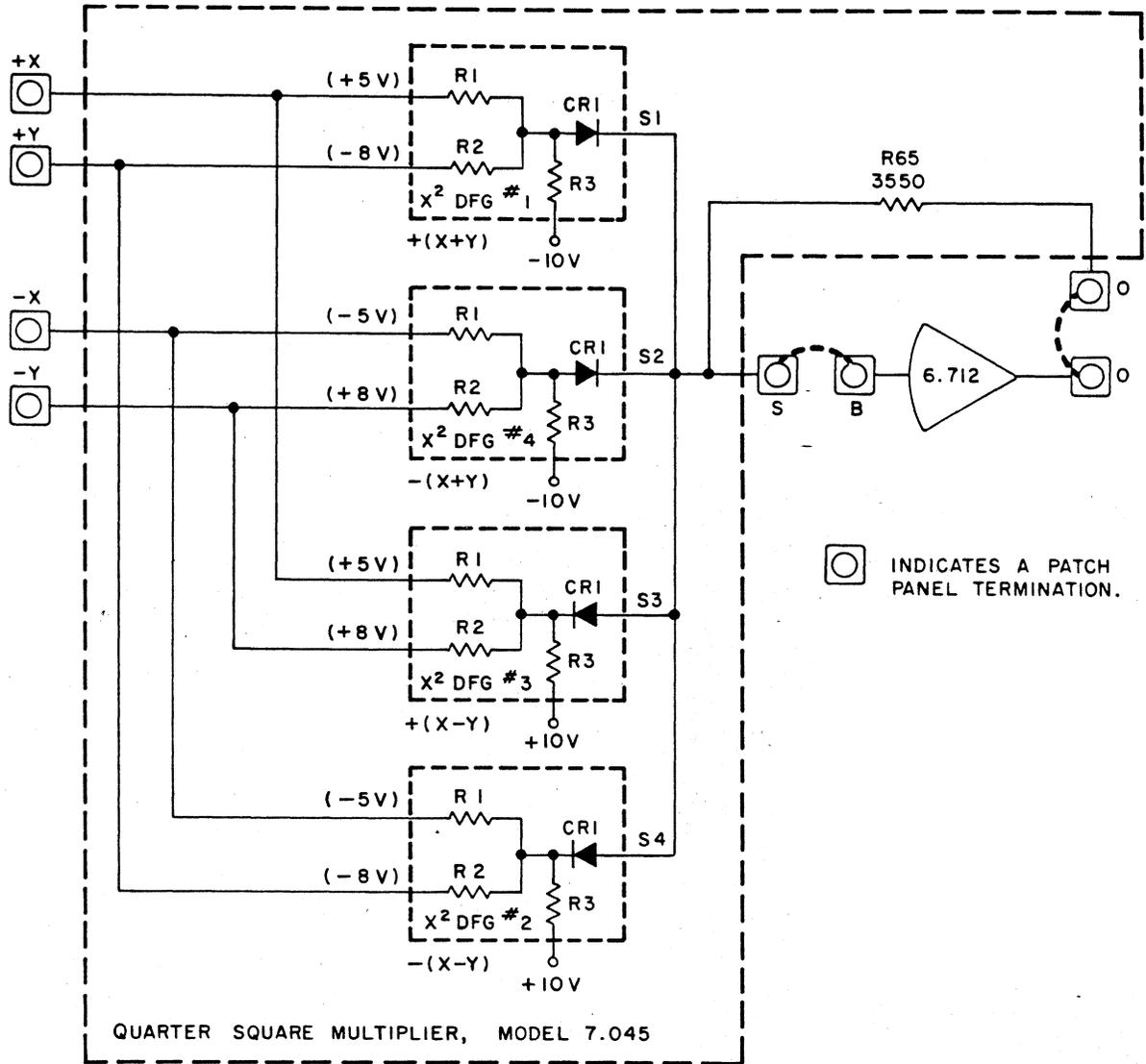


Figure 25. Quarter-Square Multiplier, Simplified Schematic

which agrees with the designated output of $-XY/10$ or $-(+5)(-8)/10 = +4$ volts. For other input voltages, different combinations of the DFG's conduct. Thus input voltages of any polarity combination result in a product.

The Quarter-Square Multiplier, Model 7.045, contains two etched-circuit cards, Type 7.044, each of which contains two biased-diode squaring circuits. The DFG on the left side of Drawing C007 044 0S accepts net positive inputs; the DFG on the right side accepts net negative inputs. The diode function generators produce a seven segment straight-line approximation to an X^2 function. Since both circuits are similar, the circuit description is confined to the positive input DFG.

Diodes CR1 to CR7 are biased to conduct at progressively increasing voltage magnitudes. As each diode conducts, the equivalent input impedance of the external amplifier is decreased, the gain of the amplifier is increased. Thermistors R14, R16, and R24 are used in the bias circuits to compensate for the effects of temperature variations. Variable padders are included in the bias networks so that the breakpoints of the segments can be adjusted. Inputs to the function generator (INPUT 1 and INPUT 2) are applied at circuit board terminals 5 and 6.

The two Type 7.044 cards are connected as shown in Drawing C007 045 0A to form a Model 7.045 Multiplier. Resistor R65 is the feedback resistor for the external amplifier.

5. MAINTENANCE

The Model 7.045 Multiplier requires very little maintenance. The adjustments are very stable and normally the unit is tested only to ensure the operator's faith in its performance.

a. Error Test

The following test provides a convenient means of checking the operation of the multiplier.

(1) Connect the circuit shown in Figure 26a. Balance the amplifiers. Be sure that computer reference voltages are within specifications. The input and feedback resistors for amplifier number two and the input resistors for amplifier number four should be matched resistors. If desired, the oscilloscope may be replaced by an XY recorder.

(2) Adjust the oscillator controls so that it is operating at 5 cycles per second, 20 volts peak-to-peak. Set the oscilloscope Y sensitivity to 10 mv/cm dc with a zero volt reference in the center of the screen; set the X sensitivity to 2 volts/cm.

(3) An oscilloscope pattern similar to Figure 26b should be observed. A tilted waveform is caused by misalignment or reference unbalance. Specifications call for an error not to exceed +80 millivolts; however, it is relatively simple to hold the maximum error to +50 millivolts. The error voltage is measured from

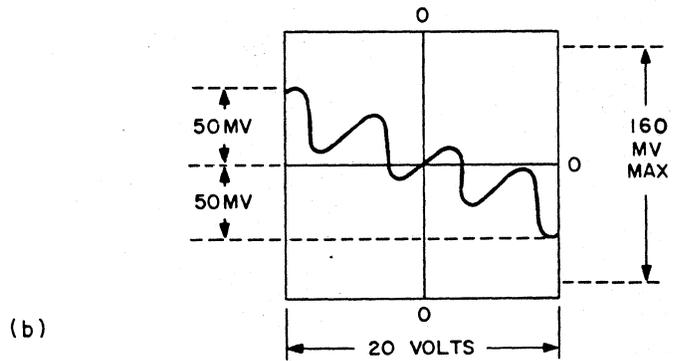
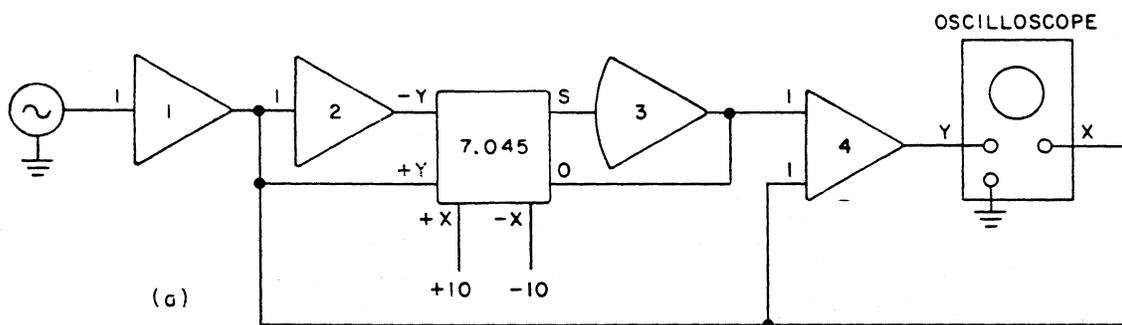


Figure 26. Error Test

the zero line to the largest peaks as shown.

(4) If the above test indicates that the multiplier is not operating within specifications, the diode function generator probably requires adjustment.

b. Adjustment Procedure

Each of the four diode function generators is checked by applying selected input voltages and observing the output voltage. Proceed as follows:

(1) Place the multiplier on a service shelf and connect the circuit shown in Figure 27a. The inputs to the multiplier are applied according to the schedule in Figure 27b. Balance the amplifiers and be sure that the computer reference voltages are within specifications.

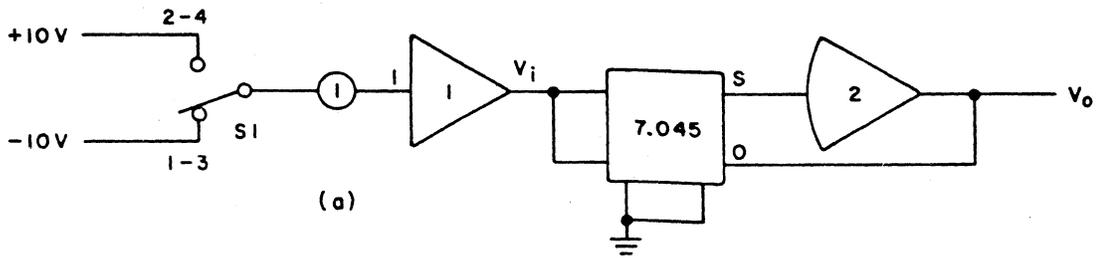
(2) Figure 27c lists the input and output check point voltages for the DFG cards. Use coefficient potentiometer number one to set the output voltage of amplifier number one to the values listed in the V_i column. Always begin with the lowest voltage and continue in order to the highest voltage.

(3) The output voltage of amplifier number two should correspond to the values listed in the V_o column. (The V_o column includes an allowable tolerance for each output voltage. The output voltage should be within the allowable tolerance when checking the DFG; when adjusting the DFG, set the output voltage to the given value.)

(4) If the output voltage is out of tolerance, adjust the appropriate potentiometer listed in the ADJUST column. Be sure to adjust the potentiometers in order, R1 to R6, R7 to R12. The location of the adjustments is shown in Figure 27d.

c. Troubleshooting

Malfunctions in the Model 7.045 can be localized by means of the adjustment procedure described above. The first segment that cannot be adjusted properly is probably at fault. Check the components in the suspected segment with an ohmmeter. Compare resistance measurements in the suspected DFG with measurements made in a DFG that is known to be good. Test the unit after replacing any components.



CARD NUMBER	POLARITY OF V_i	APPLY V_i TO	GROUND INPUTS
1	PLUS	+X, +Y	-X, -Y
2	MINUS	-X, +Y	+X, -Y
3	MINUS	+X, -Y	-X, +Y
4	PLUS	-X -Y	+X +Y

V_i (VOLTS)	ADJUST		V_o (VOLTS)
	CARDS 1 & 4	CARDS 2 & 3	
2.50	R1	R7	$0.64 \pm .02$
3.90	R2	R8	$1.54 \pm .02$
5.30	R3	R9	$2.82 \pm .02$
6.70	R4	R10	$4.50 \pm .02$
8.10	R5	R11	$6.58 \pm .02$
9.50	R6	R12	$9.04 \pm .02$

(b)

(c)

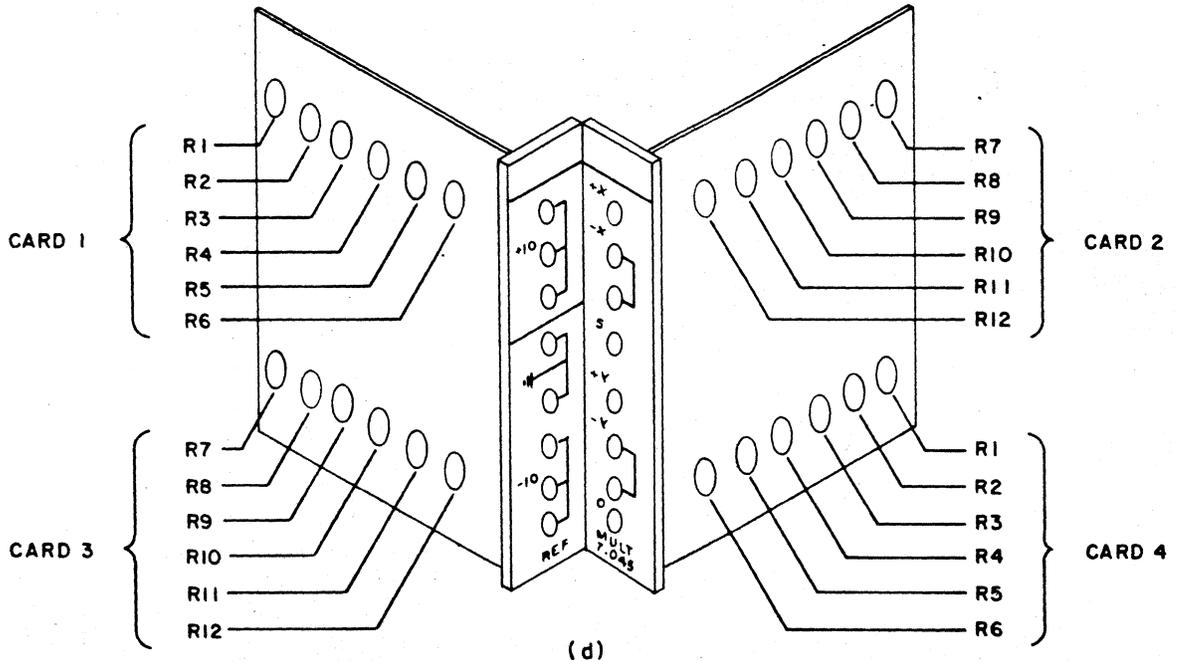


Figure 27. Quarter-Square Multiplier Adjustment

CHAPTER V

X^2 DIODE FUNCTION GENERATOR, MODEL 16.101

1. GENERAL DESCRIPTION

The X^2 Diode Function Generator, Model 16.101, is used in conjunction with a dc amplifier, such as the Model 6.712, to produce an output voltage that is proportional to the square or square root of an input voltage. The Model 16.101 contains two independent sections which generate quadratic curves. One accepts positive input voltages; the other accepts negative input voltages. Precision resistors and solid-state diodes are used to approximate the X^2 function by a series of seven straight line segments. An output voltage proportional to the square root of an input voltage is obtained by placing the X^2 DFG in the feedback loop of an amplifier.

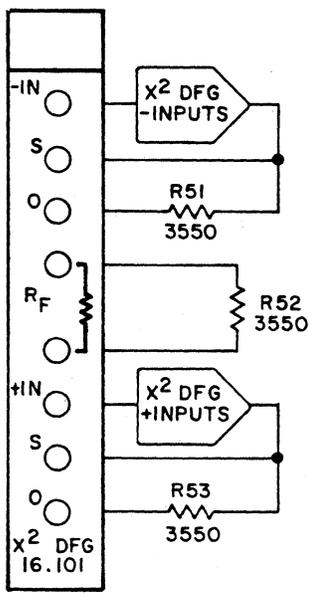
2. TECHNICAL DATA

Input Voltage Range.....	0 to $\pm 10V$
Output Voltage Range.....	0 to $\pm 10V$
Segments per Generator.....	7
Error (full scale)	
Typical.....	0.2%
Maximum.....	0.4%
Frequency Response.....	Compatible with Associated Amplifier

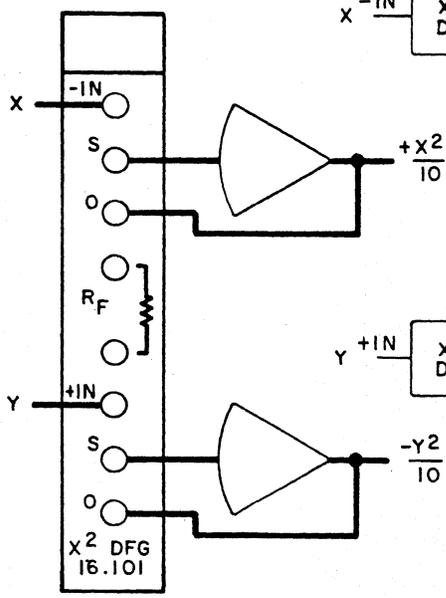
3. PATCHING

A simplified diagram and a typical patching scheme for the X^2 DFG are shown in Figure 28. The DFG terminated on the upper portion of the patching module accepts a negative voltage X and produces a positive voltage of $X^2/10$ from the associated amplifier. Should X be a positive voltage, the output will be zero.

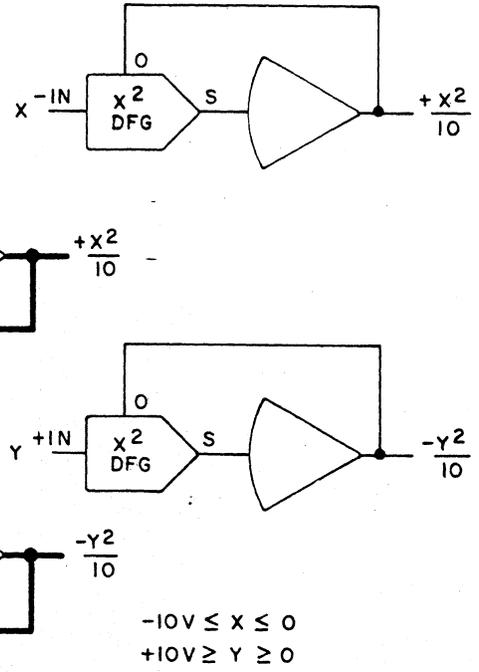
The DFG terminated on the lower portion of the patching module accepts a positive voltage Y and produces a negative voltage ($-Y^2/10$) from its associated amplifier. The output will be zero if Y is a negative voltage.



(a) SIMPLIFIED DIAGRAM OF UNIT



(b) TYPICAL PATCHING



(c) SYMBOLS

Figure 28. X² DFG Patching

4. CIRCUIT DESCRIPTION

The Model 16.101 consists of two independent X^2 function generators. Refer to Drawing C016 099 OS. The seven segment X^2 DFG on the left side of the drawing accepts positive inputs only; the one on the right side accepts negative inputs. Since both circuits are similar, the circuit description is confined to the negative input DFG. (The elementary principles of DFG's are discussed in Appendix I.)

Figure 29 contains a simplified drawing of the negative input DFG. The unit is shown connected to an external amplifier. Each diode is biased (through R37 to R43) to conduct at progressively increasing input voltage magnitudes. With zero volts at $-IN$, none of the segments conduct. When the maximum input of -10 volts is applied, all the diodes conduct. As each diode conducts, the equivalent input impedance of the amplifier is decreased; the gain of the amplifier is increased. The circuit resistance values are selected so that the output of the amplifier is $+X^2/10$.

The actual networks, shown on Drawing C016 099 OS, contain variable padder resistors so that the breakpoints can be adjusted. Thermistors R33, R35, and R43, (R14, R16, and R24 in the positive input DFG) are used in the bias networks to compensate for the effects of temperature variations.

5. MAINTENANCE

a. Adjustment Procedure

Use the following procedure to adjust or to test the X^2 DFG.

(1) Use a service shelf to extend the module so that the adjustment potentiometers are accessible. Connect the circuit shown in Figure 30a. Balance the amplifiers. Be sure that the computer reference voltages are within specifications.

(2) Figure 30b lists the input and output check point voltages for the X^2 DFG. Use coefficient potentiometer number one to set the output of amplifier one to the values listed in the INPUT VOLTAGE column. The output of amplifier two should correspond to the values listed in the OUTPUT VOLTAGE column. If the output voltage is out of tolerance, adjust the appropriate potentiometer listed in the ADJUSTMENT column. (The OUTPUT VOLTAGE column includes an allowable tolerance for each output value. The output voltage should be within the allowable tolerance when checking the X^2 DFG; when adjusting the function generator, set the output voltage to the given value.)

(3) Place switches S1 and S2 to the positions shown in Figure 30a. Adjust coefficient potentiometer number one until V_i is +2.50 volts. The output voltage V_o should be -0.64 volts. If an error exists, adjust R1 (see Figure 30c). Place S1 in the down position; V_o should be +0.64 volts. If an error exists, adjust R7. Proceed in this manner through the other check values.

(4) Resistors R52 and R53 can be checked at the last checkpoint voltage. Remove the lead patched into the 0 termination and patch it into the other 0 termination. The output voltages should remain within specification. Remove the

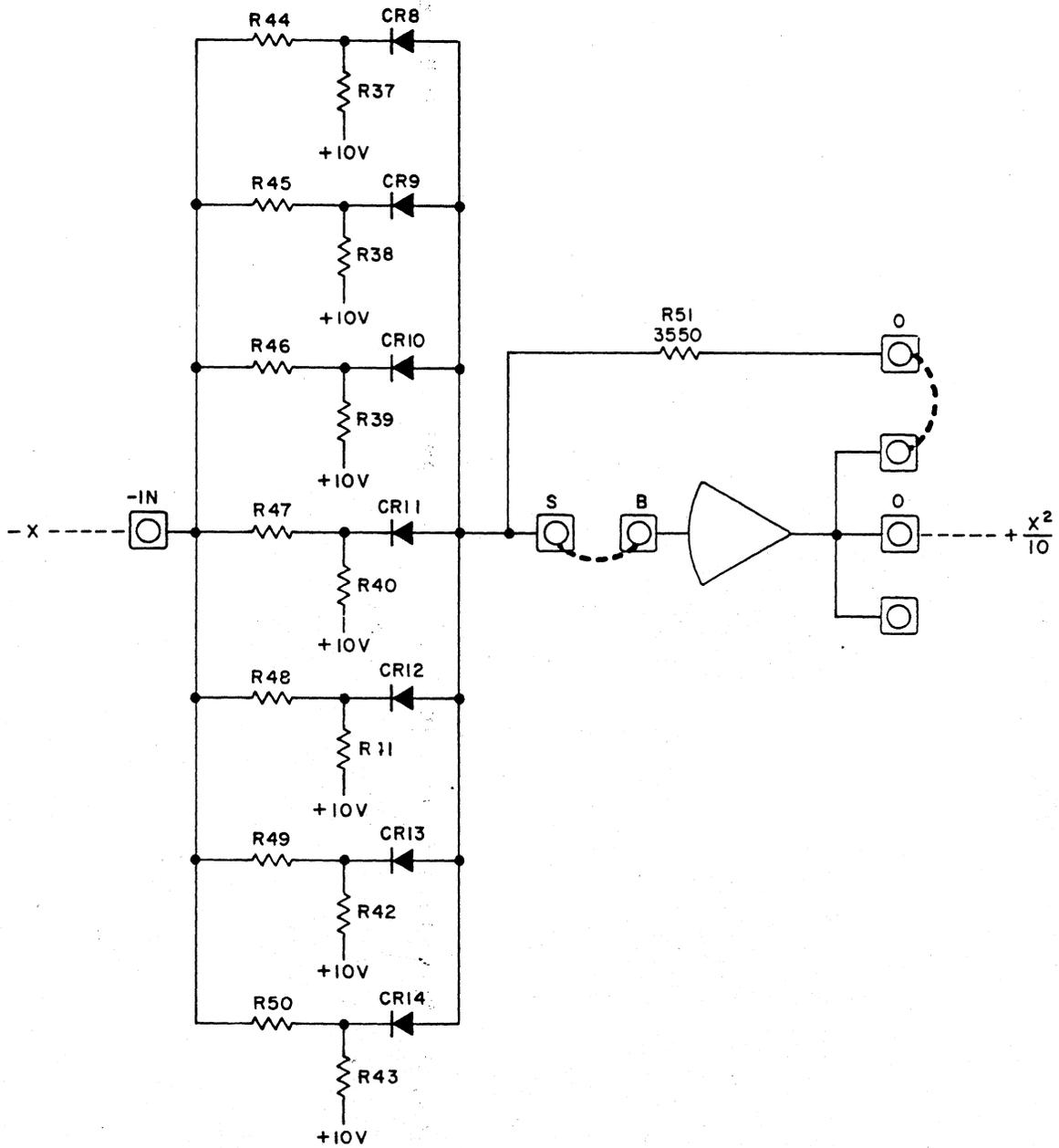
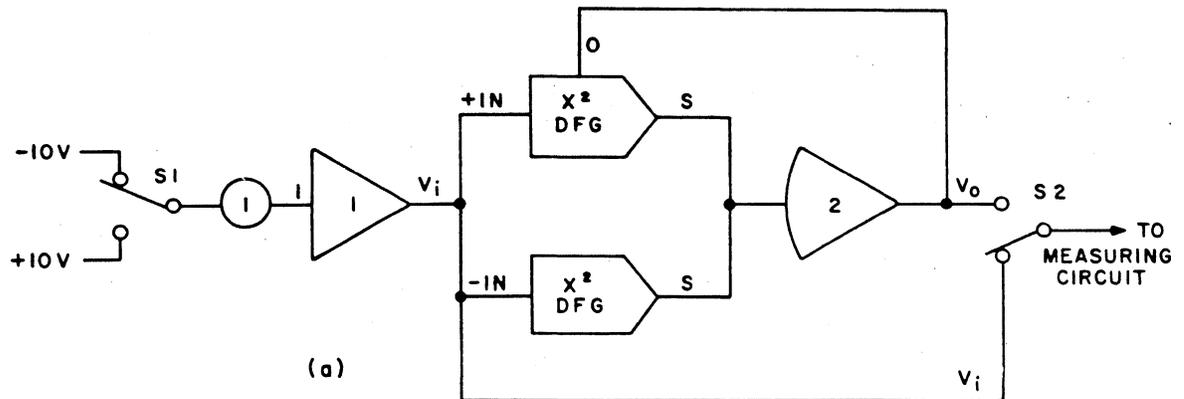


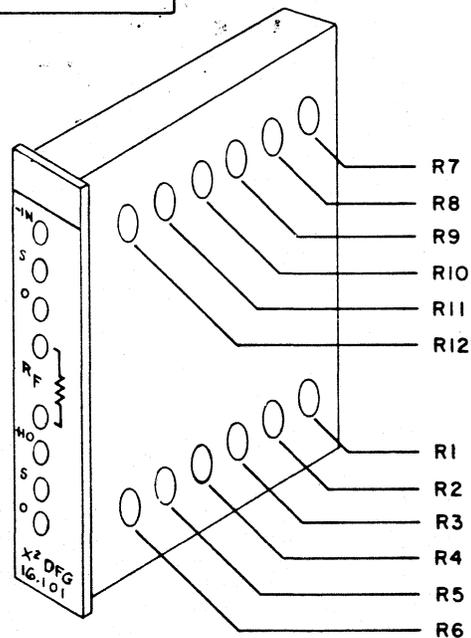
Figure 29. X^2 DFG, Simplified Schematic



(a)

INPUT VOLTAGE V_i	ADJUSTMENT		OUTPUT VOLTAGE V_o
	$+V_i$	$-V_i$	
2.50	R1	R7	0.64 \pm .02
3.90	R2	R8	1.54 \pm .02
5.30	R3	R9	2.82 \pm .02
6.70	R4	R10	4.50 \pm .02
8.10	R5	R11	6.58 \pm .02
9.50	R6	R12	9.04 \pm .02

(b)



(c)

Figure 30. X^2 DFG Adjustment Information

lead patched into the 0 termination and patch it to one end of R_f ; connect the other end of R_f to the base of amplifier two. The output voltage should remain within specification.

b. Troubleshooting

Malfunctions in the X^2 DFG can be localized by means of the adjustment procedure described in Section 5a. above. The first segment that cannot be adjusted properly is probably at fault. Refer to Drawing C016 099 0S for component values and location. Check the components in the suspected segment with an ohmmeter. (Compare resistance measurements made in the minus and plus cards.) Recalibrate the unit after replacing any components.

CHAPTER VI

DUAL LOG X DFG, 16.126, AND DUAL ONE-HALF LOG X DFG, 16.133

1. GENERAL DESCRIPTION

The Log X DFG's operate in conjunction with a dc amplifier to produce an output voltage that is proportional to the logarithm of the input signal voltage. The output of the generators is in the form of seven straight-line voltage segments that closely approximate a logarithmic curve for a single polarity input voltage.

The Dual Log X DFG, Model 16.126, consists of two logarithmic function generators. One generator accepts a positive input voltage X and produces a negative output voltage $Y = -5 \log_{10} 10X$. The other generator accepts a negative input voltage X and produces a positive output voltage $Y = +5 \log_{10} 10X$.

The Dual 1/2 Log X DFG, Model 16.133, consists of two logarithmic function generators. One generator accepts a positive input voltage X and produces a negative output voltage $Y = -2.5 \log_{10} 10X$. The other generator accepts a negative input voltage X and produces a positive output voltage $Y = 2.5 \log_{10} 10X$.

2. TECHNICAL DATA

The data below applies to both the Model 16.126 and the Model 16.133 unless otherwise noted.

Input Voltage Range	0.1 to 10V
Output Voltage Range	0 to 10V
Segments per Generator	7
Input Current (at zero volts in)	
Model 16.126	3 MA
Model 16.133	1.5 MA
Static Error	
Log X, Referred to Input	
Maximum	$\pm 1\%$, Full Scale
Typical.....	$\pm 0.5\%$, Full Scale
Frequency Response	Compatible with Associated Amplifier

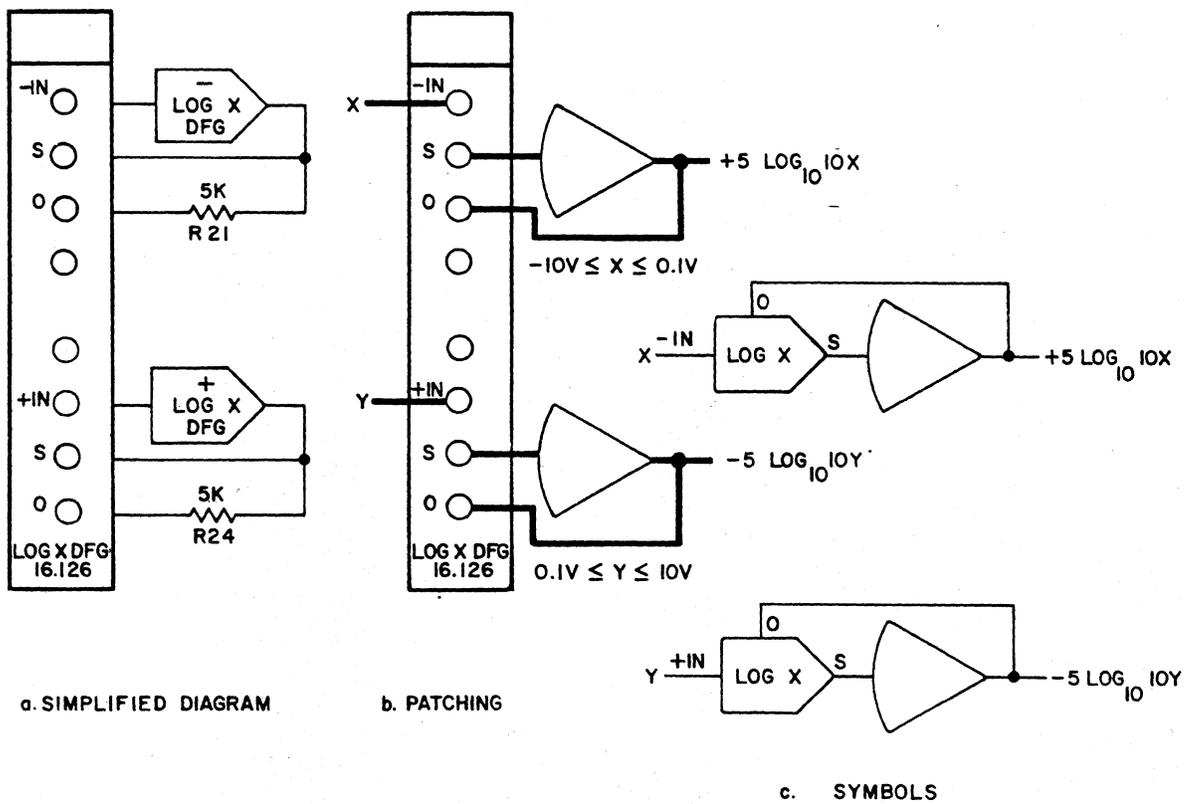


Figure 31. Log X and 1/2 Log X DFG Patching

3. PATCHING

A simplified diagram and a typical patching scheme for the Dual Log X DFG and the Dual 1/2 Log X DFG are shown in Figure 31. The Model 16.126 is shown in the figure but the information is applicable to the Model 16.133. The DFG terminated on the upper portion of the patching module accepts a negative voltage X and produces a positive voltage of $5 \log_{10} 10X$ from the associated amplifier. The lower DFG accepts a positive voltage Y and produces a negative voltage of $-5 \log_{10} 10Y$ from its associated amplifier. The input voltage magnitude should be greater than 0.1 volts in order to maintain accuracy and/or avoid overloads. Care should be taken not to apply an input voltage of the wrong polarity; doing so will not damage the DFG but it does constitute a severe overload on the associated amplifiers.

4. CIRCUIT DESCRIPTION

The Model 16.126 and Model 16.133 each consist of two independent logarithmic function generators. Since the generators are basically the same, only the positive input function generator in the Model 16.126 is described. (The elementary principles of DFG's are discussed in Appendix I.)

A simplified diagram of the positive input logarithmic function generator is shown in Figure 32. The DFG is connected to an external amplifier. The feedback element for the amplifier is R24; the biased diode network forms the input impedance. When the input voltage X is near zero, all the diodes are conducting and the equivalent input impedance of the amplifier is at a minimum. As the input voltage increases in magnitude, the diodes are cut off one at a time. The amplifier's equivalent input impedance increases and its gain is decreased.

The circuit resistance values are chosen so that the output voltage of the amplifier is $-5 \log_{10} 10X$. Variable padding resistors are included in the networks so that the diode breakpoints can be adjusted.

5. MAINTENANCE

The Dual Log X and Dual 1/2 Log X DFG's require very little maintenance. The adjustments are stable and normally the unit is tested only to insure the operator's faith in its performance.

a. Adjustment Procedure

(1) Use a service shelf to extend the module so that the adjustment potentiometers are accessible. Connect the circuit shown in Figure 33a.

(2) Balance the amplifiers. Be sure that the computer reference voltages are within specifications.

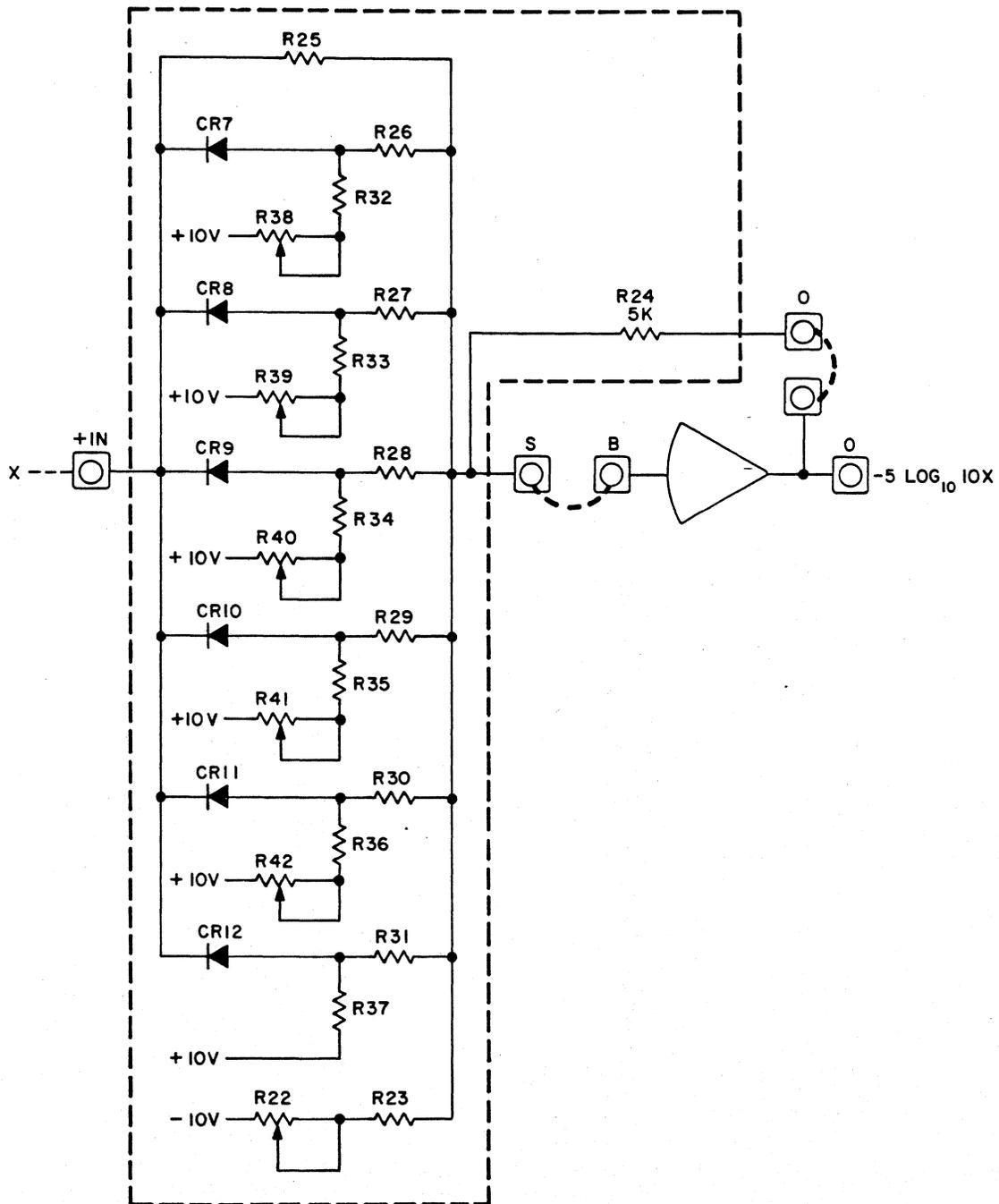
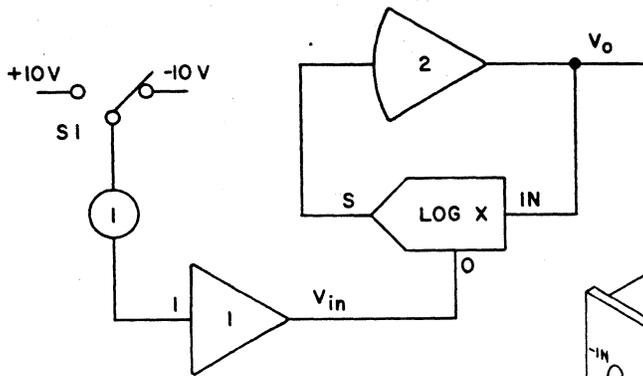
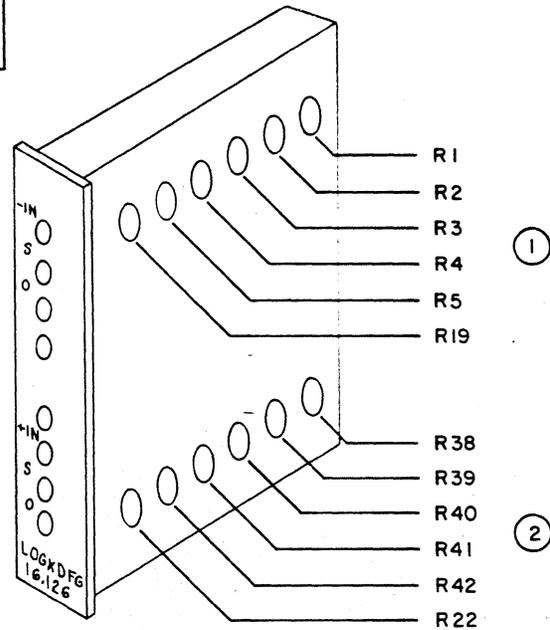


Figure 32. +Input Log X DFG, Simplified Diagram



(a) TEST CIRCUIT



(c) ADJUSTMENT LOCATION

ADJ. NO.	INPUT VOLTAGE V_{in}		ADJUST	OUTPUT VOLTAGE V_o
	16.126	16.133		
1	+2.15	+1.08	R19	$-0.32 \pm .05$
2	+5.23	+2.62	R5	$-1.16 \pm .05$
3	+6.92	+3.46	R4	$-2.47 \pm .05$
4	+8.13	+4.07	R3	$-4.28 \pm .05$
5	+9.05	+4.53	R2	$-6.51 \pm .05$
6	+9.79	+4.90	R1	$-9.13 \pm .05$
1	-2.15	-1.08	R22	$+0.32 \pm .05$
2	-5.23	-2.62	R42	$+1.16 \pm .05$
3	-6.92	-3.46	R41	$+2.47 \pm .05$
4	-8.13	-4.07	R40	$+4.28 \pm .05$
5	-9.05	-4.53	R39	$+6.51 \pm .05$
6	-9.79	-4.90	R38	$+9.13 \pm .05$

MINUS DFG CARD
①

POSITIVE DFG CARD
②

(b) ADJUSTMENT DATA

Figure 33. Adjustment Information Log X DFG's

(3) Figure 33b lists the input and output check point voltages for the DFG's. The OUTPUT VOLTAGE column includes an allowable tolerance for each output voltage. The output voltage should be within the allowable tolerance when checking the unit. Set to the given output voltage when adjusting the unit. Use coefficient potentiometer 1 to set V_{in} to the value listed in the INPUT VOLTAGE column. If the output voltage V_o is out of tolerance, adjust the specified potentiometer. Figure 33c shows the location of the adjustment potentiometers.

(4) There is some interaction between adjustments. The adjustments must be completed in order, from number 1 to 6, and after each adjustment, the previous adjustments should be checked.

(5) For example, to adjust the minus DFG card of the Model 16.126, use the patching terminations labeled ① to connect the DFG in the test circuit. Set V_{in} to +2.15 volts. Adjust R19 until V_o measures -0.32 volts. Set V_{in} to +5.23; adjust R5 until V_o measures -1.16 volts. Recheck adjustment number 1 and reset R19 if necessary. Recheck adjustment 2 and reset if necessary. Set adjustment 3; recheck adjustments 1 and 2. The recheck procedure is necessary for adjustments 1, 2, and 3, but should not be necessary for adjustments 4, 5, and 6. However, it is desirable to recheck several times until one is familiar with the adjustment procedure.

b. Troubleshooting

Malfunctions in the Log X DFG's can be localized by checking circuit resistance values with an ohmmeter. Remove all power to the unit and compare resistance measurements made on the plus DFG to measurements made on the minus DFG. Recalibrate the unit after replacing any components.

CHAPTER VII

VARIABLE DIODE FUNCTION GENERATOR GROUPS 2.645 AND 2.713

1. GENERAL DESCRIPTION

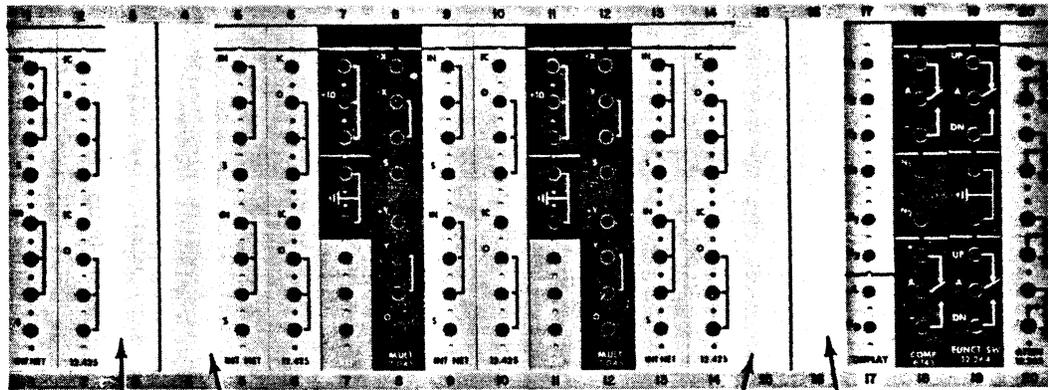
The variable diode function generators (VDFG's) are used in conjunction with dc amplifiers to produce a segmented straight-line approximation to an arbitrary function. They accept an input voltage X and produce an output voltage $Y = f(X)$, where f is a predetermined, single-valued function that can be non-monotonic. The desired function is produced by summing the outputs from biased diode networks. As the input voltage changes, the diodes effectively switch the input resistors of a summing amplifier, thus varying the amplifier gain. The output voltage of the amplifier changes in accordance with the input voltage by a sequence of straight-line segments.

Two basic VDFG groups are available. The 2.645 Group provides plus and minus units with variable slopes and breakpoints; the 2.713 Group has variable slopes and fixed breakpoints. The groups are listed below.

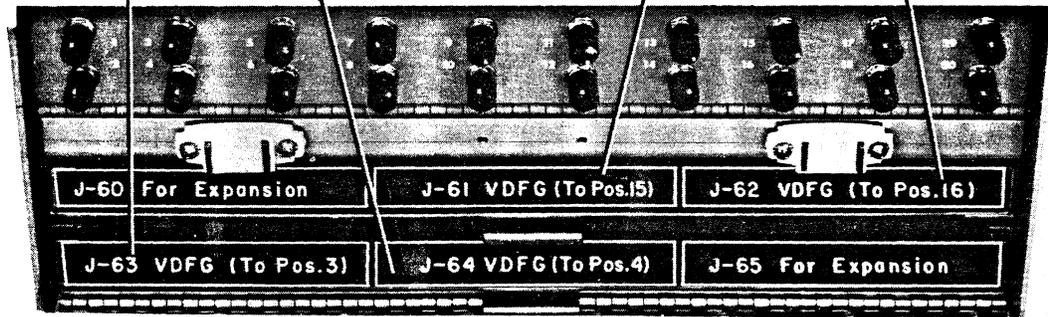
GROUP NUMBER	+VDFG UNIT	READOUT MODULE	-VDFG UNIT
2.713-0	16.156-1	16.310	16.154-1
2.713-1	16.156-1	16.310	----
2.713-2	----	16.310	16.154-1
2.645-0	16.304-1	16.308	16.306-1
2.645-1	16.304-1	16.308	----
2.645-2	----	16.308	16.306-1

The VDFG units are mounted on slide-out shelves below the control panel (see Figure 33a), making the adjustment potentiometers readily accessible.

The readout modules are wired-through units which couple signals between the patch panel and the VDFG units.



READOUT MODULES



VDFG UNITS

VDFG MOUNTING LOCATIONS

NOTE: The 16.165-1 \pm VDFG Unit may be located in J-61, J-62, J-63, or J-64.

Figure 33a. VDFG Mounting Locations

2. TECHNICAL DATA

Number of Segments

Models 16.154 and 16.156 10

Models 16.304 and 16.306 11

Maximum Slope

(All Units)

Initial Segment 2V/V

Remaining Segments 1V/V

Diode Breakpoints

Model 16.154 -1V, -2V, -3V, -4V,
-5V, -6V, -7V, -8V, -9V

Model 16.156 +1V, +2V, +3V, +4V,
+5V, +6V, +7V, +8V, +9V

Model 16.306 Variable from 0V to -9.5V

Model 16.304 Variable from 0V to +9.5V

Breakpoint Tolerance

Models 16.154 and 16.156 $\pm 0.15V$

Frequency Response

All Units Compatible with Associated
Amplifier

3. OPERATING INSTRUCTIONS

a. Scope

The 16.154 Minus VDFG Unit is identical to the 16.156 Plus VDFG, except that the diodes and internal reference voltages are reversed. Similarly, the 16.306 and 16.304 Units are identical except for diode and reference polarities. Therefore, the 16.156 Plus (fixed breakpoint) VDFG and the 16.304 Plus (variable breakpoint) VDFG are the only units described.

Complete operating information is provided in the Operator's Handbook; the data provided in this chapter consists only of information sufficient for testing and servicing the units. Appendix I of this manual includes a section on the basic theory of diode function generation.

b. Patching

Patching is similar for all units. Figure 34 provides a simplified diagram and patching symbols for a +VDFG unit.

4. CIRCUIT DESCRIPTION

a. Fixed Breakpoint VDFG

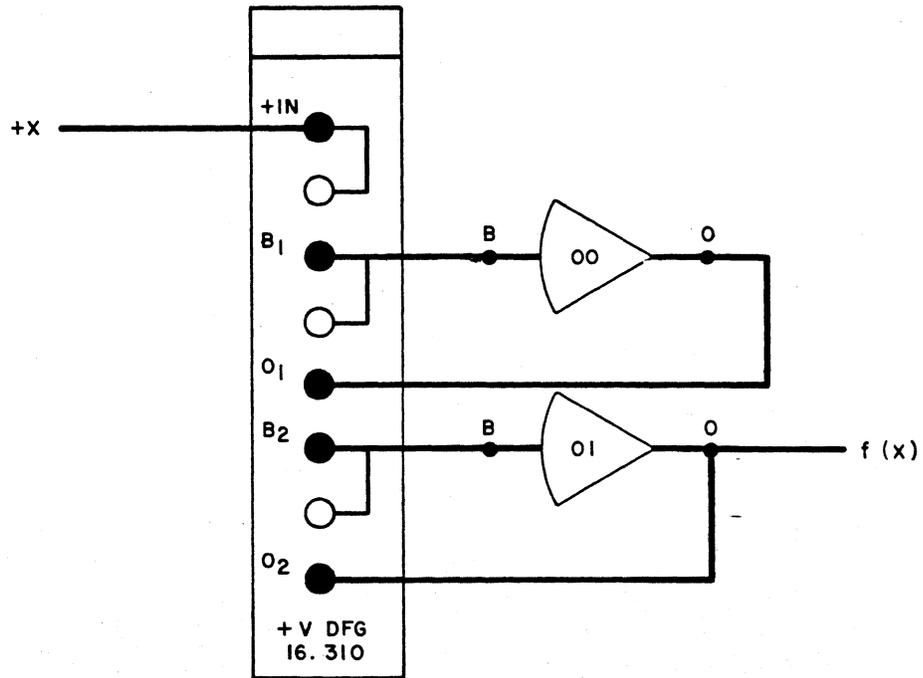
A simplified schematic of the 16.156 Plus VDFG is provided in Figure 35. Arbitrary identification numbers have been assigned to some of the resistors for explanation purposes, and the 4 volt through 8 volt networks have been deleted for clarity.

Nine diodes are provided in this unit. Each diode is reverse-biased at a different potential. For example, CR9 has a reverse bias of -1 volt, provided by R2 and R3, and CR8 is reverse biased at -2 volts by R4 and R5. An input signal therefore must exceed the preset bias level in order to cause a given diode to conduct. An X input signal between 0 volt and +1 volt is not sufficient to cause any of the diodes to conduct, but it does cause a current to pass through R1 to the wiper of the 1V slope pot. The right end of the 1V slope pot (as shown on Figure 35) is connected to the B₁ terminal which is patched directly to the base of an amplifier (the amplifier designated 00). The left end of the pot is connected to B₂ and the base of amplifier 01. The position of the wiper of this pot then determines the division of the input current between the two amplifiers. If the wiper is moved completely to the right, most of the input current is routed to amplifier 00. Since the input is positive, the output of amplifier 00 goes in a negative direction. This negative signal is coupled through R7 to the base of amplifier 01, causing the output at the f(X) terminal to go positive.

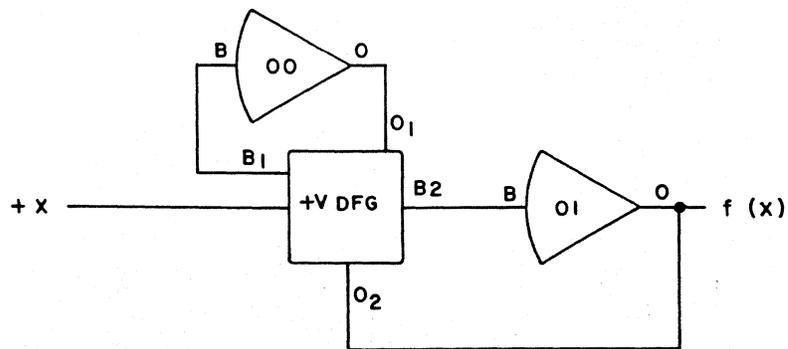
If the wiper of the 1V pot is moved to the left, the majority of the input current is routed directly to the base of amplifier 01, and the f(X) output goes negative.

As the input potential increases to one volt, the reverse bias on diode CR9 is overcome and current flows through R2 and CR9 to the wiper of the 2V slope pot. The position of this wiper again determines the division of the input current between the two amplifiers.

At this point, current is entering the output amplifiers through two branches: Resistor R1 and the 1V slope pot, and R2 and the 2V slope pot. This indicates that the slope of the output function at any given point is equal to the sum of the slopes produced by all the networks conducting at that point.



a. SIMPLIFIED PATCHING



b. COMPUTER SYMBOL

Figure 34. +VDFG Patching and Symbol

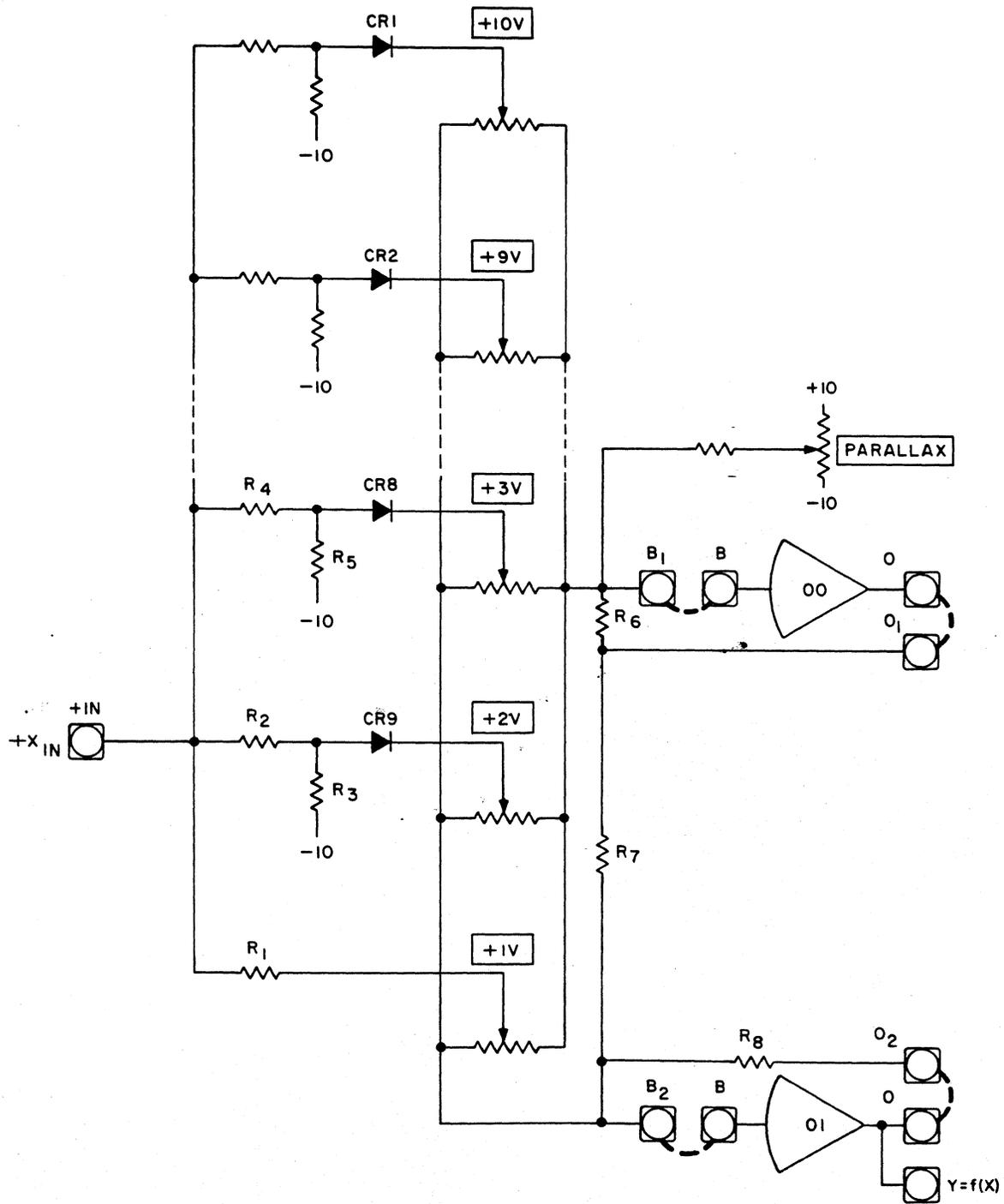


Figure 35. +Fixed Breakpoint VDFG Unit, Simplified Schematic

The PARALLAX pot, shown at the right side of Figure 35, provides an adjustable offset current to the base of amplifier 00. This input sets the value of $f(X)$ when $X = 0$. If the wiper is moved completely to the top (as shown), the function value is equal to +10 volts when $X = 0$. If the wiper is moved to its lower extreme, the output equals -10 volts when $X = 0$. This fixed current is also additive to the currents produced by an X input, so that adjusting this pot offsets the output function for the total range of X inputs.

Resistor R6 provides feedback for the first amplifier (amplifier 00), and resistor R7 couples the output of this amplifier to the base of amplifier 01. Resistor R8 provides feedback for the output amplifier.

b. Variable Breakpoint VDFG

Refer to Figure 36, a simplified schematic of the 16.304 plus variable breakpoint VDFG, for the following description. The circuit for this unit is very similar to the circuit of the fixed breakpoint units. In Figure 36, diode networks 2 through 9 have been deleted for clarity, and arbitrary numbers applied to some of the resistors for explanation purposes. Each diode is provided with a bias network which consists of fixed resistors (R2 through R5 for CR1) and a potentiometer. The potentiometer for each network allows the voltage on each diode to be varied from a slight forward bias to a reverse bias of approximately 9.5 volts. This potentiometer is designated the Breakpoint pot and permits the operator to select a breakpoint voltage which is consistent with the function being generated. The resistor designated R4 in the simplified schematic actually consists of a fixed resistor in series with a thermistor, providing temperature compensation networks for each breakpoint in the unit. The PARALLAX pot provides an adjustable offset current which determines the value of the function at $X = 0$. The SLOPE pots determine the direction and degree of slope for each diode network, and the CENTRAL SLOPE pot determines the function slope from $X = 0$ until the first diode conducts as determined by the BREAKPOINT 1 pot.

5. MAINTENANCE

a. Fixed Breakpoint VDFG's

There are no calibration adjustments for the VDFG's. Performance of the fixed breakpoint units can be checked quickly with the following procedure.

(1) Connect the circuit shown in Figure 37. Rotate all potentiometers fully counter-clockwise.

(2) Apply an input of zero volts. Rotate the PARALLAX control. The output should vary from -10 to +10 volts. Set the PARALLAX control for zero volts output.

(3) Apply an input of +1 volt (-1 volt for the 16.154 Unit). Rotate the 1V potentiometer. The output should swing between +2 volts. Set the 1V pot for and output of zero volts.

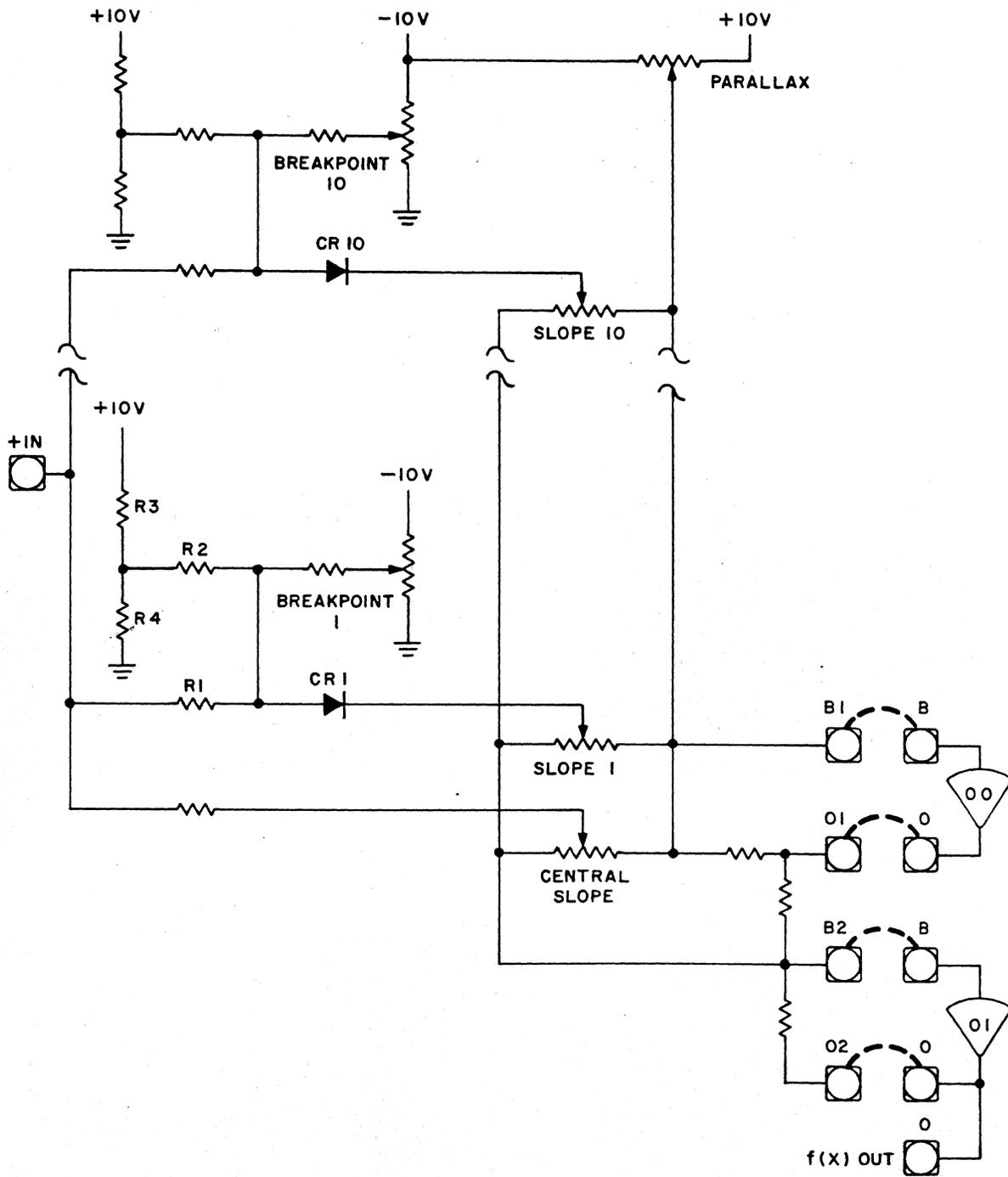


Figure 36. +Variable Breakpoint VDFG Unit, Simplified Schematic

(4) Apply an input of +2 volts (-2 volts for the 16.154 Unit). Rotate the 2V pot. The output should swing between +1 volt. Set the pot for an output of zero volts.

(5) Repeat Step (4) with inputs of 4, 5, ..., 10 volts (plus for the 16.156 Unit; minus for the 16.154 Unit). In each case, the slope potentiometer should cause the output to swing between +1 volt.

b. Variable Breakpoint VDFG's

The following procedure may be used to check the variable breakpoint VDFG's.

(1) Patch the circuit of Figure 37. Rotate all BREAKPOINT pots (1 through 10) fully clockwise. Rotate SLOPE POTS 1 through 10 alternately counter-clockwise and clockwise.

(2) With a zero volt input, rotate the PARALLAX control from limit to limit. The output should swing from -10 volts to +10 volts. Set the PARALLAX pot accurately for a zero volt output.

(3) Apply an input of 1 volt (plus for the 16.304; minus for the 16.306). Rotate the CENTRAL SLOPE pot. The output should swing between +2 volts. Apply an input of 8 volts (observing polarity) and set the CENTRAL SLOPE pot for an output of zero volts as accurately as possible.

(4) Apply an input of zero volts and rotate the BREAKPOINT 1 pot fully counter-clockwise. Adjust the PARALLAX control for zero volt output. Apply an input of 1 volt, and observe the output. The voltage should be at least 1 volt (plus or minus, depending on the direction of the slope). Apply an input of zero volts and rotate the SLOPE 1 pot fully in the opposite direction (clockwise, for example, if it had been counter-clockwise). Adjust the PARALLAX pot for an output of zero volts. Apply an input of 1 volt. The output should again be at least 1 volt (with a polarity opposite to that of the previous test). Again rotate the BREAKPOINT 1 pot fully clockwise. Apply zero volts in, and adjust the PARALLAX control for zero volts output.

(5) Apply an input of 1 volt, again observing polarity. Rotate the BREAKPOINT 2 pot counter-clockwise until the output goes +100 millivolts. Apply an input of 2 volts. The output voltage should be at least +1.1 volts. Rotate the SLOPE 2 pot to its opposite limit. The output should again be +1.1 volt (polarity opposite to that of previous reading). Rotate the BREAKPOINT 2 pot fully clockwise.

(6) Repeat Step (5) for 2, 3, ..., 9 volts in and breakpoints 3, 4, ..., 10. In each case, the appropriate BREAKPOINT pot is adjusted for an output of +100 millivolts with a given input. The input is then increased by 1 volt and the output examined. If each network is capable of producing a slope of 1 volt per volt, the output should increase by 1 volt as the input increases by one volt. Difficulty with any of the tests immediately isolates the problem to a given diode network.

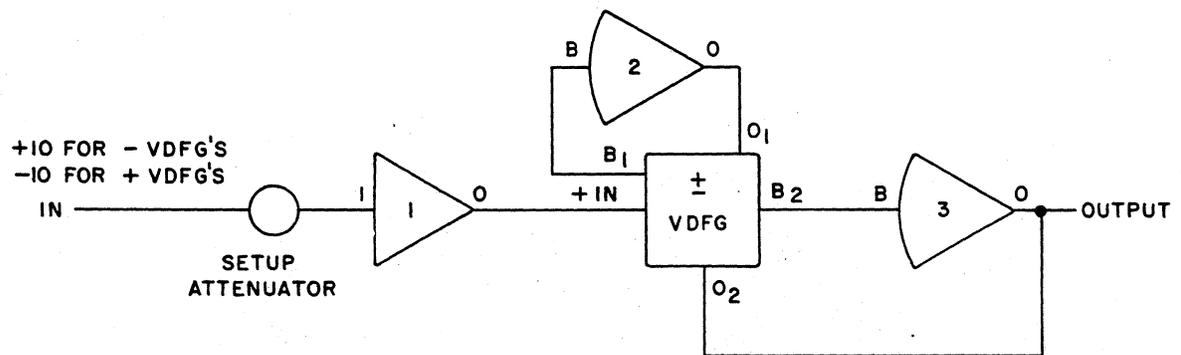


Figure 37. VDFG Test Circuit

CHAPTER VIII

COEFFICIENT ATTENUATOR GROUPS

1. GENERAL DESCRIPTION

Four types of attenuator groups are available for use in the TR-20. All groups use ten-turn, 5000 ohm potentiometers. The groups are listed below.

GROUP	NO. OF POTS	TYPE OF POT	DIAL	REMARKS
42.183	2	Carbon	Uncalibrated	No readout switches
42.187	2	Carbon	Uncalibrated	Equipped with readout switches
42.188	2	Wirewound	Calibrated	Equipped with readout switches
2.128 (42.185 and 12.265)	4	Wirewound	Calibrated	Pots located in Control Panel area. Equipped with readout switches.

2. CIRCUIT DESCRIPTION

The coefficient attenuators (or potentiometers) are energized with reference voltage in order to obtain a fixed accurate voltage less than the reference, or with a signal voltage in order to multiply the signal voltage by a constant less than unity. To facilitate coefficient setting, a pushbutton switch is located next to each attenuator (except for the 42.183 Group). See Figure 38. Depressing the switch connects the wiper to the Pot Bus, removes the voltage applied at the patch panel, and applies +10 volts to the top of the attenuator. The wiper is still patched to its load. The wiper voltage, on the Pot Bus, can be measured by the null comparison method by using the NULL POT on the Control Panel.

The Type 42.183 Attenuator Group does not include the pushbutton switches. The wiper of each attenuator is brought out to a termination next to the attenuator to facilitate readout under loaded conditions.

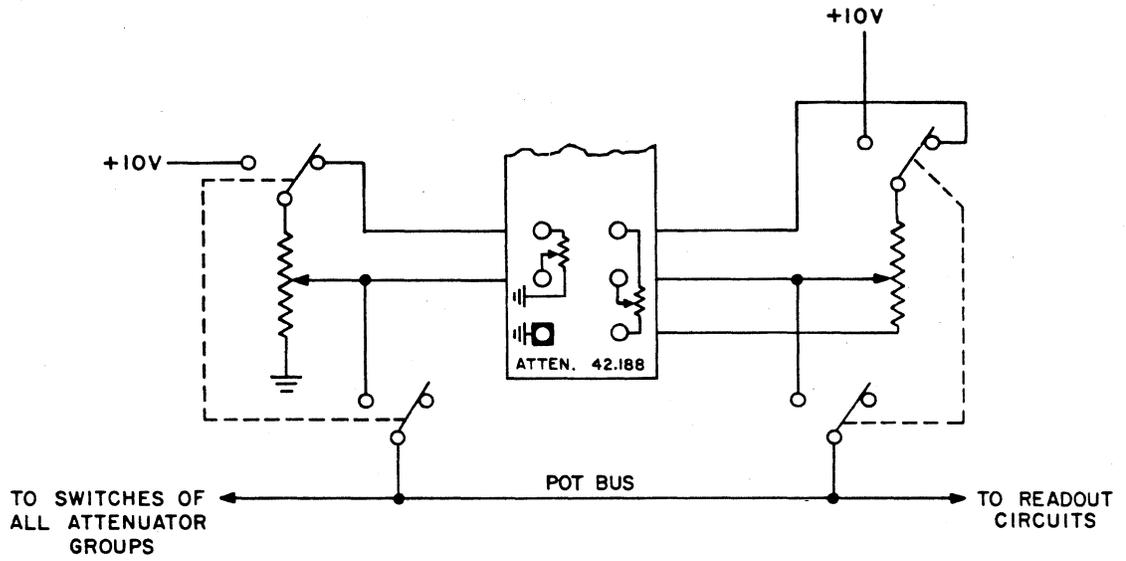


Figure 38. Attenuator Schematic

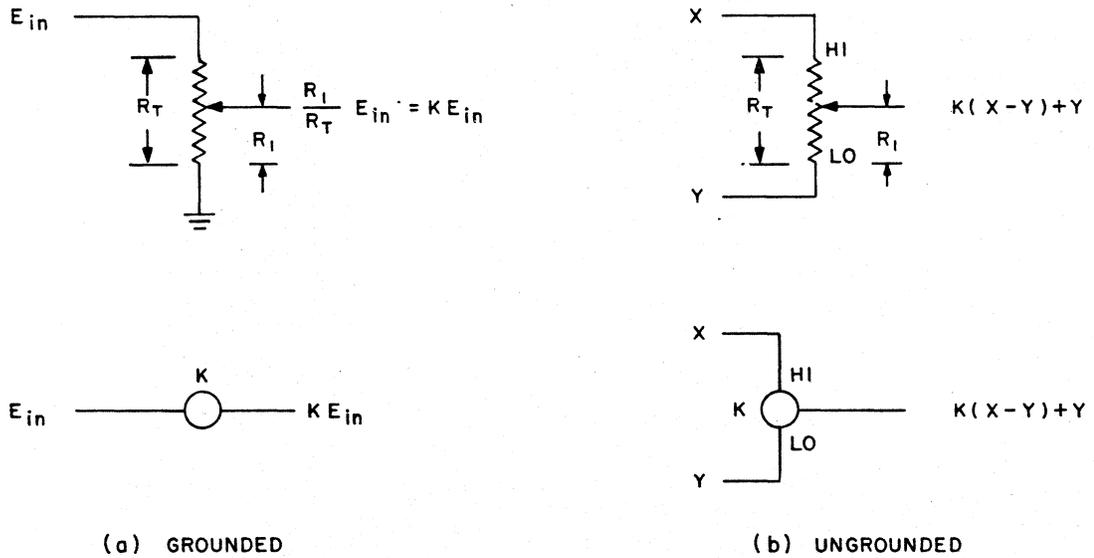


Figure 39. Schematics and Symbols for Attenuators

The Type 42.183, Type 42.187, and Type 42.188 Groups have similar patching terminations. The upper potentiometer is terminated on the left side of the patching module and the lower end of the potentiometer is grounded. The lower potentiometer is terminated on the right side of the patching module and both ends of the potentiometer are available at the patch panel. The Type 2.128 Group consists of a patching module (Type 12.265) that mounts in the non-linear row of computing components, and Quad Coefficient Assembly, Type 42.185 that mounts in the control panel area. The lower end of each potentiometer is grounded. The potentiometers are terminated in order, top to bottom, on the patching module.

The symbols used to represent the attenuators on computer circuit diagrams are shown in Figure 39.

3. MAINTENANCE

The attenuators are relatively rugged and rarely are a source of trouble. Misalignment of the vernier dial can occur. This is corrected by unclamping the dial from the attenuator shaft, turning the attenuator to one end of its travel, lining up the dial to the appropriate reading, then carefully fastening the dial back onto the attenuator shaft. Operators occasionally forget to ground the lower end of ungrounded attenuators with the result that the wiper voltage remains at a high level for all dial settings.

CHAPTER IX

SIGNAL COMPARATORS AND FUNCTION SWITCHES

1. RELAY COMPARATOR, MODEL 6.143

a. General Description

The Model 6.143 Signal Comparator consists of a high-gain amplifier and a double-pole, double-throw relay. The amplifier compares a variable input voltage to an arbitrary reference input voltage, and operates the relay when the weighted algebraic sum of the input voltages is negative. The relay is de-energized when the weighted algebraic sum of the input voltages is positive.

b. Technical Data

Sensitivity (the Change in Input Voltage Required to Cause Switching)

Maximum 3 Millivolts

Typical 1 Millivolt

Relay Throw Time

Maximum 10 Milliseconds

Typical 7 Milliseconds

Relay Contact Rating

30 Volts (Non-inductive
Load) 2 Amperes

c. Circuit Description

A simplified diagram of the Relay Comparator is shown in Figure 40. The signal input is applied to IN_1 ; the reference input is applied to IN_2 . When the inputs produce a negative voltage at the summing junction of the amplifier, the amplifier energizes the relay and the relay arms are connected to the minus contacts. The relay is de-energized when the summing junction is positive; the relay arms are connected to the plus contacts. Since the input resistors, R_1 and R_2 , have different values, the voltage applied to IN_1 and IN_2 have different weights in their effect on the summing junction voltage. Therefore, the setup procedure described in Sub-paragraph d. must be followed if precise switching levels are desired.

Refer to Drawing B006 134 OS for the following description. The signal input (IN_1) is applied to R_2 ; the reference input (IN_2) is applied to R_1 . Assume that the relay

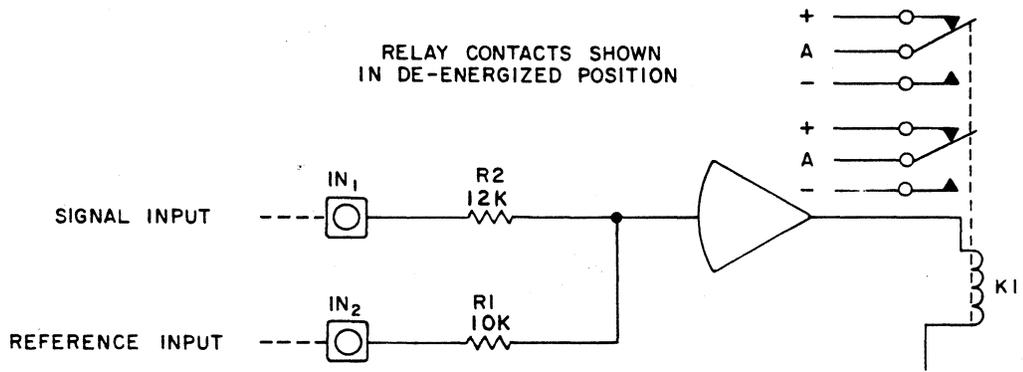


Figure 40. Relay Comparator, Simplified Diagram

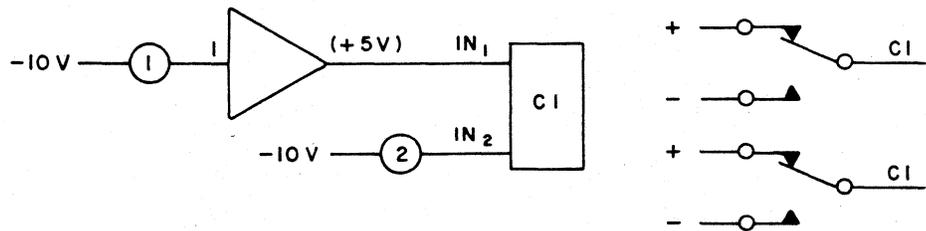


Figure 41. Circuit for Setting Voltage Switching Level

is to be energized when the signal input is +5 volts. The reference input is then supplied with approximately -5 volts. As long as the signal input is greater than +5 volts, the base of Q1 is positive and the transistor is cut off. Under this condition, relay driver Q6 is also cut off and relay K1 is de-energized. The relay contacts remain in the position shown, the arms closed to the plus contacts.

The conditions in the amplifier at this time are as follows. Transistor Q1 is cut off and the resulting negative potential at its collector causes Q3 to conduct. The resulting collector negative voltage of Q3 cuts off Q5. No current flows through the emitter resistor (R10) of Q5 and relay driver Q6 is reverse biased to cut off.

The effects of drift due to temperature changes are reduced by means of Q2 and Q4. An increase in temperature will increase I_{CO} in transistor Q1 and Q2. These changes are applied to the base and emitter of Q3 respectively, causing the two increases to cancel.

When the signal input drops to +5 volts, the base of Q1 is at zero potential, and the transistor conducts due to the slight forward bias applied to the emitter through R5. The collector current through R3 biases Q3 to cut off, and, as a result, Q5 is driven into conduction. Relay driver Q6 also conducts due to the forward bias developed across R11. Relay K1 in the collector circuit is energized and the relay arms transfer to the minus contacts.

When Q1 conducts, the emitter current through R6 develops cutoff bias for the emitter of Q2. As Q2 is turned off, Q4 conducts, drawing current through R9 and reverse biasing the emitter of Q3 receives a negative signal at the same time that a positive signal is applied to the base.

Diodes CR1 and CR2 protect Q1 by limiting the voltage which can be applied across the base-emitter junction. Diode CR3 protects Q6 against the momentary application of a high forward bias to the collector caused by a collapsing field around the relay coil.

d. Adjustment of Voltage Switching Level

To obtain a precise voltage switching level, say +5 volts, proceed as follows:

(1) Refer to Figure 41. Connect a coefficient potentiometer to the input of an amplifier and adjust the wiper until the output of the amplifier is at the desired switching level (+5 volts). Connect the output of the amplifier to the IN_1 termination of the comparator.

(2) Connect the appropriate computer reference voltage (-10 vdc in this case) to a second potentiometer. Connect the wiper to the IN_2 termination.

(3) Adjust the wiper of the second potentiometer until switching occurs. Remove the amplifier input to IN_1 and apply any arbitrary input.

e. Maintenance

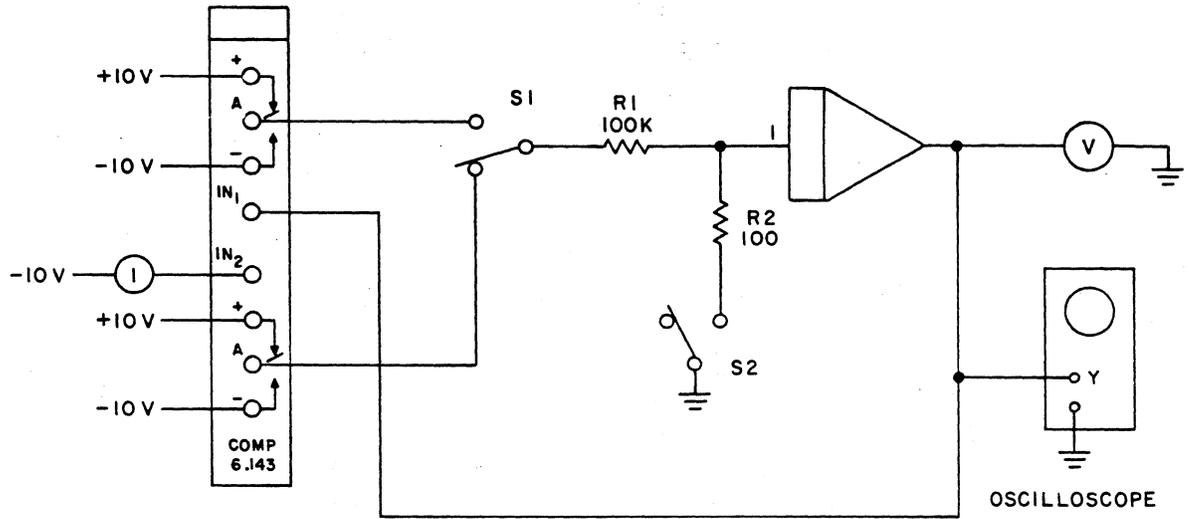


Figure 42. Sensitivity and Switching Time Test Circuit

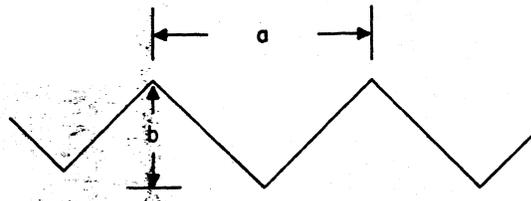


Figure 43. Test Waveform

(1) Troubleshooting. The Relay Comparator rarely malfunctions. If it does, the first thing to check is relay K1. If relay replacement fails to cure the trouble, the amplifier may be tested by grounding IN₂ and applying a negative voltage to IN₁. The amplifier stages are best checked with an oscilloscope or VTVM. Transistor Q1 should be conducting (as indicated by its collector voltage), Q3 should be cut off, Q5 and Q6 should be conducting, and the relay coil should be energized. A positive input causes the opposite effect.

The following sensitivity and switching time test should be performed after any repairs.

(2) Sensitivity. The sensitivity and switching time of the Relay Comparator are checked by means of the circuit in Figure 42. Proceed as follows:

- (a) Place switches S1 and S2 to the positions indicated. Place the computer in the reset mode. Place the voltmeter on the 0.1 volt range. Set the oscilloscope sensitivity to 0.1 volts/cm dc and the sweep to 2 milliseconds/cm.
- (b) Switch the computer to OPERATE and adjust coefficient potentiometer number one until the voltmeter (VM) reads zero. At this point, the comparator relay arms should begin to oscillate between the plus and minus contacts.
- (c) The oscilloscope should display a waveform similar to the one in Figure 43. On the display, the zero level represents the time when the relay should switch. The positive and negative peaks represent actual switching times. Thus the difference between the zero level and the adjacent peak represents the switching time. For convenience, the switching time may be calculated as 1/4 the time between any pair of adjacent peaks (i.e., a/4) since this technique eliminates the need for determining the zero level.
- (d) Place switch S2 to the right thus grounding R2. Set the oscilloscope sensitivity to 0.5 millivolts/cm and the sweep to 50 milliseconds/cm.
- (e) The oscilloscope waveform again should be similar to Figure 43. Distance "b" represents the switching sensitivity.
- (f) Repeat Steps (a) to (e) with switch S1 in the up position to test the other set of contacts.

2. ELECTRONIC COMPARATOR, MODEL 40.538

a. General Description

The Model 40.538 Electronic Signal Comparator (Figure 44) consists of a comparator

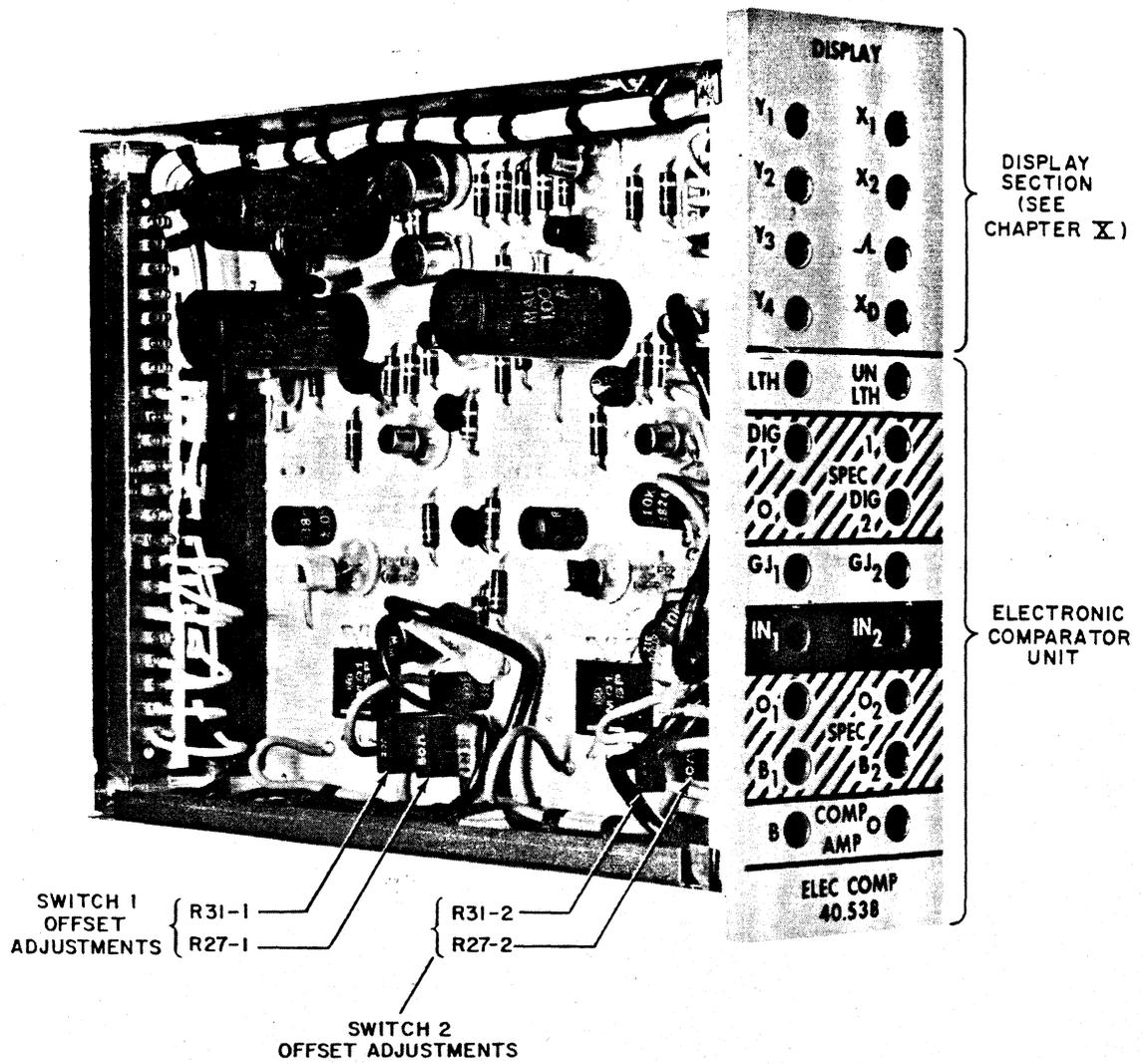


Figure 44. Model 40.538 Electronic Comparator

circuit and two electronic switch circuits, housed in a dual-width module. This unit operates in conjunction with external amplifiers to provide sensitive high speed switching.

b. Technical Data

(1) Comparator

Switching Sensitivity	<u>+1.0</u> MV
Switching Time	1.0 Microsecond
Digital Output Levels	
Binary ONE	+5.0 VDC <u>+0.5</u> VDC
Binary ZERO	0.0 VDC <u>+0.5</u> VDC

(2) Electronic Switch Units

Signal Input Impedance (IN Terminal)	10,000 Ohms
Switching Time	1.0 Microsecond
DC OFFSET	<u>+500</u> Microvolts

c. Block Diagram Analysis

(1) Comparator Circuit. A simplified block diagram of the comparator is shown in Figure 45. The analog signals to be compared are applied to the summing junction of an amplifier. The amplifier is supplied with a special feedback network within the comparator consisting of two back-to-back diodes. Since it requires approximately 0.6 volts to cause either of the diodes to conduct, the amplifier gain is essentially equal to "open loop" gain between the output range of -0.6 to +0.6 volt. Therefore, if the sum of the analog inputs to the amplifier goes even slightly positive, the amplifier output goes instantly negative to -0.6 volt. This change is coupled through the buffer to the flip-flop circuit, and causes the output designated 1 to go to binary ONE (+5.0 volts). The output designated 0 goes to binary ZERO simultaneously.

If the sum of the analog inputs at the amplifier summing junction goes negative, the amplifier output immediately changes to +0.6 volt. This level is coupled through the Buffer to the flip-flop, causing the 1 output to go to binary ZERO (0.0 volt) and the 0 output to go to binary ONE. In this way the comparator circuit provides an output consisting of two discrete levels (0.0 volt for binary ZERO and +5.0 volts for binary ONE) from an indefinite number of continuously varying analog inputs.

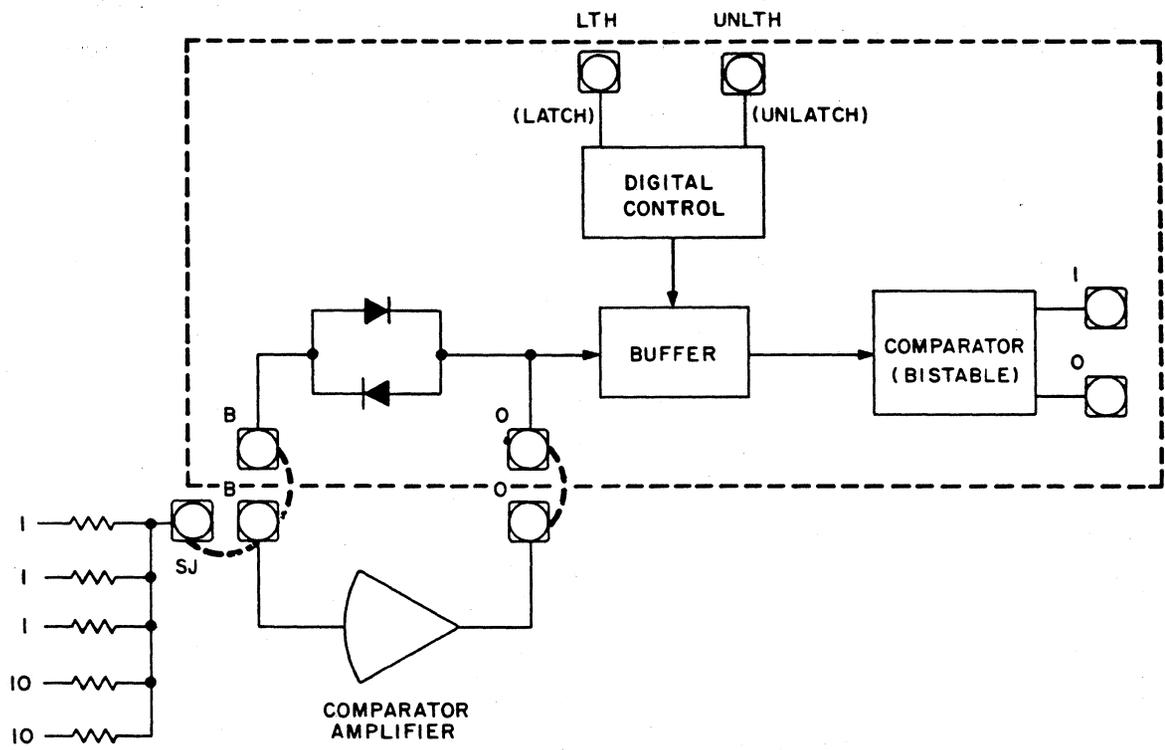


Figure 45. Comparator Unit, Functional Block Diagram

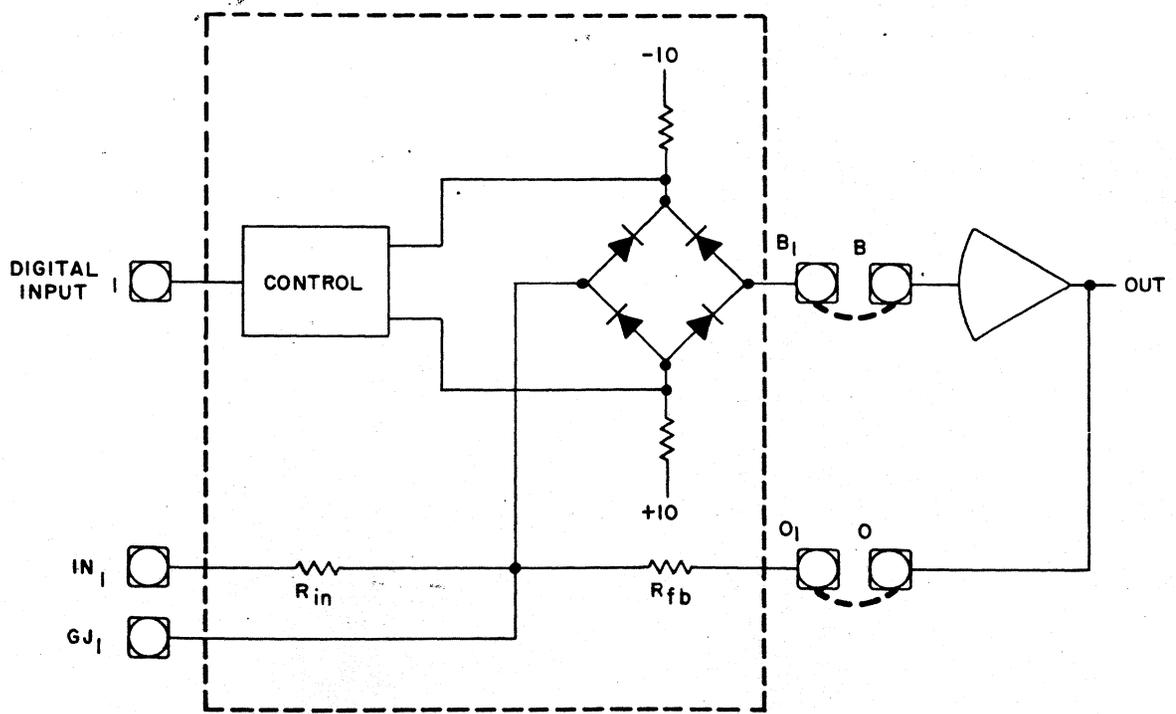


Figure 46. Electronic Switch Unit, Functional Block Diagram

In addition to the analog inputs, terminals are provided for entry of a binary ONE latch or a binary ZERO unlatch command. If a binary ONE is applied to the latch terminal, the output of the comparator amplifier is effectively disconnected from the flip-flop circuit, forcing the flip-flop to remain in its existing state regardless of analog input variations. A binary ZERO applied to the unlatch terminal overrides the latch input, allowing the analog inputs to control the state of the flip-flop.

(2) Electronic Switch Circuits. In addition to the comparator circuit, two electronic switch circuits are contained within the Model 40.538 Electronic Comparator. A simplified block diagram of one of the switch circuits is provided in Figure 46. The electronic switch is a four-diode bridge circuit which is actuated by a transistorized control circuit. When a binary ONE is applied to the digital input terminal, the control circuit allows an analog input to pass through the bridge to the associated output amplifier. A binary ZERO at the digital input terminal causes the control circuit to effectively clamp the top and bottom of the bridge to ground (as shown on Figure 46), thus preventing the analog input from passing through the bridge to the output amplifier. The binary ONE and binary ZERO inputs to the electronic switch circuit ordinarily are supplied by the comparator circuit, but for special applications these signals may be supplied by an external digital circuit. Patching of the switch units is described in the Appendix of the TR-20 Operator's Handbook. The patching shown in Figure 46 is strictly to show switch to amplifier patching. It assumes feedback is provided for the amplifier when the switch is cut off. This feedback could be provided by another switch unit, driven by the complement of the signal assumed to be driving the switch of Figure 46.

d. Circuit Description

Refer to Figure 47 for the following description.

(1) The Electronic Comparator. The comparator circuit consists of transistors Q1 through Q4 and associated components shown on the simplified schematic, Figure 47. The external dc amplifier is shown, shunted by diodes CR1 and CR2, in the emitter circuit of Q1. Since the summing junction of an operational amplifier is held at virtual ground by circuits within the amplifier (see Chapter II), the output of the amplifier may not exceed approximately ± 0.6 volt. This voltage is coupled to the emitter of buffer transistor Q1 which is normally forward biased by resistor R1, so that the negative change that occurs when the sum of the amplifier inputs goes positive is coupled through Q1 and resistor R4 to the base of Q3. Transistors Q3 and Q4 form a flip-flop circuit. A negative change at the base of Q3 causes this transistor (NPN) to cut off, and its collector goes positive. The positive from the collector of Q3 is coupled through resistor R9 to the base of Q4, causing this stage to conduct. As Q4 conducts, its collector potential changes from a positive level to ground. This change is coupled back to the base of Q3 through resistor R7, causing this stage to remain cut off. The collectors of Q3 and Q4 are directly connected to the terminals designated 1 and 0 respectively. Therefore, when Q3 is cut off, the 1 terminal has a potential of +5 volts and the 0 terminal is at ground.

If the sum of the amplifier inputs goes negative, the output immediately goes in a positive direction. This positive change is again coupled through buffer Q1 to the Q3-Q4 flip-flop. The flip-flop now changes state, with Q3 conducting and Q4 cut off. The output at the 1 terminal becomes binary ZERO (0.0 volt) and the 0 terminal has a binary ONE output (+5.0 volts).

Transistor Q2 controls the operation of buffer transistor Q1. If a binary ONE is connected to the latch (LTH) terminal, transistor Q2 conducts, providing a positive voltage through resistors R3 and R2 to the base of Q1. This causes Q1 to cut off, so that changes in the output of the comparator amplifier cannot be coupled to the flip-flop. Therefore, the flip-flop remains in its present state and is insensitive to analog input variations. If a binary ZERO is patched to the unlatch (UNLTH) terminal, this level is coupled through diode CR3 to the junction of R2 and R3, clamping this point at ground. This returns Q1 to the conducting state regardless of the latch input level, and allows the analog inputs to resume control of the flip-flop.

(2) The Electronic Switch Circuits. A simplified schematic of one of the switch circuits is shown in Figure 48. Transistors Q5 through Q8 comprise a complementary-symmetry control circuit. A binary ONE level at the digital input (DIG) terminal is coupled through diode CR8 and resistor R20 to the base of Q5, turning the transistor off. The collector of Q5 goes in a negative direction, and the negative change is coupled through R17 to the base of Q6, also turning this stage (NPN) off. The collector of Q6 goes in a positive direction, adding to the reverse bias on Q5 through R14. The collectors of Q5 and Q6 are connected to the bases of Q8 and Q7 through R30 and R28 respectively. The negative voltage from the collector of Q5 drives Q8 into cutoff and the positive voltage from Q6 turns off Q7. With Q8 and Q7 cut off, the four matched diodes (CR12 through CR15) comprising the analog switch are forward biased, allowing the analog input at the input (IN_1) or gate junction (GJ_1) terminal to pass through the gate to the base of the external amplifier.

If a binary ZERO is provided to the digital input terminal, transistor Q5 is saturated. The positive level from the collector of Q5 is coupled through resistor R17 to the base of Q6, turning on this stage. The positive level from the collector of Q5 saturates Q8, and the negative level from Q6 saturates Q7. Therefore, the emitters of Q8 and Q7 are at virtual ground, clamping the upper and lower junctions of the diode bridge (as shown in Figure 48) at ground potential. This prevents any analog input at the IN_1 or GJ_1 terminal from being coupled to the base of the output amplifier.

Diodes CR9 and CR10 are connected from the gate junction to ground, preventing the voltage at this point from rising beyond about +0.6 volt. This keeps the output amplifier from being severely overloaded should a patching error occur.

Resistors R22 and R24 are precision input and feedback resistors respectively. These resistors are arranged to include the diode gate in both the input and feedback circuits to assure a gain of unity despite minor variations in diode

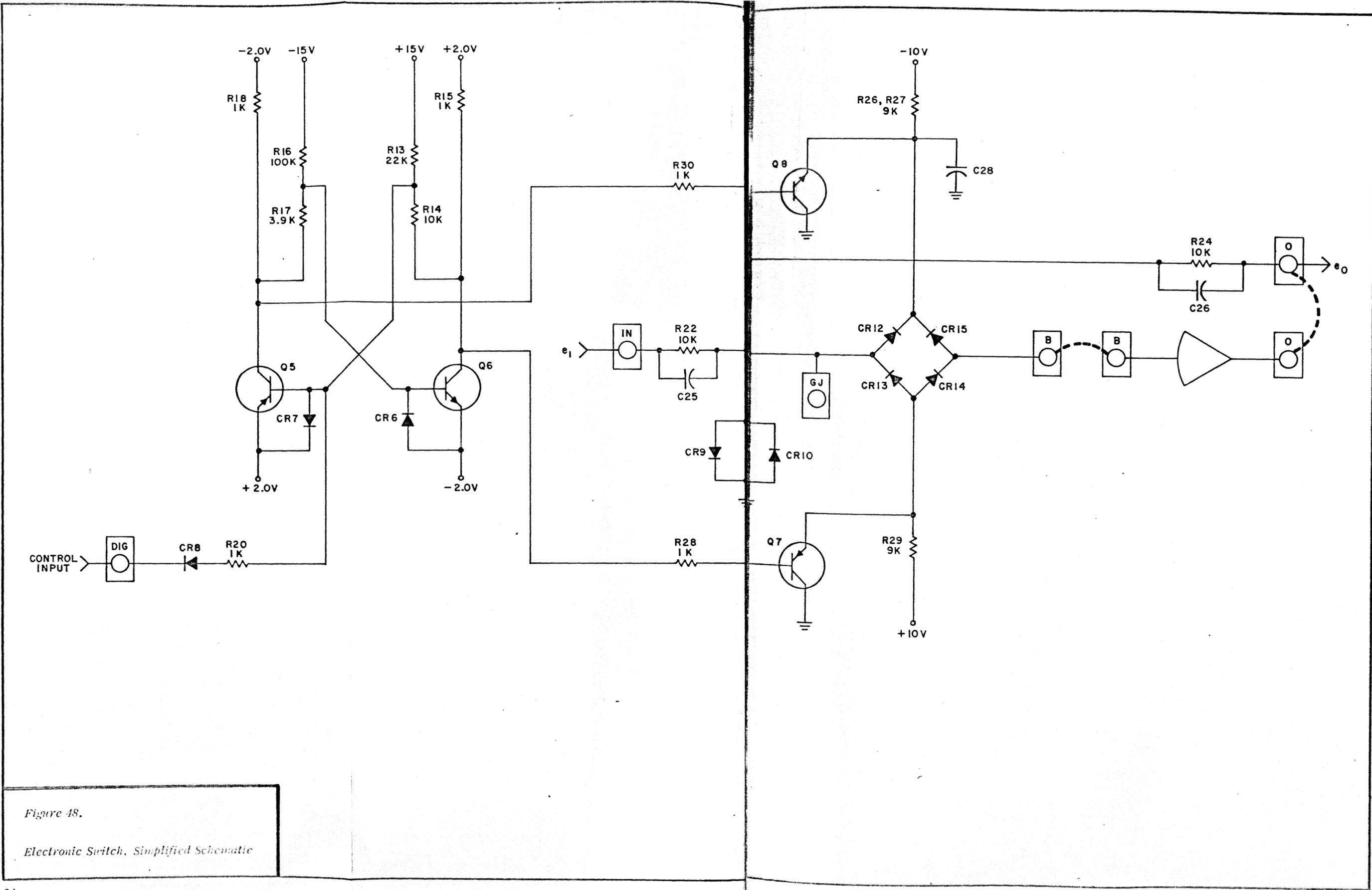


Figure 48.
Electronic Switch, Simplified Schematic

network characteristics. The capacitors shunting these resistors (C25 and C26 respectively), together with C28 assure proper phase characteristics for the complete network including the output amplifier.

The circuits associated with Zener diodes CR5 and CR18 (see Schematic D040 538 0S in Appendix IV) provide biasing voltages for the switch circuits, and decouple the comparator unit from the +15 and -15 volt power supplies. As an example, the network associated with CR18 consists of an inductor (L1-2), and a filter network (resistor R34 and capacitor C27). The inductor presents a high impedance path to transients which might be coupled through the -15 volt supply. The diode (CR18) is a Zener which provides a constant drop of approximately 13 volts, creating a bias level of approximately -2 volts. Resistor R34 provides a constant minimum load on CR18 to assure that the diode remains within the proper current range for Zener operation. Capacitor C27 filters the -2 volt bias level. CR5 and its associated components function in the same way to decouple the +15 volt supply and provide a +2 volt bias level for the switch circuits.

e. Maintenance

The comparator unit is ruggedly constructed of solid-state components and should require little servicing. The high sensitivity and switching speed are primarily functions of the external comparator amplifier.

Adjustments are provided in each switch circuit for gate junction and output offset. These adjustments are set at the factory for optimum operation, but should be checked periodically and set if necessary.

Before checking or performing any adjustments, allow the computer to warm up for at least 30 minutes. Check the +15 and -15 volt power supplies and adjust them if necessary. Carefully balance the plus and minus reference supplies (see Chapter XI, Sub-paragraph 2d.).

(1) Gate Output Offset Test. To perform this test, patch the circuit shown in Figure 49, and balance amplifier 1.

- (a) Set the function switch to the down position, and carefully balance amplifier 2.
- (b) Set the voltmeter to the 1.0 volt range and set the function switch to the up position.
- (c) The voltmeter should read 0.5 volt or less. This is equivalent to an offset of 500 microvolts.
- (d) If the reading in Step (c) is greater than 0.5 volt, or if a more accurate adjustment is desired, set potentiometer R27-1 for a minimum reading.
- (e) Repeat this procedure for switch 2, adjusting R27-2 if required.

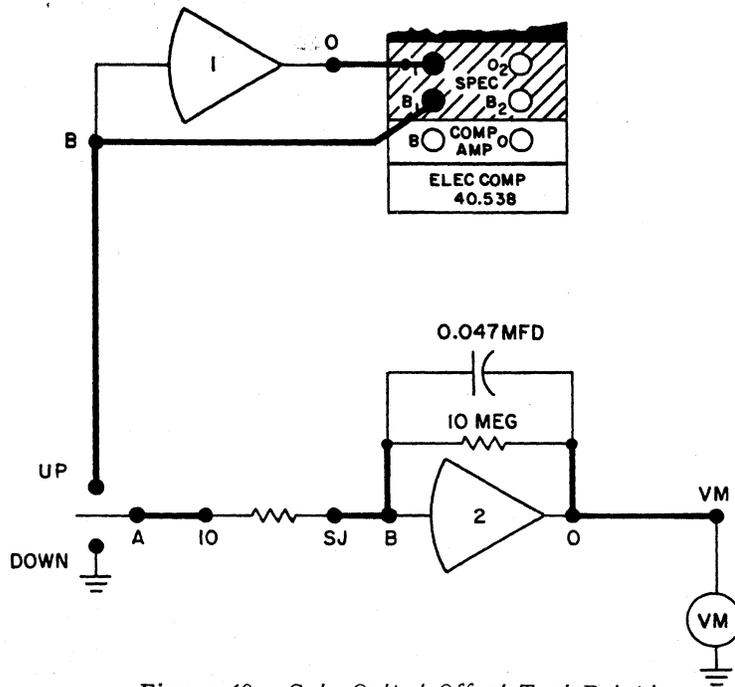


Figure 49. Gate Output Offset Test Patching

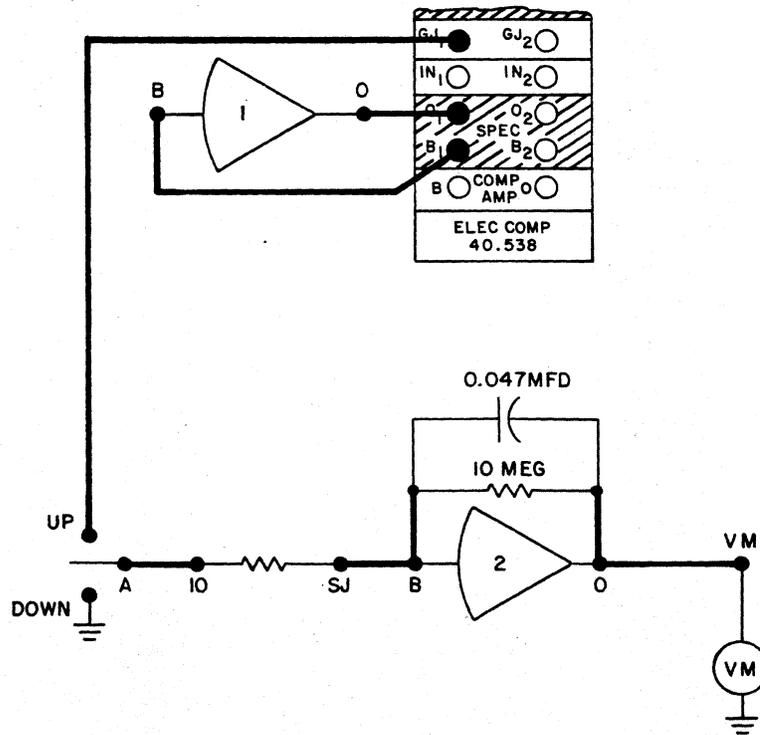


Figure 50. Gate Junction Offset Test Patching

(2) Gate Junction Offset Test. To perform this test, patch the circuit of Figure 50. It is assumed that the power supply and amplifier balancing adjustments of test (1) have been carried out.

- (a) Set the voltmeter to the 1.0 volt range and place the function switch in the up position.
- (b) The voltmeter should read 0.5 volt or less.
- (c) If the reading in Step (b) is greater than 0.5 volt or if a more accurate adjustment is required, adjust R31-1 for a minimum reading.
- (d) Repeat this procedure for switch 2, adjusting R31-2 if required.

3. DUAL FUNCTION SWITCH GROUP 2.127

The dual function switch group consists of a Patching Module, Type 12.264, and a Dual Function Switch Assembly, Type 20.366. The function switches are mounted in the control panel and are terminated on a patching module which is located in the middle row of the patch panel. Each function switch is a single-pole, double-throw switch with a center off position. The upper switch is terminated on the upper portion of the patching module; the lower switch is terminated on the lower portion of the patching module. The switch contacts are rated at 120 volts, 10 amperes (resistive load).

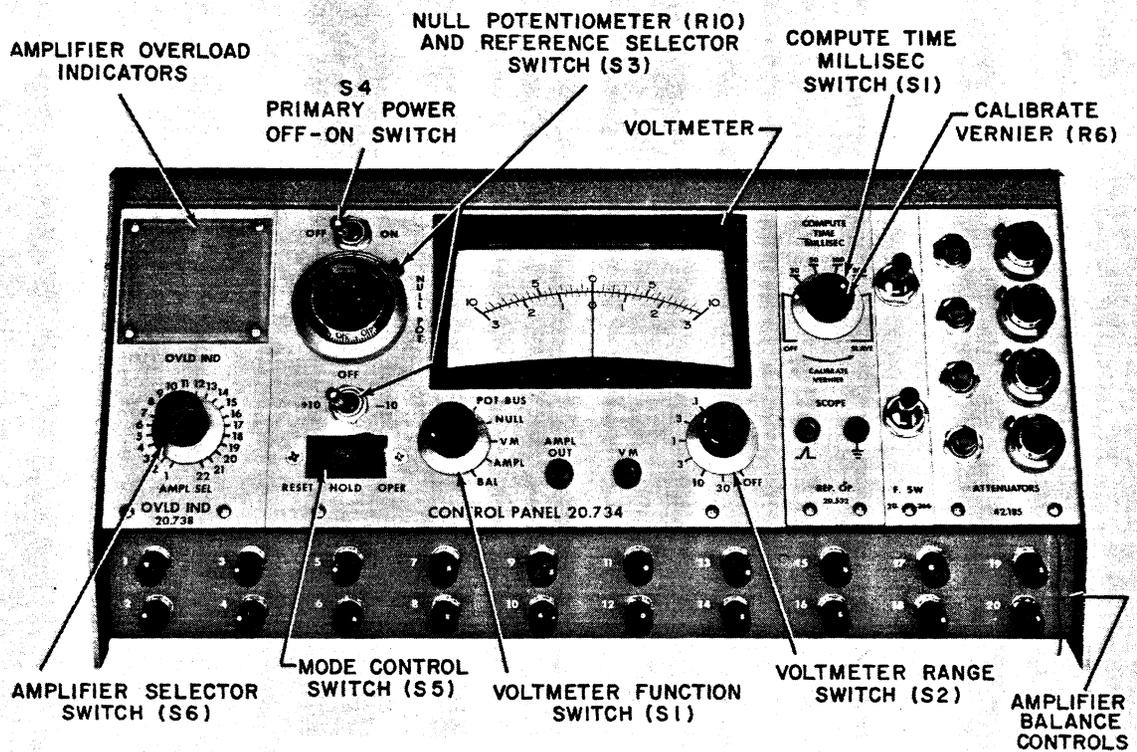


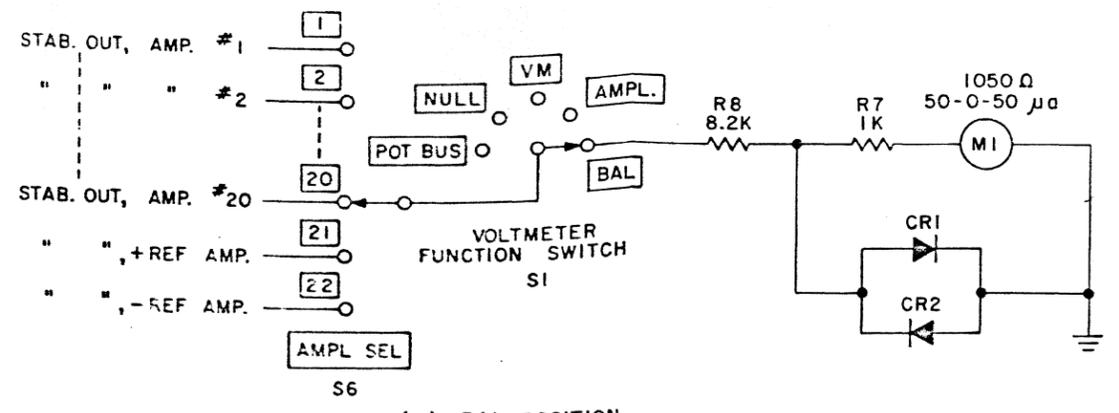
Figure 51. Control Area of the TR-20

CHAPTER X

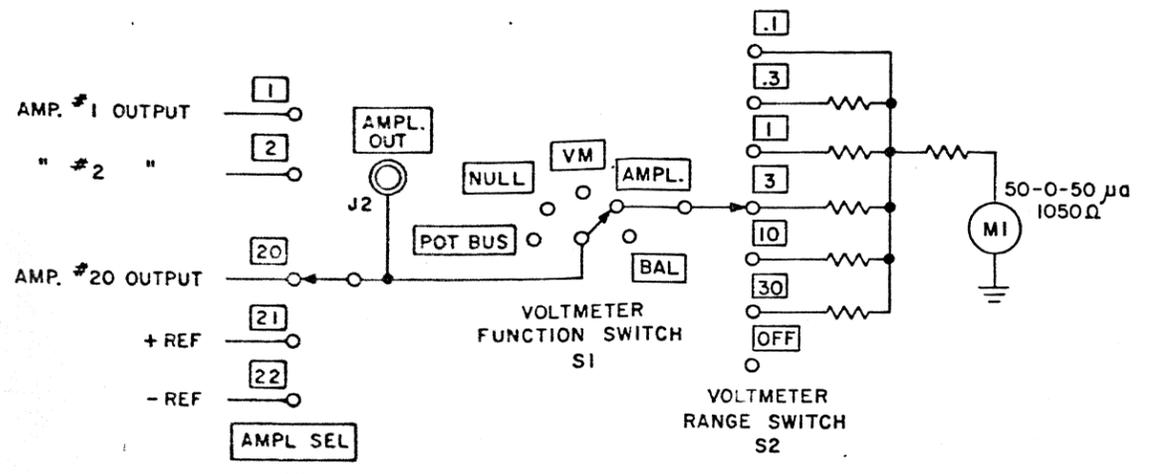
MANUAL MODE CONTROL, REPETITIVE OPERATION, AND MONITORING CIRCUITS

This chapter provides maintenance information for the manual mode control, repetitive operation, slaving, readout, and overload alarm circuits for the TR-20. The operating controls for these circuits are grouped on the sloping control area below the component cradles, as shown in Figure 51. The functions of the controls are:

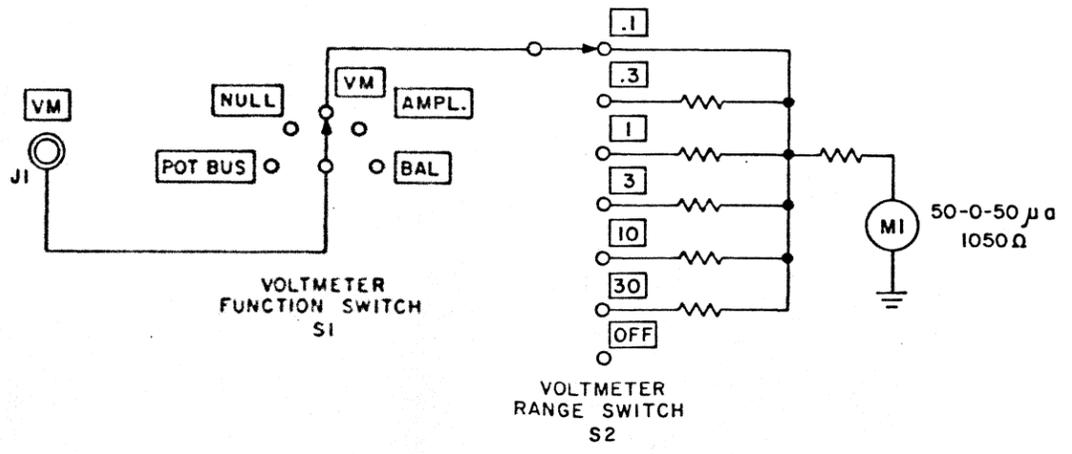
<u>Control</u>	<u>Function</u>
Power ON-OFF Switch (S4)	Controls application of primary ac power to the Model 10.179 Power Supply. The voltmeter is illuminated when power is applied.
Mode Control Switch (S5)	Controls the operational mode of the computer. Positions are RESET, HOLD, and OPER.
Amplifier Selector Switch (AMPL SEL - S6)	Selects the output or the stabilizer output of the indicated amplifier for connection to the monitoring circuits.
Voltmeter Function Switch (S1)	Controls voltmeter operation. Positions are POT BUS, NULL, VM, AMPL, and BAL.
Voltmeter Range Switch (S2)	Selects sensitivity for voltmeter. Full scale ranges of .1, .3, 1, 3, 10 and 30 volts are provided.
NULL POT and Reference Selector Switch, +10/OFF/-10	Used in conjunction with the voltmeter to measure voltages by the null comparison method.
VM Jack	Supplies inputs to the voltmeter when Voltmeter Function switch is in the NULL or VM position.
AMPL OUT Jack	Connected to the wiper of the AMPL SEL switch; facilitates connecting any amplifier output to external monitoring or measuring equipment.
Overload Indicators (OVL D IND)	Indicate an overload in the associated amplifier when illuminated.



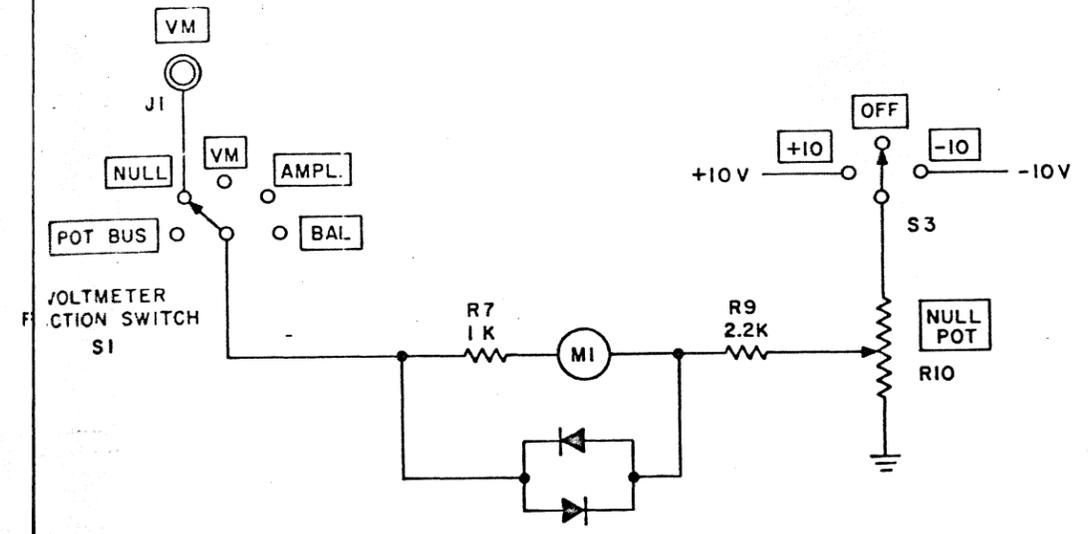
(a) BAL POSITION



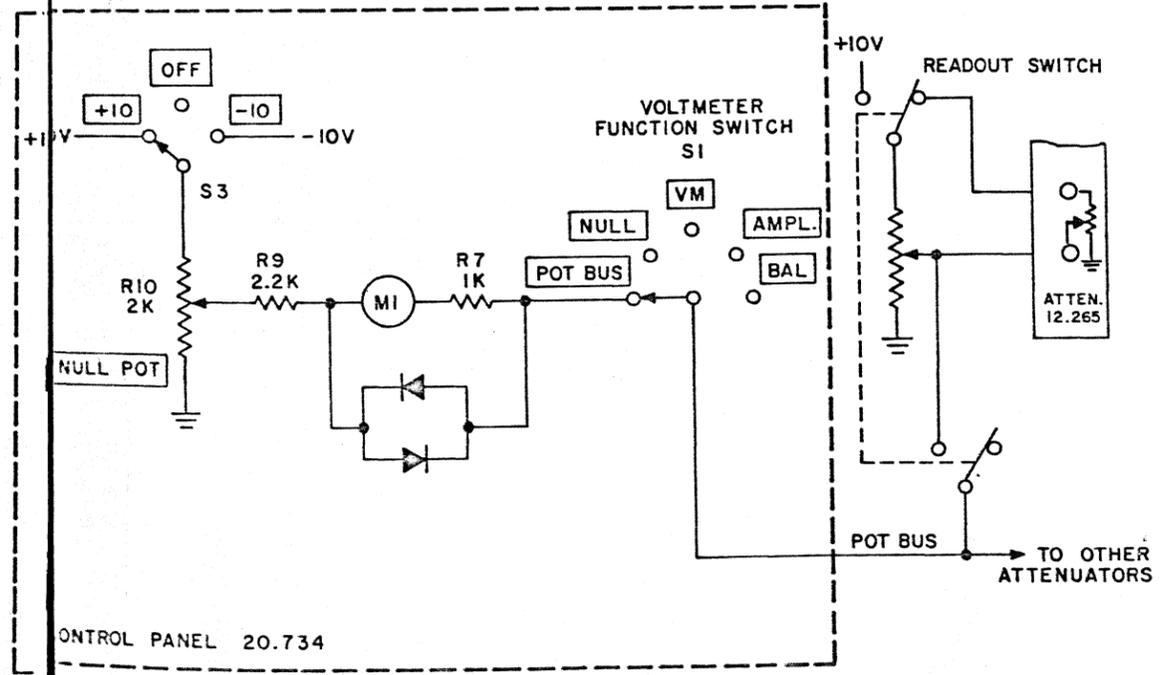
(b) AMPL POSITION



(c) VM POSITION



(d) NULL POSITION



(e) POT BUS POSITION

Figure 52. Readout Circuits
Simplified Schematics

1. READOUT FACILITIES

The readout facilities consist of a sensitive voltmeter, selector switches for connecting the voltmeter to various points in the computer, and a precision ten-turn potentiometer used as a null-voltage source. The readout circuits with the exception of the AMPL SEL switch, are shown on Drawing C020 734 OS.

The BAL position of the Voltmeter Function Switch S1 is used when balancing the operational amplifiers. The AMPL SEL switch is used to select the stabilizer output of the amplifier to be balanced. See Figure 52a. The balance potentiometer of the amplifier is rotated until the meter reads zero.

The AMP position of S1 establishes the circuit shown in Figure 52b where the AMPL SEL switch provides the input to the voltmeter. Note that the wiper of the AMPL SEL switch is connected to the AMPL OUT jack so that amplifier outputs can be monitored with external equipment.

The VM position of S1 connects the VM jack to the Voltmeter Range switch. Voltages patched into the VM jack are read on the voltmeter. (See Figure 52c.)

The NULL position of S1 provides a means of accurately measuring unknown voltages with respect to the computer reference voltage. The circuit arrangement is shown in Figure 52d. The voltage to be measured is patched to the VM jack and connected to one side of the meter. The wiper of the NULL POT is connected to the other side of the meter. The Reference Selector switch S3 is switched to the position that supplies reference voltage with the same polarity as the voltage to be measured. The NULL POT is varied until the meter reads zero. The position of the turn-counting dial indicates the magnitude of the unknown voltage; the position of S3 indicates the polarity of the unknown voltage. The null comparison method of voltage measurement results in an error that is less than $\pm 0.1\%$ of full scale. A feature of the method is that no current is drawn from the source being measured once a balance is attained. Thus the resistance of the source has no effect on the measurement. A large source resistance, however, will decrease the sensitivity of the meter to unbalanced conditions.

The POT BUS position of S1 is used when setting attenuators. See Figure 52e. The readout circuit is connected to measure the voltage on the Pot Bus by the null comparison method. When the pushbutton switch associated with an attenuator is depressed, +10 volts is connected to the top of the attenuator; the wiper is connected to the Pot Bus. The Reference Selector switch S3 is in the +10 position. The NULL POT is set to the desired attenuator coefficient. The attenuator is adjusted until the meter reads zero. The attenuator is then set to the same coefficient as the NULL POT.

2. MANUAL MODE CONTROL

The Mode Control switch (S5) on the Control Panel provides a means of starting and stopping the computer solutions and of establishing initial conditions when the computer is not in repetitive operation. The switch controls the operation of the Relay Bus Driver which in turn actuates the Reset and Operate relays of the integrators. Refer to Figure 53. The Reset relays are connected between ground and the emitter of Q1; the Operate relays are connected between ground and the

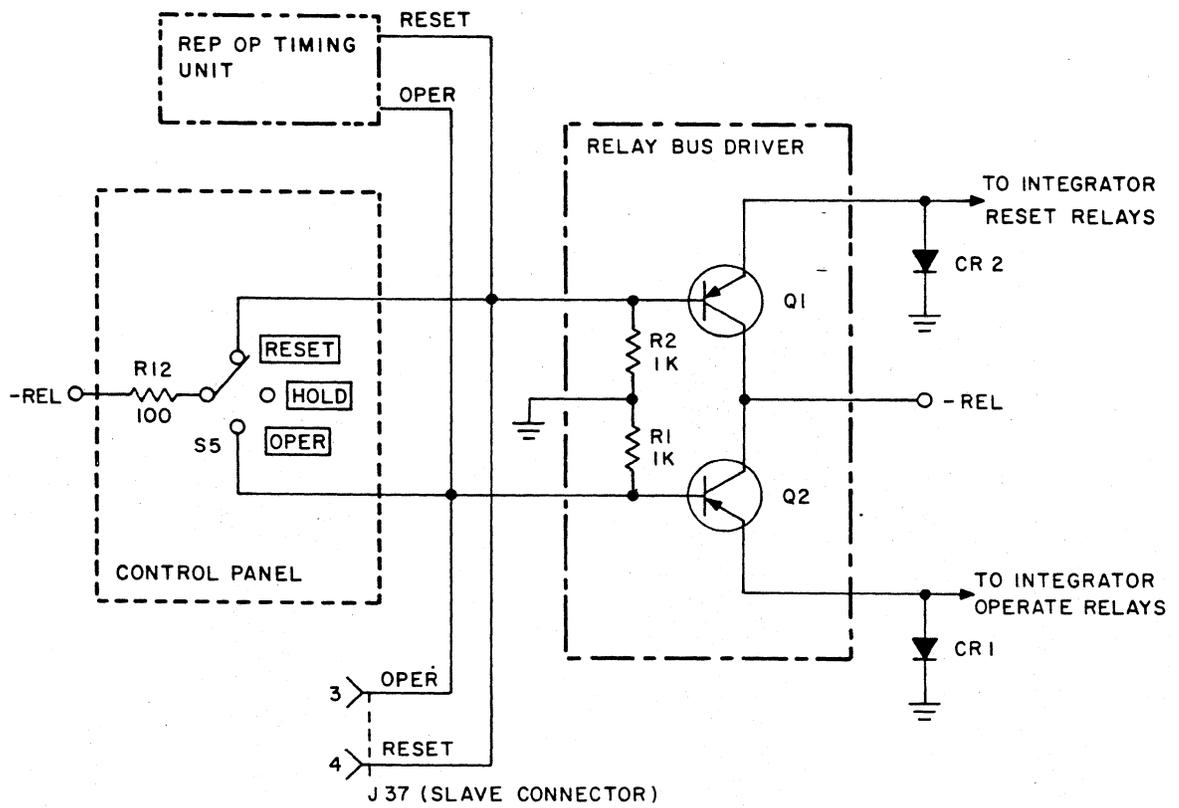


Figure 53. Relay Bus Driver, Simplified Schematic

emitter of Q2. When S5 is placed in the RESET position, relay voltage is applied through R12 to the base of Q1 causing it to conduct. The Reset relays are energized and the computer is in the reset mode. When S5 is placed in the hold position, Q1 and Q2 are cut off; the Reset and Operate relays are de-energized and the computer is in the hold mode. When the MODE Control Switch is placed in the oper position, Q2 conducts and energizes the Operate relays. Diodes CR1 and CR2 protect the transistors from excessive collector-emitter voltages caused by collapsing relay fields. These diodes are located on the rear of connector J11.

Inputs to the Relay Bus Driver can also come from the Rep Op Timing Unit or the Slave Connector. When the computer is placed in repetitive operation, the Mode Control switch must be placed in the HOLD position; the Timing Unit controls the conduction of Q1 and Q2. When the computer is slaved to another computer, S5 is placed in the hold position and Q1 and Q2 are controlled by the Mode Control switch or Timing Unit of the master computer.

3. SLAVING

Two TR-20's can be slaved in order to accommodate a larger problem. Slave Cable 510.038 is connected between the Slave Connectors (J37) of each computer. The position of the computer controls is summarized in the table below.

Computer	Control	Non-Repetitive Operation	Repetitive Operation	Special Repetitive Operation ②
SLAVE	S1	OFF	SLAVE	-
	S5	HOLD	HOLD	ANY
MASTER	S1	OFF	①	①
	S5	①	HOLD	HOLD

S1: COMPUTE TIME MILLISEC Switch

S5: Mode Control Switch

① This control is used to control the mode of both computers.

② Only one computer, the Master, equipped with Rep-Op. Do not use integrators in Slave computer.

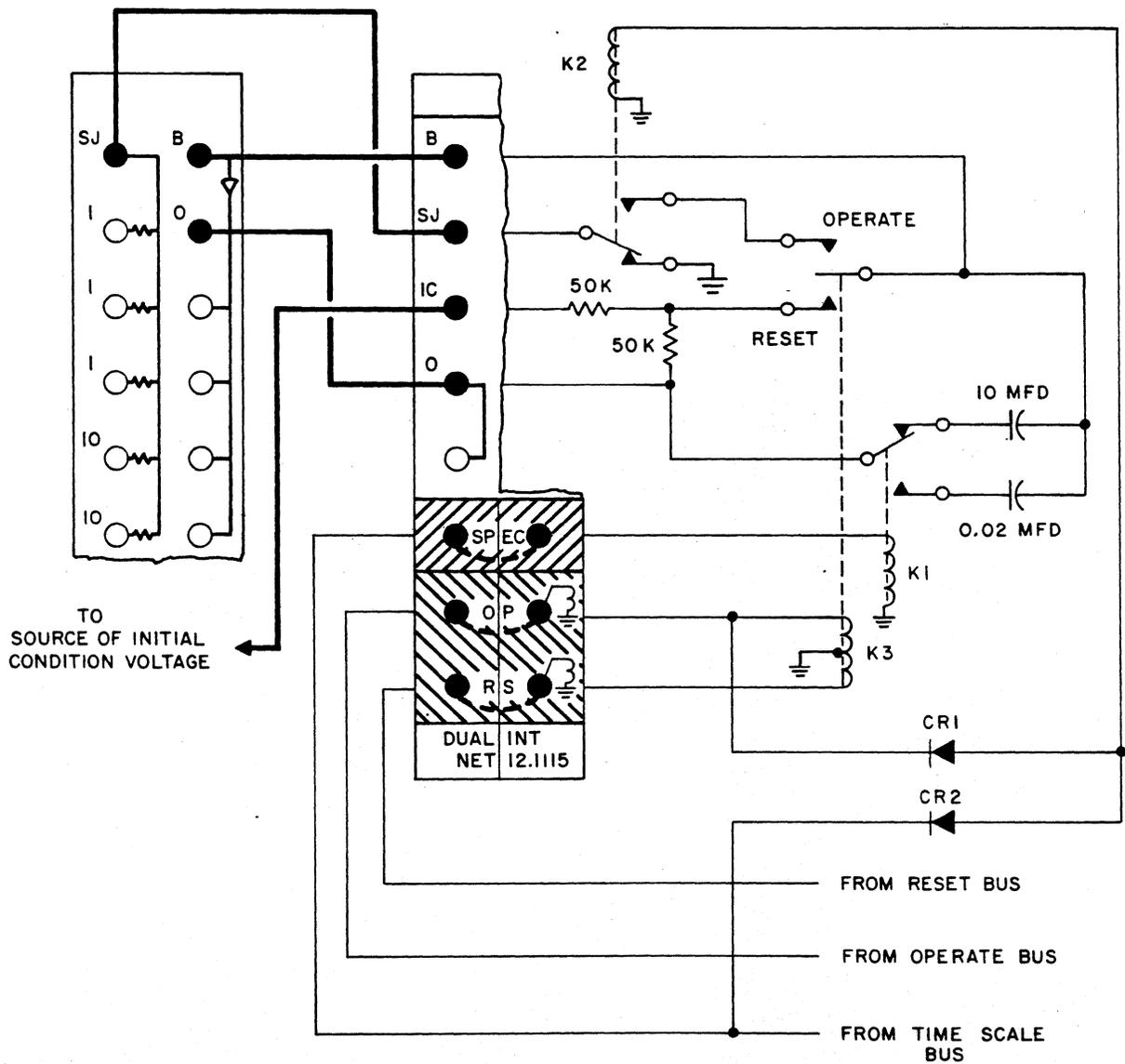


Figure 54. Patching an Amplifier to a Rep-Op Integrator, Showing Simplified Schematic of Integrator Network

4. REPETITIVE OPERATION GROUP, 2.715

a. General Description

The addition of the Repetitive Operation (Rep Op) Group to the TR-20 provides a means of switching the integrators between the reset and operate modes at rates greater than 30 cycles per second. The usual 10 mfd integrator feedback capacitors are replaced with 0.02 mfd capacitors to change the problem time scale by a factor of 500. Thus the Rep Op Group gives the operator faster acquisition of problem solutions. The problem variables are displayed on a Model 34.035 Repetitive Operation Display Unit, or on an external oscilloscope. The computer can still be used as a real time simulator when the Rep Op Group is installed.

The Repetitive Operation Group consists of Rep Op Control Panel, Model 20.532 Timing Unit, Model 36.082, and Dual Integrator Networks Model 12.1115. The Rep Op Control Panel is mounted next to the Model 20.734 Control Panel. The Timing Unit is mounted in the rear of the TR-20 next to the Audio Overload Alarm. The Integrator Networks are positioned in the middle row of computing components.

b. Dual Integrator Network 12.1115

This network differs from the integrator network described in Chapter III principally by providing two values of feedback capacitor. These values (10 mfd and 0.02 mfd) allow a 500 to 1 change in time scale. Figure 54 illustrates the patching connections and a simplified schematic of the network. Note that the patching connections to the amplifier are identical to those for a 12.1116 Network. An additional patching connection is required on the integrator network in the cross-hatched area designated SPEC, if the integrator is to be used in the standard rep-op mode.

The Operate and Reset relay functions (K1 and K2 of Figure 18) are provided by a balanced single-armature relay (K3 of Figure 54). This allows the integrator to be switched between the operate and reset modes very rapidly, a necessary requirement for repetitive operation. Relay K1 selects the correct value of feedback capacitors for normal or repetitive operation. If the connection in the SPEC area is deleted, the integrator has a feedback capacitance of mfd for either mode. This patching is described in the Appendix of the Operator's Reference Handbook.

When the computer is used in non-repetitive operation, relays K2 and K3 are controlled by the Mode Control Switch (S5) on the Control Panel. When S5 is placed in the RESET position, the Relay Bus Driver energizes the Reset bus. Relay K3 is energized and its contacts connect the junction point of the amplifier. The integrator is in the reset mode. When S5 is placed in the OPERATE position, the Relay Bus Driver energizes the Operate bus. The lower portion of K3 is energized and the relay arm closes to the lower contact. Relay K2 is energized through CR1. The integrator is operational. When S5 is placed in the HOLD position, the Reset bus and the Operate bus are de-energized, the relays are de-energized as shown in the figure; the integrator is in the hold mode. Relay K1 is not energized when the computer is in non-repetitive operation; therefore the integrator always has a 10 mfd feedback capacitor.

In repetitive operation, the Relay Bus Driver is controlled by the Timing Unit which supplies pulses that energize the Reset bus for a constant 10 milliseconds and the Operate bus for a variable time ranging from 20 to 500 milliseconds. The arm of K3 switches back and forth between its contacts thus cycling the integrator between the reset and operate modes.

c. Repetitive Operation Control Panel, 20.532

The repetition rate of the pulses from the Timing Unit is determined by two controls, the COMPUTE TIME MILLISEC switch and the CALIBRATE VERNIER potentiometer, located on the Model 20.532 Rep Op Control Panel. The COMPUTE TIME MILLISEC switch (S1) has an OFF position, four COMPUTE TIME positions (labeled in milliseconds) and a SLAVE position. The CALIBRATE VERNIER permits continuous coverage between the fixed COMPUTE TIME positions, and can increase the selected COMPUTE TIME by a factor of 2.5.

Refer to Drawing C020 532 OS. Switch section S1a (contacts 1 to 6) connects various resistor combinations into the timing circuit of the Timing Unit.

Switch S1b (contacts 1 to 6) controls the application of -15 volts to Timing Units. Switch S1b (contacts 7 to 12) operates the Time Scale relays (K1) in the Integrator Networks. The CALIBRATE VERNIER potentiometer (R6) varies the voltage in the timing circuit and, as previously stated, can expand each of the fixed COMPUTE TIME positions of S1 by a factor of 2.5. Resistors R1 through R4 provide internal adjustment of the fixed COMPUTE TIMES of 20, 50, 100, and 200 milliseconds.

d. Timing Unit, Model 36.082

The Timing Unit provides a reset pulse that has a constant 10 millisecond duration and an operate pulse whose duration is determined by the position of the COMPUTE TIME MILLISEC switch and the CALIBRATE VERNIER potentiometer. The pulses from the Timing Unit are supplied to the Relay Bus Driver which energizes the Operate and Reset buses thus cycling K3 in the Integrator Networks.

Refer to Drawing C036 082 OS for the following description. Assume initially that C1 (connected between the emitter of Q1 and ground) is charged to a negative voltage and continues to charge towards zero volts through Q7 and the resistor selected by the COMPUTE TIME MILLISEC switch on the Rep Op Control Panel. (Pin K, labeled Control, connects to the Rep Op Control Panel. Note that the charging rate of C1 can also be varied by the CALIBRATE VERNIER control.) Capacitor C1 charges until the emitter of Q1 goes slightly positive. Then Q1 (a blocking oscillator) begins to conduct and is driven into saturation by the action of T1 in its base-collector circuit; C1 is charged to approximately -15 volts. The sawtooth voltage across C1 is applied to Q2, an emitter follower, and the output of Q2 serves as a sweep voltage for an external oscilloscope. The sweep voltage is available at the front panels of the Timing Unit and the Rep Op Control Panel.

The sharp negative going pulse at pin 4 of T1 is coupled to a monostable multivibrator, Q3 and Q4, that provides the system timing. The multivibrator operates with Q3 normally biased to cutoff, so that the circuit is stable and inactive until a trigger is received from the blocking oscillator. When the trigger is received, the multivibrator changes to the unstable state, Q3 conducting. The discharge of C3 through R6, R8, and R9 holds the circuit in the unstable state for 10 milliseconds, then returns to the stable state. Potentiometer R9 adjusts the duration of the negative-going pulse from the collector of Q4 which should be a fixed 10 millisecond pulse with an amplitude of approximately -15 volts. The pulse at the collector of Q4 is applied to Q5, an emitter follower. The output of Q5 (Rep Rate) appears on the front panel of the Timing Unit and is used when making the reset time adjustment. The output of Q5 is also applied to the base of Q6 and Q8. Q6 is part of the sweep circuit; it conducts during the 10 millisecond reset time and clamps the emitter of Q7 to ground thus cutting off Q7 and preventing C1 from being discharged.

Transistors Q8 to Q11 comprise the circuit that provides the reset and operate commands to the Relay Bus Driver. Q8 and Q11 conduct simultaneously and Q9 and Q10 conduct simultaneously. Q8 is the control transistor for Q9, and when Q8 conducts, Q9 is cut off. Q10 is the control transistor for Q11, and when Q10 conducts, Q11 is cut off. In the operate mode, Q8 and Q11 are off; Q9 and Q10 are conducting.

The reset output (Pin Y) is at zero volts; the operate output (Pin X) is at -20 volts (approximate level). In the reset mode, the pulse from Q5 turns on Q8 and turns off Q10. The operate output is at zero volts; the reset output is at -20 volts (approximate level). Thus the reset output is at -20 volts for 10 milliseconds and the operate output is at -20 volts for the time selected by the COMPUTE TIME MILLISEC switch and the CALIBRATE VERNIER control.

e. Adjustment of Reset and Operate Times

The reset time is adjusted according to the following procedure:

(1) Mount the Timing Unit on a service shelf. Connect an integrator as shown in Figure 55. Set the oscilloscope controls as follows: vertical sensitivity to 1 volt/cm, sweep to 5 millisc/cm (calibrated), use external sync.

(2) Place the Mode Control switch (S5) in the hold position. Place the COMPUTE TIME MILLISEC switch to the 20 position; turn the CALIBRATE VERNIER fully counter-clockwise. Adjust the amplitude of the oscilloscope waveform by varying the setting of coefficient attenuator 1.

(3) The displayed waveform should be similar to the one shown in Figure 55. Adjust R9 in the Timing Unit until the indicated reset time is 10 milliseconds ± 0.5 milliseconds. (The reset time shown in Figure 55 includes a hold time of 0.25 to 0.30 milliseconds before the next compute time.)

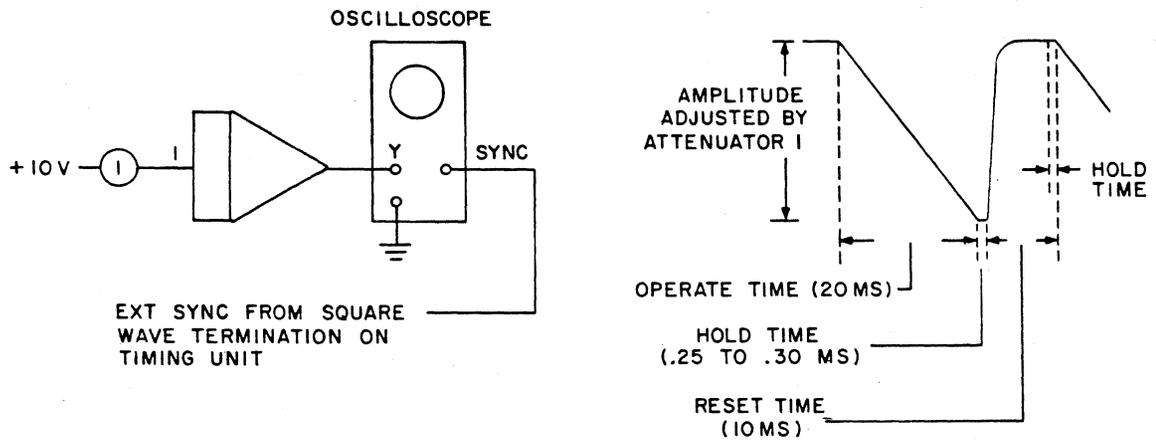


Figure 55. Reset and Operate Time Adjustment

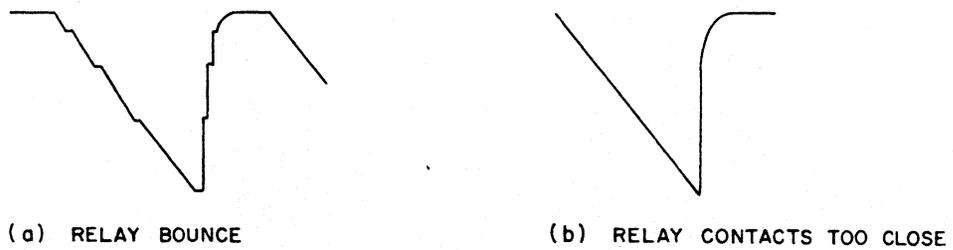


Figure 56. Improper Waveforms

The operate time is adjusted according to the following procedure:

- (1) Remove the retaining screws from the front of the Rep Op Control Panel and lift the panel away from the computer. Do not disconnect connector J38.
- (2) Complete Steps (1) and (2) of the reset time adjustment procedure.
- (3) Place the COMPUTE TIME MILLISEC switch to the 50 position. Reduce the input to the integrator (to prevent overload) by varying coefficient attenuator 1. Adjust R2 in the Rep Op Control Panel to produce an operate time of 50 milliseconds $\pm 5\%$.
- (4) Repeat Step (3) with the COMPUTE TIME MILLISEC switch in positions 100 and 200. Adjust R3 on the Rep Op Control Panel for an operate time of 100 milliseconds $\pm 5\%$; adjust R4 for an operate time of 200 milliseconds $\pm 5\%$. In each case, reduce the integrator input.
- (5) Rotate the CALIBRATE VERNIER clockwise and verify a scale expansion of at least 2.5.

f. Repetitive Relay Checks

The high-speed repetitive relay (K3) in the Model 12.1115 Integrator Network seldom, if ever, requires adjustment during its service life. If adjustment is required, it is recommended that the relay be returned to EAI since adjustment is a tedious task that requires special equipment. Each relay can be checked by performing Steps (1) and (2) of the reset time adjustment procedure. A waveform similar to Figure 55 should be observed. Improper waveforms that might be observed are shown in Figure 56. Relay bounce (small steps) during the reset time may appear but cannot be tolerated during the operate time.

In addition to proper adjustment, all of the repetitive relays in the integrator networks must be synchronized so that the integrators are placed in the operate mode at the same time. The start time test is simplified if an "average" integrator is used. An average integrator can be located by means of the following procedure:

- (1) Connect the circuit shown in Figure 57. Place the Mode Control switch in the HOLD position; select a compute time of 20 milliseconds. Set the vertical sensitivity of the oscilloscope to 2 volts/centimeter; set the sweep to 100 microseconds/centimeter; use external sync if necessary.

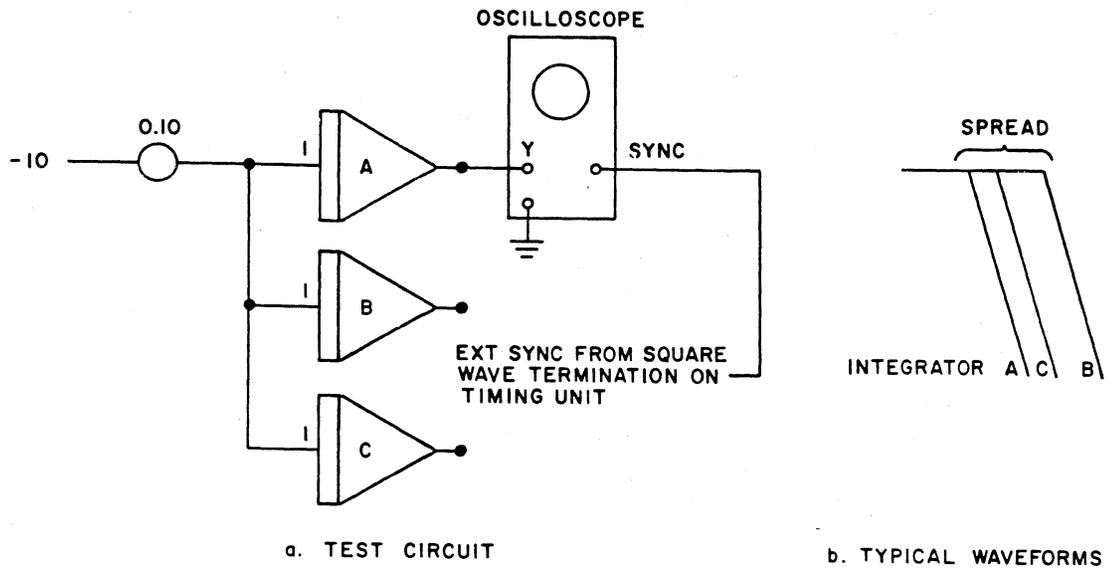


Figure 57. Locating an Integrator with an Average Start Time

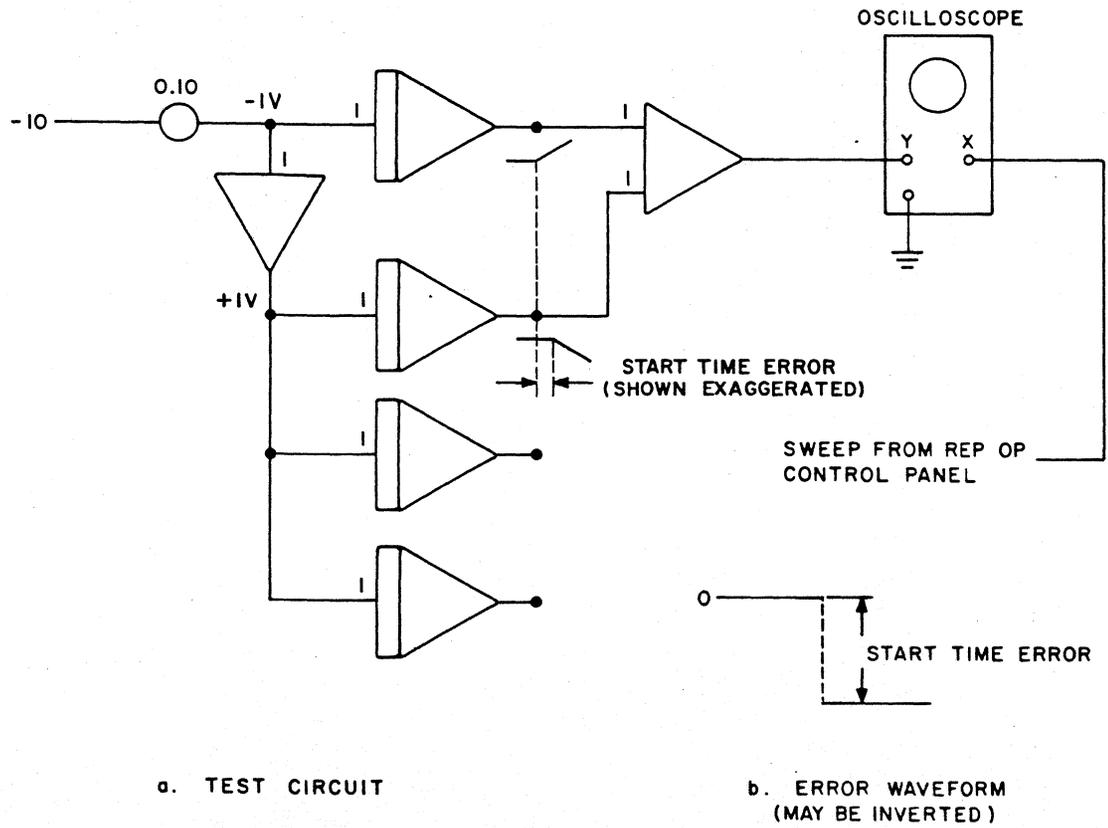


Figure 58. Start Time Error Test

(2) Monitor the output of each of the integrators. The observed waveforms will be similar to the one in Figure 57; usually each integrator will have a different start time, i.e., integrator C starts later than A and sooner than B.

(3) Choose the integrator that starts near the midpoint of the spread as the average integrator.

The start time error test is performed as follows:

(1) Patch the circuit shown in Figure 58. Place the computer in repetitive operation and select a compute time of 20 milliseconds. Set the vertical sensitivity of the oscilloscope to 50 millivolts/centimeter; set the horizontal sweep speed to 5 milliseconds/centimeter.

(2) Compare each integrator to the average integrator and observe the resulting waveform. A typical error waveform is shown in Figure 58. The maximum height of the step is 50 millivolts (50 mv = 100 microseconds). The rise time of the start time error (shown dotted) may show a slope.

(3) If an integrator has an excessive start time error, return the repetitive relay (K3) to EAI for adjustment.

5. READOUT AND DISPLAY NETWORKS

Networks are available for the TR-20 to allow simple patching from various computing components to external display or recording devices.

a. Model 12.987 Display Network

This unit is a plug-in wired through module. It may be mounted in position 17 of the non-linear row only. The network may be used with the Model 6.143 Signal Comparator or by itself; it is not used if the computer is equipped with a Model 40.538 Electronic Comparator.

b. Model 40.538 Electronic Comparator

The electronic comparator unit is housed in a dual-width module, occupying positions 17 and 18. The upper two-by-four terminal area (labeled DISPLAY) provides the same patching connections as the 12.987 Network. These terminals are wired through to a connector which mates with the connector in position 17.

Figure 59 is a simplified diagram of the wiring from either patching area to the DISPLAY connector (J56) and the Model 36.082 Timing Unit.

Cables are available to connect the Model 34.035 Repetitive Operation Display Unit or an 1110 Series VARI PLOTTER to J56, providing easy addition of these accessories.

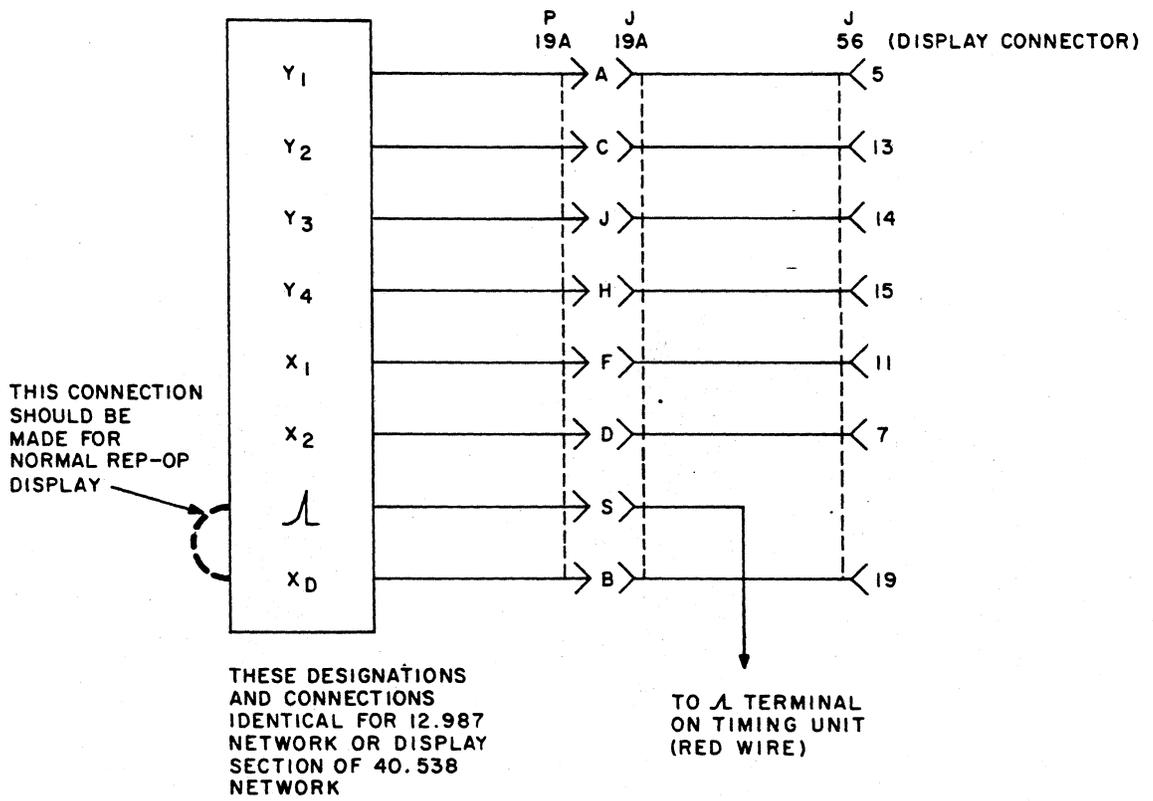


Figure 59. Simplified Diagram of Wiring for Display Networks

6. OVERLOAD INDICATORS

a. Visual Overload Indicators

(1) General Description. The Overload Indicators, Type 20.919, mounted on Overload Indicator Panel, Type 20.738, provide a visual indication of an overloaded amplifier by illuminating an indicator lamp labeled with the number associated with the amplifier. When an amplifier overloads, it is unable to provide the output voltage required to keep the summing junction at virtual ground. The rise in the summing junction voltage is greatly amplified by the stabilizer section of the amplifier. The signal at the output of the stabilizer is used to trigger the overload indicator which informs the user that the amplifier is overloaded.

The circuit arrangement is such that the Overload Indicator is capable of detecting non-linear amplifier performance due to excessive output current, and most other amplifier malfunctions, in addition to excessive output voltage. Furthermore, it allows the amplifier output voltage to exceed +10 volts without an overload indication if the amplifier is still operating linearly (up to +13 volts, depending on load).

(2) Circuit Description. When an amplifier is overloaded, a large 60 cycle square wave signal appears at the output of the stabilizer section. This signal is applied to the overload indicator circuit associated with the amplifier as shown in Figure 60. The square wave signal is applied through a capacitor (C1) to the anode control gate of silicon controlled rectifier CR1. The positive alternation of the square wave input, developed across R_1 , cause the SCR to conduct illuminating DS1. Once conduction is initiated in the diode, the gate loses control over conduction. Therefore, in order to extinguish the lamp, the anode to cathode voltage must be reduced to a point insufficient to cause current flow. This is accomplished by supplying the +6 volts from an unfiltered power supply. This causes the voltage to fall to zero 120 times each second, causing the lamp to go out when the overload is removed.

The unfiltered +6 volts is obtained from the 10.179 Power Supply. If the Model 13.017 Audio Overload Alarm is installed, the +6 volts is connected through J-34 as indicated on Figure 61.

b. Audio Overload Alarm, Model 13.017

(1) General Description. The Model 13.017 provides an audible indication whenever an amplifier is overloaded. The unit is driven by a signal from the visual overload indicators. When a visual indicator lamp is illuminated, current flows through resistor R11 in the audio overload circuit triggering the alarm.

(2) Circuit Description. Refer to Drawing B013 017 0S for the following description. The circuit consists of five stages: A trigger amplifier (Q5), an ac amplifier Q1, emitter-follower Q2, oscillator Q3, and an audio amplifier Q4. The unfiltered 6 volts for the visual indicators is connected through the parallel combination of R11 and CR3-CR4. When an overloaded amplifier causes a lamp to be illuminated, the current flow through R11 creates a voltage drop between the cathode and cathode gate of silicon controlled switch Q5. This causes the switch to conduct, coupling the 120 cycle ripple component through R12 and C7 to the

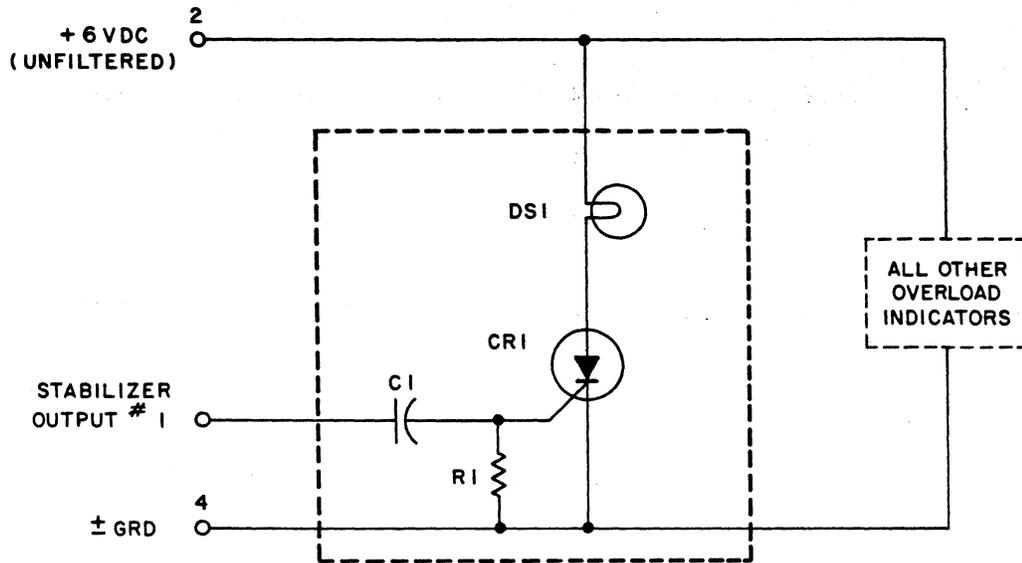


Figure 60. Overload Indicator, Simplified Schematic

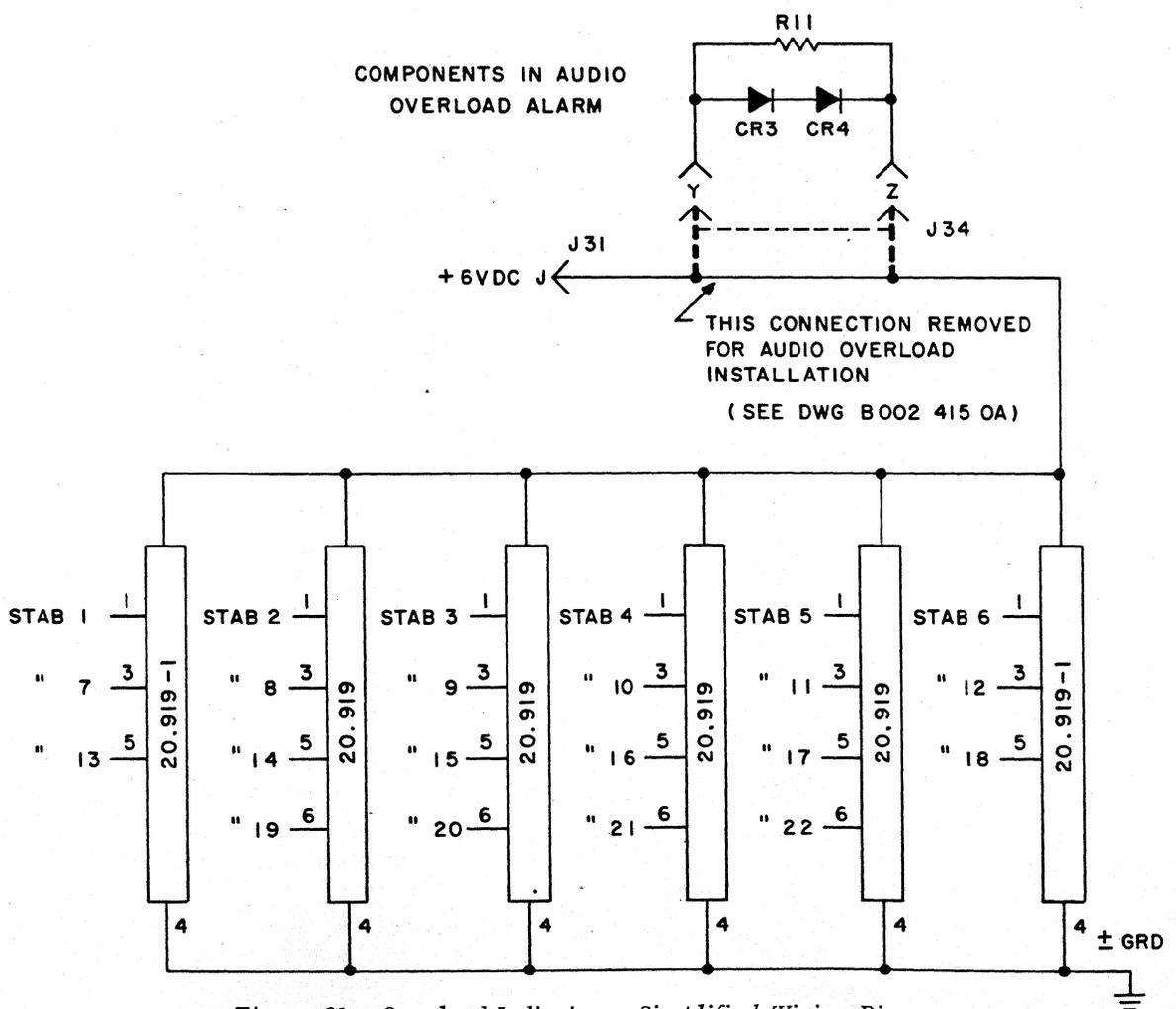


Figure 61. Overload Indicators, Simplified Wiring Diagram

base of Q1. Diodes CR3 and CR4 prevent the input signal from exceeding approximately 0.8 volts when more than one lamp is illuminated. Transistor Q1 amplifies the input signal, which is clamped and rectified by CR1 and CR2. Capacitor C3 charges through CR2 and develops a positive potential at the base of Q2, cutting off its collector current. The emitter-coupled positive-going signal causes Q3 to become forward biased and oscillation starts. Transformer coupling between collector and base provides feedback for the oscillator. The output of the oscillator is amplified by Q4; audio output transformer T2 couples the alarm signal to the loudspeaker. Potentiometer R8, connected across the secondary of T2, is a volume control.

CHAPTER XI

POWER AND REFERENCE VOLTAGE SUPPLIES

This chapter provides maintenance information for the power and reference supplies of the TR-20. Section 1 covers the Model 10.179 Power Supply and includes some ac wiring information. (More ac wiring information is contained in Chapter I under the Operational Checkout Section.) Section 2 describes the Model 43.037 Reference Regulator; the Power Bus By-pass Network is discussed in Section 3. A list of drawings that are applicable to the power and reference circuits is contained in Section 4.

1. REGULATED POWER SUPPLY, MODEL 10.179

a. General Description

The Model 10.179 Regulated Power Supply furnishes operating voltages for the components in the TR-20. The unit provides the following outputs:

+30 VDC, series regulated	-22 VDC, unregulated (relay drive)
+15 VDC, series regulated	+6.3 VDC, unregulated (overload lights)
-15 VDC, series regulated	+6.3 VAC, unregulated (chopper drive)

The Model 10.179 is located at the rear of the computer cabinet, as shown in Figure 62. The fuses, voltage-adjustment potentiometers and output voltage monitoring terminals are located on the front of the unit.

b. Technical Data

Specification	+15 VDC	-15 VDC	+30 VDC
Output Current (amperes) maximum	0.5	0.75	0.15
Output Impedance (ohms) typical	0.15	0.10	0.75
Regulation from No Load to Full Load (mv) maximum	150	150	150
Ripple at Full Load (mv,p-p) typical	0.375	0.375	0.375
maximum	1.0	1.0	1.0

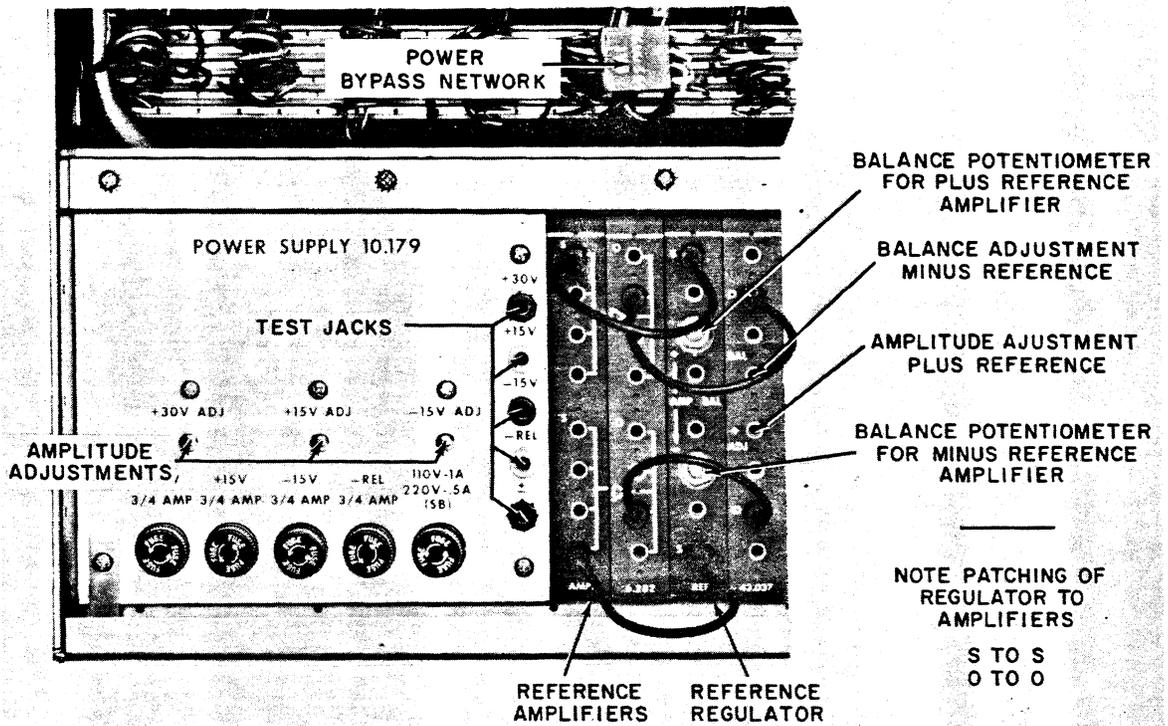


Figure 62. Power and Reference Supplies

Specification	-Relay	+6.3 VDC
Output Voltage (VDC) no load full load	-22 \pm 3 -15	+6.3 \pm 1.5 +4.0
Output Current (am- peres) maximum	0.75	0.9

c. Circuit Description

Primary power (110 or 220 vac, 50/60 cps) is connected to the TR-20 by a three-wire power cable supplied with the computer. One side of the ac line is routed through the OFF-ON switch (S4) on the Control Panel to the primary of transformer T1 in the Model 10.179. Refer to Drawing D010 179 OS. The two primary windings can be connected in parallel or in series for 110 vac or 220 vac operation respectively. The details are shown in the table of Unit Numbers on the drawings. The secondary to T1 supplies power to the three regulated power supplies and to the unregulated sections of the supply.

The relay drive supply is composed of a full-wave rectifier (CR7 and CR8) and a large shunt-capacitor filter (C4). Taps 12 and 13 of T1 provide 6.3 vac (nominal) for chopper drive. This source is also applied to a bridge rectifier (CR9, CR10, CR11, and CR12) to provide 6.3 vdc to power the overload indicator lights.

The regulated sections of the supply are basically the same; therefore, the following circuit description is confined to the -15 vdc section. Diodes CR1 and CR2 are connected as a full-wave rectifier; capacitor C1 provides filtering. Unregulated dc from the filter is applied across the series regulator (Q1) and the load on the supply (connected between pins A and D of P1). The output voltage of the supply is regulated by varying the voltage drop across Q1 which simulates a variable resistor. If the output voltage of the supply tends to increase, the resistance of the series regulator is increased, thus increasing the voltage drop across the regulator. The output voltage then remains constant.

The resistance of the series regulator is controlled by an error signal obtained from a comparison between a portion of the regulated output voltage and a stable zener reference voltage. A portion of the regulated output voltage is supplied to the base of Q6 by a voltage divider (R20, R21, and R18). The emitter of Q6 is maintained at a stable potential by zener diode CR3. Resistor R21 is used to set the operating point of Q6 and thus controls the magnitude of the output voltage. Any change in the collector current of Q6 is amplified by Q5 which varies the emitter-collector resistance of Q1. Thus, any supply voltage variation appears across Q1 and not across the load. Capacitor C7 reduces the attenuation of the voltage divider at higher frequencies thus aiding in the reduction of ripple and decreasing the output impedance at these frequencies by presenting a low impedance path to the base of Q6. Diode CR6 is used to protect Q1 in the event two supply voltages of opposite polarity are inadvertently connected together.

The three 15 volt supplies are arranged to produce potentials of +15 volts, -15 volts, and +30 volts. The -15 volt source is provided by grounding the positive terminal (pin D of P1) of one supply, while the +15 volt supply is obtained by grounding the negative terminal (pin F of P1) of the second supply. The +30 volts output is obtained by connecting the negative terminal (pin M of P1) of the third 15 volt supply to the +15 volt bus (pin L of P1). This connects two 15-volt sections in series and produces a +30 volt supply. The above connections are described on Drawing B045 078 OW, Sheet 20.

d. Output Voltage Adjustment

The output voltages of the supply should only be adjusted if a meter of sufficient accuracy is available (+1.0%).

The output voltages of the supply are adjusted as follows:

(1) Connect a voltmeter to the output of the -15 vdc supply (use the monitoring jacks). Rotate the potentiometer that is labeled -15V/ADJ until the voltmeter reads -15 vdc.

(2) Monitor the output of the +15 vdc supply. Rotate the +15V/ADJ potentiometer until the voltmeter reads +15 vdc.

(3) Connect the voltmeter to the output of the +30 vdc supply. Rotate the +30V/ADJ potentiometer until the meter reads +30 vdc. (The +15 vdc supply should be adjusted first.)

e. Troubleshooting

Malfunctions in the Model 10.179 can be isolated with the following procedure.

(1) Note which output voltage is abnormal. Malfunctions in the +15 vdc supply commonly affect the +30 vdc supply. Check all fuses on the front panel. Be sure that all connections to the regulator amplifier board are secure.

(2) If the supply passes the above check, the malfunction is probably in the regulator amplifier. Remove the supply from the computer; remove the regulator amplifier board. Compare resistance readings in the suspected amplifier with readings in one of the amplifiers that is known to be good. (The three regulator amplifiers are identical.) Note that the polarity of the ohmmeter leads can affect the ohmmeter readings.

(3) Check the rectifier of the defective supply with an ohmmeter.

(4) Check the series regulator transistor (Q1, Q2, or Q3) with an ohmmeter. A simple check is outlined in Appendix II.

An extension cable for the Model 10.179 is available as a maintenance aid. The EAI part number for this cable is 019 263 0.

2. REFERENCE REGULATOR, MODEL 43.037

a. General Description

The Model 43.037 Reference Regulator, Figure 62, is used in conjunction with a Dual DC Amplifier, Model 6.282, to produce stable and precise reference voltages of plus and minus ten volts. The reference system consists of a stable zener diode voltage source followed by two operational amplifiers, with emitter-follower power output stages. The gain of the plus reference amplifier is adjusted so that +10 vdc is obtained at the regulator output with the zener voltage as an input. The plus-ten-volt reference is used as the input voltage to the minus reference amplifier. The amplifier has unity gain and thus provides -10 vdc. Two potentiometers, labeled +ADJ and BAL, on the front panel of the Model 43.037, control the magnitudes of the reference voltages. The balance potentiometers for the associated amplifiers are also located on the front panel of the unit.

The reference voltages are supplied to the power bus bars for distribution to the computing components and to the REF patching modules located in the middle row of components. The AMPL SEL switch (S6) on the Control Panel monitors the plus reference regulator in position 21, and the minus reference regulator in position 22. The reference voltage output of the regulators is monitored at these positions when the Voltmeter Function switch (S1) is in the AMPL position. When S1 is in the BAL position, the stabilizer output of the associated amplifier is available at these positions so that the amplifier balance can be checked.

b. Technical Data

Absolute Amplitude	10 VDC <u>+5</u> MV
Reference Balance	<u>+1</u> MV
Output Current	<u>+50</u> MA
Short Circuit Current Limited to Approximately	75 MA
Noise (peak-to-peak) Less Than	0.6 MV, RMS

c. Circuit Description

A simplified schematic of the plus and minus reference supplies is shown in Figure 63. Zener diode CR1 and resistor R11 are connected across the -15 volt supply and provide a stable source of approximately -5.6 volts. Resistors R7, R2, and R3 form the input resistor for amplifier two, R6 is the feedback resistor. Emitter-follower Q2 is considered as part of the amplifier since it is within the feedback loop of the amplifier. The emitter-follower increases the current capability of the Model 6.282 Amplifier to 50 ma. Incandescent lamps I3 and I4 stabilize and protect the output stage by limiting the maximum current flow through the transistor. The resistance of the lamps increases with increasing current. Potentiometer R7 (+ADJ) adjusts the magnitude of the plus reference voltage. Resistor R10 provides a constant emitter load for Q2.

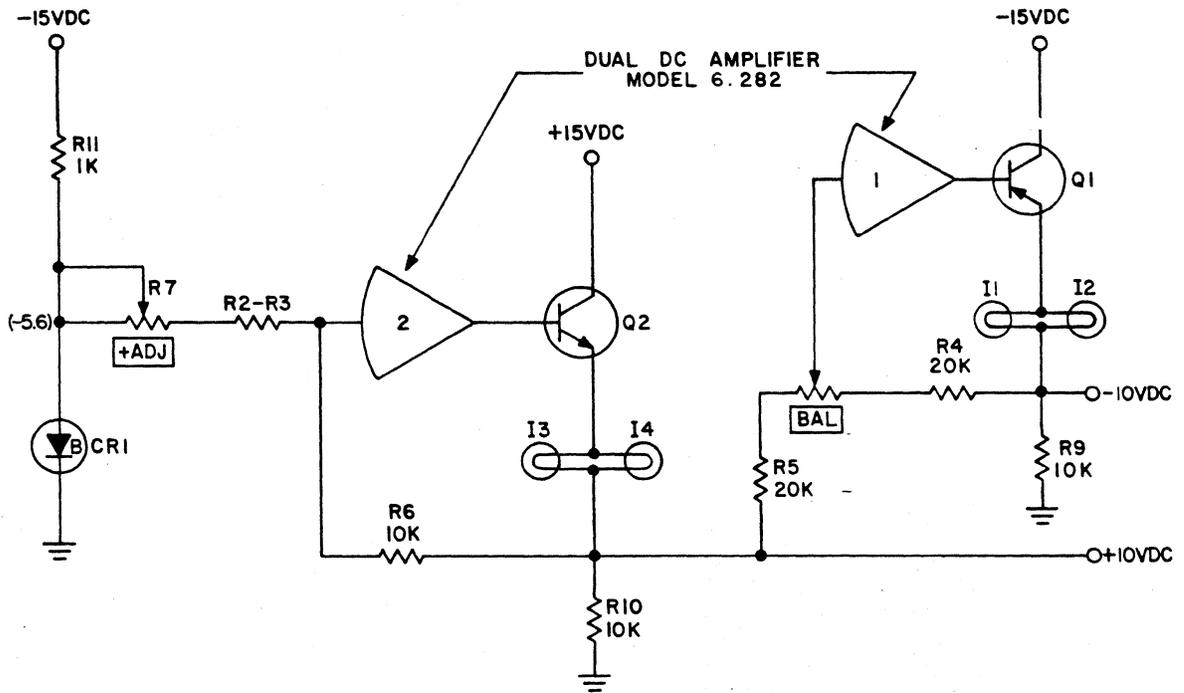


Figure 63. Reference Regulator, Model 43.037, Simplified Schematic

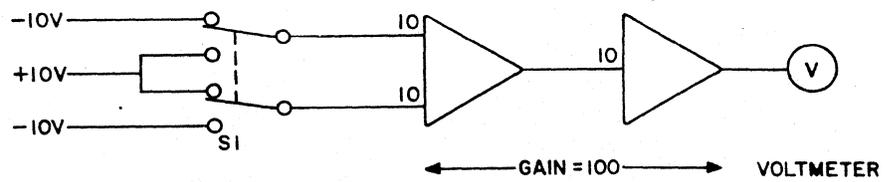


Figure 64. Reference Balance Test Circuit

The +10 volt reference is used as the input voltage to the minus reference amplifier. Since the input and feedback resistors (R5, R4) are equal, the amplifier has unity gain. Potentiometer R1 (BAL) permits a small gain adjustment so that the plus and minus reference voltages can be balanced to the same magnitude.

d. Patching

The front panel of the Reference Regulator has S and O terminations on the upper and lower halves of the panel. These terminations are used to connect the Regulator to its associated Dual DC Amplifier. The S and O terminations of the upper part of the regulator should be patched to the corresponding S and O terminations of the upper amplifier. The lower S and O terminations are connected to the corresponding S and O terminations of the lower amplifier. See Figure 62.

e. Adjustments

(1) Amplifier Balance. The amplifiers associated with the reference supply are balanced in the same manner as the operational amplifiers. Place the Voltmeter Function switch (S1) to BAL and the AMPL SEL switch to position 21. Rotate the +AMPL BAL control on the Regulator until the voltmeter reads zero. Place the AMPL SEL switch to position 22; rotate the -AMPL BAL control until the voltmeter reads zero.

(2) Magnitude and Balance Adjustment. The Model 43.037 is adjusted prior to shipment to yield +10 volts +5 millivolts; the magnitude of the minus reference is adjusted to be within +1.0 millivolts of the plus reference magnitude. These reference levels may be checked and re-adjusted at any time if sufficiently accurate equipment is available. Otherwise, EAI recommends that the Regulator be returned to the factory for adjustment or component replacement.

The magnitude of the plus reference supply is adjusted as follows:

- (a) Be sure that the -15 vdc supply is operating within specifications. Balance the dc amplifiers associated with the reference system.
- (b) Measure the plus reference voltage with an accurate voltmeter. Rotate the +ADJ potentiometer until the meter reads +10 vdc +5 mv.

While it is important that the reference voltages have the proper magnitude, it is more important that they be equal in magnitude. Balance the associated amplifiers before making any adjustment. To balance the minus reference magnitude to the plus reference magnitude, proceed as follows:

- (a) Connect the circuit shown in Figure 64. Place the voltmeter on the 0.1 volt range.
- (b) Record the voltmeter readings with S1 in both positions. The algebraic average (algebraic sum divided by two) of the two readings, divided by 100, is equal to the reference balance. Changing input resistors with S1 decreases the possibility of error caused by mis-matched resistors.

- (c) Since the voltmeter is on the 0.1 volt scale, full scale meter deflection indicates a reference balance of 1.0 millivolt. The reference supplies must be balanced to within 1.0 millivolt, but should be adjusted as close to zero as possible.
- (d) If adjustment is necessary, vary the BAL potentiometer for minimum meter reading.

f. Troubleshooting

Reference supply malfunctions can be localized by means of the following procedure.

- (1) Note which supply is malfunctioning; trouble in the +10 volt supply commonly causes malfunction symptoms in the -10 volt supply. Check that the +15 vdc levels are present at the regulators and are within specifications.
- (2) Replace the associated dual dc amplifier with a unit that is known to be operational. (A 6.712 Amplifier may be used; the units are identical except for the input network.)
- (3) If the malfunction still exists, remove the Reference Regulator and use an ohmmeter to check circuit values. Be sure to check the continuity of the incandescent lamps, and the Zener diodes, Q1 and Q2. Refer to Appendix II for details on a simple transistor check.

The value of R3 is determined by the characteristics of CR1; therefore, R3 and CR1 must be replaced as a unit that has been designated Network NW1. See the Parts List for the Model 43.037.

3. POWER BUS BYPASS NETWORK

The Power Bus Bypass Network is used to lower the high frequency impedance of the power buses in order to increase amplifier stability. The network is composed of three RC circuits each consisting of a 0.1 mfd capacitor and a 10 ohm resistor connected in series. Each power bus (+30 vdc, +15 vdc, -15 vdc) has an RC network connected from the bus to ground. The network is designated NW1 and is located at the rear of the computer cabinet in the middle of dc Bus-1.

4. APPLICABLE DRAWINGS FOR THE POWER AND REFERENCE CIRCUITS

a. Regulated Power Supply, Model 10.179

Schematic	D010 179 OS
Wiring	D010 179 OW
Rack Wiring	B045 078 OW, Sheet 20

b. Reference Regulator, Model 43.037

Schematic (Regulator)	B043 037 OS
Schematic (Amplifier) Wiring	D006 282 OS
Rack Wiring	B045 078 OW, Sheets 20 and 21

c. Power Bypass Network (NW1)

Identification	B592 007 0
Location	B045 078 OW, Sheet 2

d. Miscellaneous

AC Power Connector (AC)

Location	B045 078 OW, Sheet 2
----------	----------------------

Wiring	B045 078 OW, Sheet 3
--------	----------------------

Chassis Ground Bus

Location	D045 078 OW, Sheet 2
----------	----------------------

Wiring	D045 078 OW, Sheet 3
--------	----------------------

DC Bus-1 and 2

Location	B045 078 OW, Sheet 2
----------	----------------------

APPENDIX I

ELEMENTARY PRINCIPLES OF ANALOG DEVICES

1. THE DC AMPLIFIER

1.1 The Direct Coupled Amplifier

The amplifiers used in analog computers very often must retain the dc components that may accompany varying signals. Amplifiers that can amplify a zero-frequency input signal are then required. These amplifiers cannot employ transformer or capacitor coupling between stages since reactive components block the transmission of a dc signal. The amplifier inter-stage coupling must be direct so that both constant and varying signal voltages can be passed from one stage to the next. The resulting direct-coupled amplifier can amplify voltages that do not change with time as well as alternating signals.

A symbol to represent a direct-coupled amplifier is shown in Figure A1.1. According to convention, the rounded side represents the input of the amplifier and the pointed end represents the amplifier output. A common reference level or ground exists between the amplifier input and output and all voltages are measured with respect to it. The ground reference line is understood and is usually omitted from the symbol. The input terminal of the amplifier is often called the base because it connects to the base of a transistor in the input stage. More frequently it is called the summing junction of the amplifier.

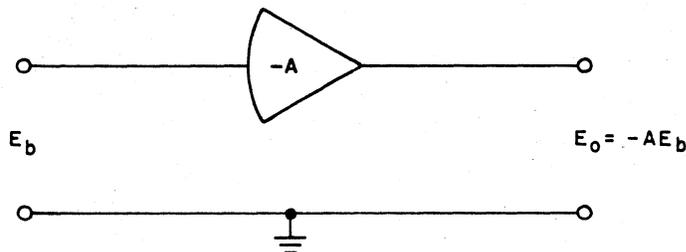


Figure A1.1. Symbol for a High-Gain, Direct-Coupled Amplifier

The internal connections in the amplifier are such that if the summing junction is positive with respect to ground, the amplifier output voltage is negative with respect to ground. The amplifier has an open loop voltage gain of $-A$; therefore, an input voltage of E_b results in an output voltage of $-AE_b$. The gain of a good computing amplifier can be as high as several million. An input voltage of one microvolt can produce several volts at the amplifier output. Unfortunately, no matter how well constructed the amplifier might be, the electronic components within it will produce undesirable noise and distortion in the output signal. If the amplifier is to serve as a precision device, these undesirable effects must be reduced to extremely low levels. For most uses, an amplifier that has a noise-free, distortionless gain of one to twenty is required. By making use of the properties of negative feedback, it is possible to exchange the extremely high gain of the amplifier for lower gain with greatly reduced noise and distortion. Negative feedback trades quantity for quality.

The term feedback signifies that a portion of the output voltage of the amplifier is returned to the input. When the returned voltage is opposite in polarity to the input voltage, it is known as negative feedback. Figure A1.2 shows an amplifier with negative feedback applied to its input through resistor R_f . In order to perform certain mathematical operations and to properly take advantage of the feedback resistor, a resistor R_{in} is added in series with the summing junction. The amplifier input voltage is now shown as E_{in} while E_b is the actual voltage at the summing junction.

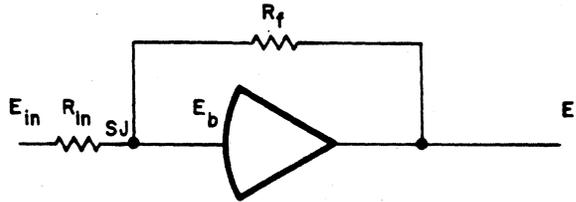


Figure A1.2. A High-Gain Amplifier with Feedback Resistor R_f and Input Resistor R_{in}

The circuit operation can be viewed in the following manner. A dc voltage E_{in} applied to input resistor R_{in} produces a summing junction voltage E_b . The summing junction voltage is amplified and appears at the amplifier output as a voltage E_o which is equal to $-A E_b$ where A is the open loop voltage gain of the amplifier. Part of the output voltage E_o is returned through R_f to the summing junction. Since the returned or feedback voltage is of opposite polarity to the voltage at the summing junction, it will tend to reduce the magnitude of E_b . This, in turn, reduces E_o which reduces the feedback voltage and thus tends to raise the value of E_b . This process continues until a point of equilibrium is reached. Actually, this point is reached almost instantaneously. It can readily be seen that if the amplifier gain is very large, then E_b will be reduced to a very small value. In fact, the summing junction voltage is so small that it is considered to be at zero potential in order to simplify the mathematical expressions that arise from this circuit configuration. The summing junction is said to be at *virtual ground* or is practically at zero volts (a typical value for the summing junction voltage is 25 microvolts).

Several desirable features are realized with this circuit arrangement. The resulting amplifier gain is extremely stable and the performance of the amplifier is nearly independent of the amplifier components. The gain of the circuit can be changed by varying the ratio of the feedback resistor to the input resistor.

One of the laws of electrical circuits states that the sum of the electrical currents flowing towards a junction of three or more wires must be equal to the sum of the electrical currents flowing away from the junction. The summing junction of the circuit in Figure A1.3 is such a junction, therefore:

$$i_{in} = i_f + i_b$$

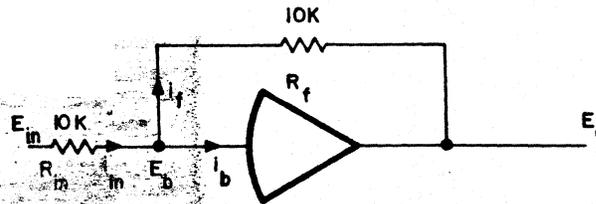


Figure A1.3. The Summing Junction Currents in an Operational Amplifier

The amplifier is designed so that it has a high resistance to the flow of current into or out of its input terminal. The input current i_p can then be considered to be equal to zero. The resulting current equation states that the input current i_{in} is equal to the feedback current i_f . If the amplifier has a very large gain, the summing junction voltage is very nearly zero. The voltage drop across R_{in} is E_{in} , the voltage drop across R_f is E_o . Therefore,

$$i_{in} = i_f$$

$$\frac{E_{in}}{R_{in}} = - \frac{E_o}{R_f}$$

$$E_o = - \frac{R_f}{R_{in}} E_{in}$$

This expression is the fundamental relationship for the amplifier in Figure A1.3. As long as the amplifier has a high gain and draws negligible current from the summing junction, the amplifier input and output voltages are related by the ratio of two resistors and are not affected by the components of which the amplifier is made.

When a dc amplifier is used in conjunction with input and feedback networks to perform mathematical operations, the resulting system is generally referred to as an operational amplifier.

1.2 The Inverting Amplifier

When the same value resistor (for instance 10K ohms) is used for both the feedback and input resistor, the amplifier output voltage will have the same amplitude as the input voltage but will be of opposite polarity.

$$E_o = - \frac{R_f}{R_{in}} E_{in} = - \frac{10K}{10K} E_{in} = -E_{in}$$

A +10 volt input results in a -10 volt output. The amplifier has a gain of minus one and is called an inverter. The accuracy of this sign changing or inversion process depends only on the ratio of the two resistors.

1.3 Multiplication by a Constant

A change in the ratio of the resistors results in multiplication by a constant. With R_f equal to 100K and R_{in} equal to 10K the amplifier output is:

$$E_o = - \frac{100K}{10K} E_{in} = -10 E_{in}$$

An input voltage of plus one volt results in an output of minus ten volts. The operational amplifier has a gain of ten. The multiplying constant can be made smaller than one by using a 10K feedback resistor with a 100K input resistor.

$$E_o = - \frac{10K}{100K} E_{in} = -0.1 E_{in}$$

An input voltage of minus ten volts produces an output of plus one volt.

Thus, a *constant* current of 30 microamps flows through the 10 mfd capacitor when the voltage across it is changing at the rate of three volts-per-second.

When a *constant* three-volt input is applied to the 100K input resistor of the integrator in Figure A1.5, the input current is a *constant* 30 microamps. The feedback current must also be a *constant* 30 microamps. Therefore, the voltage across the feedback capacitor must change at the rate of three volts-per-second, and the output of the amplifier must change at the rate of three volts-per-second. It can then be said that the integration of an input voltage with respect to time represents a continuous summation or accumulation of voltage over a specified period of time. In fact, to integrate a voltage that is a function of time simply requires finding the area under the input voltage-time curve.

The output of the integrator in Figure A1.5 is mathematically described as:

$$E_o = - \frac{1}{R_1 C_1} \int E_1 dt - \frac{1}{R_2 C_1} \int E_2 dt = - \int (E_1 + 10 E_2) dt$$

The minus sign indicates that the amplifier performs an inversion. The symbol \int is the mathematical symbol for integration. The dt term indicates that the integration process is carried out over a period of time with respect to time. The term RC is a time constant, which for $R = 100K$ and $C = 10$ mfd, is equal to one second. Under this condition, the output voltage of the integrator changes at the rate of minus one volt-per-second for each positive input volt. The number one is then placed in front of the integrator symbol (Figure A1.5). When a 10K input resistor is used with a 10 mfd feedback capacitor, the output of the integrator changes at the rate of minus ten volts-per-second for each positive input volt. The number ten is then placed before the integrator symbol for this input (Figure A1.5).

The curves in Figure A1.6 show integrator outputs for various step inputs. Note that when the input voltage goes to zero, the output voltage remains constant. With zero input current, the feedback current must be zero. Therefore, the potential across the feedback capacitor must be constant (not necessarily zero). The integrator input in Figure A1.6 is +2 volts for four seconds; its output changes 2 volts-per-second for four seconds, thus reaching -8 volts. The input in Figure A1.6b is one volt for one second and is applied to a gain-of-ten input of the integrator. The integrator output reaches -10 volts in one second. The integrator in Figure A1.6c has an output that increases at a rate of 2 volts-per-second for two seconds, then decreases at a rate of 2 volts-per-second for three more seconds, finally reaching -2 volts.

When the inputs to an integrator go to zero or are removed, the integrator "holds" the value of voltage reached while it was operating. In the computer this *hold* mode is established with relay contacts that disconnect all inputs. It is often necessary for the integrator output voltage to have a value other than zero when time is equal to zero. This means that the feedback capacitor must receive an initial charge. This charging process takes place in the *reset* mode. In this mode, the integrator can be considered to be a simple inverter.

1.6 Other Uses of the DC Amplifier

The operational amplifier is so versatile that any attempt to catalog its uses would result in a formidable list. The presentation here has been based on the use of linear components in the input and feedback networks of the amplifier. The basic concepts that were developed can be expanded to include non-linear components. The use of non-linear components can be illustrated with the circuit in Figure A1.7. An ideal diode is connected in parallel with R_f . The diode will conduct whenever its anode, connected to the amplifier output, becomes positive.

As long as E_{in} is a positive voltage, the amplifier output voltage is negative and the diode does not conduct. The circuit functions normally as an inverter. When E_{in} becomes negative, the amplifier output attempts to go positive and the diode conducts. The ideal diode effectively shorts R_f making the net feedback resistance equal to zero. The amplifier output is zero volts and remains so for all negative values of E_{in} .

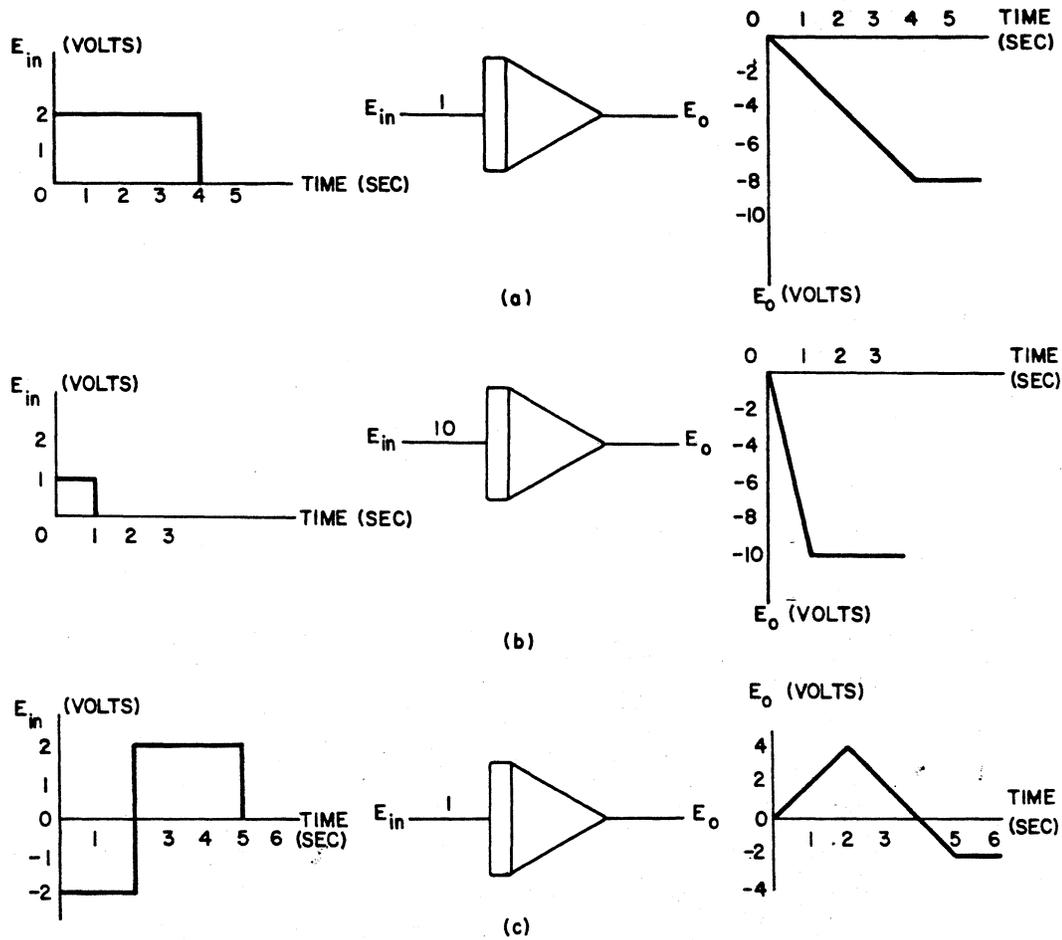


Figure A1.6. Integrator Outputs for Various Step Inputs

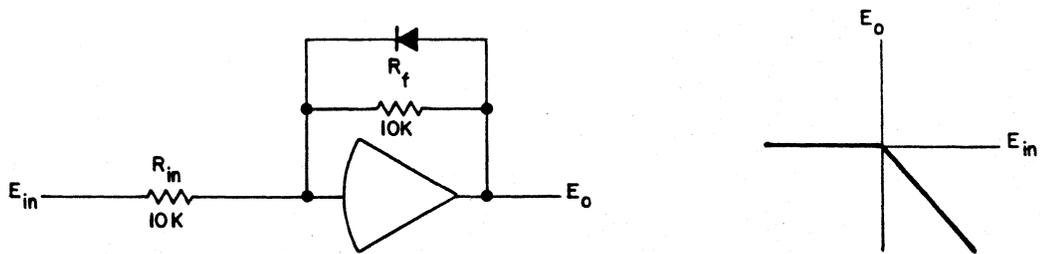


Figure A1.7. A Simple Feedback Limiter or Half-Wave Rectifier

1.7 Simple Circuits and Symbols

Figure A1.8 contains some simple operational amplifier circuits and their equivalent symbols. The numbers on the inputs to the triangular symbols indicate the gain for the particular input. All of the input voltages shown have constant values but the amplifier is, of course, quite capable of handling inputs that vary with time.

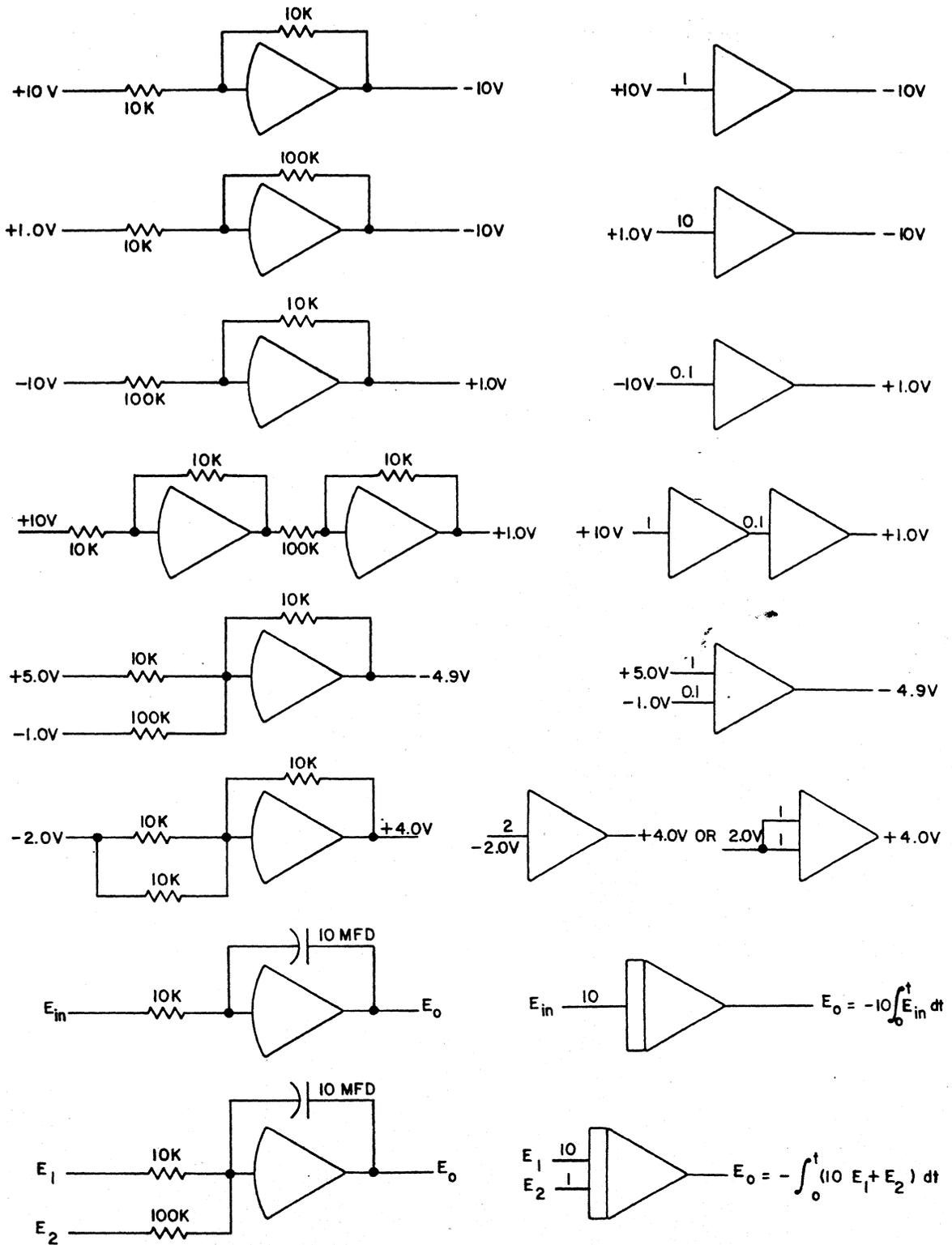


Figure A1.8. Simple Amplifier Circuits and Their Symbols

1.8 The Problem of Drift

In order to pass dc signals, an amplifier must have direct coupling between its stages. This method of coupling, however, presents some complications. In an ac amplifier, such as an audio amplifier, the quiescent voltage at the plate of one tube is isolated from the grid of the next stage by a capacitor. Thus slow time-varying changes in the operating level of the first stage are blocked by the capacitor and do not affect the second stage. In a direct-coupled amplifier, any change in the operating level of a stage is coupled to the next stage where it is amplified and perhaps passed on to still another stage. A number of things can cause changes in the operating level of an amplifier stage: power supply variations, resistor values changing with temperature, vacuum tube or transistor gain changing with age and temperature, etc. Note that all of these changes are slow-time-varying changes. Therefore, even when the input of a dc amplifier is grounded, the output voltage may drift away from zero. Drift in the output voltage prevents accurate computation because it has the same effect as a spurious signal applied to the input of the amplifier.

Suppose that drift originating in one of the stages of the amplifier in Figure A1.9 causes the output voltage to go positive; this positive voltage is coupled to the summing junction by the feedback resistor causing the summing junction to become more positive. The amplifier output becomes more negative, thus cancelling most of the original drift-produced output voltage. The negative feedback around the amplifier reduces the effect of drift but does not provide complete correction. The major effect of drift is to place the summing junction at some voltage other than virtual zero. Since all mathematical operations performed by the amplifier depend on the summing junction being at virtual ground, a more effective means of stabilizing the amplifier against drift must be used.

As noted earlier, ac amplifiers do not amplify drift. This suggests that any drift-compensating circuit should use an ac amplifier. But since the drift produced in a direct-coupled amplifier is dc or a slowly changing voltage, it must be converted to an ac signal if it is to be used in an ac amplifier. In the Model 6.282, the drift voltage at the summing junction is converted to ac by a chopper or synchronous vibrator, amplified, rectified and filtered, then applied as a correction signal to the dc amplifier. This method of drift correction is known as chopper stabilization.

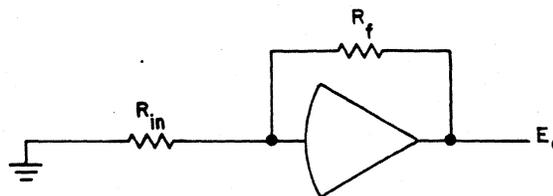


Figure A1.9. Operational Amplifier with Grounded Input

2. DIODE FUNCTION GENERATORS AND QUARTER-SQUARE MULTIPLIERS

An elementary function generator is shown in Figure A1.10a. The basic relationship for the amplifier is $E_o = -(R_f/R_i)E_i$, where R_f and R_i are the feedback and input resistors respectively. If R_i is decreased, the gain of the amplifier is increased. The function shown in Figure A1.10b could be generated by continuously decreasing R_i as the input voltage E_i increases. Using a simple potentiometer as R_i , however, leads to difficulty because the desired function cannot be reproduced with accuracy. A more practical method of changing R_i is to switch in different input resistors by means of diodes. A diode function generator uses biased diode networks to approximate a function by means of straight line segments.

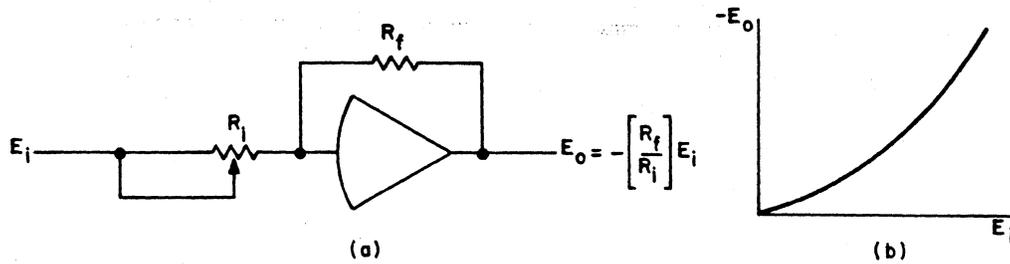


Figure A1.10. Elementary Function Generator

An ideal diode can be regarded as a voltage-sensitive on-off switch (Figure A1.11a). The circuit is closed when the anode of the diode is positive with respect to the cathode, and the circuit is open when the anode is negative with respect to the cathode. In the circuit shown, the ideal diode has infinite resistance until the input voltage E_i is equal to the bias voltage E_b . When the input voltage becomes greater than the bias voltage, the diode conducts and has zero resistance. The resulting current through resistance R produces an output voltage that is equal to $(E_i - E_b)$.

A diode can be connected in series with a battery and the input resistor of an amplifier as shown in Figure A1.12. The cathode of the diode is connected to the amplifier's summing junction (SJ) which is at virtual ground potential. The anode is at minus two volts; the diode is cutoff. The input current to the summing junction is zero. When the input voltage E_i is greater than plus two volts, the anode of the diode is positive and the diode conducts. The net voltage across the input resistor R_i is $(E_i - 2)$ volts. The amplifier output is $-1/2 (E_i - 2)$ volts since the ratio of R_f to R_i is $1/2$. The amplifier output voltage is plotted against the input voltage in Figure A1.12b. The point at which the diode begins to conduct is called the breakpoint. The slope of the output is determined by the ratio of R_f to R_i .

Biased diode networks can be paralleled as shown in Figure A1.13. The input network of the amplifier contains three parallel paths. When all three diodes conduct, the net input resistance is the parallel combination of R_1 , R_2 , and R_3 . Assume that E_i is a positive going ramp that starts at zero. When E_i is less than one volt, none of the diodes conduct. When E_i reaches one volt, diode CR1 conducts and produces the segment one output shown in Figure A1.13b. The slope of the resulting segment is $-R_f/R_1$. Segment two conducts when E_i reaches three volts and contributes the segment shown in Figure A1.13b. Segment three conducts when E_i reaches five volts. The net output voltage E_o is the sum of the contributions from the three segments.

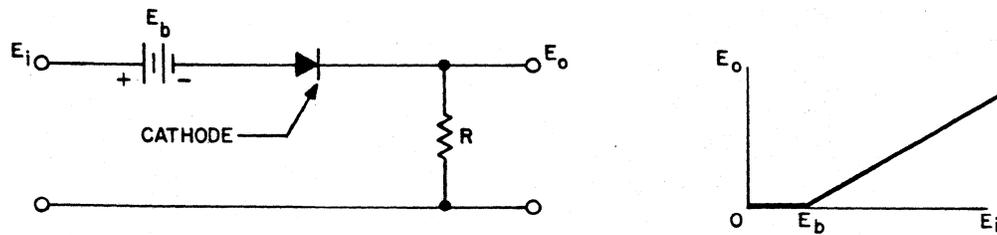


Figure A1.11. Series Diode Circuit

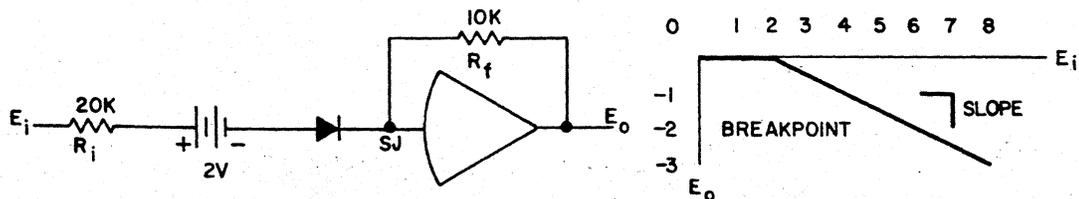


Figure A1.12. Amplifier with Biased Diode Network

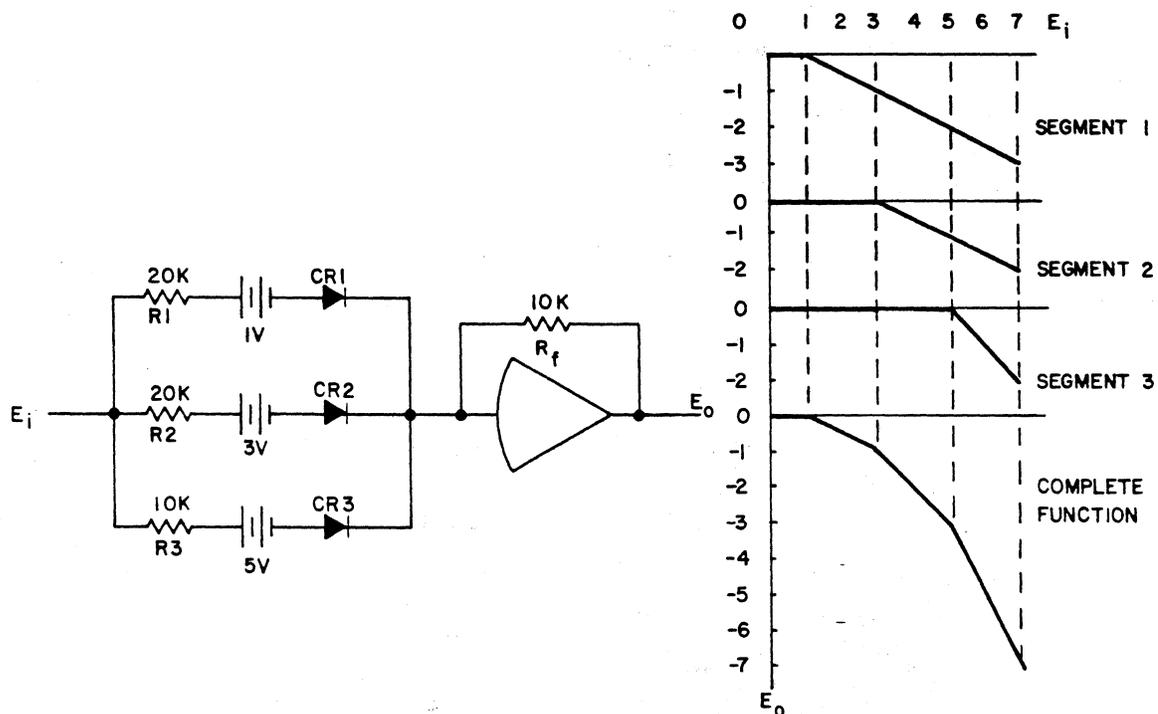


Figure A1.13. Simple Diode Function Generator

The complete function is a four segment straight line approximation to a desired function. Note that the output voltage is zero for negative inputs since a negative input voltage would add to the reverse bias of the diodes.

Practical diode function generators replace the battery used in the preceding discussion with a bias or reference power supply as shown in Figure A1.14. The diode is biased to cutoff by the -10 volts applied through R3. The diode does not conduct until the input voltage E_i reaches +5 volts. The resulting output is plotted in Figure A1.14b. By adding more segments in parallel with the first, a function can be represented by a series of straight line segments. Note, however, that the function must have a slope that increases after each breakpoint. Networks of this type are used in the X^2 Diode Function Generator.

The biased diode networks discussed thus far can only generate monotonic functions that have a second derivative that does not change sign in any one quadrant. However, non-monotonic functions can be generated by summing monotonic functions as illustrated in Figure A1.15. The Variable Diode Function Generators use operational amplifiers to sum the component functions as shown in Figure A1.16. The ratio of resistors R1 and R2 determines the breakpoint of the diode. When the diode conducts, the input signal is applied to the wiper of the SLOPE potentiometer. The setting of the SLOPE potentiometer determines the slope of each segment by controlling the ratio of signal levels applied through a direct input and an inverted input to amplifier two. If the wiper of the SLOPE potentiometer is at the top of its travel, the signal applied to the direct input is larger than the signal to the inverted input (through amplifier one). The two amplifiers are used to sum the contributions from additional diode networks so that any single valued function can be represented by a series of straight line segments.

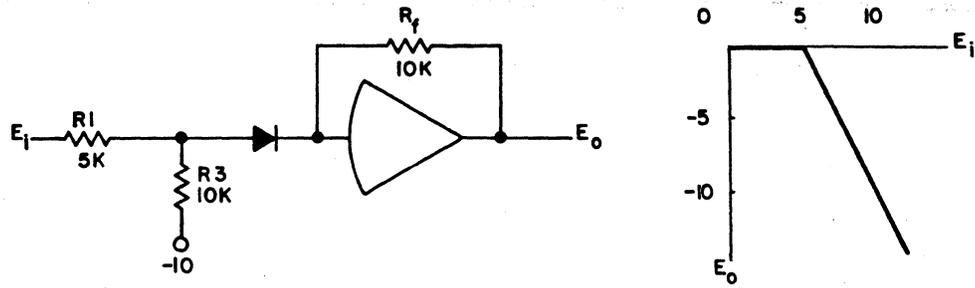


Figure A1.14. A Practical Diode Network

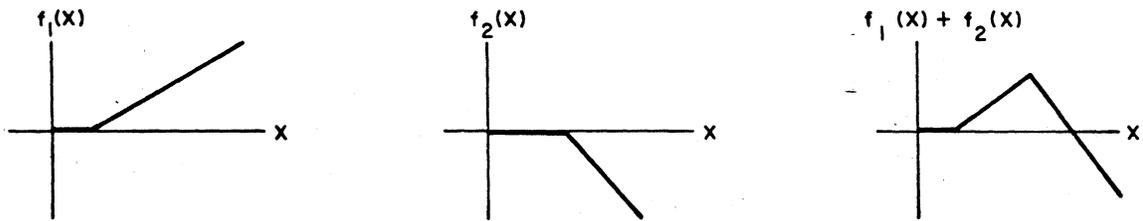
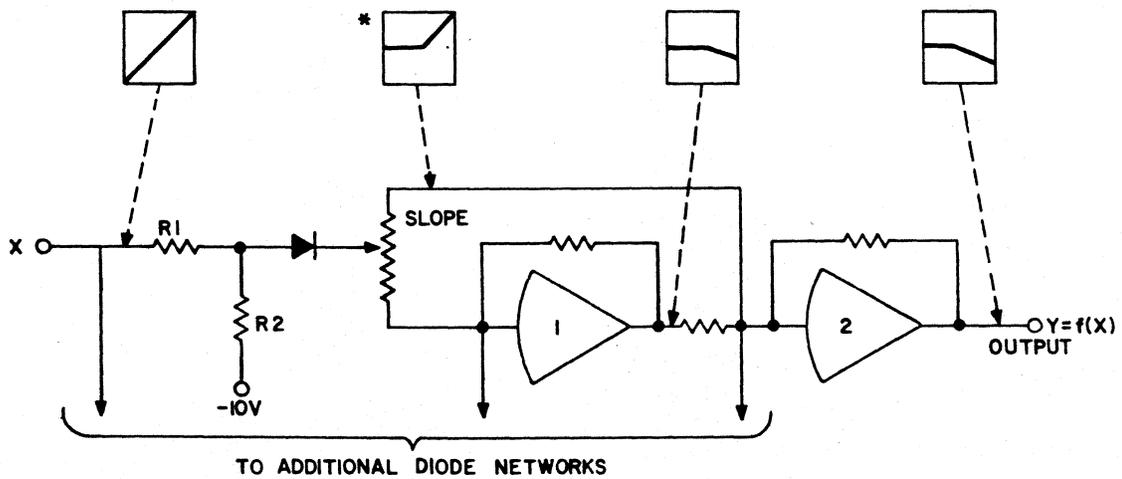


Figure A1.15. Generation of a Non-Monotonic Function



*The second curve illustrates the current flow through the top of the SLOPE potentiometer.

Figure A1.16. VDFG, Simplified Schematic

Biased diode networks are also used in the Quarter-Square Multiplier which makes use of the identity:

$$XY = \frac{1}{4} [(X + Y)^2 - (X - Y)^2] = \left(\frac{X + Y}{2}\right)^2 - \left(\frac{X - Y}{2}\right)^2$$

The product of two input variables, X and Y, can be obtained by subtracting the square of $\left(\frac{X - Y}{2}\right)$ from the square of $\left(\frac{X + Y}{2}\right)$. The summing and squaring operations are performed by diode function generators that contain networks similar to those in the X^2 DFG.

In the Quarter-Square Multiplier, the squaring circuits must produce voltages proportional to $\left(\frac{X + Y}{2}\right)^2$ and $\left(\frac{X - Y}{2}\right)^2$. This can be accomplished by modifying the basic circuit in Figure A1.14 by the addition of another input resistor R2 as shown in Figure A1.17a. By making $R1 = R2$, it can be shown that the circuit in Figure A1.17b is equivalent to the one in Figure

A1.17a. The equivalent input voltage to the network is $\left(\frac{X + Y}{2}\right)$ volts. By adding more segments in parallel with the one shown in Figure A1.17a, a function generator can be formed that accepts inputs of X and Y, sums them, and produces an output that is proportional to $\left(\frac{X + Y}{2}\right)^2$ as long as (X + Y) is positive. If X and Y can be input voltages with any combination of polarities, then four X^2 DFG's are required for each Quarter-Square Multiplier.

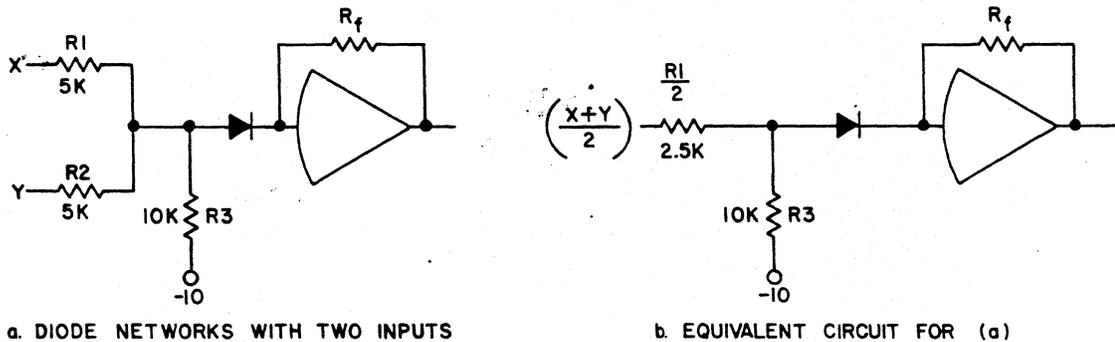


Figure A1.17. Diode Networks for the Quarter-Square Multiplier

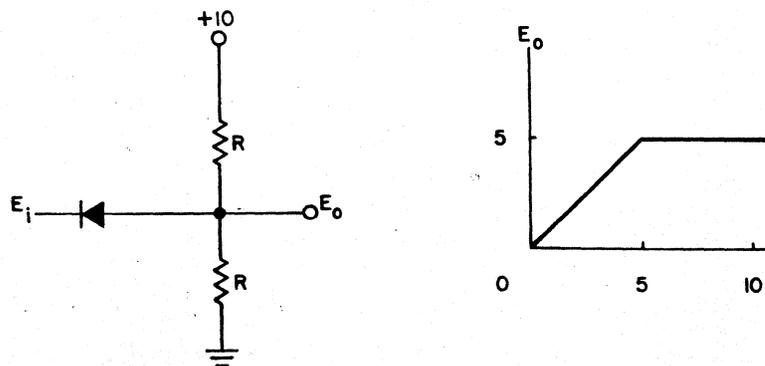


Figure A1.18. A Diode Limiter

Biased diode networks are also used in Log X DFG and the 1/2 Log X DFG's. The basic circuit is modified slightly. The ideal diode shown in Figure A1.18 has zero resistance as the input voltage E_i varies from zero to +5 volts; the output voltage E_o is equal to the input voltage. When the input voltage is greater than +5 volts, the diode is cut off and the output voltage is equal to +5 volts. This type of diode limiter can be used in conjunction with an amplifier as shown in Figure A1.19. Since the summing junction of the amplifier is at virtual ground, the circuit behaves as before. When E_i is between zero and +5 volts, the diode conducts and E_i is applied to R_2 , the input resistor of the amplifier. When E_i is greater than +5 volts, the diode is cut off and +10 volts is applied to R_1 and R_2 which now form the input impedance of the amplifier.

The diode networks can be placed in parallel in the input network of an amplifier as shown in Figure A1.20. The resistor values can be chosen so that each diode network contributes the segment shown in Figure A1.20b. The composite function is the sum of the individual segments and is a straight-line approximation to some desired function. When E_i is at zero volts, all diodes are conducting. As the input voltage increases, the diodes are cut off, one at a time. The equivalent input impedance of the amplifier is increased; the gain of the amplifier is decreased. Note that networks of this type can only generate functions that have a decreasing slope as the input voltage becomes larger.

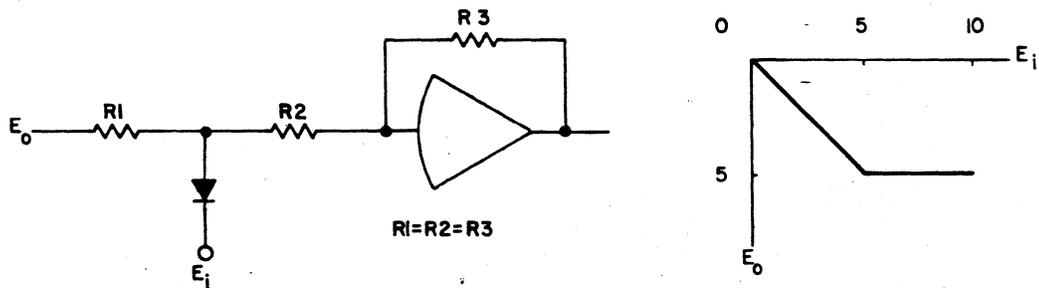


Figure A1.19. Amplifier with Diode Limiter

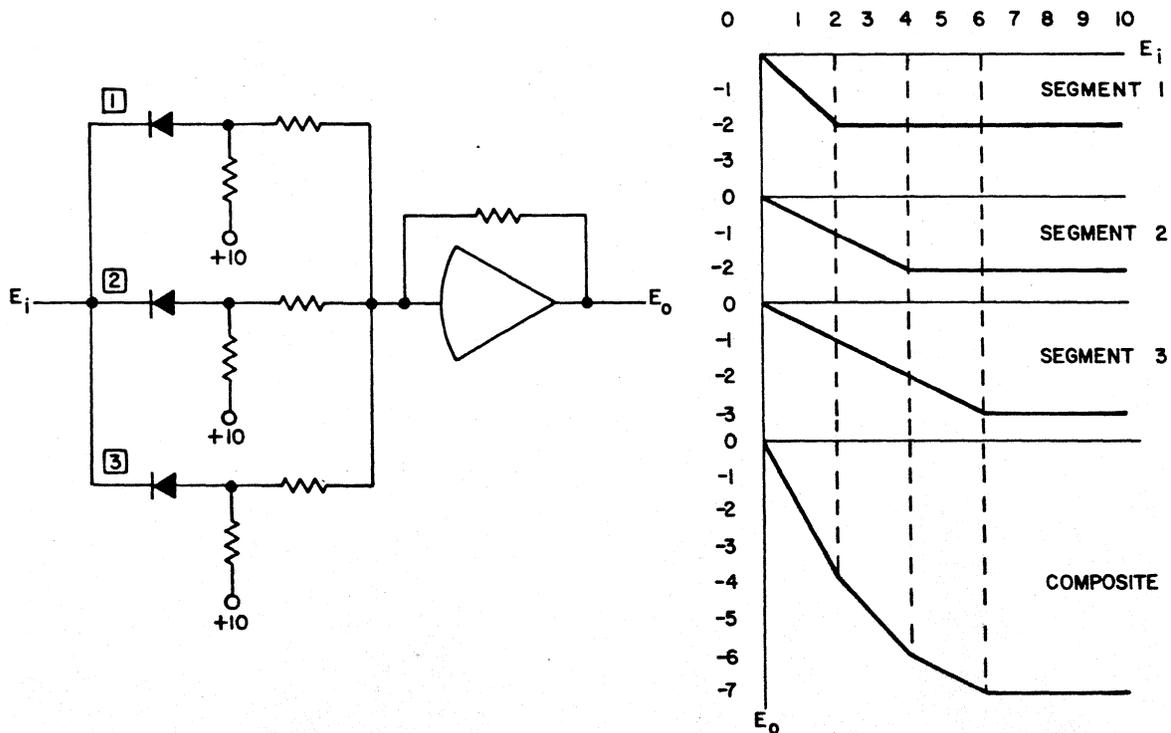


Figure A1.20. A Simple Function Generator

APPENDIX II

SERVICING TECHNIQUES

1. TRANSISTOR SERVICING AND TROUBLESHOOTING TECHNIQUES

Although servicing and troubleshooting procedures applicable to transistor circuits are similar in many ways to the techniques used with vacuum tube circuits, certain differences exist and some extra precautions are necessary when servicing transistor circuits. The following suggestions and techniques are given to aid maintenance personnel who are not familiar with servicing transistorized equipment.

a. Servicing Techniques

Most transistors are mechanically rugged, but they are easily damaged by excessive heat. If it becomes necessary to solder near a socket-mounted transistor, the transistor should be removed to prevent damage. When the transistor is soldered to the board, extreme care should be taken to prevent damage to it from overheating. Always use a small, well-tinned soldering iron and work as quickly as possible.

Transistors and small diodes which are soldered directly to the board should be removed only when there is strong reason to believe they are defective, as they are often over-heated while being removed. When soldering transistors or diodes a heat sink should be used, whenever practicable, on each lead as it is soldered. Holding the lead with a pair of long-nose pliers, or clipping an alligator clip, the jaws of which have been filled with solder, on the lead are two common methods of protecting these semi-conductors from overheating while soldering.

Power transistors, which are usually used in power amplifiers and power supplies, are mounted on metal chassis plates which function as heat sinks to dissipate the heat generated during normal operation. The metal case of a power transistor is usually the collector and is generally operated at some potential other than ground. For this reason they must be mounted so that they are electrically insulated from the heat sink. At the same time, heat from the transistor must be transferred easily to the heat sink. A common method of accomplishing this is to use a mica, anodized aluminum, or fiber glass washer coated with silicone grease. The washer provides electrical insulation, and the silicone grease increases the heat conduction. When replacing a power transistor, use only a single washer, and coat both sides with silicone grease (Dow Corning Number 4 Compound or equivalent). As a final precaution before applying power to the unit, check the resistance between the body of the transistor and the heat sink to ensure that no short or high resistance leakage path exists between these points.

Diodes, electrolytic capacitors, and the transistors themselves used in transistor circuits are easily damaged by voltage overload. For this reason transistors should never be removed or inserted with power applied, and special care must be taken in the selection and use of test equipment. Signal generators commonly used in servicing vacuum tube circuits are often capable of producing enough output to overload and permanently damage the diodes, electrolytic capacitors, and transistors used in transistor circuits. Always start with the minimum output signal and slowly increase it to the desired level.

The meter used for continuity and resistance checks must be chosen carefully. Some ohmmeters use batteries with a voltage higher than the rating of the transistors and capacitors under test and can destroy them. For this reason, a meter with a 1-1/2 volt battery (Triplett, Model 630A or equivalent) is recommended. Determine the polarity of the ohmmeter leads by using another meter set to a low dc range.

The electrolytic capacitors in transistor circuits usually have low rated working voltages and can be damaged by a conventional capacitor tester that employs a high test voltage. If an electrolytic capacitor is suspected of being faulty, disconnect one lead from the circuit and make a resistance check on the unit. Since these units have relatively high capacitance, use the $R \times 10,000$ range of the ohmmeter. When the ohmmeter leads are connected across the capacitor (observe the proper polarity), the meter needle will deflect across the scale and gradually return to the infinite resistance position. The smaller the capacitance, the quicker the return to the infinite resistance position. An open capacitor will not produce a meter deflection. A leaky capacitor will have a finite resistance value and the meter needle will not return to the infinite resistance position. This test can also be employed on ceramic, mica, and paper capacitors. A slight deflection on a high resistance range ($R \times 1$ megohm) will be observed. The lower the capacitance, the smaller the deflection; the test is inconclusive when the capacitance becomes too small.

b. Troubleshooting Techniques

As with any other type of electronic circuit, the first step in troubleshooting transistor circuits is a visual inspection for charred, discolored, or leaky components; broken, shorted, or loose connections; heavily tarnished or broken connectors; and physical damage to the board itself. The next step is to replace any relays, ovens, or choppers, which are socket mounted on the board, with units known to be good. This is done not only because it is fairly easy, but also because each contains mechanical moving parts which may fail due to normal wear. If the trouble is not located by either of these steps, the board may be dynamically tested by applying all supply voltages, a signal input, and then checking voltages and signals on the board until the trouble is isolated. If dynamic testing is impossible due to the lack of suitable test equipment, or availability of "down time" on the equipment in which it is used, the trouble can usually be located through resistance and continuity checks.

Remove all power before making resistance checks. Connect an ohmmeter across the resistors in the circuit and compare the resistance measured with values on the schematic diagram or with values obtained from another unit that operates properly. In many cases, the polarity of the ohmmeter test probes affects the in-circuit resistance measurement; compare measurements made with both polarities. Observe the correct meter polarity when checking electrolytic capacitors.

When the board is removed many components are naturally isolated by the plug or pin connections. Others are effectively isolated by capacitors in series with them. When it becomes necessary to unsolder and lift one end of a component from the board to isolate it for resistance checks, resistors should be chosen whenever possible as they are the component least likely to be damaged by the heat. In many cases, by carefully selecting the correct lead to disconnect, several components may be isolated at one time. It is not usually necessary to risk overheating a transistor by unsoldering it to make resistance checks. For example, lifting one end of the collector load resistor and one end of the emitter resistor would effectively isolate the transistor in a normal transistor amplifier stage.

Once a transistor is isolated, it may be checked using the following procedure:

- (1) Set the ohmmeter to a high range and connect it between the base and the collector leads; reverse the leads and note which connection caused the higher reading. This is the reverse-bias direction.
- (2) Connect the ohmmeter to reverse-bias the transistor and note the reading. Short the base to the emitter. The reading should decrease. Remove the short.
- (3) Move the lead on the base to the emitter and note the reading. Reconnect the short. The reading should increase.

This test will indicate an open or shorted transistor but not a low gain, noisy, or high-leakage transistor. If the transistor is still suspected, and no other troubles are found, substitute one known to be good.

2. ETCHED CIRCUIT BOARD SOLDERING TECHNIQUES

The following suggested procedures are included to aid personnel not familiar with repairing etched circuit boards. The techniques and precautions employed while soldering any electronic equipment still apply, but there are several additional factors to be considered.

Wire leads or components fastened to the board by their leads may be replaced by using the following procedure:

(1) Grip the lead to be removed with a pair of long-nose pliers, (in cases where this is impossible due to short or hidden leads, the component itself must be carefully grasped). While applying pressure to the lead, touch a well-tinned, small (40 watt or less), soldering iron to the fillet. If the lead does not slip out immediately, remove the soldering iron and recheck to be sure the correct fillet is being heated.

(2) Clear the excess solder from the hole by touching the iron to it briefly and either blowing the excess solder out or carefully pushing it out with a soldering aid (GC Electronic Number 9093 or equivalent).

(3) Bend the leads on the new component or jumper to fit the board connections. Insert the component, but *do not* cut the leads.

(4) With the component or jumper held in place, touch the soldering iron to the lead and allow solder to run down the lead and form a fillet. Heat should be applied to the lead only until the fillet has formed. It is not necessary to fill the hole with solder, and some components such as transistors and diodes may be damaged by prolonged application of the soldering iron.

(5) After both leads have been soldered, use a pair of diagonal cutters to cut the lead off as close to the board as possible. Use the soldering aid to carefully scrape any excess flux or solder off the board.

Replacing components such as transistors, relay and chopper sockets, potentiometers, or networks with multiple connections is accomplished in essentially the same manner. Removal of these components is much easier if special tips such as the Ungar Electric Tool Number 856 (5/8" diameter cup) and Number 858 (bar) are used. These tips are used for component *removal* only, and permit all leads to be freed simultaneously.

If the above procedures are strictly adhered to, no trouble with the etched conductor itself should be encountered. If, however, a conductor becomes cracked or broken it may be repaired by carefully soldering a tinned piece of bus wire over it. Again extreme care should be taken not to overheat the strip and cause it to separate from the board.

APPENDIX III

REPLACEABLE PARTS LISTS TR-20 COMPUTER, MODEL 45.078

This appendix contains a Replaceable Parts List for the equipment described in this manual. In each case, a brief description of the part is listed. Where applicable, a reference symbol (schematic designation) is included. To enable a particular sheet to be readily located, an index precedes the individual replaceable parts lists.

The category column in the parts list indicates the availability of each listed part so that a replacement part can be obtained as quickly as possible.

Category "A" - The parts in category "A" are standard electronic items that are usually available from any commercial electronic supplier. In order to expedite obtaining items of this nature, it is suggested that they be purchased from a local source whenever possible. If necessary these parts may be purchased from EAI by specifying the EAI Part Number.

Category "B" - The parts in category "B" are proprietary items that are available only from EAI.

CAUTION

If other than factory parts are used for replacement of Category "B" items, EAI cannot assume the responsibility if a unit does not perform within its published specifications.

ORDERING INFORMATION

In order to enable us to process your requests for spare parts and replacement items quickly and efficiently, we request your conformance with the following procedure:

1. Please specify the type number and serial number of the basic unit as well as the EAI part number and the description of the part when inquiring about replacement items such as potentiometer assemblies or cups, relays, transformers, precision resistors, etc.
2. When inquiring about items such as servo multipliers, resolvers, networks, printed circuit assemblies, etc., please specify the serial numbers of the major equipment with which the units are to be used, such as: Console, Type 8811, Memory Module, Type 4.204, Serial No. 000, etc. If at all possible, please include the purchase order or the EAI project number under which the equipment was originally procured.

Your cooperation in supplying the required information will speed the processing of your requests and aid in assuring that the correct items are supplied.

PLEASE NOTE THAT EAI RESERVES THE RIGHT TO MAKE PART SUBSTITUTIONS WHEN REQUIRED. IN ALL CASES EAI GUARANTEES THAT THESE SUBSTITUTIONS ARE ELECTRICALLY AND PHYSICALLY COMPATIBLE WITH THE ORIGINAL COMPONENT.

PARTS LIST INDEX

TR-20 COMPUTER, MODEL 45.078

<u>Title</u>	<u>Page</u>
45.078 TR-20 Computer (Main Frame Components and Operating Equipment).....	AIII-4
2.127 Dual Function Switch Group	- -
12.264 Function Switch Network	AIII-6
20.366 Function Switches	AIII-7
2.128 Quad Coefficient Potentiometer Setting Group	- -
12.265 Attenuator Network	AIII-8
42.185 Attenuator Panel	AIII-9
2.713 Accessory Installation Variable Diode Function Generator	- -
16.154-1 -Variable Diode Function Generator	AIII-10
16.156-1 +Variable Diode Function Generator	AIII-11
16.310 Variable Diode Function Generator	AIII-12
2.715 Repetitive Operation Accessory Installation	- -
12.1115 Dual Integrator Network	AIII-13
20.532 Repetitive Operation Control	AIII-14
36.082 Timing Unit	AIII-15
2.752 Accessory Installation Variable Diode Function Generator	- -
16.165-1 Variable Diode Function Generator	AIII-17
16.310 Variable Diode Function Generator	AIII-12
6.143 Relay Comparator Amplifier	AIII-18
6.282 Dual DC Amplifier	AIII-20
6.283-4 Dual DC Amplifier	AIII-21

PARTS LIST INDEX (Cont)

<u>Title</u>	<u>Page</u>
6.712 Dual DC Amplifier	AIII-24
6.283-4 Dual DC Amplifier	AIII-21
7.045 $(1/4)^2$ Multiplier	AIII-25
7.044 $(1/4)^2$ Multiplier	AIII-25
7.044-1 $(1/4)^2$ Multiplier (Identical with 7.044 less Item 19)	- -
10.179 Regulated Power Supply	AIII-27
43.107 Power Supply Regulator	AIII-28
12.266 Reference Network	AIII-29
12.267 Tie Point Network	AIII-30
12.987 Display Network	AIII-31
12.1116 Dual Integrator Network	AIII-32
13.017 Audio Overload Alarm	AIII-33
16.101 X^2 Diode Function Generator	AIII-35
16.126 Log X Diode Function Generator	AIII-36
16.133 $1/2$ Log X Diode Function Generator	AIII-37
16.304-1 +Variable Diode Function Generator	AIII-38
16.306-1 -Variable Diode Function Generator (Identical with 16.304-1)	- -
16.308 +Variable Diode Function Generator	AIII-39
20.734 Control Panel	AIII-40
20.738 Overload Indicator	AIII-42
40.538 Electronic Comparator	AIII-43
40.493-1 Electronic Comparator Card	AIII-44
42.183 Attenuators	AIII-47
42.187 Attenuators.....	AIII-48
42.188 Attenuators	AIII-49
43.037 Reference Regulator	AIII-50
45.058 Bus Driver	AIII-51

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode	00 614.0007-0	B
2	DS1	Lamp, Incandescent: 6.3V, 0.15 amps; #47	00 578.0003-0	A
3	NW1	Circuit Module	00 592.0007-0	B
4	R1 thru 20	Resistor, Variable, Composition: 50K ohms $\pm 30\%$, 0.2W (Chicago Telephone Supply Series 70 #HH1860 or equal)	00 642.0351-0	A
5	R21	Resistor, Fixed, Composition: 2.2 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0229-0	A
6	S6	Switch	00 656.0126-0	B
7		Service Shelf	00 051.0039-0	B
8		**Patch Cord Set: c/o Bottle Plug (4 Prong) Bottle Plug (2 Prong) Patch Cord: Black; 6" Patch Cord: Brown; 12" Patch Cord: Orange; 18" Patch Cord: Blue; 30" Receptacle	00 100.0007-0 00 005.0172-0 00 005.0174-0 00 510.0253-0 00 510.0254-0 00 510.0255-0 00 510.0278-0 00 542.0605-0	B B B B B B B B
9		Slave Cable	00 510.0038-0	B
10		Power Cord	00 510.0040-0	B
11		Connector, Receptacle: 22 Contacts; Female (Amphenol 143-022-01 or equal)	00 542.0091-0	A
12		Connector, Receptacle: 4 Contacts; Female (Cinch 261-12-04-010 or equal)	00 542.0158-0	A
13		Connector, Receptacle: 3 Prong; Male (Tower Mfg. Co. H-1061 or equal)	00 542.0888-0	A
14		Connector, Receptacle: 3 Wire Grounding Type; Female (Hubbell 5258 or equal)	00 542.1157-0	A
15		Fuse, Cartridge, Fast Acting: 3/4 amp, 250V (Used on 10.179) (Littelfuse 312.750 or equal)	00 570.0084-0	A

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	<p>UNIT TITLE TR-20 COMPUTER (MAIN FRAME COMPONENTS AND OPERATING EQUIPMENT)</p>
	<p>MODEL NO. 45.078</p>

DATE 4 / 20 / 66

Sh. 1 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
16		Fuse, Cartridge, Slow Acting: 1 amp, 125V (Used on 10.179) (Littelfuse 313001 or equal)	00 570.0111-0	A
17		Diode, Plug-In	00 614.0051-0	B
18		Resistor, Plug-In: 1K ohms $\pm 0.1\%$, 1/8W	00 646.0005-0	B
19		Resistor, Plug-In: 10K ohms $\pm 0.1\%$, 1/8W	00 646.0006-0	B
20		Resistor, Plug-In: 100K ohms $\pm 0.1\%$, 1/8W	00 646.0007-0	B
21		Resistor, Plug-In: 1 Megohm $\pm 0.1\%$, 1/8W	00 646.0008-0	B
22		Nut Driver	00 777.0030-0	B
23		Insert Tool	00 777.0034-0	B
24		Wrench	00 777.0037-0	B
25		Allen Key (1/16")	00 777.0040-0	B
26		Allen Key (3/32")	00 777.0042-0	B

NOTE

**The patch cord set components may be ordered separately as shown or as a complete set by specifying EAI Part Number 00 100.0007-0.

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE TR-20 COMPUTER
(MAIN FRAME COMPONENTS AND OPERATING EQUIPMENT)

MODEL NO.

DATE 4 / 20 / 66

45.078

Sh. 2 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1		Connector Block: Lettered (FUNCT SW 12.264)	00 542.0363-8	B
2		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 FUNCTION SWITCH NETWORK

MODEL NO.
 12.264 Sh. 1 of 1 Sh.

DATE 4 / 20 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	S1,2	Switch, Lever: 3 Locking Positions, Including Neutral Position; 1 Form F Contacts each at Sections C1 and C3 (Gen. Control Co. MCT1-T1-F-0-F-0 or equal)	00 654.0009-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
FUNCTION SWITCHES

MODEL NO.
20.366

DATE 4 / 20 / 66

Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1		Connector Block: Lettered (ATTEN 12.265)	00 542.0363-9	B
2		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 ATTENUATOR NETWORK

MODEL NO.
 12.265

DATE 4 / 20 / 66

Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	CAT.
1	R1,2,3,4	Potentiometer	00 642.0433-0	B
2	S1,2,3,4	Switch	00 656.0010-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 ATTENUATOR PANEL

MODEL NO.
 42.185 Sh. 1 of 1 Sh.

DATE 4 / 20 /66

ITEM	REP. DESIG.	DESCRIPTION	EAI NO.	CAT.
1	CR1 thru 9	Diode	00 614.0007-0	B
2	PP	Connector Block: Lettered (-VDFG 16.154-1)	00 542.0937-8	B
3	R1 thru 4, 6 thru 11, 26	Potentiometer	00 642.0452-0	B
4	R14,16,18, 20,22,24, 27,29,31	Resistor, Precision	00 638.0565-0	B
5	R15	Resistor, Precision	00 638.0556-0	B
6	R17	Resistor, Precision	00 638.0561-0	B
7	R19	Resistor, Precision	00 638.0557-0	B
8	R21	Resistor, Precision	00 638.0562-0	B
9	R23	Resistor, Precision	00 638.0558-0	B
10	R25	Resistor, Precision	00 638.0563-0	B
11	R28	Resistor, Precision	00 638.0559-0	B
12	R30	Resistor, Precision	00 638.0564-0	B
13	R32	Resistor, Precision	00 638.0560-0	B
14	R33	Resistor, Precision	00 638.0476-0	B
15	R34	Resistor, Precision	00 638.0477-0	B
16		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

-VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.

16,154-1 Sh. 1 of 1 Sh.

DATE 4 / 20 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1 thru 9	Diode	00 614.0007-0	B
2	PP	Connector Block: Lettered (-VDFG 16.156-1)	00 542.0937-7	B
3	R1 thru 4, 6 thru 11, 26	Potentiometer	00 642.0452-0	B
4	R14,16,18, 20,22,24, 27,29,31	Resistor, Precision	00 638.0565-0	B
5	R15	Resistor, Precision	00 638.0556-0	B
6	R17	Resistor, Precision	00 638.0561-0	B
7	R19	Resistor, Precision	00 638.0557-0	B
8	R21	Resistor, Precision	00 638.0562-0	B
9	R23	Resistor, Precision	00 638.0558-0	B
10	R25	Resistor, Precision	00 638.0563-0	B
11	R28	Resistor, Precision	00 638.0559-0	B
12	R30	Resistor, Precision	00 638.0564-0	B
13	R32	Resistor, Precision	00 638.0560-0	B
14	R33	Resistor, Precision	00 638.0476-0	B
15	R34	Resistor, Precision	00 638.0477-0	B
16		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

+VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.

16.156-1 Sh. 1 of 1 Sh.

DATE 4 / 20 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	PP	Connector Block: Lettered (VDFG 16.310)	00 542.1225-8	B
3	R13,14	Resistor, Precision	00 638.0764-0	B
4	R15	Resistor, Precision	00 638.0883-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.
16.310 Sh. 1 of 1 Sh.

DATE 4 / 20 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	CAT.
1	C1,3	Capacitor	00 521.0064-0	B
2	C2,4	Capacitor	00 521.0146-0	B
3	CR1,2	Diode	00 614.0007-0	B
4	K1	Relay: 12.6 vdc, 425 ohm Coil, 2 Form C Contacts (C.P. Clare Type F RP-7641-G40 or equal)	00 618.0097-0	A
5	K2	Relay: 26.5 vdc, 600 ohm Coil, 2 Form C Contacts (General Electric 3S2791CC310A21 or equal)	00 618.0188-0	A
6	K3	Relay	00 618.0149-0	B
7	R1 and 2, R3 and 4	Resistor, Precision (Matched Pair)	00 640.0021-0	B
8	XK3	Socket, Tube: 90° Printed Circuit, 9 Contacts (Elco Corp. 05-4008 or equal)	00 650.0075-0	A
9		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
10		Connector Block: Lettered (DUAL NET)	00 542.1260-4	B
11		Connector Block: Lettered (INT 12.1115)	00 542.1260-5	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
DUAL INTEGRATOR NETWORK

MODEL NO.
12.1115 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1	Resistor, Variable, Composition: 20K ohms $\pm 20\%$, 0.2W (Bourns Lab. 276-1-203 or equal)	00 642.0471-0	A
2	R2	Resistor, Variable, Composition: 50K ohms $\pm 20\%$, 0.2W (Bourns Lab. 276-1-503 or equal)	00 642.0472-0	A
3	R3	Resistor, Variable, Composition: 100K ohms $\pm 20\%$, 0.2W (Bourns Lab. 276-1-104 or equal)	00 642.0482-0	A
4	R4	Resistor, Variable, Composition: 200K ohms $\pm 20\%$, 0.2W (Bourns Lab. 276-1-204 or equal)	00 642.0490-0	A
5	R5	Resistor, Precision	00 638.0439-0	B
6	R6	Potentiometer	00 642.0486-0	B
7	R7	Resistor, Fixed, Composition: 4.7K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0472-0	A
8	S1	Switch	00 658.0180-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.	UNIT TITLE REPETITIVE OPERATION CONTROL
	MODEL NO. 20.532

DATE 4 / 21 / 66

Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor	00 521.0077-0	B
2	C2	Capacitor, Fixed, Ceramic: 1 nf ±20%, 1000V (Cornell Dubilier BYA10D1M or equal)	00 515.0005-0	A
3	C3	Capacitor, Fixed, Paper: 0.05 uf ±20%, 200V (Aerovox P8292ZN9 or equal)	00 520.0210-0	A
4	C4	Capacitor	00 516.0198-0	B
5	C5	Capacitor	00 516.0191-0	B
6	CR1 thru 6	Diode (Clevite CTP-462 or equal)	00 614.0043-0	A
7	CR7,8	Rectifier	00 614.0035-0	B
8	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
9	Q1 thru 7	Transistor	00 686.0032-0	B
10	Q8,10	Transistor: 2N321	00 686.0004-0	A
11	Q9,11	Transistor: 2N242	00 686.0018-0	A
12	R1,2	Resistor, Fixed, Composition: 47K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0473-1	A
13	R3	Resistor, Fixed, Composition: 18K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0183-1	A
14	R4	Resistor, Fixed, Composition: 2.2K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0222-1	A
15	R5,13,16	Resistor, Fixed, Composition: 10K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0103-1	A
16	R6,14	Resistor, Fixed, Composition: 15K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0153-1	A
17	R7,18,19, 20	Resistor, Fixed, Composition: 1K ohms ±10%, 1/2W (Allen-Bradley EB or equal)	00 626.0102-1	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

TIMING UNIT

MODEL NO.

DATE 4 / 21 / 66

36.082

Sh. 1 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
18	R8	Resistor, Fixed, Composition: 220K ohms $\pm 10\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0224-1	A
19	R9	Potentiometer	00 642.0476-0	B
20	R10,11	Resistor, Fixed, Composition: 4.7K ohms $\pm 10\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0472-1	A
21	R12	Resistor, Fixed, Composition: 22K ohms $\pm 10\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0223-1	A
22	R15,17	Resistor, Fixed, Composition: 560 ohms $\pm 10\%$, 1W (Allen-Bradley GB or equal)	00 627.0561-1	A
23	R21	Resistor, Fixed, Composition: 100 ohms $\pm 10\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0101-1	A
24	T1	Transformer	00 684.0125-0	B
25		Connector Block: Lettered (TIMING UNIT)	00 542.0371-8	B
26		Connector Block: Lettered (36.082)	00 542.0371-9	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
TIMING UNIT
MODEL NO.
36.082

DATE 4 / 21 /66

Sh.2 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1 thru 10	Diode	00 614.0007-0	B
2	PP	Connector Block: Lettered (±VDFG 16.165-1)	00 542.0937-9	B
3	R1 thru 11, 26	Potentiometer	00 642.0452-0	B
4	R14,16,18, 20,22,27,29, 31,33,35	Resistor, Precision	00 638.0565-0	B
5	R15,36	Resistor, Precision	00 638.0556-0	B
6	R17,34	Resistor, Precision	00 638.0557-0	B
7	R19,32	Resistor, Precision	00 638.0558-0	B
8	R21,30	Resistor, Precision	00 638.0559-0	B
9	R23,28	Resistor, Precision	00 638.0560-0	B
10	R24	Resistor, Precision	00 638.0476-0	B
11	R25	Resistor, Precision	00 638.0477-0	B
12		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.
16.165-1 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode	00 614.0007-0	B
2	CR3	Diode (I.T.T. G187 or equal)	00 614.0043-0	A
3	K1	Relay: 430 ohm Coil, 2 Form C Contacts (General Electric 3S2791G210-A-29 or equal)	00 618.0126-0	A
4	Q1 thru 5	Transistor	00 686.0032-0	B
5	Q6	Transistor: 2N321	00 686.0004-0	A
6	R1	Resistor, Precision	00 638.0288-0	B
7	R2	Resistor, Precision	00 638.0289-0	B
8	R3,4,8	Resistor, Fixed, Composition: 27K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0273-0	A
9	R5	Resistor, Fixed, Composition: 15K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0153-0	A
10	R6,13	Resistor, Fixed, Composition: 47K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0473-0	A
11	R7	Resistor, Fixed, Composition: 4.7K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0472-0	A
12	R9	Resistor, Fixed, Composition: 8.2K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0822-0	A
13	R10	Resistor, Fixed, Composition: 2.2K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0222-0	A
14	R11	Resistor, Fixed, Composition: 12K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0123-0	A
15	R12	Resistor, Fixed, Composition: 100 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0101-0	A
16	XX1	Socket, Relay: 8 Contacts (Viking Ind. Inc. VB8/3DV3 or equal)	00 650.0046-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

RELAY COMPARATOR AMPLIFIER

MODEL NO.

6.143

Sh. 1 of 2 Sh.

DATE 8 / 16 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
17		Connector Block: Lettered (COMP 6.143)	00 542.0363-5	B
18		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
RELAY COMPARATOR AMPLIFIER
MODEL NO.
6,143

DATE 4 / 21 / 66

Sh. 2 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1		Connector Block: Lettered (AMPL)	00 542.0363-3	B
2		Connector Block: Lettered (6.282)	00 542.0940-0	B

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 DUAL DC AMPLIFIER

MODEL NO.
 6.282

DATE 4 / 21 / 66

Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,10	Capacitor	00 516.0273-0	B
2	C2,9,11,18	Capacitor	00 516.0184-0	B
3	C3,12	Capacitor, Fixed, Ceramic: 47 pf $\pm 10\%$, 1000V (Cornell Dubilier LA10Q47-S3 or equal)	00 515.0017-0	A
4	C4,13	Capacitor, Fixed, Ceramic: 20 nf $\pm 10\%$, 75V (Glenco Corp. MIN-M-.02-K or equal)	00 515.0182-0	A
5	C6,15	Capacitor, Fixed, Ceramic: 750 pf $\pm 10\%$, 500V (Solar Mfg. CD8X751K500V or equal)	00 515.0158-0	A
6	C7,16	Capacitor	00 516.0266-0	B
7	C8,17	Capacitor	00 516.0182-0	B
8	C19,20,23, 24,25,26	Capacitor, Fixed, Ceramic: 50 nf $+100\%$ -20%, 30V (Centralab DA-503 or equal)	00 515.0183-0	A
9	C21,22	Capacitor, Fixed, Ceramic: 33 pf $\pm 5\%$, 500V (Solar Mfg. CD17C330J500V or equal)	00 515.0155-0	A
10	CR1 thru 6	Diode	00 614.0007-0	B
11	D1	Chopper	00 530.0042-0	B
12	I1 thru 4	Lamp	00 578.0047-0	B
13	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-23 or equal)	00 542.0419-0	A
14	Q1,2,3,9, 10,11	Transistor	00 686.0242-0	B
15	Q4,12	Transistor	00 686.0091-0	B
16	Q5,13	Transistor	00 686.0039-0	B
17	Q6,7,8,14, 15,16	Transistor	00 686.0032-0	B
18	Q17,18	Transistor	00 686.0255-0	B

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

DUAL DC AMPLIFIER

MODEL NO.

6.283-4 Sh. 1 of 3 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
32	R18,50	Resistor, Fixed, Composition: 2.2K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0222-0	A
33	R19,20,47, 49	Resistor, Fixed, Composition: 220 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0221-0	A
34	R21,22,42, 43	Resistor, Fixed, Composition: 22K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0223-0	A
35	R23,45	Resistor, Fixed, Composition: 120K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0124-0	A
36	R24,44	Resistor, Fixed, Composition: 10 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0100-0	A
37	R25,26,51, 52	Resistor, Fixed, Composition: 68K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0683-0	A
38	R53,54	Resistor, Fixed, Composition: 180K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0184-0	A
39	R55,56	Resistor, Fixed, Composition: 4.7 Megohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0475-0	A
40	R57,58	Resistor, Fixed, Composition: 270K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0274-0	A
41	R59	Resistor, Fixed, Composition: 8.2K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0822-0	A
42	XD1	Socket, Tube: 9 Contacts, 90° Printed Circuit (Elco Corp. 05-4008 or equal)	00 650.0075-0	A
43	XQ1 thru 18	Socket, Transistor: 3 Contacts (Augat Inc. 8069-1G1 or equal)	00 650.0121-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

DUAL DC AMPLIFIER

MODEL NO.

6.283-4

Sh. 3 of 3 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1		Connector Block: Letterd (DUAL DC AMPL 6.712)	00 542.1226-0	B
2		Resistor, Precision (Matched Set)	00 640.0081-0	B

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	UNIT TITLE DUAL DC AMPLIFIER
	MODEL NO. 6.712 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R65	Resistor, Precision	00 638.0244-0	B
2		Connector Block: Lettered (MULT 7.045)	00 542.0363-0	B
3		Connector Block: Lettered (REF)	00 542.0363-1	B
<u>7.044 (1/4)² MULTIPLIER</u>				
1	CR1 thru 14	Diode	00 614.0042-0	B
2	R1,7	Potentiometer	00 642.0457-0	B
3	R2,3,8,9	Potentiometer	00 642.0445-0	B
4	R4,5,6,10, 11,12	Potentiometer	00 642.0444-0	B
5	R13,39	Resistor, Fixed, Composition: 300 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0301-0	A
6	R14,40	Thermistor	00 646.0004-0	B
7	R15,41	Resistor, Fixed, Composition: 12K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0123-0	A
8	R16,42	Thermistor	00 646.0003-0	B
9	R17,43	Resistor, Fixed, Composition: 820K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0824-0	A
10	R18,44	Resistor, Precision	00 638.0282-0	B
11	R19,45	Resistor, Precision	00 638.0283-0	B
12	R20,46	Resistor, Precision	00 638.0284-0	B
13	R21,47	Resistor, Precision	00 638.285-0	B
14	R22,48	Resistor, Precision	00 638.0286-0	B
15	R23,49	Resistor, Precision	00 638.0541-0	B
16	R24,50	Thermistor	00 646.0002-0	B

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
(1/4)² MULTIPLIER
MODEL NO.
7.045 Sh. 1 of 2 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.												
17	R25 thru 36 51 thru 62	Resistor, Precision (Matched Pair) The resistors below are to be matched in pairs as indicated. <table> <tr> <td>R25 and R26</td> <td>R51 and R52</td> </tr> <tr> <td>R27 and R28</td> <td>R53 and R54</td> </tr> <tr> <td>R29 and R30</td> <td>R55 and R56</td> </tr> <tr> <td>R31 and R32</td> <td>R57 and R58</td> </tr> <tr> <td>R33 and R34</td> <td>R59 and R60</td> </tr> <tr> <td>R35 and R36</td> <td>R61 and R62</td> </tr> </table>	R25 and R26	R51 and R52	R27 and R28	R53 and R54	R29 and R30	R55 and R56	R31 and R32	R57 and R58	R33 and R34	R59 and R60	R35 and R36	R61 and R62	00 640.0048-0	B
R25 and R26	R51 and R52															
R27 and R28	R53 and R54															
R29 and R30	R55 and R56															
R31 and R32	R57 and R58															
R33 and R34	R59 and R60															
R35 and R36	R61 and R62															
18	R37 and R38, R63 and R64	Resistor, Precision (Matched Pair)	00 640.0049-0	B												
19		Connector, Plug: 22 Contacts (Amphenol 133-022-23 or equal)	00 542.0419-0	A												

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
(1/4)² MULTIPLIER

MODEL NO.
7.045 Sh. 2 of 2Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,2,3,4	Capacitor	00 516.0253-0	B
2	CR1 thru 12	Rectifier, Silicon: PIV 100V @ 750 MA (Solitron Devices Inc. CER-68 or equal)	00 614.0110-0	A
3	F1,2,3,4	Fuse, Cartridge, Fast Acting: 3/4 amp, 250V (Littelfuse 312.750 or equal)	00 570.0084-0	A
4	F5	Fuse, Cartridge, Slow Acting: 1 amp, 125V (Littelfuse 313001 or equal)	00 570.0111-0	A
5	F6	Fuse, Fast Acting: 1.5 amp, 250V; Visual Window (Bussman GJV1 1/2 or equal)	00 570.0169-0	A
6	Q1,2,3	Transistor: 2N242	00 686.0018-0	A
7	T1	Transformer	00 684.0161-0	B
8	XQ1,2,3	Kit, Transistor Mounting (Bendix Aviation Corp. 210-6500 or equal)	00 650.0104-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.	UNIT TITLE
	REGULATED POWER SUPPLY
	MODEL NO.
DATE 8 / 25 / 67	10.179 Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C7	Capacitor	00 516.0199-0	B
2	C8,9	Capacitor	00 516.0198-0	B
3	CR3	Diode: 1N754	00 614.0046-0	A
4	CR6	Rectifier, Silicon: PIV 100V @750 MA (Solitron Devices Inc. CER-68 or equal)	00 614.0110-0	A
5	Q5	Transistor: 2N1377	00 686.0079-0	A
6	Q6	Transistor	00 686.0028-0	B
7	R15	Resistor, Fixed, Composition: 10K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0103-0	A
8	R16,17	Resistor, Fixed, Composition: 4.7K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0472-0	A
9	R18	Resistor, Fixed, Composition: 470 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0471-0	A
10	R19	Resistor, Fixed, Composition: 1K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0102-0	A
11	R20	Resistor, Fixed, Composition: 560 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0561-0	A
12	R21	Potentiometer	00 642.0443-0	B
13	R24	Resistor, Fixed, Composition: 75 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0750-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
POWER SUPPLY REGULATOR

MODEL NO.
43.107 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	PP	Connector Block: Lettered (REF 12.266)	00 542.0371-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 REFERENCE NETWORK

MODEL NO.
 12.266 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1		Connector Block: Lettered (TIE PT 12.267)	00 542.0371-1	B
<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>			<p>UNIT TITLE TIE POINT NETWORK</p> <hr/> <p>MODEL NO. 12.267</p>	
DATE 4 / 21 / 66			Sh. 1 of 1 Sh.	

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	PP	Connector Block: Lettered (DISPLAY)	00 542.1166-1	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
DISPLAY NETWORK

MODEL NO.
12.987 Sh. 1 of 1 Sh.

DATE 4/ 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1,2	Capacitor	00 521.0064-0	B
2	C3,4	Capacitor	00 516.0183-0	B
3	K1	Relay: 26.5 vdc, 600 ohm Coil, 2 Form C Contacts (General Electric 3S2791GC310A21 or equal)	00 618.0188-0	A
4	K2	Realy: 26.6 vdc, 425 ohm Coil, 2 Form C Contacts (C.P. Clare Type F RP-7641-G40 or equal)	00 618.0097-0	A
5	R1 and 2, R3 and 4	Resistor, Precision (Matched Pair)	00 640.0093-0	B
6	R5	Resistor, Fixed, Composition: 560 ohms \pm 5%, 1/2W (Allen-Bradley EB or equal)	00 626.0561-0	A
7		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
8		Connector Block: Lettered (DUAL NET)	00 542.1260-6	B
9		Connector Block: Lettered (INT 12.1116)	00 542.1260-7	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.	UNIT TITLE
	DUAL INTEGRATOR NETWORK
	MODEL NO.
DATE 8 / 25 / 67	12.1116 Sh.1 of 1Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	CAT.
1	C1	Capacitor	00 516.0182-0	B
2	C2	Capacitor	00 516.0131-0	B
3	C3	Capacitor	00 516.0190-0	B
4	C4	Capacitor, Fixed, Plastic: 0.047 uf $\pm 20\%$, 150V (Gudeman 338Y473M or equal)	00 521.0041-1	A
5	C5	Capacitor	00 516.0183-0	B
6	C6	Capacitor, Fixed, Electrolytic: 50 uf, 25V (Cornell Dubilier NLW50-25 or equal)	00 516.0149-0	A
7	C7	Capacitor, Fixed, Ceramic: 200 nf $+80\%$ -10%, 10V (Centralab UK10-204 or equal)	00 515.0208-0	A
8	CR1	Diode	00 614.0007-0	B
9	CR2	Diode (I.T.T. G187 or equal)	00 614.0043-0	A
10	CR3,4	Rectifier, Silicon: PIV 100V @750 MA (Solitron Devices Inc. CER-68 or equal)	00 614.0110-0	A
11	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
12	Q1,2	Transistor	00 686.0032-0	B
13	Q3	Transistor	00 686.0029-0	B
14	Q4	Transistor: 2N1377	00 686.0079-0	A
15	Q5	Silicon Controlled Switch: 3N60	00 648.0008-0	A
16	R1	Resistor, Fixed, Composition: 4.7K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0472-0	A
17	R2,6	Resistor, Fixed, Composition: 10K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0103-0	A
18	R3	Resistor, Fixed, Composition: 15K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0153-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

AUDIO OVERLOAD ALARM

MODEL NO.

DATE 4 /21 /66

13.017

Sh.1 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
19	R4	Resistor, Fixed, Composition: 560K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0564-0	A
20	R5	Resistor, Fixed, Composition: 62K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0623-0	A
21	R8	Potentiometer	00 642.0475-0	B
22	R9	Resistor, Fixed, Composition: 100 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0101-0	A
23	R10	Resistor, Fixed, Composition: 56K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0563-0	A
24	R11	Resistor, Fixed, Composition: 24 ohms $\pm 5\%$, 2W (Allen-Bradley HB or equal)	00 628.0240-0	A
25	R12	Resistor, Fixed, Composition: 150 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0151-0	A
26	T1	Transformer	00 684.0147-0	B
27	T2	Transformer	00 684.0146-0	B
28		Connector Block: Lettered (13.017)	00 542.0937-0	B
29		Connector Block: Lettered (OVL D ALARM)	00 542.0936-1	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

AUDIO OVERLOAD ALARM

MODEL NO.

13.017

Sh. 2 of 2 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1 thru 14	Diode	00 614.0042-0	B
2	R1,7	Potentiometer	00 642.0457-0	B
3	R2,3,8,9	Potentiometer	00 642.0445-0	B
4	R4,5,6,10, 11,12	Potentiometer	00 642.0444-0	B
5	R13,32	Resistor, Fixed, Composition: 300 ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0301-0	A
6	R14,33	Thermistor	00 646.0004-0	B
7	R15,34	Resistor, Fixed, Composition: 12K ohms $+5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0123-0	A
8	R16,35	Thermistor	00 646.0003-0	B
9	R17,36	Resistor, Fixed, Composition: 820K ohms $+5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0824-0	A
10	R18,37	Resistor, Precision	00 638.0282-0	B
11	R19,38	Resistor, Precision	00 638.0283-0	B
12	R20,39	Resistor, Precision	00 638.0284-0	B
13	R21,40	Resistor, Precision	00 638.0285-0	B
14	R22,41	Resistor, Precision	00 638.0286-0	B
15	R23,42	Resistor, Precision	00 638.0541-0	B
16	R24,43	Thermistor	00 646.0002-0	B
17	R25 thru 30, 44 thru 49	Resistor, Precision	00 638.0280-0	B
18	R31,50	Resistor, Precision	00 638.0281-0	B
19	R51,52,53	Resistor, Precision	00 638.0244-0	B
20		Connector Block: Lettered (X ² DFG 16.101)	00 542.0363-2	B
21		Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

X² DIODE FUNCTION GENERATOR

MODEL NO.

16.101

Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1 thru 12	Diode	00 614.0042-0	B
2	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
3	R1,2,38,39	Potentiometer	00 642.0448-0	B
4	R3,4,40,41	Potentiometer	00 642.0444-0	B
5	R5,42	Potentiometer	00 642.0688-0	B
6	R6,32	Resistor, Precision	00 638.0609-0	B
7	R7,33	Resistor, Precision	00 638.0611-0	B
8	R8,34	Resistor, Precision	00 638.0470-0	B
9	R9,35	Resistor, Precision	00 638.0610-0	B
10	R10,36	Resistor, Precision	00 638.0608-0	B
11	R11,37	Resistor, Precision	00 638.0440-0	B
12	R12,25	Resistor, Precision	00 638.0447-0	B
13	R13,26	Resistor, Precision	00 638.0450-0	B
14	R14,27	Resistor, Precision	00 638.0449-0	B
15	R15,28	Resistor, Precision	00 638.0444-0	B
16	R16,29	Resistor, Precision	00 638.0441-0	B
17	R17,30	Resistor, Precision	00 638.0438-0	B
18	R18,31	Resistor, Precision	00 638.0437-0	B
19	R19,22	Resistor, Variable, Wirewound: 100 ohms $\pm 5\%$, 1W (Int. Resistance Co. Model #100 or equal)	00 642.0571-0	A
20	R20,23	Resistor, Precision	00 638.0439-0	B
21	R21,24	Resistor, Precision	00 638.0376-0	B
22		Connector Block: Lettered (LOG X DFG 16.126)	00 542.0371-2	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
LOG X DIODE
FUNCTION GENERATOR

MODEL NO.
16.126 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1 thru 12	Diode	00 614.0042-0	B
2	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
3	R1,2,38,39	Potentiometer	00 642.0487-0	B
4	R3,4,5,40, 41,42	Potentiometer	00 642.0448-0	B
5	R6,32	Resistor, Precision	00 638.0613-0	B
6	R7,33	Resistor, Precision	00 638.0615-0	B
7	R8,34	Resistor, Precision	00 638.0434-0	B
8	R9,35	Resistor, Precision	00 638.0614-0	B
9	R10,36	Resistor, Precision	00 638.0612-0	B
10	R11,37	Resistor, Precision	00 638.0427-0	B
11	R12,25	Resistor, Precision	00 638.0433-0	B
12	R13,26	Resistor, Precision	00 638.0436-0	B
13	R14,27	Resistor, Precision	00 638.0435-0	B
14	R15,28	Resistor, Precision	00 638.0430-0	B
15	R16,29	Resistor, Precision	00 638.0428-0	B
16	R17,30	Resistor, Precision	00 638.0424-0	B
17	R18,31	Resistor, Precision	00 638.0423-0	B
18	R19,22	Resistor, Variable, Wirewound: 500 ohms $\pm 20\%$, 2W (Chicago Telephone Supply Type #115 or equal)	00 642.0579-0	A
19	R20,23	Resistor, Precision	00 638.0425-0	B
20	R21,24	Resistor, Precision	00 638.0376-0	B
21		Connector Block: Lettered (1/2L X DFG 16.133)	00 542.0371-3	B

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

1/2 LOG X DIODE
FUNCTION GENERATOR

MODEL NO.

16.133

Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1	Diode	00 614.0007-0	B
2	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
3	R1	Potentiometer	00 642.0452-0	B
4	R2	Resistor, Fixed, Film: 21.5K ohms $\pm 1\%$, 1/8W (Int. Resistance Co. CEA-T0 or equal)	00 634.0491-4	A
5	R3	Resistor, Fixed, Film: 29.4K ohms $\pm 1\%$, 1/8W (Int. Resistance CEA-T0 or equal)	00 634.0491-2	A
6	R4	Thermistor: 31.7K ohms $\pm 5\%$, 0.82W @25°C (Keystone Carbon RL-1215-17.6K-118-S1 or equal)	00 646.0072-0	A
7	R5	Resistor, Fixed, Film: 499K ohms $\pm 1\%$, 1/8W (Int. Resistance Co. CEA-T0 or equal)	00 634.0491-1	A
8	R6,8	Resistor, Precision	00 638.0923-0	B
9	R7	Potentiometer	00 642.0453-0	B
10	R9	Resistor, Precision	00 638.0924-0	B
11	R10,11	Resistor, Variable, Wirewound 50K ohms $\pm 5\%$, 1W @50°C (Int. Resistance Co. 100 or equal)	00 642.0692-7	A
12	R12	Resistor, Precision	00 638.0945-0	B
13	R13	Resistor, Fixed, Film: 249K ohms $\pm 1\%$, 1/8W (Int. Resistance Co. CEA-T0 or equal)	00 634.0544-0	A
14		Connector Block: Lettered (VDFG 16.304-1)	00 542.1225-1	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

+VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.

16.304-1 Sh. 1 of 1 Sh.

DATE 8 / 16 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Ceramic: 180 pf $\pm 10\%$, 600V (Erie Resistor 315X5U181K or equal)	00 515.0040-0	A
2	C2	Capacitor, Fixed, Ceramic: 18 pf $\pm 10\%$, 1000V (Cornell Dubilier LA10Q18-SL or equal)	00 515.0013-0	A
3	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
4	PP	Connector Block: Lettered (VDFG 16.308)	00 542.1225-6	B
5	R13,14	Resistor, Precision	00 638.0950-0	B
6	R15	Resistor, Precision	00 638.0944-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

+VARIABLE DIODE FUNCTION
GENERATOR

MODEL NO.

DATE 4 / 21 / 66

16.308

Sh. 1 of 1Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode (I.T.T. G187 or equal)	00 614.0043-0	A
2	M1	Meter	00 590.0032-0	B
3	R1	Resistor, Fixed, Film: 198K ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0064-0	A
4	R2	Resistor, Fixed, Film: 58K ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0098-0	A
5	R3	Resistor, Fixed, Film: 18K ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0097-0	A
6	R4	Resistor, Fixed, Film: 4K ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0096-0	A
7	R5	Resistor, Fixed, Film: 598K ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0099-0	A
8	R6	Resistor, Fixed, Film: 700 ohms $\pm 1\%$, 1/2W (Int. Resistance Co. Type MEC-T2 or equal)	00 634.0339-0	A
9	R7	Resistor, Fixed, Composition: 1K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0102-0	A
10	R8	Resistor, Fixed, Composition: 8.2K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0822-0	A
11	R9	Resistor, Fixed, Composition: 2.2K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0222-0	A
12	R10	Resistor, Variable, Wirewound: 2K ohms $\pm 3\%$, 5W (Helipot Model AR2KL.1 or equal)	00 642.0134-0	A
13	R11	Potentiometer	00 642.0289-0	B
14	R12	Resistor, Fixed, Composition: 100 ohms $\pm 5\%$, 1W (Allen-Bradley GB or equal)	00 627.0101-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

CONTROL PANEL

MODEL NO.

DATE 4 / 19 / 66

20.734

Sh. 1 of 2 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
15	S1	Switch, Rotary: 2 Sections, 3 Poles per Section, 2 to 5 Positions, Non-Shorting (Centralab PA-2021 or equal)	00 658.0023-0	A
16	S2	Switch	00 658.0156-0	B
17	S3	Switch, Toggle: AC Only, DPDT w/Center Off (Cutler Hammer 7563K4 or equal)	00 664.0010-0	A
18	S4	Switch, Toggle: AC Only, SPST (Cutler Hammer 7501K13 or equal)	00 664.0009-0	A
19	S5	Switch, Push (Rocker): DPDT w/Center Off (Cutler Hammer 8132K20E6V51 or equal)	00 656.0075-0	A

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	<p>UNIT TITLE</p> <p>CONTROL PANEL</p>
<p>DATE 4 / 19 / 66</p>	<p>MODEL NO.</p> <p>20.734 Sh. 2 of 2 Sh.</p>

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C1	Capacitor, Fixed, Electrolytic: 0.22 uf <u>+10%</u> , 50V (Kemet KR22C50K or equal)	00 516.0369-0	A
2	CR1	Silicon Controlled Rectifier	00 648.0006-0	B
3	DS1	Lamp, Incandescent: 0.075A, 6.3V, Red Base (Tungsol #2334 or equal)	00 578.0077-0	A
4	R1	Resistor, Fixed, Composition: 2.2K ohms <u>+5%</u> , 1/4W (Allen-Bradley CB or equal)	00 625.0222-0	A

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	UNIT TITLE
	OVERLOAD INDICATOR
	MODEL NO.
DATE 8 16 / 66	20.738 Sh.1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C25,26	Capacitor, Fixed, Ceramic: 220 pf $\pm 10\%$, 600V (Cornell Dubilier LA6T22-S3 or equal)	00 515.0020-0	A
2	J1	Connector Block: Lettered (ELEC COMP 40.538)	00 542.1226-1	B
3	P2	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
4	R22-(1,2), R24-(1,2)	Resistor, Precision (Matched Pair)	00 640.0093-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
ELECTRONIC COMPARATOR

MODEL NO:
40.538 Sh. 1 of 1 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	C2,5,27	Capacitor	00 516.0267-0	B
2	C3,6,28	Capacitor, Fixed, Ceramic: 100 pf $\pm 10\%$, 1000V (Cornell-Dubilier LA10T1-S3 or equal)	00 515.0019-0	A
3	C4	Capacitor, Fixed, Ceramic: 68 pf $\pm 10\%$, 1000V (Cornell Dubilier LA10Q68-S3 or equal)	00 515.0018-0	A
4	C11	Capacitor, Fixed, Ceramic: 470 pf $\pm 10\%$, 600V (Aerovox BCD-DI-1-471K or equal)	00 515.0272-0	A
5	C20	Capacitor, Fixed, Ceramic: 27 pf $\pm 5\%$, 1000V (Sprague 19C420(10TC-Q27) or equal)	00 515.0016-0	A
6	CR1,2	Diode	00 614.0007-0	B
7	CR3,6 thru 10	Diode (I.T.T. G187 or equal)	00 614.0043-0	A
8	CR4	Diode: Zener; 10V $\pm 1\%$, 1/4W (Dickson - 1/4Z10D5 or equal)	00 614.0179-0	A
9	CR5,18	Diode: Zener; 13V $\pm 2\%$, 3/4W (Dickson - 3/4Z13D2 or equal)	00 614.0178-0	A
10	CR12,15	Diode: Matched Quad (General Electric 4-JF4-MQ-2 or equal)	00 614.0203-0	A
11	L1-1,L1-2	Inductor: 240 uh $\pm 5\%$, 1/2WMAX @90°C (Miller 9210-94 or equal)	00 538.0017-0	A
12	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-23 or equal)	00 542.0419-0	A
13	Q1,5	Transistor: 2N964	00 686.0103-0	A
14	Q2	Transistor: 2N3646	00 686.0230-0	A
15	Q3,4	Transistor: 2N1304	00 686.0074-0	A
16	Q6	Transistor	00 686.0120-0	B
17	Q7	Transistor: 2N2276	00 686.0144-0	A
18	Q8	Transistor	00 686.0107-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

ELECTRONIC COMPARATOR CARD

MODEL NO.

40.493-1 Sh. 1 of 3 Sh.

DATE 4 / 21 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
19	R1	Resistor, Fixed, Composition: 36K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0363-0	A
20	R2	Resistor, Fixed, Composition: 6.2K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0622-0	A
21	R3,15,18, 19,20,34	Resistor, Fixed, Composition: 1K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0102-0	A
22	R4	Resistor, Fixed, Composition: 1.5K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0152-0	A
23	R5,10	Resistor, Fixed, Composition: 270K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0274-0	A
24	R6,12	Resistor, Fixed, Composition: 1.8K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0182-0	A
25	R7,9	Resistor, Fixed, Composition: 15K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0153-0	A
26	R11	Resistor, Fixed, Composition: 2.2K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0222-0	A
27	R13	Resistor, Fixed, Composition: 22K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0223-0	A
28	R14	Resistor, Fixed, Composition: 10K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0103-0	A
29	R16,35	Resistor, Fixed, Composition: 100K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0104-0	A
30	R17	Resistor, Fixed, Composition: 3.9K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0392-0	A
31	R26	Resistor, Precision	00 638.0906-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

ELECTRONIC COMPARATOR CARD

MODEL NO.

40.493-1 Sh. 2 of 3 Sh.

DATE 8 / 16 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
32	R27	Resistor, Variable, Wirewound: 50 ohms $\pm 5\%$, 1W (Daystrom Type 25500 or equal)	00 642.0591-0	A
33	R28,30	Resistor, Fixed, Composition: 470 ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0471-0	A
34	R29	Resistor, Precision	00 638.0907-0	B
35	R31	Resistor, Variable, Wirewound: 20 ohms $\pm 5\%$, 1W (Daystrom Type 25500 or equal)	00 642.0592-0	A
36	R36	Resistor, Fixed, Composition: 2K ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0202-0	A
37	R37	Resistor, Fixed, Composition: 15 ohms $\pm 5\%$, 1/4W (Allen-Bradley CB or equal)	00 625.0150-0	A
38	R38	Resistor, Variable, Film: 50 ohms $\pm 30\%$, 1/2W @70°C (Beckman Helipot #62P-R50 or equal)	00 642.0756-0	A
39	XQ1,2,5,6,7	Socket, Transistor	00 650.0162-0	B
40	XQ3,4,8	Socket, Transistor: 3 Contacts (Augat Inc. 8069-1G1 or equal)	00 650.0121-0	A

*NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.	UNIT TITLE
	ELECTRONIC COMPARATOR CARD
	MODEL NO.
DATE 4 / 21 / 66	40.493-1 Sh.3 of 3 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	R1,2	Potentiometer	00 642.0360-0	B
3		Connector Block: Lettered (ATTEN 42.183)	00 542.0366-0	B

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	UNIT TITLE ATTENUATORS
DATE 4 / 21 / 66	MODEL NO. 42.183 Sh. 1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	PP	Connector Block: Lettered (ATTEN 42.187)	00 542.0366-1	B
3	R1,2	Potentiometer	00 642.0360-0	B
4	S1-(a,b), S2-(a,b)	Switch, Sensitive: Single Pole Double Throw 1 Form C Contacts (Micro-Switch LSM22-T or equal)	00 662.0010-0	A

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	UNIT TITLE ATTENUATOR'S
	MODEL NO. 42.187 Sh. 1 of 1 Sh.

DATE 4 / 19 / 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-21 or equal)	00 542.0569-0	A
2	PP	Connector Block: Lettered (ATTEN 42.188)	00 542.0366-2	B
3	R1,2	Potentiometer	00 642.0432-0	B
4	S1-(a,b), S2-(a,b)	Switch, Sensitive: Single Pole Double Throw, 1 Form C Contacts (Micro-Switch 1SM22-T or equal)	00 662.0010-0	A

<p>NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS. A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY. B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.</p>	UNIT TITLE ATTENUATORS
	MODEL NO. 42.188 Sh. 1 of 1 Sh.

DATE 4, 21, 66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
		NOTE		
		If replacement of either the Zener Diode (CR1) or Padder Resistor (R3) is necessary <u>both</u> units must be replaced by a 00 012.0852-0 Network (NW1).		
1	C1	Capacitor	00 516.0198-0	B
2	I1 thru 4	Lamp	00 578.0047-0	B
3	NW1	Network, Zener Resistor	00 012.0852-0	B
4	P1	Connector, Plug: 22 Contacts; Male (Amphenol 133-022-43 or equal)	00 542.0488-0	A
5	Q1	Transistor: 2N242	00 686.0018-0	A
6	Q2	Transistor: 2N1218	00 686.0025-0	A
7	R1	Resistor, Variable, Wirewound: 30 ohms $\pm 10\%$, 0.25W (Bourns 200L-1-500 or equal)	00 642.0074-0	A
8	R2	Resistor, Precision	00 638.0315-0	B
9	R3,8	Resistor, Variable, Composition: 50K ohms $\pm 30\%$ (Chicago Telephone Supply Series 70 H41860 or equal)	00 642.0351-0	A
10	R4,5	Resistor, Precision	00 638.0702-0	B
11	R6	Resistor, Precision	00 638.0243-0	B
12	R7	Resistor, Variable, Wirewound: 250 ohms $\pm 10\%$, 0.25W @70°C (Bourns 271-1-251 or equal)	00 642.0491-0	A
13	R9,10	Resistor, Fixed, Composition: 10K ohms $\pm 5\%$, 1/2W (Allen-Bradley EB or equal)	00 626.0103-0	A
14	R11	Resistor, Fixed, Composition: 1K ohms $\pm 5\%$, 1W (Allen-Bradley GB or equal)	00 627.0102-0	A
15		Connector Block: Lettered (REF 43.037)	00 542.0368-0	B

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE

REFERENCE REGULATOR

MODEL NO.

DATE 4 / 21 / 66

43.037

Sh.1 of 1 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	R1,2	Resistor, Fixed, Composition: 1K ohms <u>+5%</u> , 1/2W (Allen-Bradley EB or equal)	00 626.0102-0	A
2		Transistor: 2N242	00 686.0018-0	A
3		Kit, Transistor Mounting (Bendix Aviation Corp. 210-6500 or equal)	00 650.0104-0	A

NOTE: THE CATEGORY COLUMN IS DESIGNED TO INDICATE AVAILABILITY OF PARTS.
 A - INDICATES PARTS THAT SHOULD BE PURCHASED LOCALLY.
 B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

UNIT TITLE
 BUS DRIVER

MODEL NO.
 45.058

DATE 4 / 21 / 66

Sh. 1 of 1 Sh.

APPENDIX IV

DRAWINGS

TR-20 MAINTENANCE MANUAL

This appendix contains necessary schematics and wiring diagrams of equipment described in this manual. To facilitate locating a particular sheet, an index is provided that lists the model number of each unit or component, the type of drawings, and the associated drawing number. The drawings are bound into the manual in the order listed under the index Drawing Number column.

EAI drawings are prepared in accordance with standard drafting practices for electro-mechanical and electronic equipment. All symbols are in accordance with current government standards.

INDEX

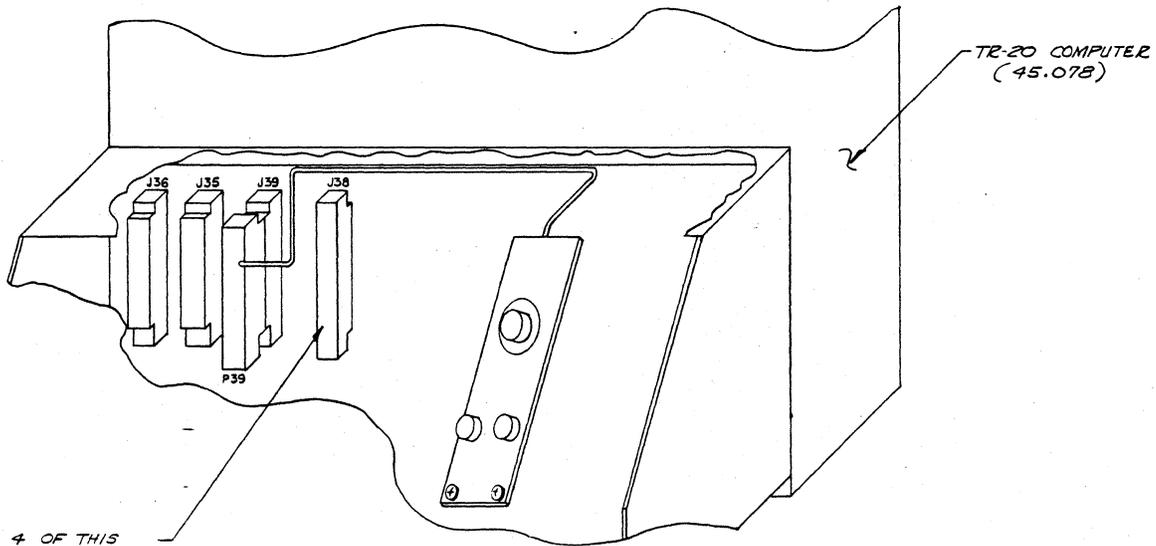
<u>Unit or Component</u>	<u>Type of Drawing</u>	<u>Drawing Number</u>
2.715 Repetitive Operation Group	Assembly	C002 715 0A
2.415 Audio Overload Alarm Expansion	Assembly (W/Wiring Information)	B002 415 0A
2.645-0 Variable DFG Group		
16.304 +Variable DFG	Schematic	B016 304 0S (Sheet 1)
16.308 Readout Module	Assembly	B016 308 0A
16.306 -Variable DFG	Schematic	B016 306 0S (Sheet 1 of 2)
2.713-0 Variable DFG Group		
16.154 -Variable DFG	Schematic	C016 154 0S (Sheet 1 of 2)
16.156 +Variable DFG	Schematic	C016 156 0S (Sheet 1 of 2)
16.310 Readout Module	Assembly	B016 310 0A

DRAWINGS (Cont)

<u>Unit or Component</u>	<u>Type of Drawing</u>	<u>Drawing Number</u>
6.143 Signal Comparator	Schematic	B006 134 OS
6.282 Dual DC Amplifier	Schematic	D006 282 OS
6.712 Dual DC Amplifier	Assembly	C006 712 OA
7.045 Quarter-Square Multiplier	Schematic	C007 044 OS (Sheet 1 of 2)
10.179 Regulated Power Supply	Schematic Wiring	D010 179 OS (Sheet 1) D010 179 OW (Sheets 1 and 2)
12.1115 Rep-Op Integrator Network	Schematic Wiring	B012 1115 OS B012 1115 OW
12.1116 Integrator Network	Schematic Wiring	C012 1116 OS B012 1116 OW
12.987 Readout Module	Assembly	C012 987 OA
13.017 Audio Overload Alarm	Schematic	B013 017 OS
16.101 Dual X ² DFG	Schematic Assembly	C016 099 OS C016 101 OA
16.126 Dual Log X DFG	Schematic	C016 126 OS
16.133 Dual 1/2 Log X DFG	Schematic	C016 133 OS
20.366 Function Switch Panel	Wiring	B020 366 OA
20.532 Repetitive Operation Control Panel	Schematic	C020 532 OS
20.734 Control Panel	Schematic Wiring	C020 734 OS C020 734 OW
20.919 Visual Overload Indica- tor (On Panel 20.738)	Schematic	B020 919 OS
36.082 Timing Unit	Schematic	C036 082 OS
40.538 Electronic Comparator	Schematic	D040 538 OS

DRAWINGS (Cont)

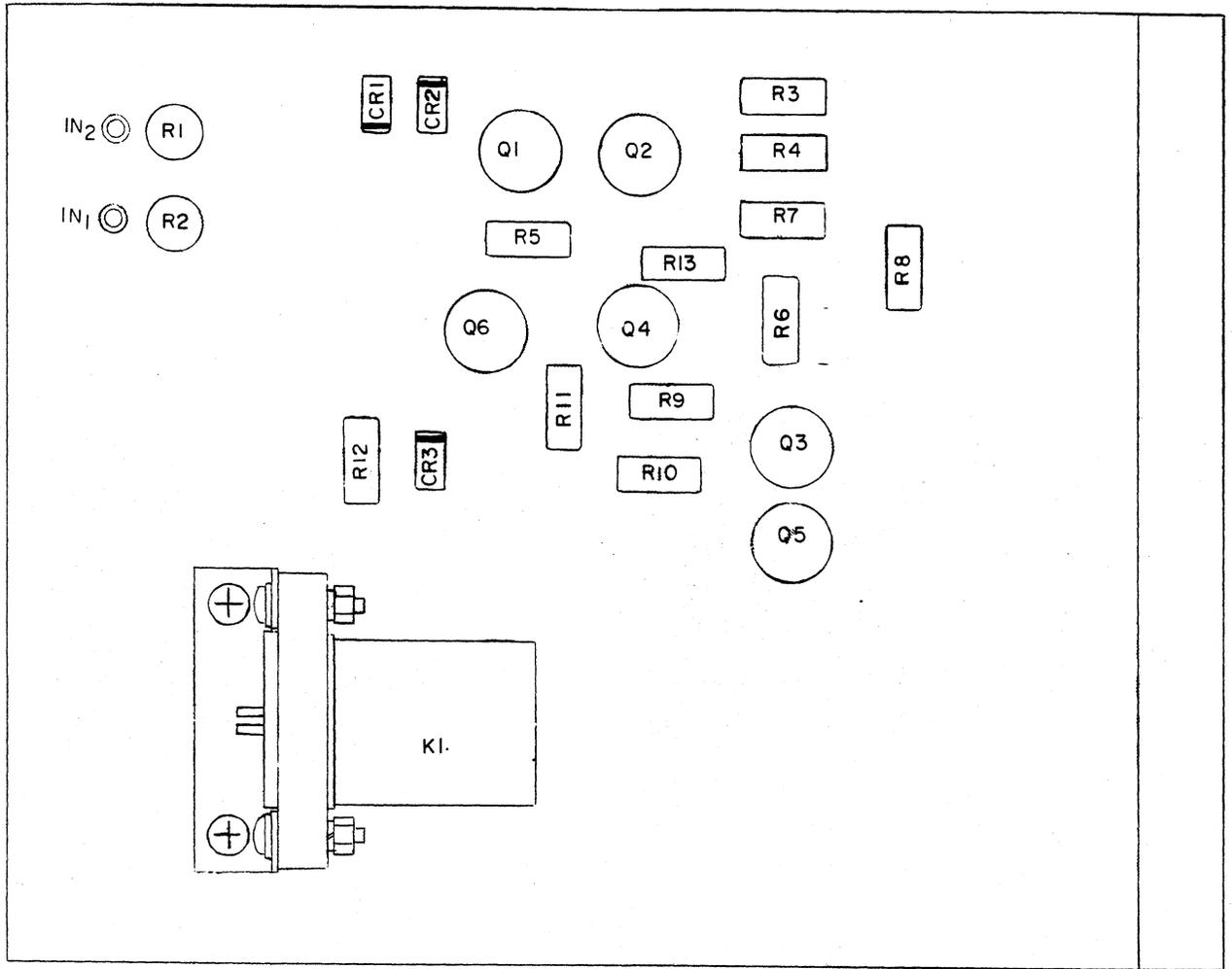
<u>Unit or Component</u>	<u>Type of Drawing</u>	<u>Drawing Number</u>
42.183 Attenuator Panel	Schematic/Wiring	C042 183 OA
42.185 Attenuator Panel	Schematic/Wiring	C042 185 OA
42.187 Attenuator Panel	Schematic/Wiring	C042 187 OA
42.188 Attenuator Panel	Schematic/Wiring	C042 188 OA
42.243 Attenuator Unit	Schematic	B042 243 OS
43.037 Reference Regulator	Schematic	B043 037 OS
45.078 TR-20 Computer Console	Wiring	D045 078 OW (Sheets 2 through 30)
592.007 Power Bus Bypass (NW1)	Schematic/Identi- fication	B592 007 O
Relay Bus Driver	Schematic	A5115



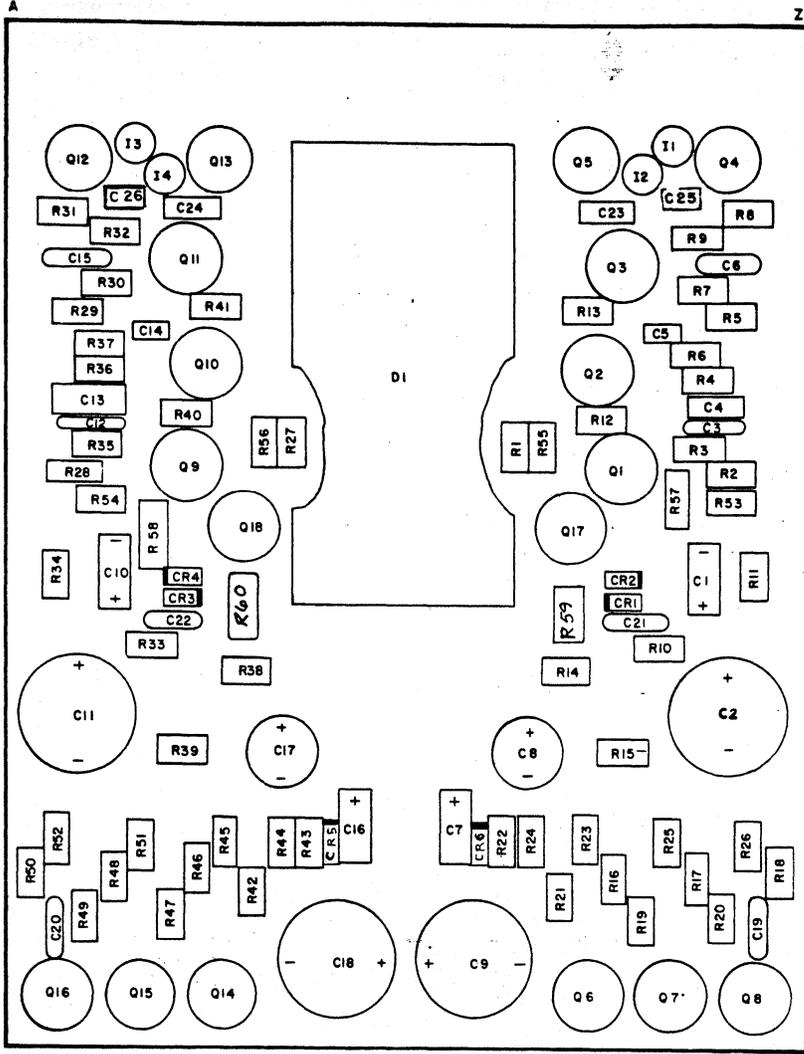
TR-20 COMPUTER
(45.07B)

TIMING UNIT, ITEM 4 OF THIS
ASSEMBLY, PLUGS INTO THIS CONNECTOR
FROM THE REAR OF THE COMPUTER.

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY REPETITIVE OPERATION NECESSARY INSTALLATION	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19066	C002 715 0A
SHEET / OF / SHEETS	



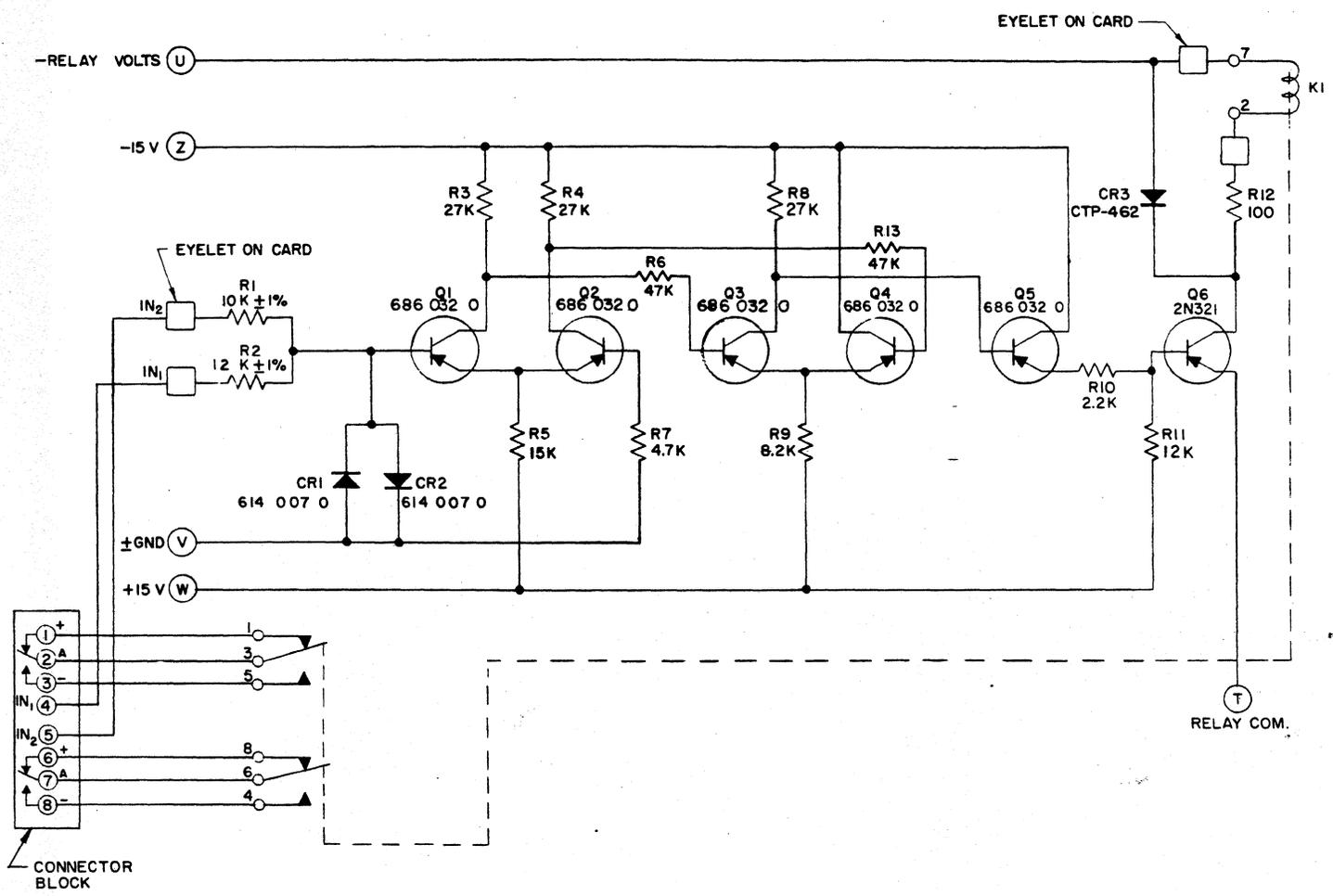
6.134 Relay Comparator



24

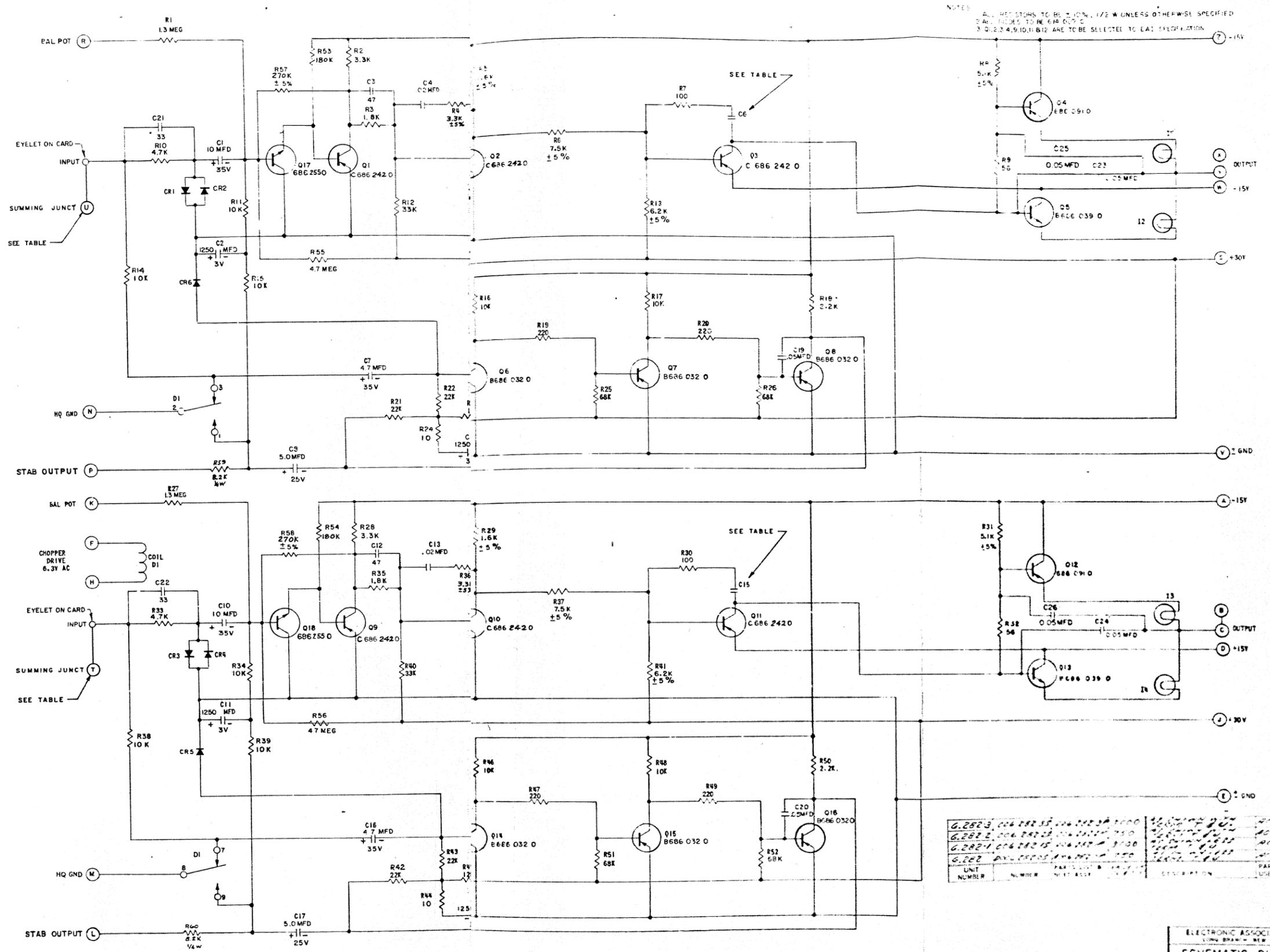
6.283 Dual DC Amplifier

NOTE:
1. ALL RESISTORS ARE 10% 1/2 W UNLESS OTHERWISE SPECIFIED.



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN MMFD
RESISTANCE IS IN OHMS
TOLERANCE ON
FRACTIONS DECIMALS ANGLES
±1/64 ±.005 ±
± TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC RELAY COMPARATOR AMPLIFIER	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1830 B 006 134 OS
SHEET / OF / SHEETS	



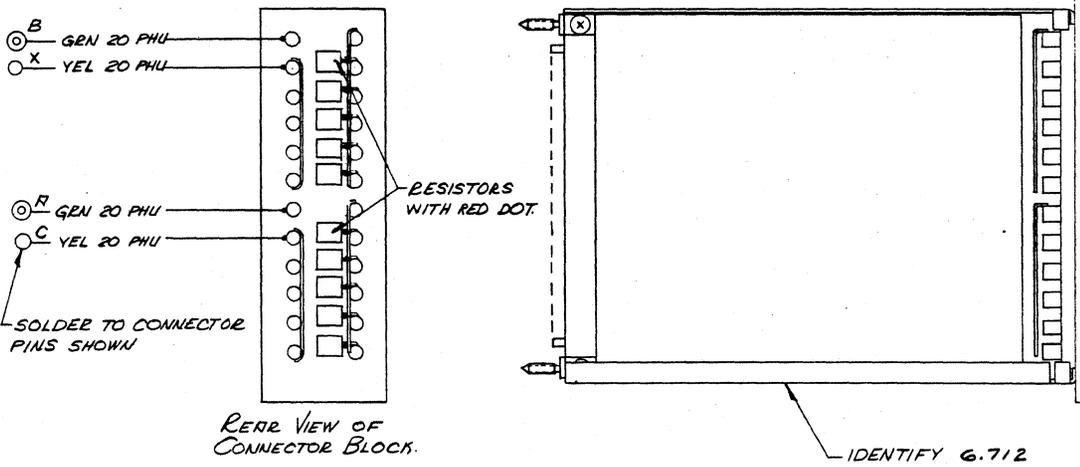
NOTES: ALL RESISTORS TO BE 10% 1/2 W UNLESS OTHERWISE SPECIFIED
 ALL CAPS TO BE 68C 007 C
 3 Q1, 2, 4, 9, 10, 11, 12 ARE TO BE SELECTED TO EAI SPECIFICATION

UNIT NUMBER	PART NUMBER	DESCRIPTION	QUANTITY	USED ON
000528201	000528201	RESISTOR	1	
000528202	000528202	RESISTOR	1	
000528203	000528203	RESISTOR	1	
000528204	000528204	RESISTOR	1	
000528205	000528205	RESISTOR	1	
000528206	000528206	RESISTOR	1	
000528207	000528207	RESISTOR	1	
000528208	000528208	RESISTOR	1	
000528209	000528209	RESISTOR	1	
000528210	000528210	RESISTOR	1	
000528211	000528211	RESISTOR	1	
000528212	000528212	RESISTOR	1	
000528213	000528213	RESISTOR	1	
000528214	000528214	RESISTOR	1	
000528215	000528215	RESISTOR	1	
000528216	000528216	RESISTOR	1	
000528217	000528217	RESISTOR	1	
000528218	000528218	RESISTOR	1	
000528219	000528219	RESISTOR	1	
000528220	000528220	RESISTOR	1	
000528221	000528221	RESISTOR	1	
000528222	000528222	RESISTOR	1	
000528223	000528223	RESISTOR	1	
000528224	000528224	RESISTOR	1	
000528225	000528225	RESISTOR	1	
000528226	000528226	RESISTOR	1	
000528227	000528227	RESISTOR	1	
000528228	000528228	RESISTOR	1	
000528229	000528229	RESISTOR	1	
000528230	000528230	RESISTOR	1	
000528231	000528231	RESISTOR	1	
000528232	000528232	RESISTOR	1	
000528233	000528233	RESISTOR	1	
000528234	000528234	RESISTOR	1	
000528235	000528235	RESISTOR	1	
000528236	000528236	RESISTOR	1	
000528237	000528237	RESISTOR	1	
000528238	000528238	RESISTOR	1	
000528239	000528239	RESISTOR	1	
000528240	000528240	RESISTOR	1	
000528241	000528241	RESISTOR	1	
000528242	000528242	RESISTOR	1	
000528243	000528243	RESISTOR	1	
000528244	000528244	RESISTOR	1	
000528245	000528245	RESISTOR	1	
000528246	000528246	RESISTOR	1	
000528247	000528247	RESISTOR	1	
000528248	000528248	RESISTOR	1	
000528249	000528249	RESISTOR	1	
000528250	000528250	RESISTOR	1	
000528251	000528251	RESISTOR	1	
000528252	000528252	RESISTOR	1	
000528253	000528253	RESISTOR	1	
000528254	000528254	RESISTOR	1	
000528255	000528255	RESISTOR	1	
000528256	000528256	RESISTOR	1	
000528257	000528257	RESISTOR	1	
000528258	000528258	RESISTOR	1	
000528259	000528259	RESISTOR	1	
000528260	000528260	RESISTOR	1	
000528261	000528261	RESISTOR	1	
000528262	000528262	RESISTOR	1	
000528263	000528263	RESISTOR	1	
000528264	000528264	RESISTOR	1	
000528265	000528265	RESISTOR	1	
000528266	000528266	RESISTOR	1	
000528267	000528267	RESISTOR	1	
000528268	000528268	RESISTOR	1	
000528269	000528269	RESISTOR	1	
000528270	000528270	RESISTOR	1	
000528271	000528271	RESISTOR	1	
000528272	000528272	RESISTOR	1	
000528273	000528273	RESISTOR	1	
000528274	000528274	RESISTOR	1	
000528275	000528275	RESISTOR	1	
000528276	000528276	RESISTOR	1	
000528277	000528277	RESISTOR	1	
000528278	000528278	RESISTOR	1	
000528279	000528279	RESISTOR	1	
000528280	000528280	RESISTOR	1	
000528281	000528281	RESISTOR	1	
000528282	000528282	RESISTOR	1	
000528283	000528283	RESISTOR	1	
000528284	000528284	RESISTOR	1	
000528285	000528285	RESISTOR	1	
000528286	000528286	RESISTOR	1	
000528287	000528287	RESISTOR	1	
000528288	000528288	RESISTOR	1	
000528289	000528289	RESISTOR	1	
000528290	000528290	RESISTOR	1	
000528291	000528291	RESISTOR	1	
000528292	000528292	RESISTOR	1	
000528293	000528293	RESISTOR	1	
000528294	000528294	RESISTOR	1	
000528295	000528295	RESISTOR	1	
000528296	000528296	RESISTOR	1	
000528297	000528297	RESISTOR	1	
000528298	000528298	RESISTOR	1	
000528299	000528299	RESISTOR	1	
000528300	000528300	RESISTOR	1	
000528301	000528301	RESISTOR	1	
000528302	000528302	RESISTOR	1	
000528303	000528303	RESISTOR	1	
000528304	000528304	RESISTOR	1	
000528305	000528305	RESISTOR	1	
000528306	000528306	RESISTOR	1	
000528307	000528307	RESISTOR	1	
000528308	000528308	RESISTOR	1	
000528309	000528309	RESISTOR	1	
000528310	000528310	RESISTOR	1	
000528311	000528311	RESISTOR	1	
000528312	000528312	RESISTOR	1	
000528313	000528313	RESISTOR	1	
000528314	000528314	RESISTOR	1	
000528315	000528315	RESISTOR	1	
000528316	000528316	RESISTOR	1	
000528317	000528317	RESISTOR	1	
000528318	000528318	RESISTOR	1	
000528319	000528319	RESISTOR	1	
000528320	000528320	RESISTOR	1	
000528321	000528321	RESISTOR	1	
000528322	000528322	RESISTOR	1	
000528323	000528323	RESISTOR	1	
000528324	000528324	RESISTOR	1	
000528325	000528325	RESISTOR	1	
000528326	000528326	RESISTOR	1	
000528327	000528327	RESISTOR	1	
000528328	000528328	RESISTOR	1	
000528329	000528329	RESISTOR	1	
000528330	000528330	RESISTOR	1	
000528331	000528331	RESISTOR	1	
000528332	000528332	RESISTOR	1	
000528333	000528333	RESISTOR	1	
000528334	000528334	RESISTOR	1	
000528335	000528335	RESISTOR	1	
000528336	000528336	RESISTOR	1	
000528337	000528337	RESISTOR	1	
000528338	000528338	RESISTOR	1	
000528339	000528339	RESISTOR	1	
000528340	000528340	RESISTOR	1	
000528341	000528341	RESISTOR	1	
000528342	000528342	RESISTOR	1	
000528343	000528343	RESISTOR	1	
000528344	000528344	RESISTOR	1	
000528345	000528345	RESISTOR	1	
000528346	000528346	RESISTOR	1	
000528347	000528347	RESISTOR	1	
000528348	000528348	RESISTOR	1	
000528349	000528349	RESISTOR	1	
000528350	000528350	RESISTOR	1	
000528351	000528351	RESISTOR	1	
000528352	000528352	RESISTOR	1	
000528353	000528353	RESISTOR	1	
000528354	000528354	RESISTOR	1	
000528355	000528355	RESISTOR	1	
000528356	000528356	RESISTOR	1	
000528357	000528357	RESISTOR	1	
000528358	000528358	RESISTOR	1	
000528359	000528359	RESISTOR	1	
000528360	000528360	RESISTOR	1	
000528361	000528361	RESISTOR	1	
000528362	000528362	RESISTOR	1	
000528363	000528363	RESISTOR	1	
000528364	000528364	RESISTOR	1	
000528365	000528365	RESISTOR	1	
000528366	000528366	RESISTOR	1	
000528367	000528367	RESISTOR	1	
000528368	000528368	RESISTOR	1	
000528369	000528369	RESISTOR	1	
000528370	000528370	RESISTOR	1	
000528371	000528371	RESISTOR	1	
000528372	000528372	RESISTOR	1	
000528373	000528373	RESISTOR	1	
000528374	000528374	RESISTOR	1	
000528375	000528375	RESISTOR	1	
000528376	000528376	RESISTOR	1	
000528377	000528377	RESISTOR	1	
000528378	000528378	RESISTOR	1	
000528379	000528379	RESISTOR	1	
000528380	000528380	RESISTOR	1	
000528381	000528381	RESISTOR	1	
000528382	000528382	RESISTOR	1	
000528383	000528383	RESISTOR	1	
000528384	000528384	RESISTOR	1	
000528385	000528385	RESISTOR	1	
000528386	000528386	RESISTOR	1	
000528387	000528387	RESISTOR	1	
000528388	000528388	RESISTOR	1	
000528389	000528389	RESISTOR	1	
000528390	000528390	RESISTOR	1	
000528391	000528391	RESISTOR	1	
000528392	000528392	RESISTOR	1	
000528393	000528393	RESISTOR	1	
000528394	000528394	RESISTOR	1	
000528395	000528395	RESISTOR	1	
000528396	000528396	RESISTOR	1	
000528397	000528397	RESISTOR	1	
000528398	000528398	RESISTOR	1	
000528399	000528399	RESISTOR	1	
000528400	000528400	RESISTOR	1	

ELECTRONIC ASSOCIATES INC.
 LONG BRANCH, NEW JERSEY
SCHEMATIC DIAGRAM
DUAL DC AMPLIFIER
 UNIT NUMBER: 1991 0 005 282 OS
 PARTS LIST USED ON

UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 DIMENSIONS IN MILLIMETERS
 FRACTIONS DECIMALS
 1/16 1/8 3/16 1/4 3/8 1/2 5/8 3/4 7/8 1
 1.25 1.5 1.75 2 2.25 2.5 2.75 3 3.25 3.5 3.75 4 4.25 4.5 4.75 5

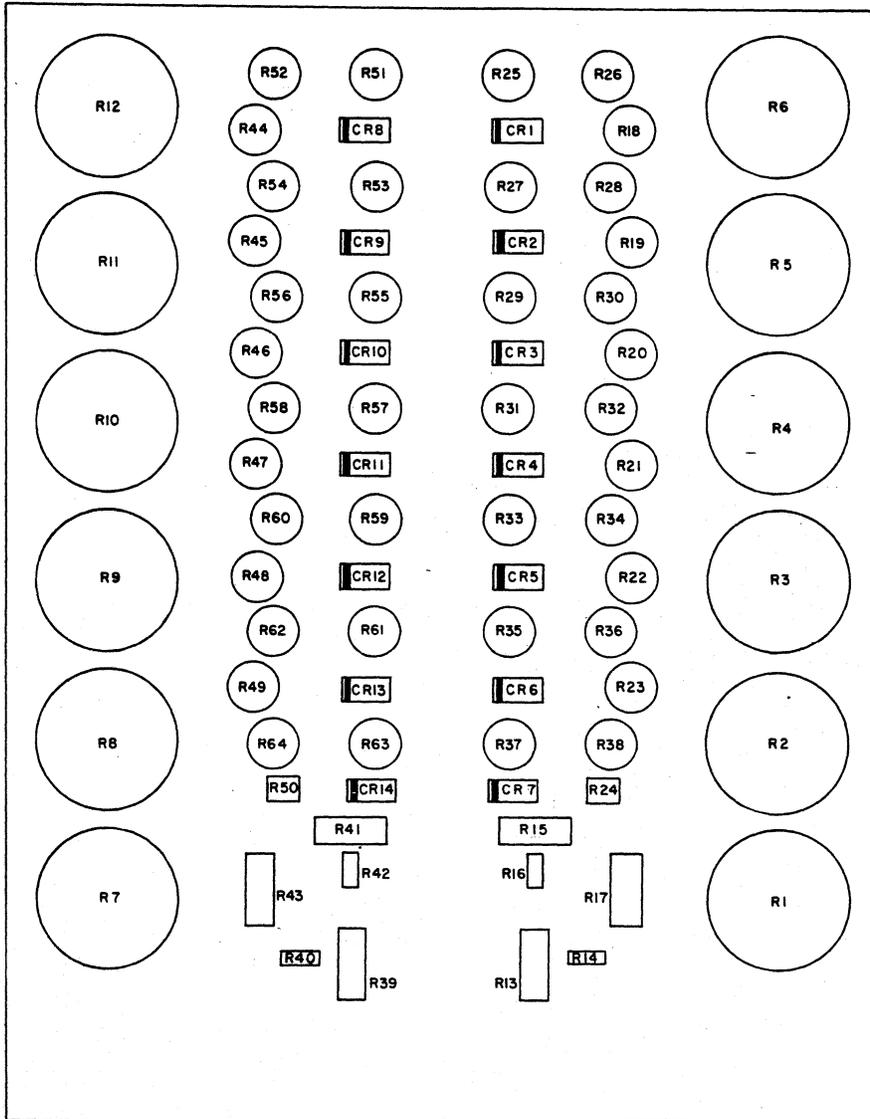
NOTE.
 1. JUMPERS TO BE #20 HD-BUS.



WIRING

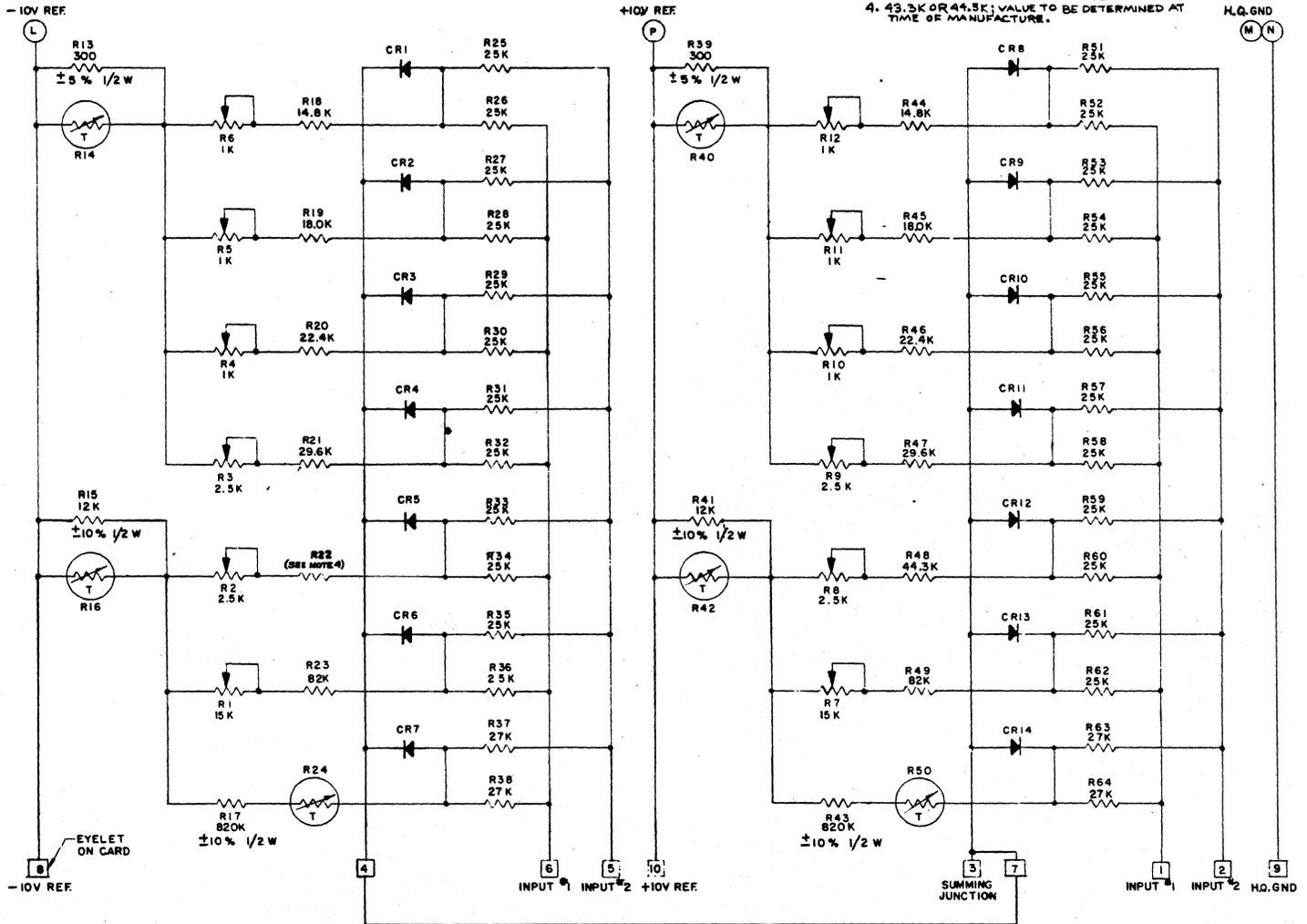
ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
ASSEMBLY	
DUAL D.C. AMPLIFIER	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	5096
	COO6 712 OR
SHEET / OF / SHEETS	

4



7.044 (1/4)² Multiplier

- NOTE:
1. ALL RECTIFIERS TO BE RADIO RECEPTOR *DR-837.
 2. ALL FIXED RESISTORS TO BE $\pm 1\%$, 0.1W UNLESS OTHERWISE SPECIFIED.
 3. RESISTORS IN PAIRS R25 & 26, 27 & 28, 29 & 30, 31 & 32, 33 & 34, 35 & 36, 37 & 38, 51 & 52, 53 & 54, 55 & 56, 57 & 58, 59 & 60, 61 & 62, 63 & 64 TO BE MATCHED TO 0.1% RES. TOL.
 4. 43.3K OR 44.3K; VALUE TO BE DETERMINED AT TIME OF MANUFACTURE.



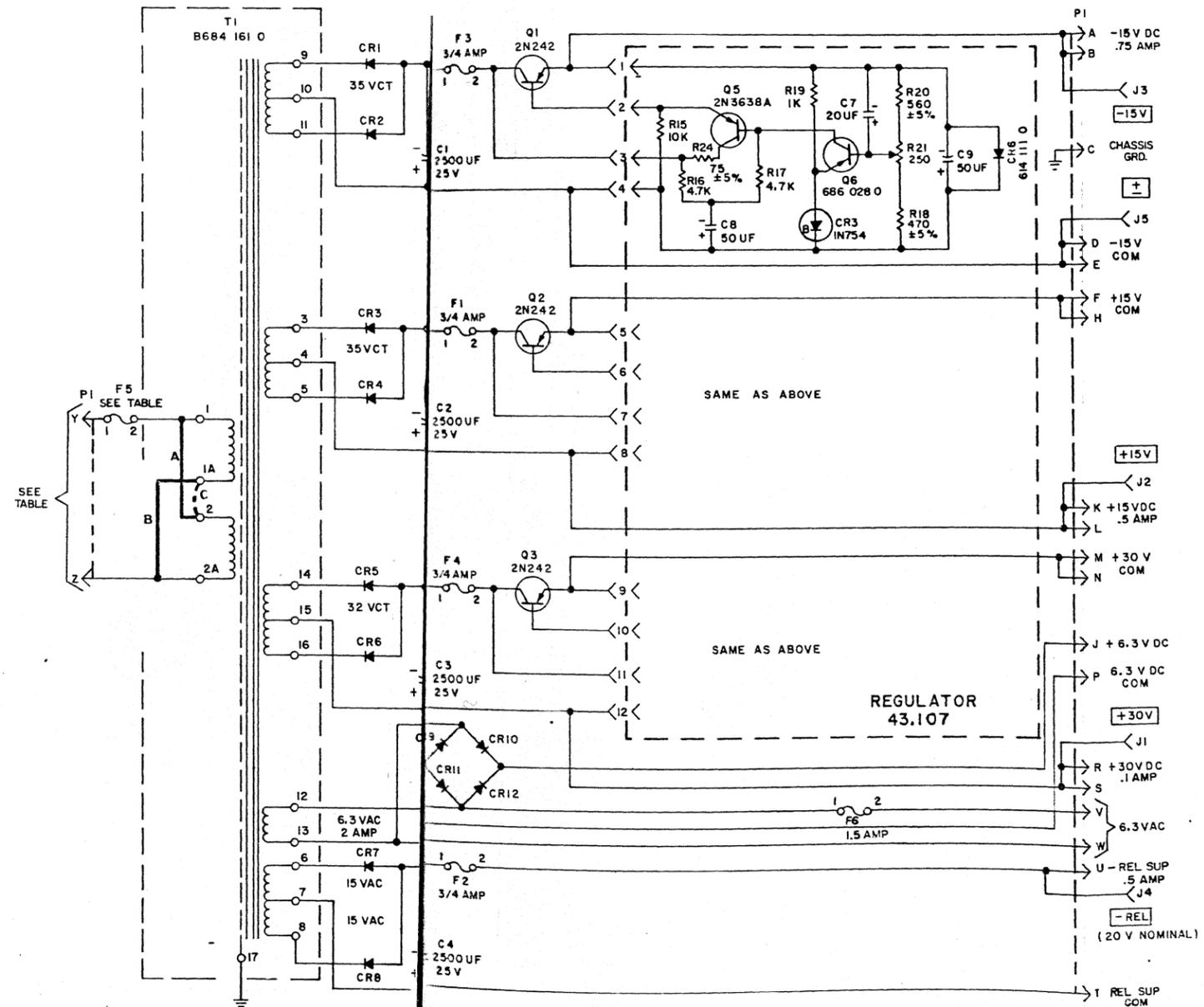
UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON
 FRACTIONS DECIMALS ANGLES
 1/4% 0.001 0.001 0.001
 0.1% 0.001 0.001 0.001
 0.1% 0.001 0.001 0.001

ELECTRONIC ASSOCIATES, INC.
 LONG BRANCH, NEW JERSEY

SCHEMATIC DIAGRAM
(1/4)² MULTIPLIER

SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1830C 007 044 OS
SHEET	OF 1 SHEETS

NOTE
1. UNLESS OTHERWISE SPECIFIED ALL DIODES ARE IN4002 TYPE.

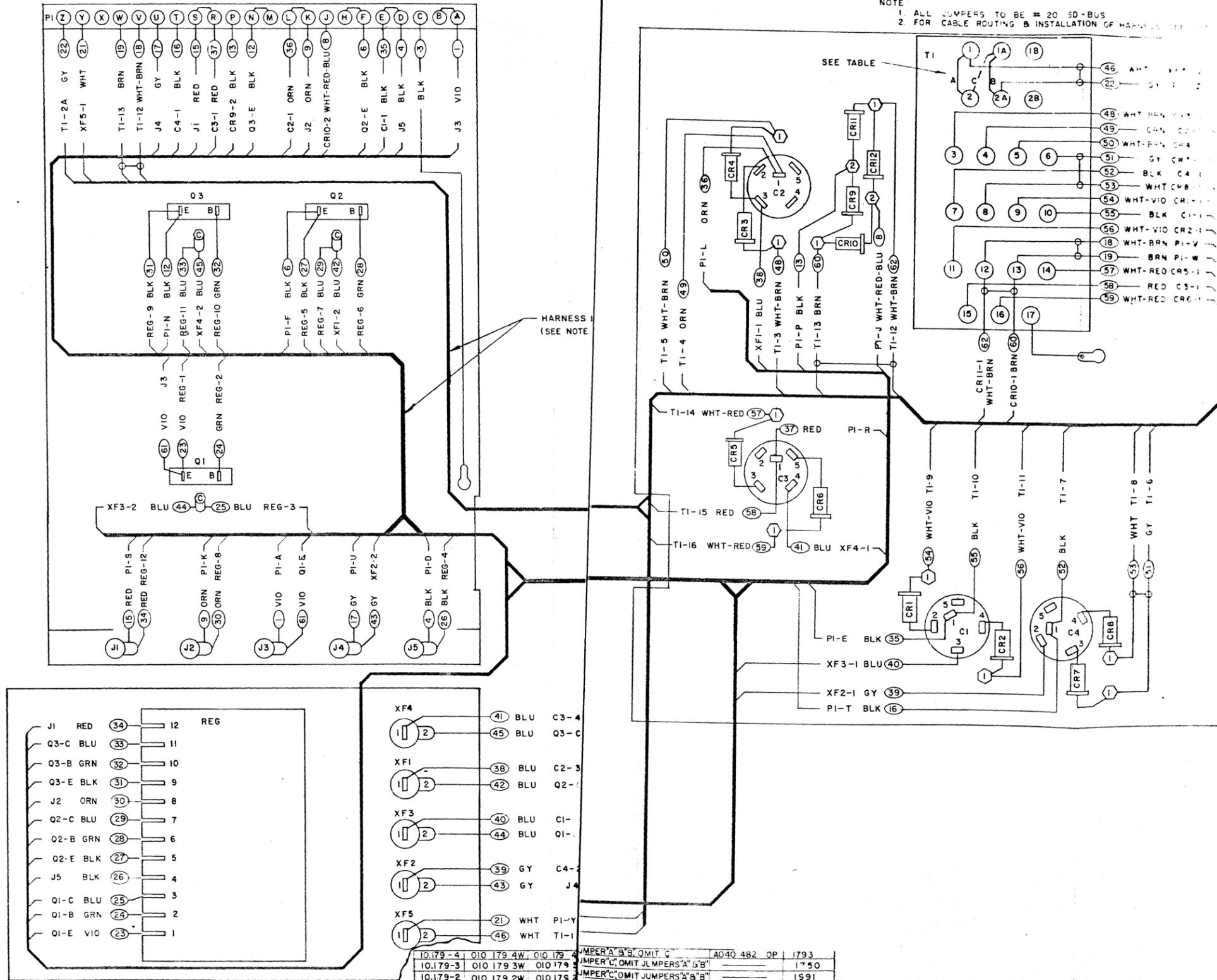


UNIT NUMBER	SCHEMATIC NUMBER	PARTS LIST & NEXT ASSY.	DESCRIPTION	PARTS LIST USED ON	PROJECT NUMBER
10 179-4	10 179 4S	O10 179 4P	SEE SHT 2	A040 482 OP	1793
10 179-3	10 179 3S	O10 179 3P	FOR 220V OPER. USE JUMPER "C"		1750
10 179-2	10 179 2S	O10 179 2P	ONLY, F5 = .5 AMP.		1991
10 179-1	10 179 1S	O10 179 1P	FOR 110V OPER USE JUMPERS "A" & "B" ONLY, F5 = 4 AMP.		1750
10 179	10 179 0S	A010 179 0P		A045 009 OP	1991

TABLE OF UNIT NUMBERS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN MICRO
RESISTANCE IS IN OHMS
TOLERANCE ON
FRACTIONS DECIMALS ANGLES
±.004 ±.005 ±.002
±.004 ±.005 ±.002

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC REGULATED POWER SUPPLY	
SHT. NO.	2
SIZE	D
REV. NO.	2
PROJECT	1091 DO10 179 0S
SHEET	OF 2 SHEETS

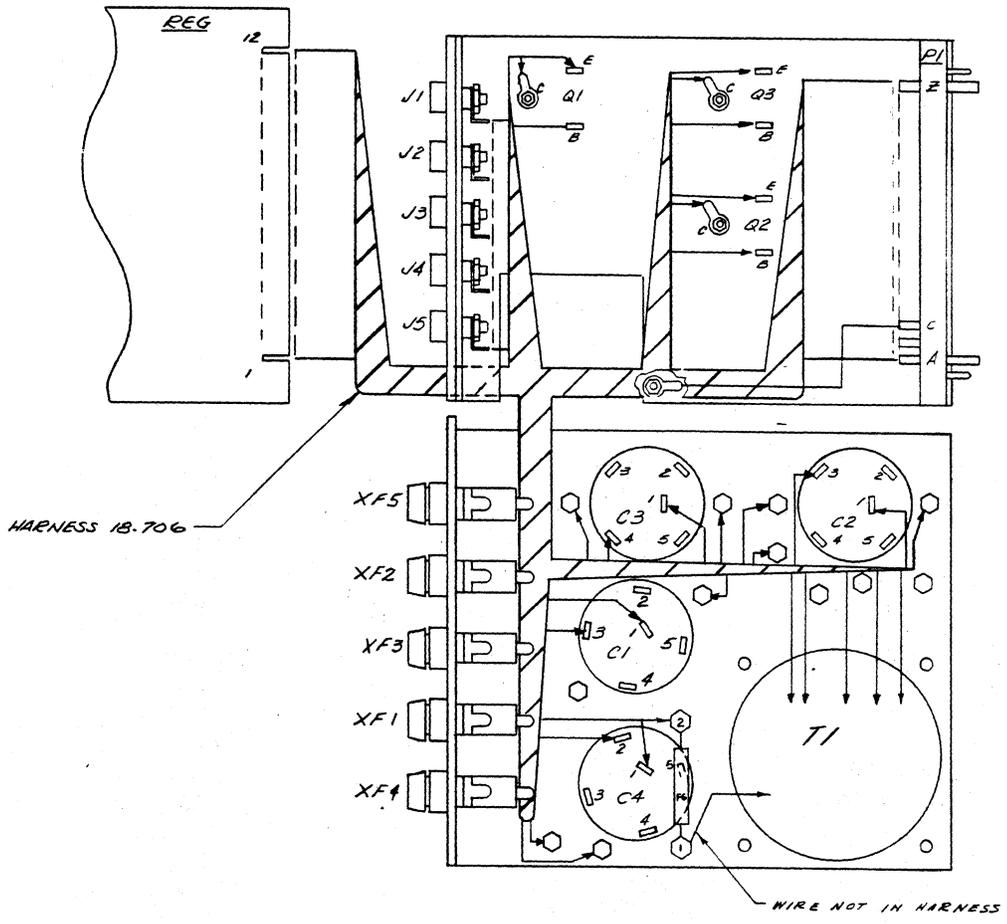


NOTE
 1. ALL JUMPERS TO BE # 20 SD-BUS
 2. FOR CABLE ROUTING & INSTALLATION OF HARNESS

HARNESS 1
 (SEE NOTE)

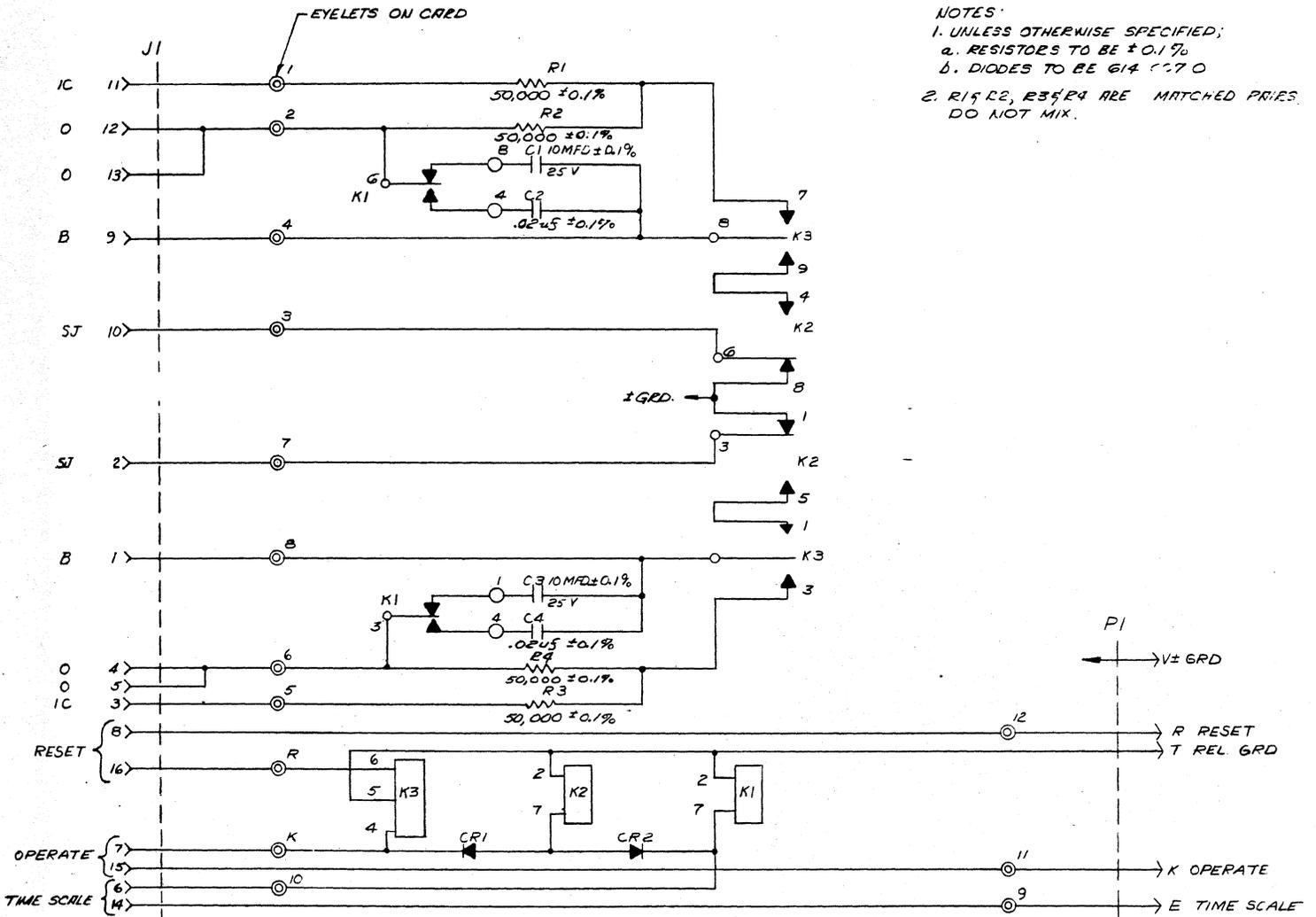
UNIT NUMBER	WIRING NUMBER	PARTS LIST NEXT ASSY	DESCRIPTION	PARTS LIST USED ON	PROJECT NUMBER
10.179-4	010 179 4W	010 179 4	JUMPER 'A', OMIT 'C'	A040 482 OP	1793
10.179-3	010 179 3W	010 179 3	JUMPER 'C', OMIT JUMPERS 'A' & 'B'		1750
10.179-2	010 179 2W	010 179 2	JUMPER 'C', OMIT JUMPERS 'A' & 'B'		1991
10.179-1	010 179 1W	010 179 1	JUMPERS 'A', 'B', OMIT 'C'		1750
10.179	010 179 0W	010 179 0	JUMPERS 'A', 'B', OMIT 'C'	A045 009 OP	1991

UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MICRO
 RESISTANCE IS IN OHMS
 FRACTIONAL DECIMALS ANALOG
 1/16 1/32 1/64
 2 3 4
 5 6 7 8 9 10 11 12
 13 14 15 16 17 18 19 20 21 22
 23 24 25 26 27 28 29 30 31 32
 33 34 35 36 37 38 39 40 41 42
 43 44 45 46 47 48 49 50 51 52
 53 54 55 56 57 58 59 60 61 62
 63 64 65 66 67 68 69 70 71 72
 73 74 75 76 77 78 79 80 81 82
 83 84 85 86 87 88 89 90 91 92
 93 94 95 96 97 98 99 100



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	C 010 179 OW
SHEET 2 OF SHEETS	

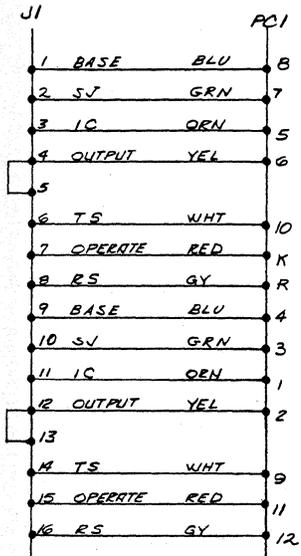
UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN P.F.
 RESISTANCE IS IN OHMS
 TOLERANCE OF: ±0.25% ±0.50% ±1.00%
 ±0.1% ±0.2% ±0.5% ±1.0%
 *TOL. BY MATERIAL SUPPLIED



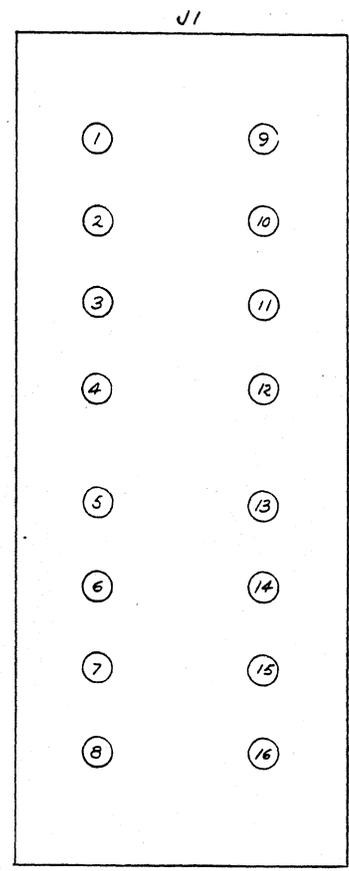
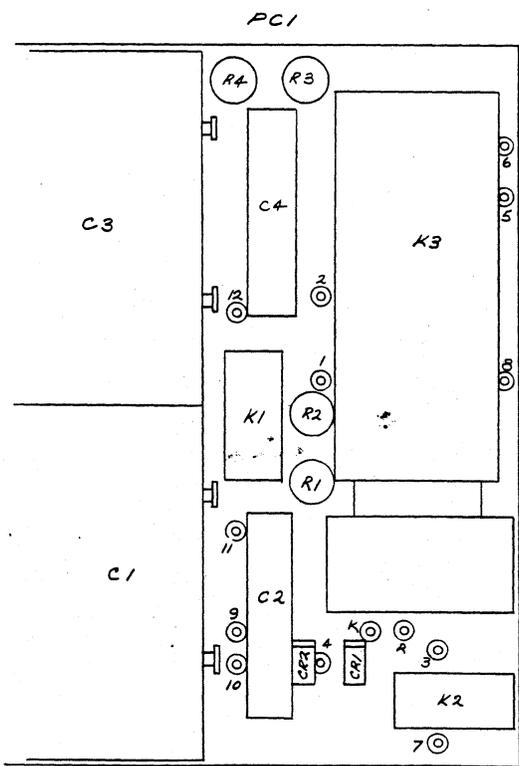
- NOTES:
1. UNLESS OTHERWISE SPECIFIED;
 2. RESISTORS TO BE ±0.1%
 3. DIODES TO BE 614 127 O
 4. R1, R2, R3, R4 ARE MATCHED PAIRS. DO NOT MIX.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN µF
RESISTANCE IS IN OHMS
TOLERANCE IS
FRACTIONS DECIMALS PERCENT
& 1/4 1/2 3/4 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC DUAL INTEGRATOR NET	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 1906B	C012 1115 05
SHEET 1 OF 7 SHEETS	



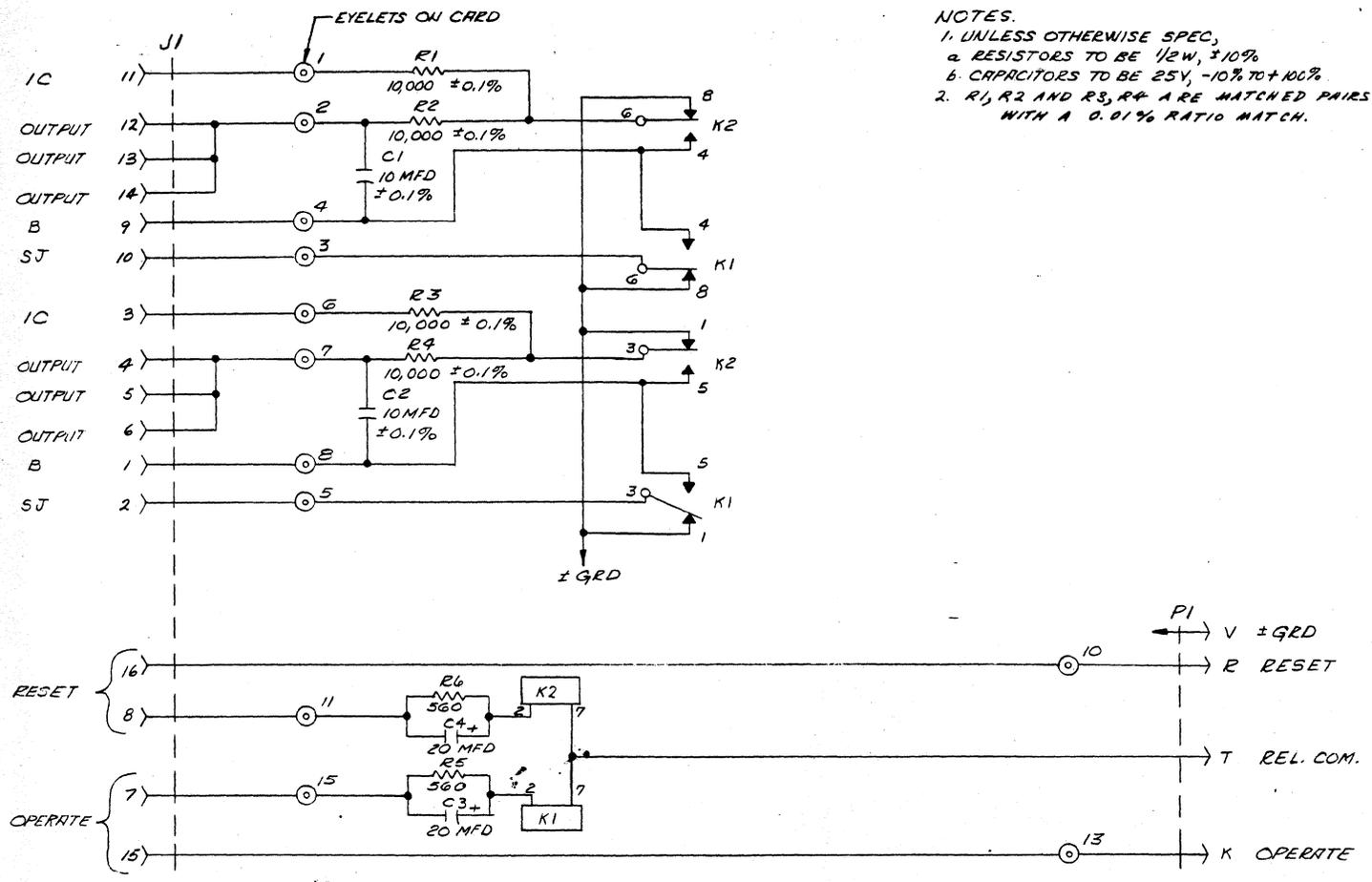
NOTES
 1. UNLESS OTHERWISE SPECIFIED,
 a. JUMPERS TO BE #20 SD-BUS
 b. WIRING TO BE #22 PHU



REAR VIEW

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
WIRING INTEGRATOR NETWORK	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19068	CO12 1115 OW
SHEET 7 OF 7 SHEETS	

NOTES.
 1. UNLESS OTHERWISE SPEC,
 a. RESISTORS TO BE 1/2W, ±10%
 b. CAPACITORS TO BE 25V, -10% TO +100%
 2. R1, R2 AND R3, R4 ARE MATCHED PAIRS
 WITH A 0.01% RATIO MATCH.



12.1116 / 012.1116.15	012.1116.1P AS SHOWN EXCEPT R1,2,3,4 ARE 2K	A1020 Q5 OP (CAL) EBN1799D
12.1116	012.1116.0S AS SHOWN	3045 078 OP 1906B
UNIT NUMBER	PARTS LIST & NEXT ASSY	DESCRIPTION
		PARTS LIST USED ON
		PROJECT NUMBER

TABLE OF UNIT NUMBERS

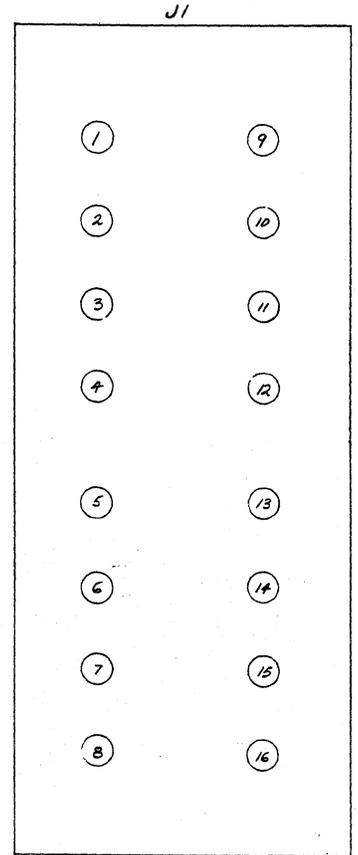
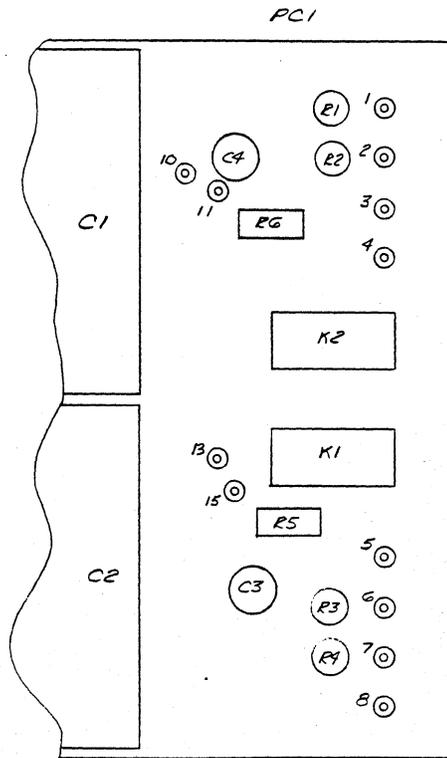
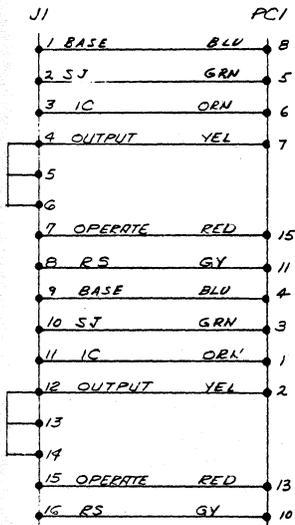
UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN μF
 RESISTANCE IS IN OHMS
 TOLERANCE ON FRACTIONS DECIMALS ANGLES
 ±.15% ±.001 ±

ELECTRONIC ASSOCIATES, INC.
 LONG BRANCH, NEW JERSEY

SCHEMATIC INTEGRATOR NET.

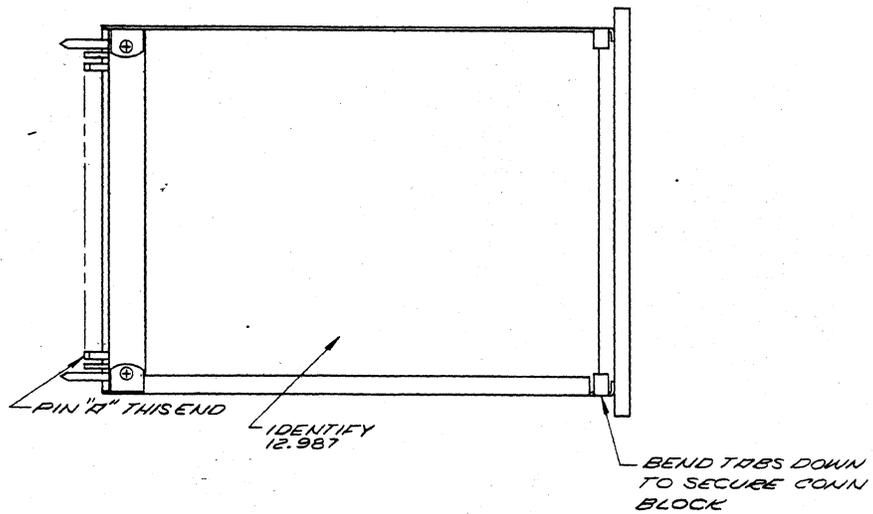
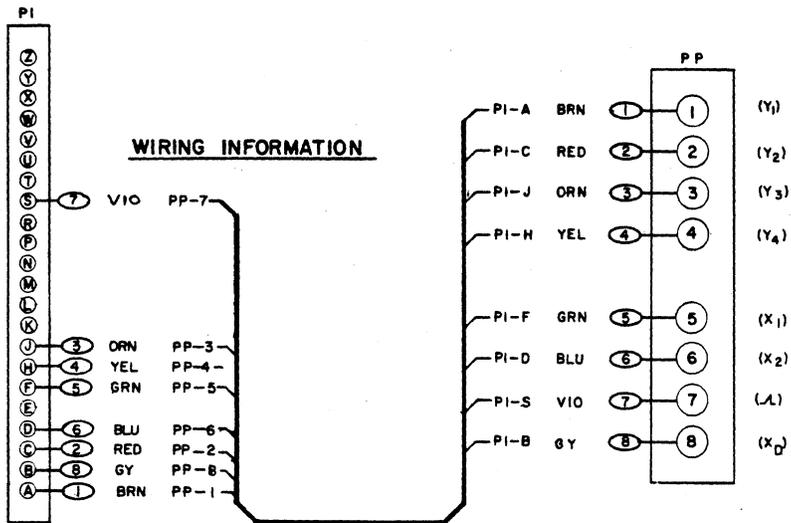
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	CO12 1116 0S
SHEET / OF SHEETS	

NOTES:
 1. UNLESS OTHERWISE SPECIFIED;
 a. WIRING TO BE #22 PHU.
 b. JUMPERS TO BE #20 SD-BUS

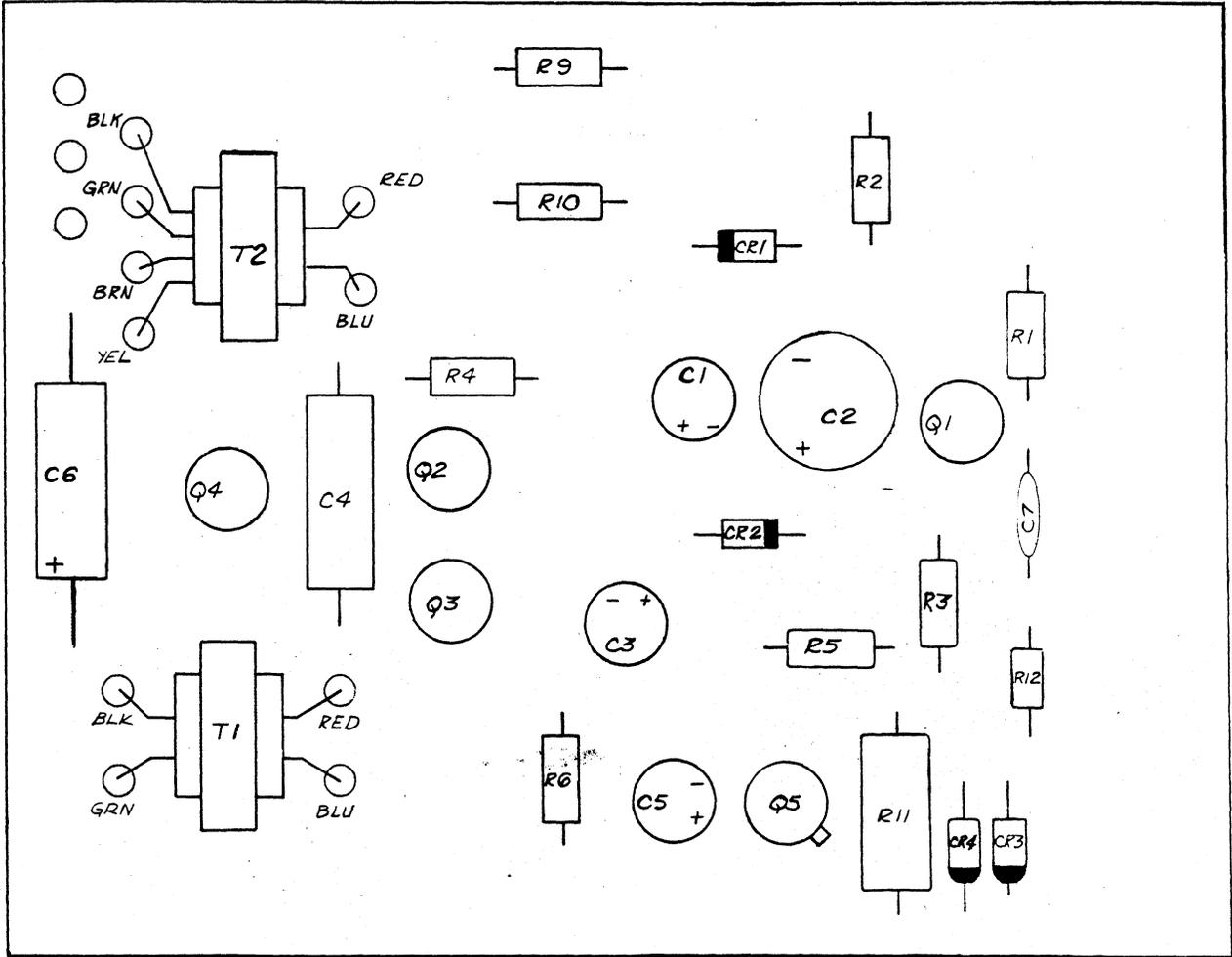


REAR VIEW

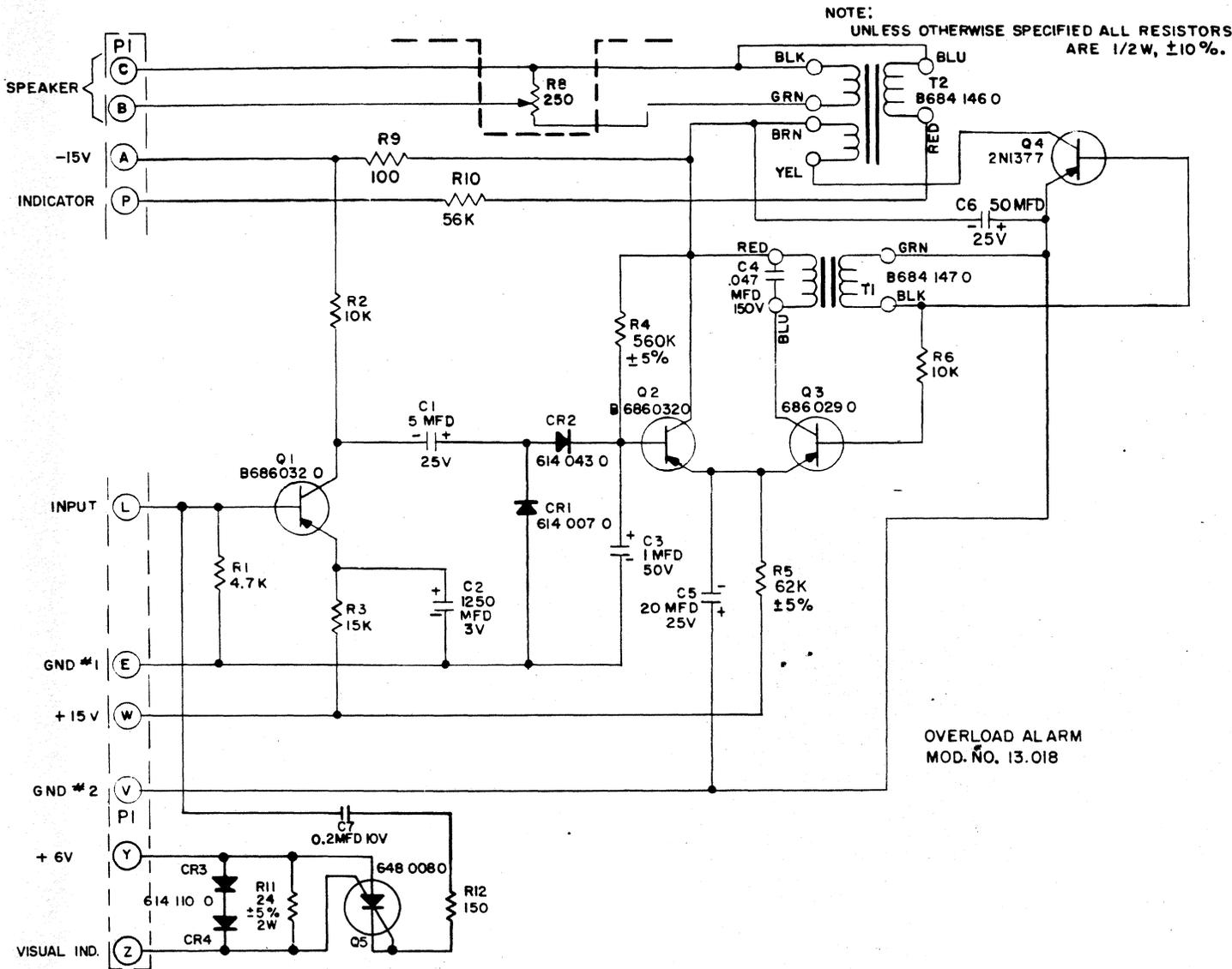
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
WIRING INTEGRATOR NETWORK	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19062	CO12 1116 0W
SHEET / OF / SHEETS	



ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
ASSEMBLY DISPLAY NET	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19006 C 012 987 OA
SHEET 1 OF 1 SHEETS	

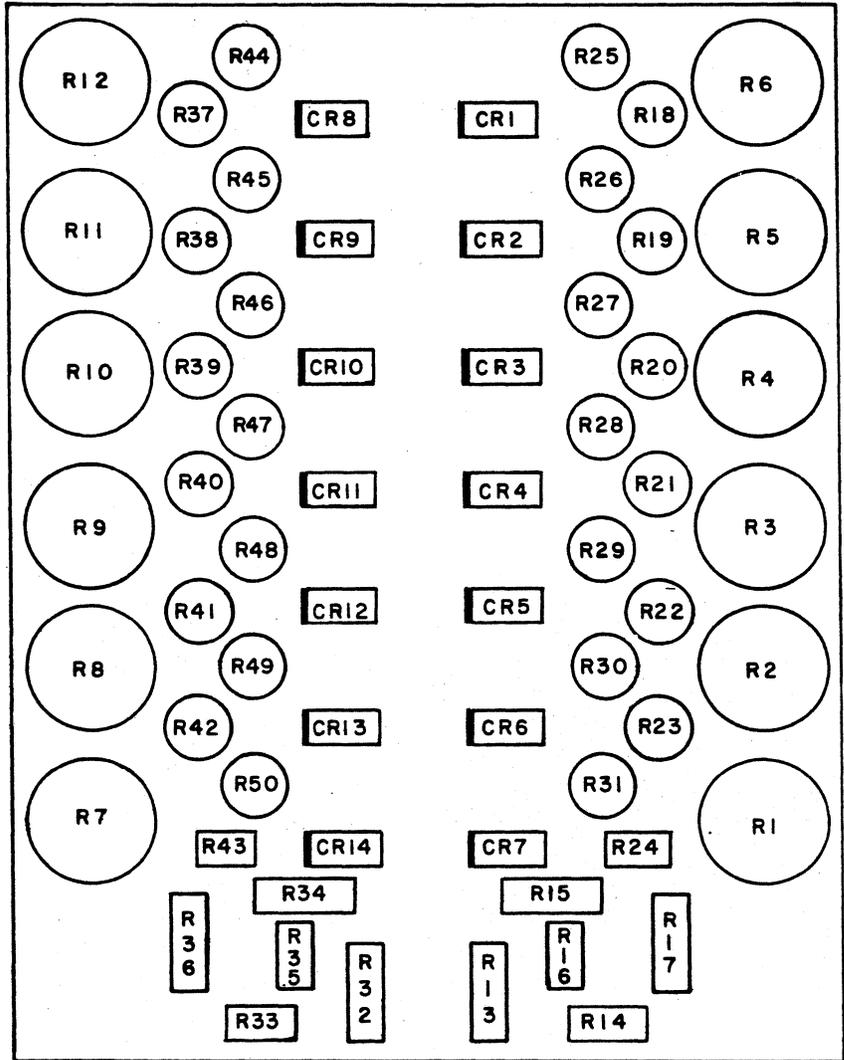


13.018 Overload Alarm



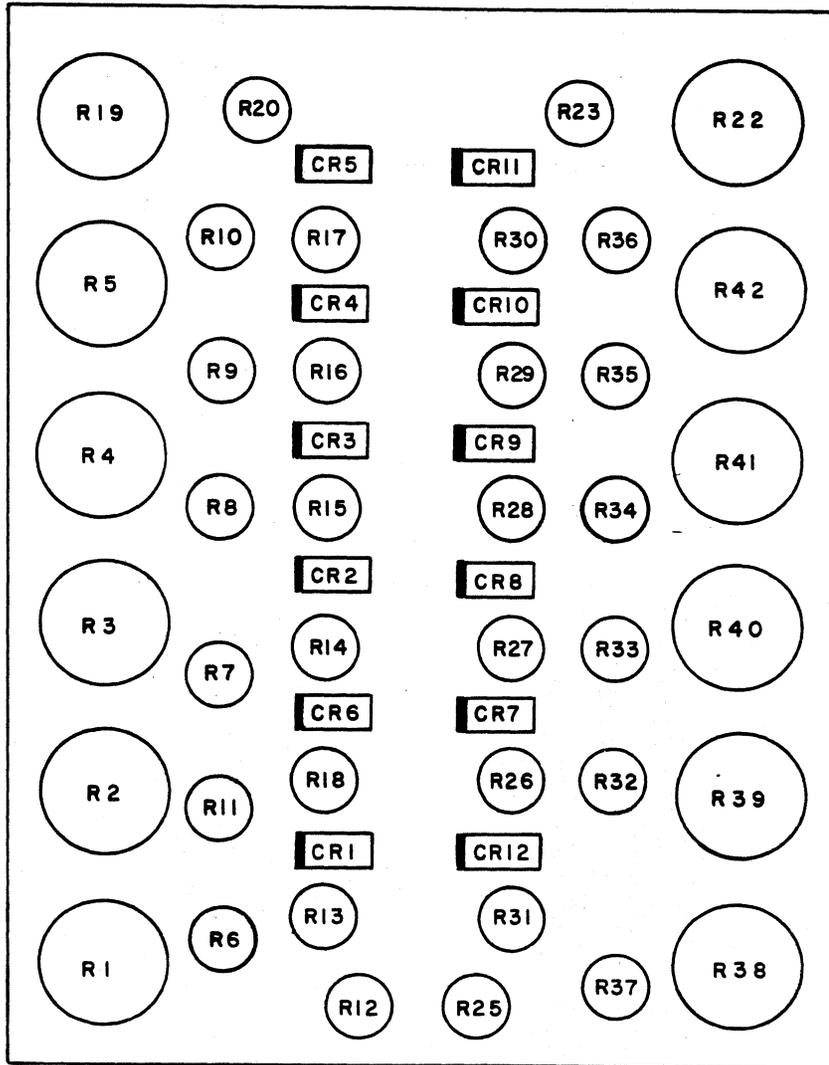
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN MMFD
RESISTANCE IS IN OHMS
TOLERANCE ON -
FRACTIONS DECIMALS ANGLES
1/8 2.005 2
* TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC OVERLOAD ALARM	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1841 B 013 017 OS
SHEET 1 OF 1 SHEETS	

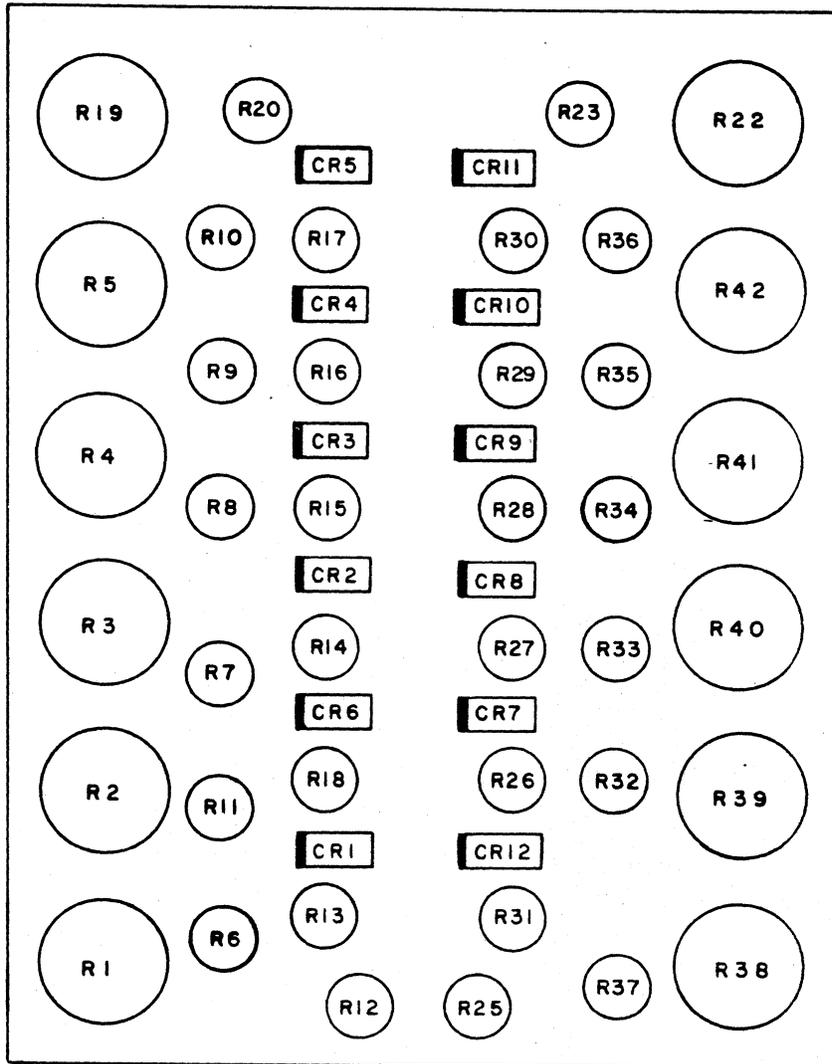


PLUG-IN END OF CARD

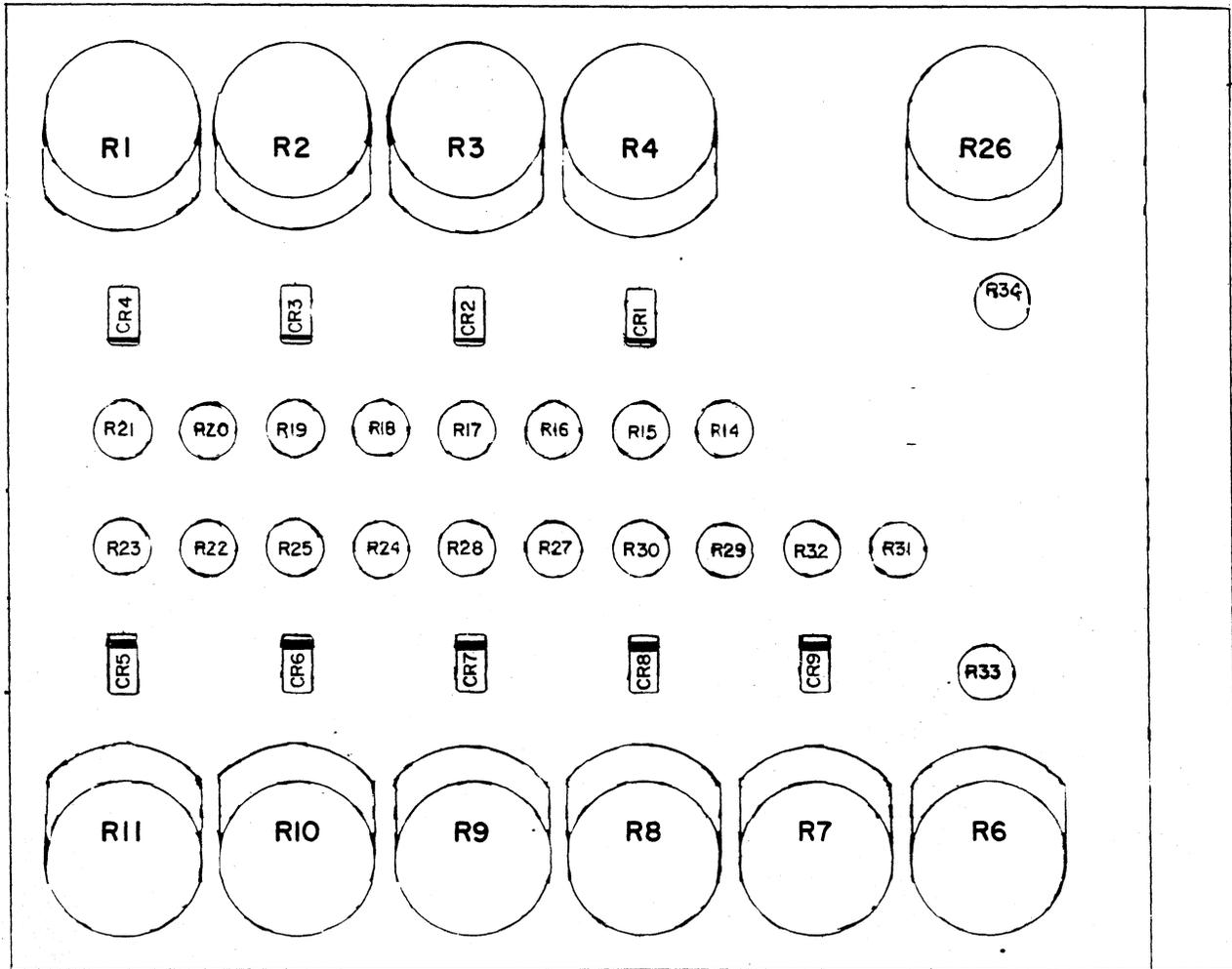
16.099 Dual X^2 Diode Function Generator



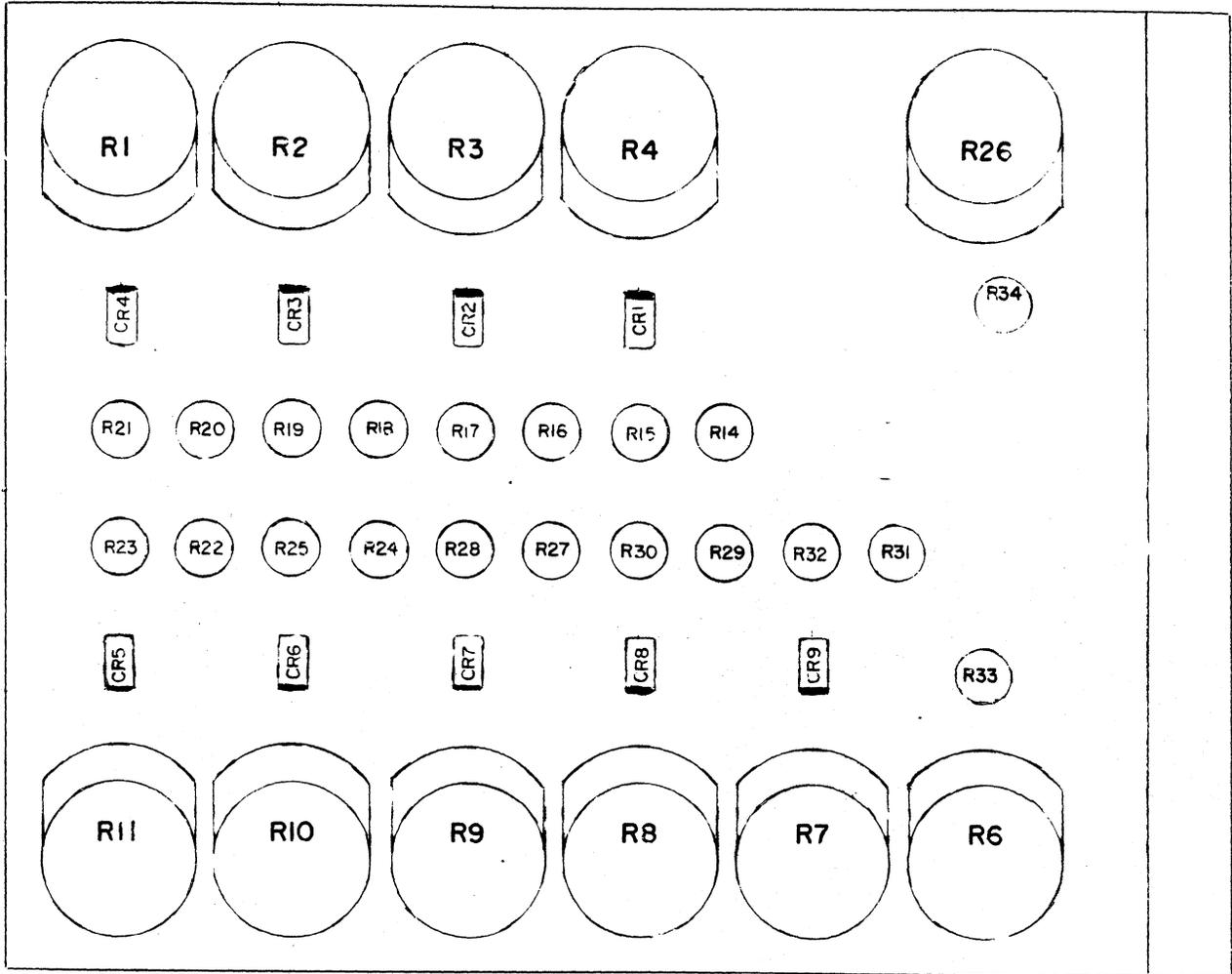
PLUG-IN END OF CARD



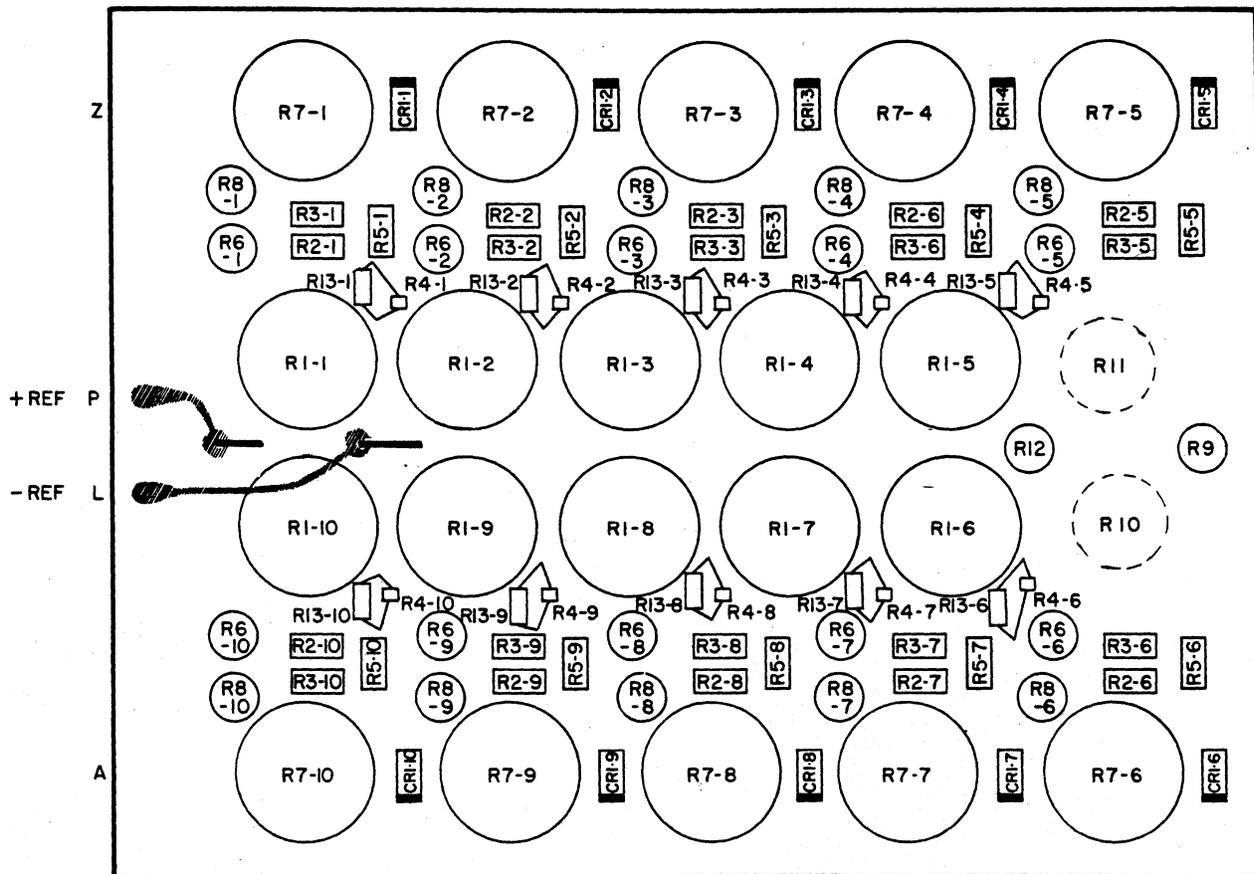
PLUG-IN END OF CARD

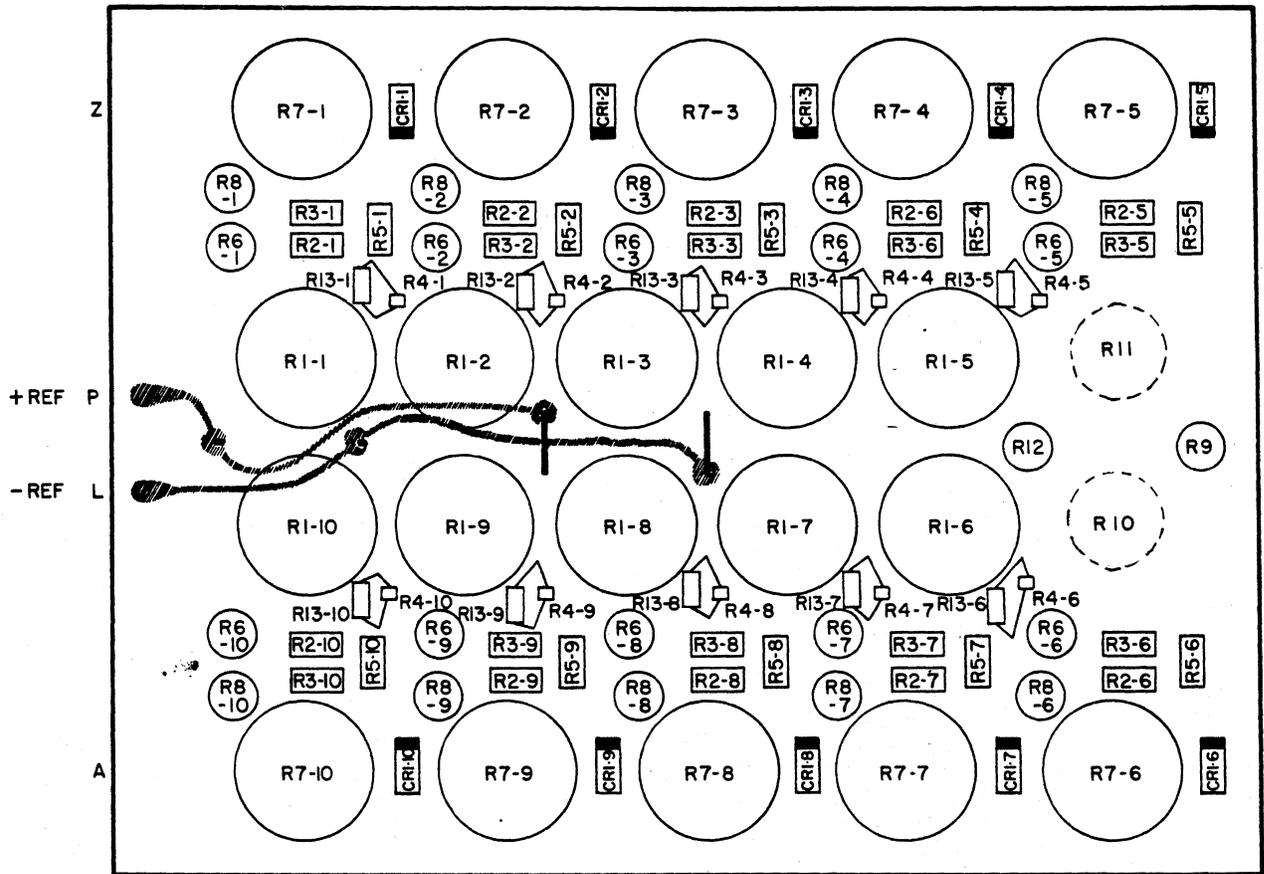


16.155 - Variable DFG



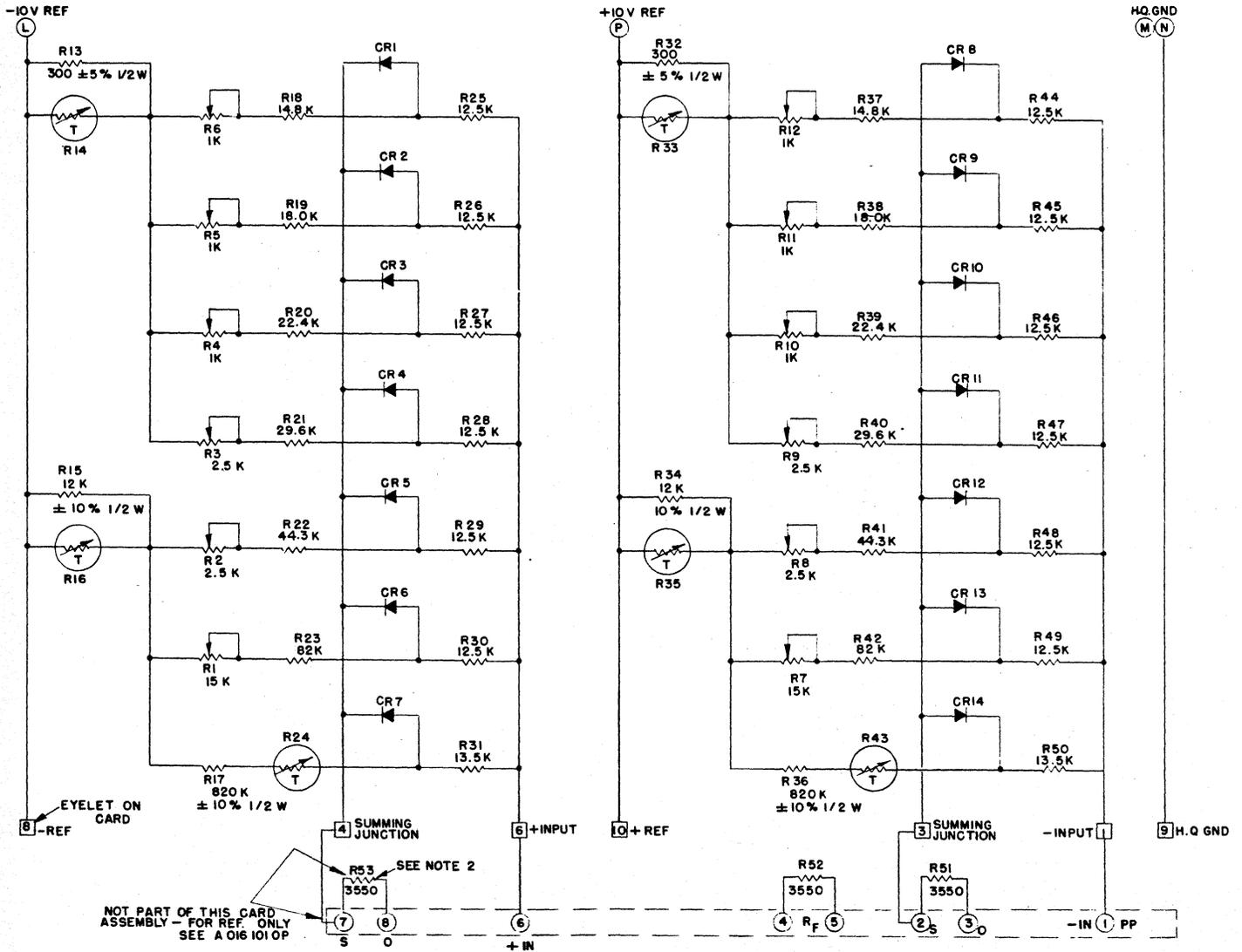
16.157 +Variable DFG





16.306 - VDFG Card, Component Location Diagram

NOTE
 1. ALL RECTIFIERS TO BE RADIO RECEPTOR NO. DR 837.
 2. ALL RESISTORS EXCEPT R51, 52, 53, TO BE $\pm 1\%$, 0.1 W, UNLESS OTHERWISE SPEC. R51, 52, 53 TO BE $\pm 0.1\%$, 0.15 W.

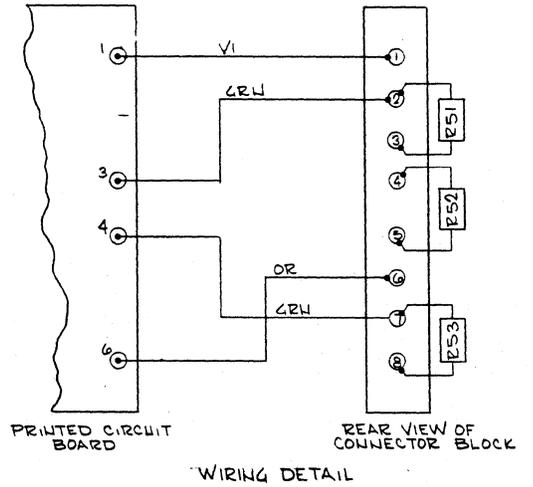
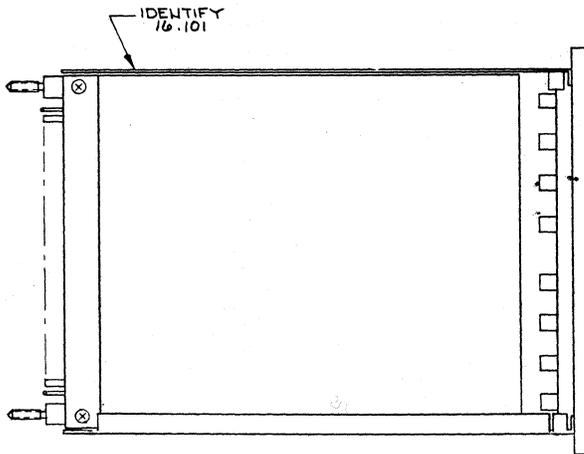
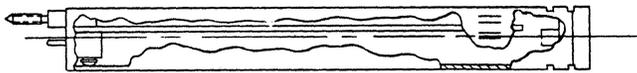


NOT PART OF THIS CARD ASSEMBLY - FOR REF. ONLY SEE A 016 101 OP

UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN PF
 RESISTANCE IS IN OHMS
 TOLERANCE ON FRACTIONS DECIMALS ANGLES
 $\pm 1/64$ $\pm .005$ \pm
 *TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC X ² D. F. G.	
SMT. NO.	
SIZE	
REV. NO.	
PROJECT	C 016 099 0S
SHEET 1 OF 1 SHEETS	

NOTE:
1. ALL JUMPERS TO BE #22 PHU UNLESS OTHERWISE SPECIFIED.

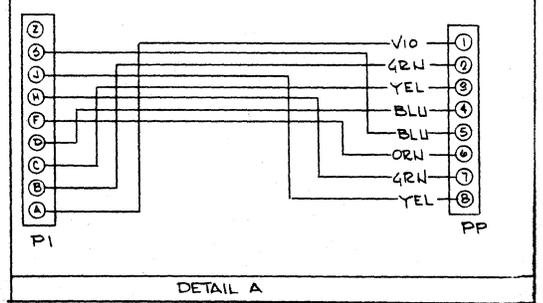


PRINTED CIRCUIT BOARD

REAR VIEW OF CONNECTOR BLOCK

WIRING DETAIL

ROUTE WIRE ON UNDERSIDE OF CARD AND SOLDER TO CONNECTOR PIN (PI) THAT EXTEND THROUGH BOTTOM OF PRINTED CIRCUIT CARD.

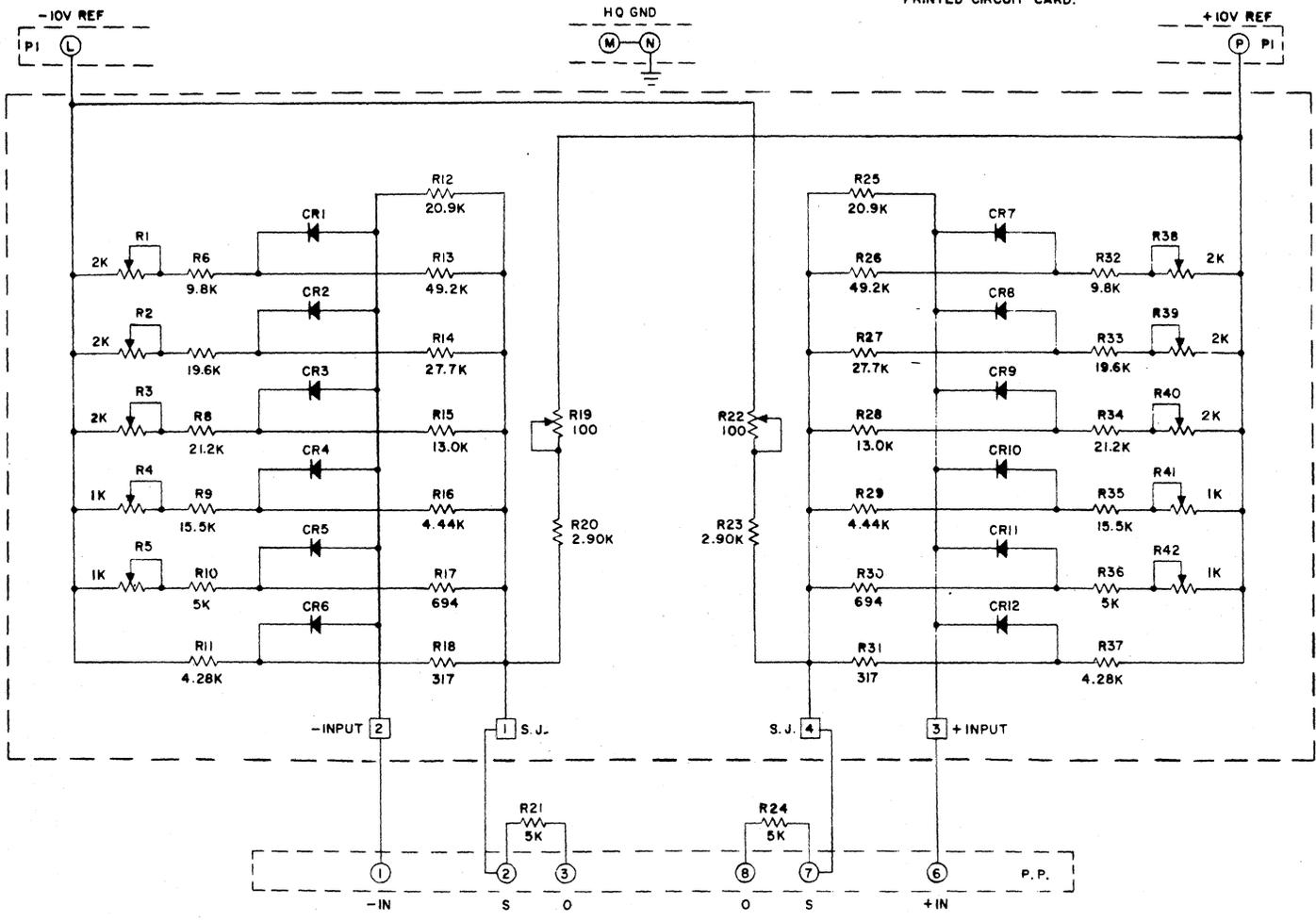


DETAIL A

16-1011	C16101A	C16101D	W/DETAIL A FOR READOUT OF PI AT PI POSITION	A0450500P	16017
16-1010	R01610A	A016101P	LESS THE TAIL A	A0450500P	1630
UNIT NUMBER	NUMBER	PARTS LIST & NEXT ASSY	DESCRIPTION	PARTS LIST USED ON	PROJECT NUMBER
TABLE OF UNIT NUMBERS					

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY X ² D.F.G.	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 1830	C 016101 0A
SHEET 1 OF 1 SHEETS	

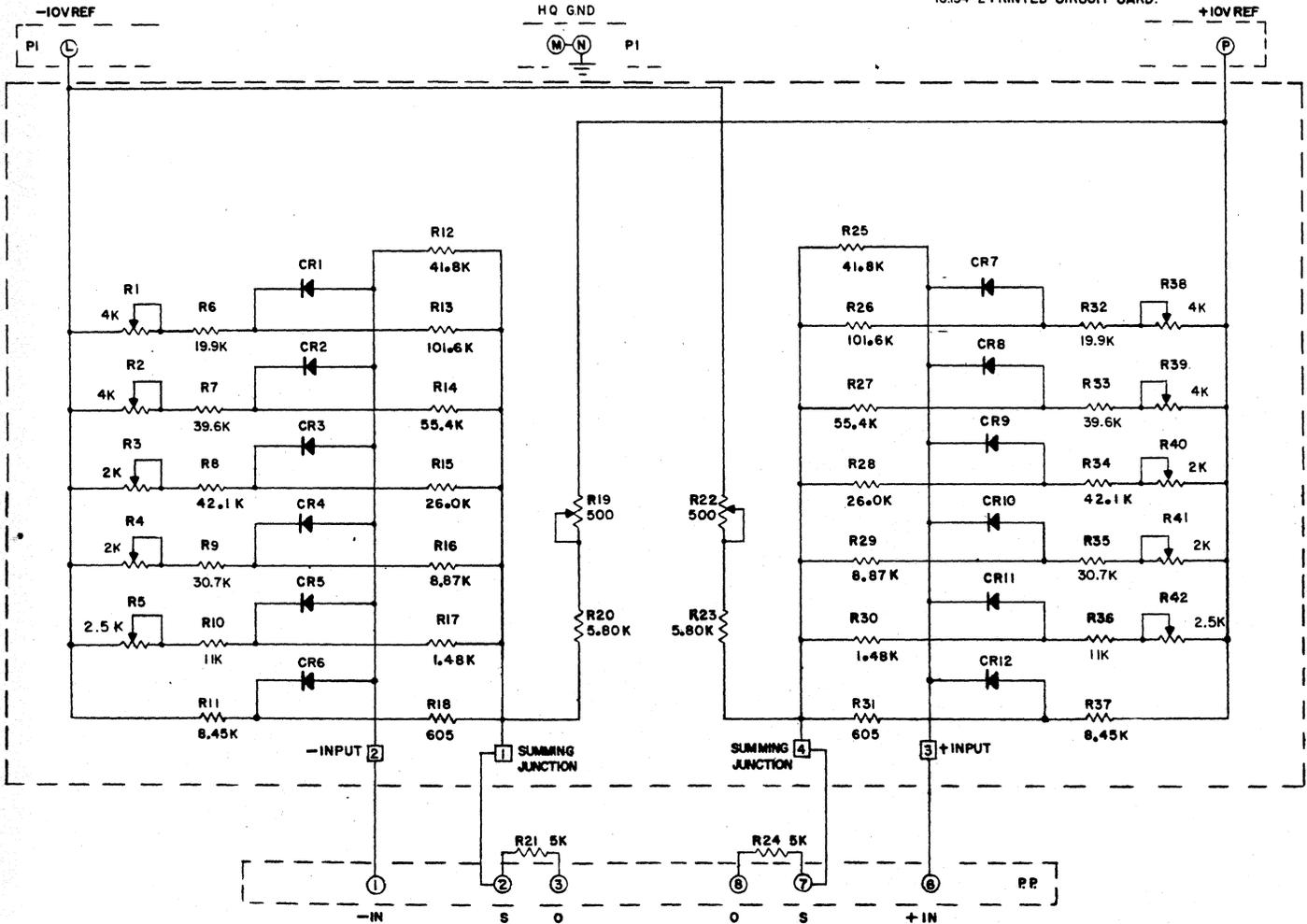
- NOTE:
1. ALL RECTIFIERS ARE SILICON DIODES PER DWG. A614 042 0.
 2. ALL FIXED RESISTORS, EXCEPT R21 & 24 ARE $\pm 1\%$, .25W. R21 & R24 ARE $\pm 0.1\%$, .15W.
 3. CIRCUITRY ENCLOSED IN DOTTED LINES IS LOCATED ON 6.127-2 PRINTED CIRCUIT CARD.



UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON
 FRACTIONS DECIMALS ANGLES
 1/164 2.008 2
 3 TOL. OF MATERIAL SUPPLIED

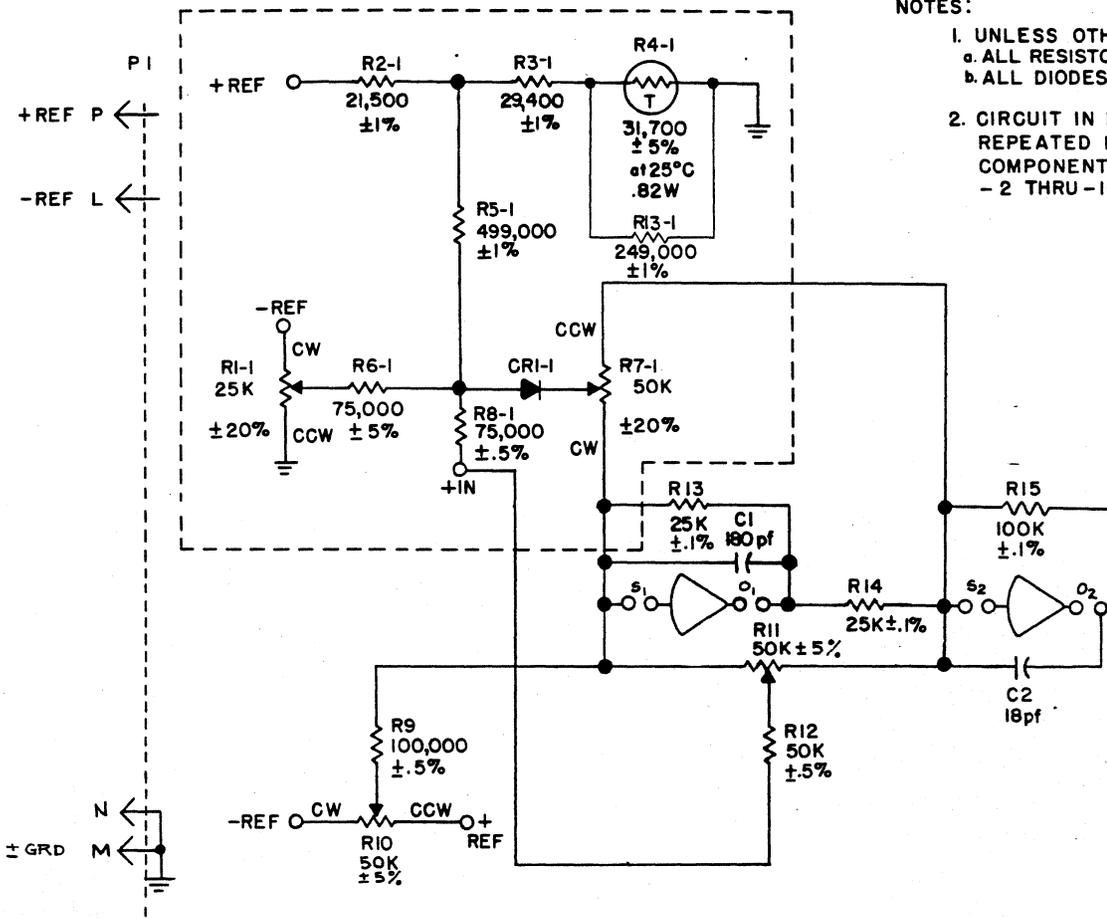
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC LOG X DFG	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1849 C 016 126 05
SHEET / OF / SHEETS	

- NOTE:
1. ALL RECTIFIERS ARE SILICON DIODES PER DWG A614 042 0.
 2. ALL FIXED RESISTORS, EXCEPT R21 & R24 ARE $\pm 1\%$ ± 25 WATT. R21 & R24 ARE $\pm 0.1\%$ ± 15 WATT.
 3. CIRCUITRY ENCLOSED IN DOTTED LINES IS LOCATED ON 16.134-2 PRINTED CIRCUIT CARD.



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC DIAGRAM 1/2 L X D.F.G.	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1849 C016 133 OS
SHEET 1 OF 1 SHEETS	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN PPMF
RESISTANCE IS IN OHMS
TOLERANCE ON
RESISTORS UNLESS SHOWN
OTHERWISE IS 0.25%
% VOL. OF MATERIAL SUPPLIED



NOTES:

1. UNLESS OTHERWISE SPECIFIED;
 - a. ALL RESISTORS ARE 1/8 W.
 - b. ALL DIODES ARE 614 007 O.
2. CIRCUIT IN DOTTED AREA IDENTICALLY REPEATED 10 TIMES EXCEPT THAT COMPONENTS REF SYMBOLS ARE - 2 THRU -10.

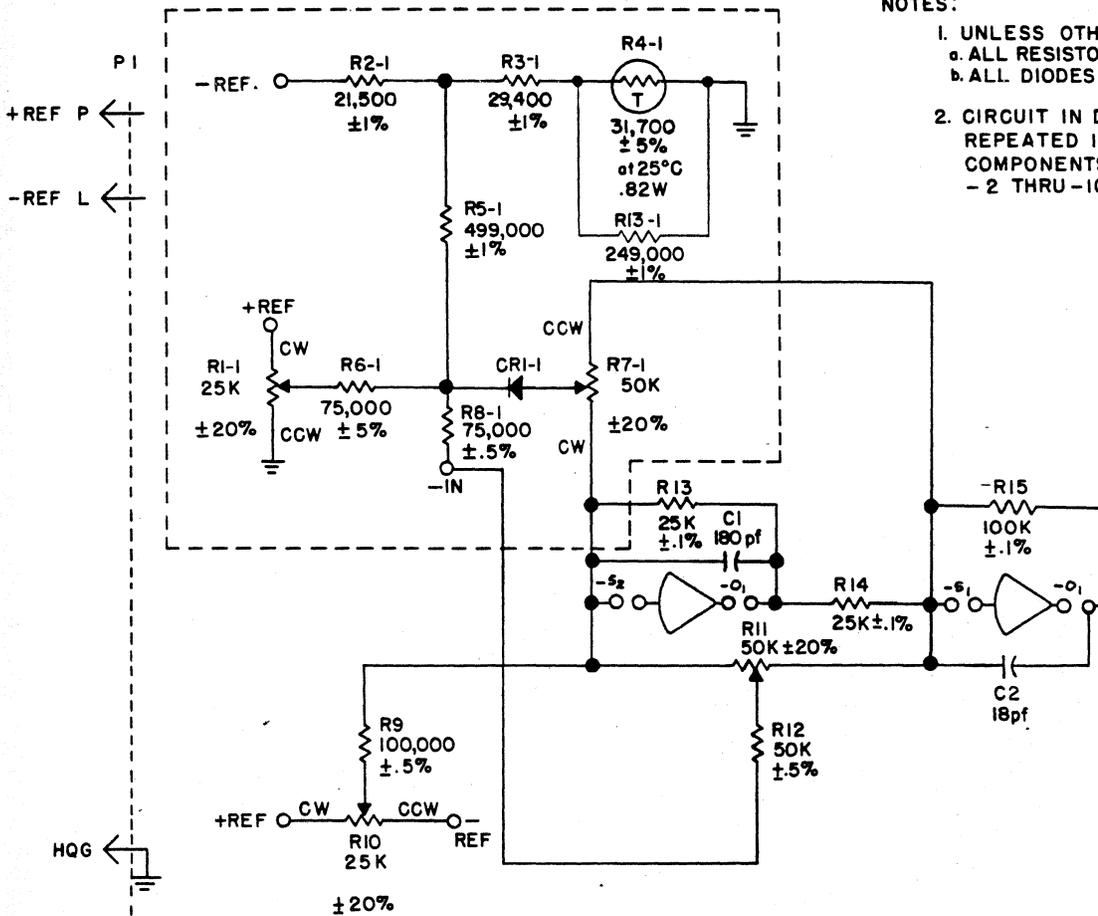
5

UNIT NUMBER	SCHEMATIC NUMBER	PARTS LIST & NEXT ASSY.	DESCRIPTION	PARTS LIST USED ON	PROJECT NUMBER
16.304 2	016 304 2S	016 304 2P	PER SHT. 2	A002 638 OP	19010
16.304-1	016 304 1S	016 304 1P	PER SHT. 2	A002 645 OP	19010
16.304	B 016 304 OS	A016 304 OP	AS SHOWN	---	19010

TABLE OF UNIT NUMBERS

UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN pf
 RESISTANCE IS IN OHMS
 TOLERANCE OR
 FRACTIONS DECIMALS ANGLES
 ± 1/64 ± .005 ±

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC + V.D.F.G.	
SHT. NO.	2
SIZE	B
REV. NO.	5
PROJECT	19010 B016 304 OS
SHEET 1 OF 2 SHEETS	



NOTES:

1. UNLESS OTHERWISE SPECIFIED;
 - a. ALL RESISTORS ARE 1/8 W.
 - b. ALL DIODES ARE 614 007 O.
2. CIRCUIT IN DOTTED AREA IDENTICALLY REPEATED 10 TIMES EXCEPT THAT COMPONENTS REF SYMBOLS ARE - 2 THRU -10.

UNIT NUMBER	SCHEMATIC NUMBER	PARTS LIST & NEXT ASSY.	DESCRIPTION	PARTS LIST USED ON	PROJECT NUMBER
16.306-2	O16 306 2S	O16 306 2P	PER SHT. 2	A002 638 OP	19010
16.306-1	O16 306 1S	O16 306 1P	PER SHT. 2	A002 645 OP	19010
16.306	B O16 306 OS	A016 306 OP	AS SHOWN		19010

TABLE OF UNIT NUMBERS

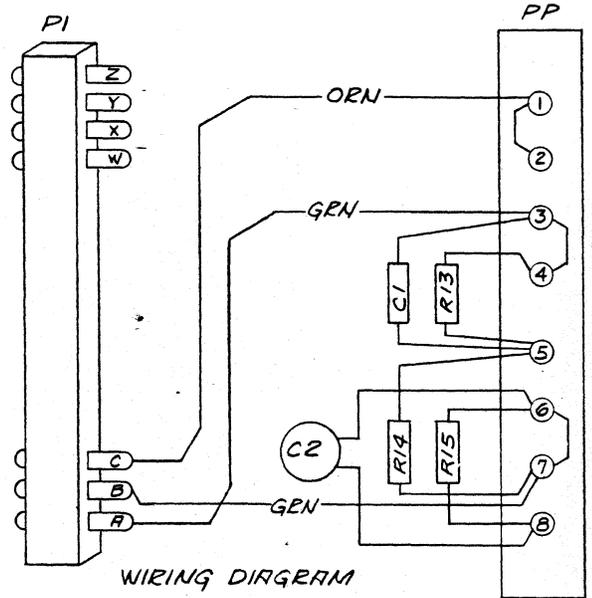
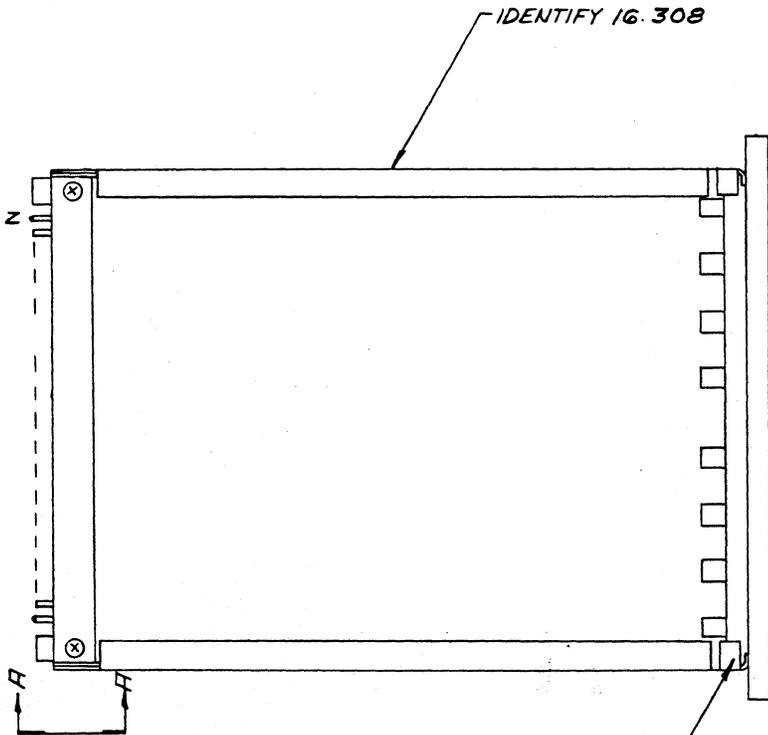
UNLESS OTHERWISE SPECIFIED		
DIMENSIONS ARE IN INCHES		
CAPACITANCE IS IN PF		
RESISTANCE IS IN OHMS		
TOLERANCE ON		
FRACTIONS	DECIMALS	ANGLES
± 1/64	± .005	±
*TOL. OF MATERIAL SUPPLIED		

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
SCHEMATIC	
- V.D.F.G.	
SHT. NO.	2
SIZE	B
REV. NO.	3
PROJECT	19010 B016 306 OS
SHEET / OF 2 SHEETS	

NOTES:

1. ALL WIRES ARE PHU #22 COLOR AS SHOWN.
2. ALL JUMPERS ARE #22 SD-BUS

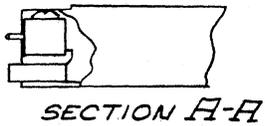
2



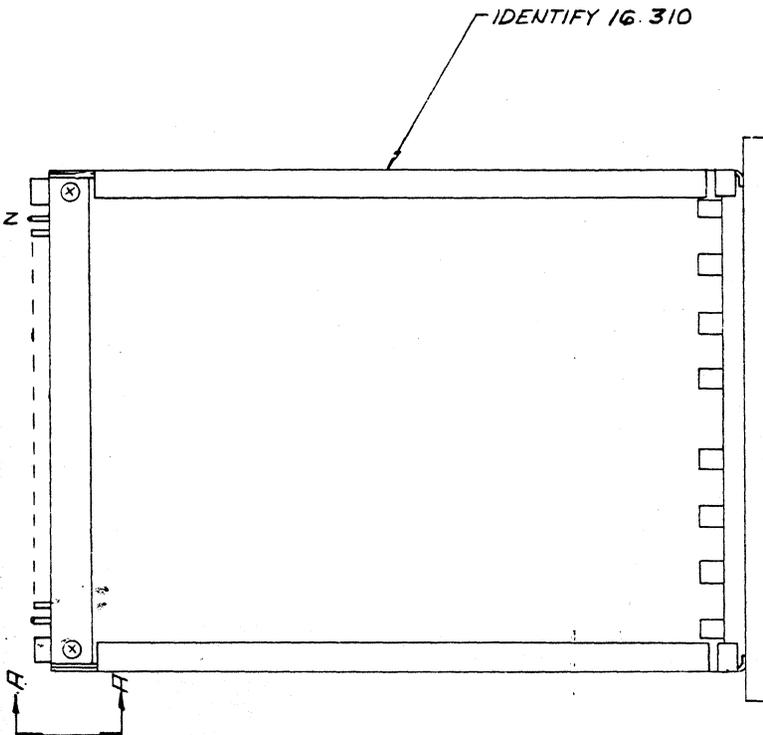
WIRING DIAGRAM

REAR VIEW OF PATCH PANEL

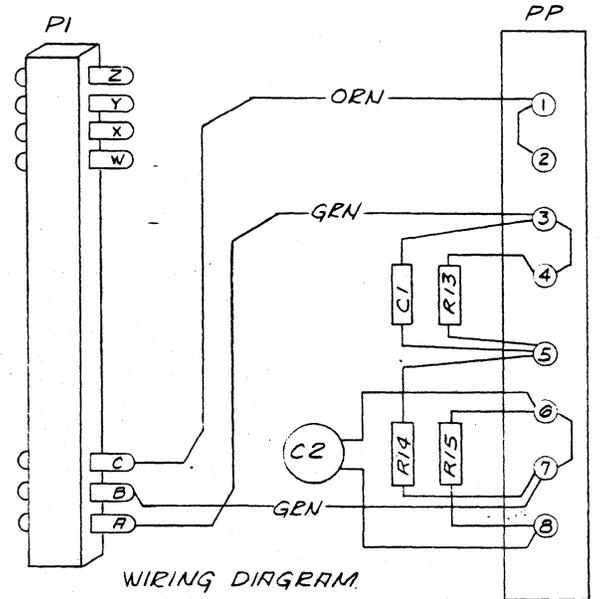
BEND TRB TO SECURE CONNECTOR BLOCK



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY + VDFG	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	BOIG 308 OA
19010	
SHEET / OF / SHEETS	

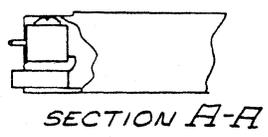


- NOTES:
1. ALL WIRES ARE PHU #22 COLOR AS SHOWN
 2. ALL JUMPERS ARE #22 SD-BUS



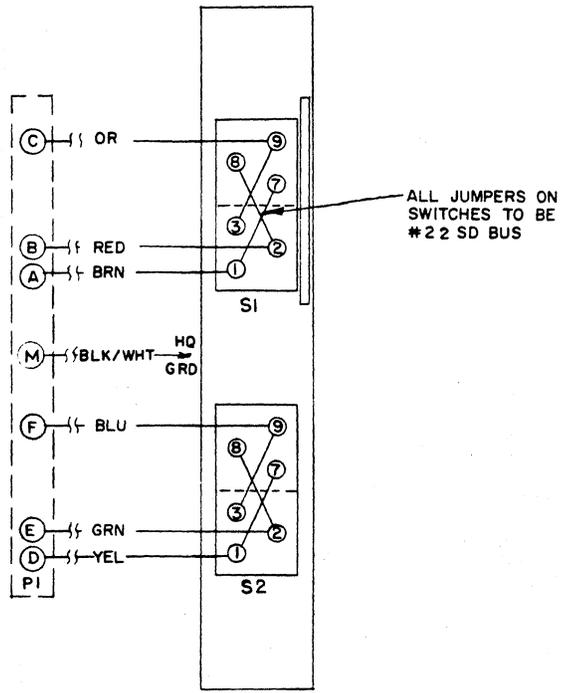
WIRING DIAGRAM.

REAR VIEW OF PATCH PANEL

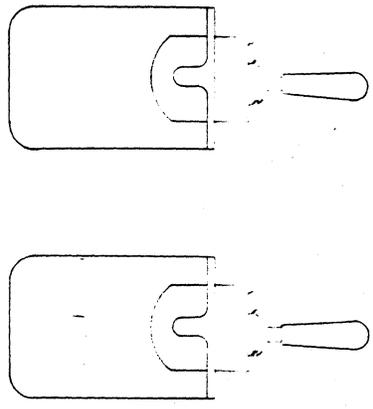


ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY + VDFG	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	BO16 310 OA
19098	
SHEET / OF / SHEETS	

IDENTIFY 20.366



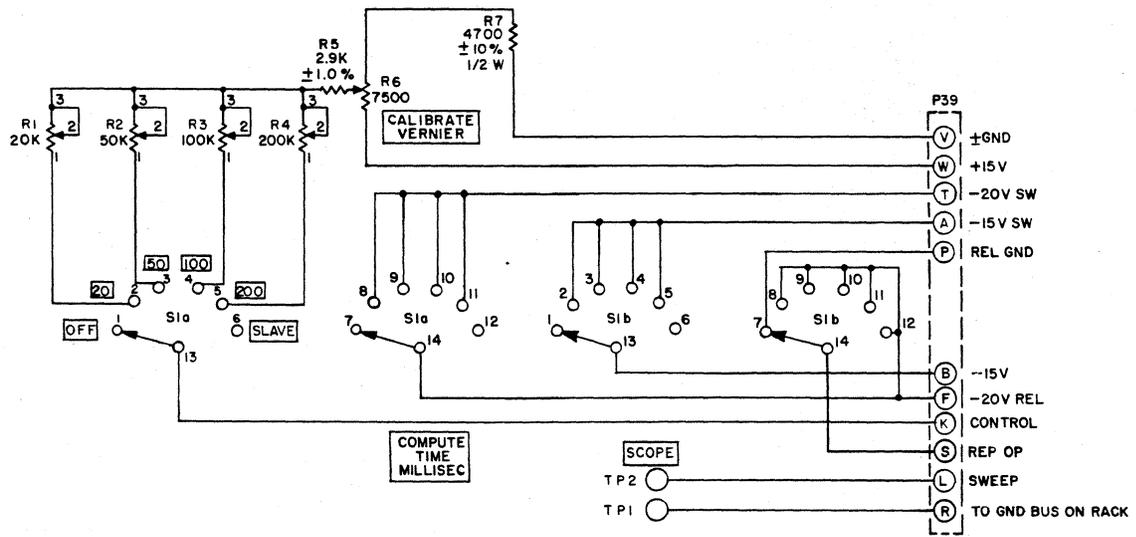
WIRING VIEW



ELECTRONIC ASSOCIATES, INC.	
500 GARDEN BRANCH, NEW JERSEY	
ASSEMBLY FUNCTION SWITCHES	
SHT. NO.	
SIZE	
REV. NO.	
PRC. NO.	19 B020 366 0A
SHEET 1 OF 1 SHEETS	

NOTES:

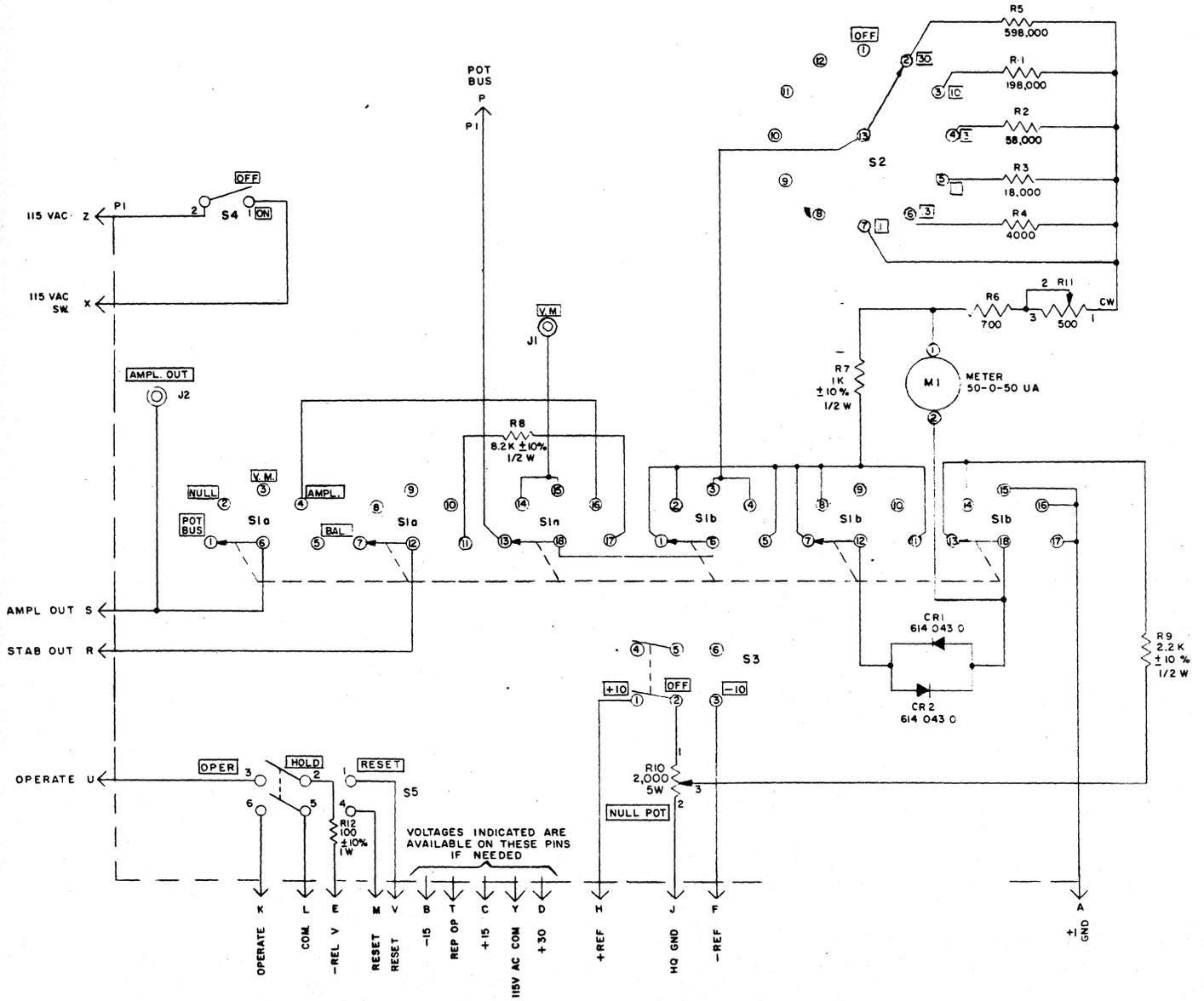
1. RESISTOR, R7, AND ALL POTS EXCEPT R6 ARE FOUND ON PARTS LIST A 020 534 OP



UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON FRACTIONS DECIMALS ANGLES
 ± 1/64 ± .005 ±

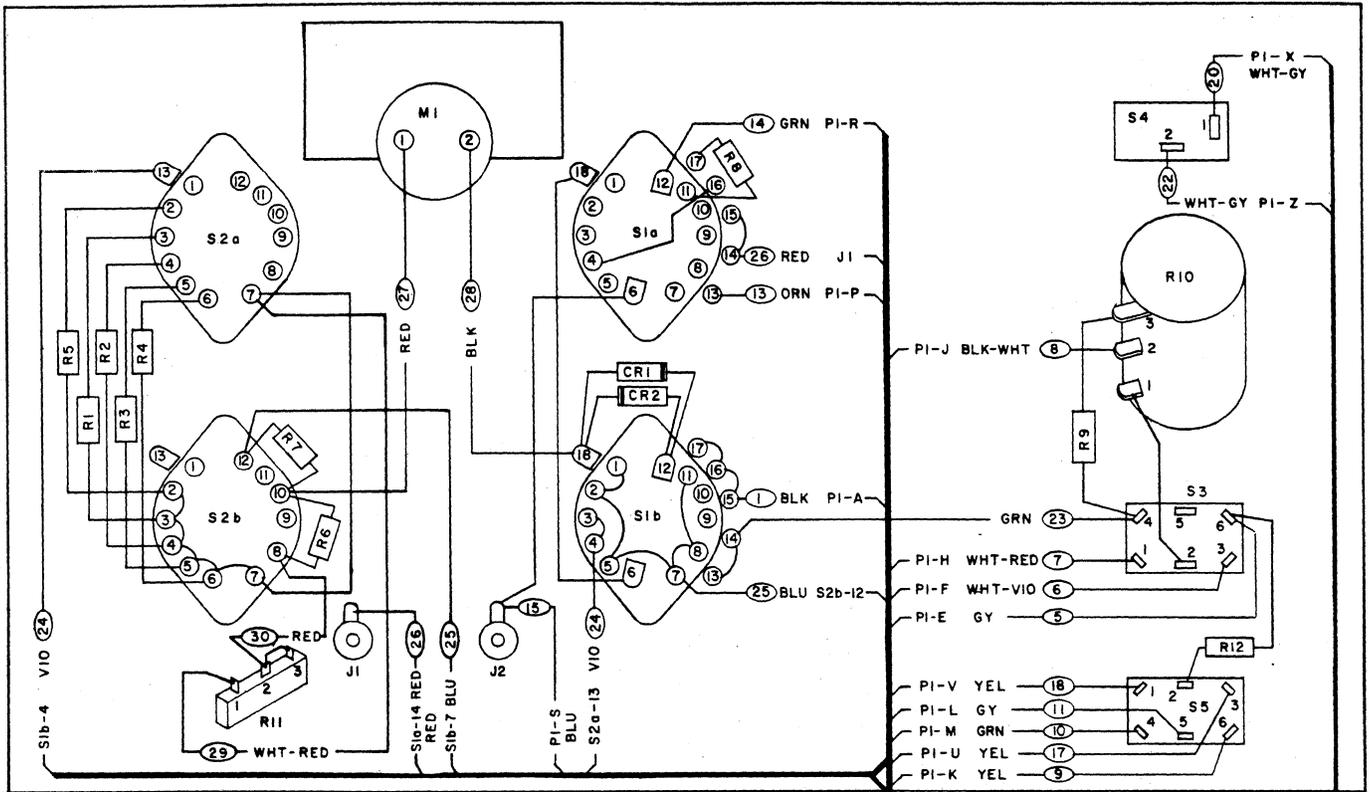
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC REP. OPER. CONTROL	
SMT. NO.	
SIZE	
REV. NO.	
PROJECT	1991 C 020 532 OS
SHEET	OF SHEETS

NOTE
UNLESS OTHERWISE SPECIFIED, RESISTORS
ARE $\pm 1\%$ 1/2 W.

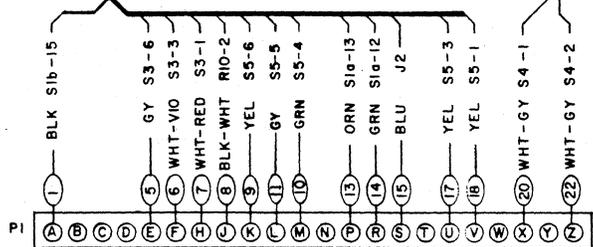


UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
CAPACITANCE IS IN MICRO
RESISTANCE IS IN OHMS
TOLERANCE ON
FRACTIONS DECIMALS ANGLES
2/16 5/100 5
© TOL. OF MATERIAL SUPPLIED

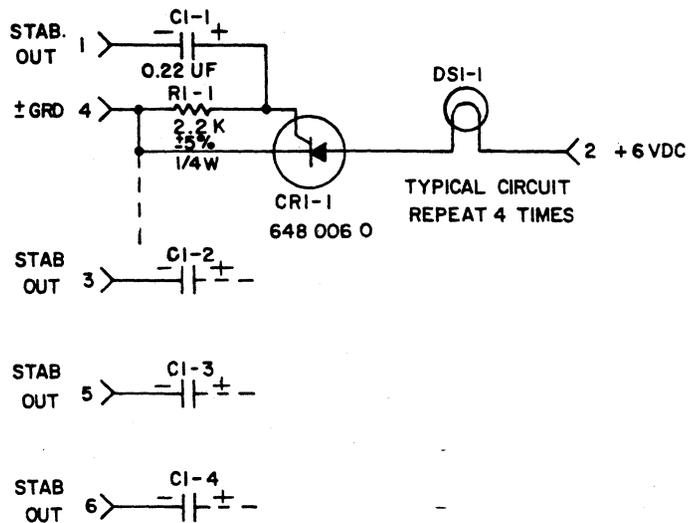
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC CONTROL PANEL	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1726 C020 734 05
SHEET 7 OF 7 SHEETS	



NOTE:
 1. ALL JUMPERS TO BE #20 SD-BUS
 COVERED WITH EXTRUDED PLASTIC
 TUBING, WHERE NECESSARY.



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
WIRING CONTROL PANEL	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	C 020 734 0W
SHEET	OF SHEETS



20.919-5	020 919 5S	020 919 5P	LESS-4-1 COMP	USES A00578 00770 LAMP
20.919-4	020 919 4S	020 919 4P	LESS-4 COMP	" "
20.919-3	020 919 3S	020 919 3P	AS SHOWN	" "
20.919-2	020 919 2S	020 919 2P	LESS-4-1 COMP	USES A00578 00770 LAMP
20.919-1	020 919 1S	020 919 1P	LESS-4 COMP	" "
20.919	B020 919 0S	020 919 0P	AS SHOWN	" "
UNIT NUMBER	SCHEMATIC NUMBER	PARTS LIST & NEXT ASSY.	DESCRIPTION	
TABLE OF UNIT NUMBERS				

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

CAPACITANCE IS IN PF

RESISTANCE IS IN OHMS

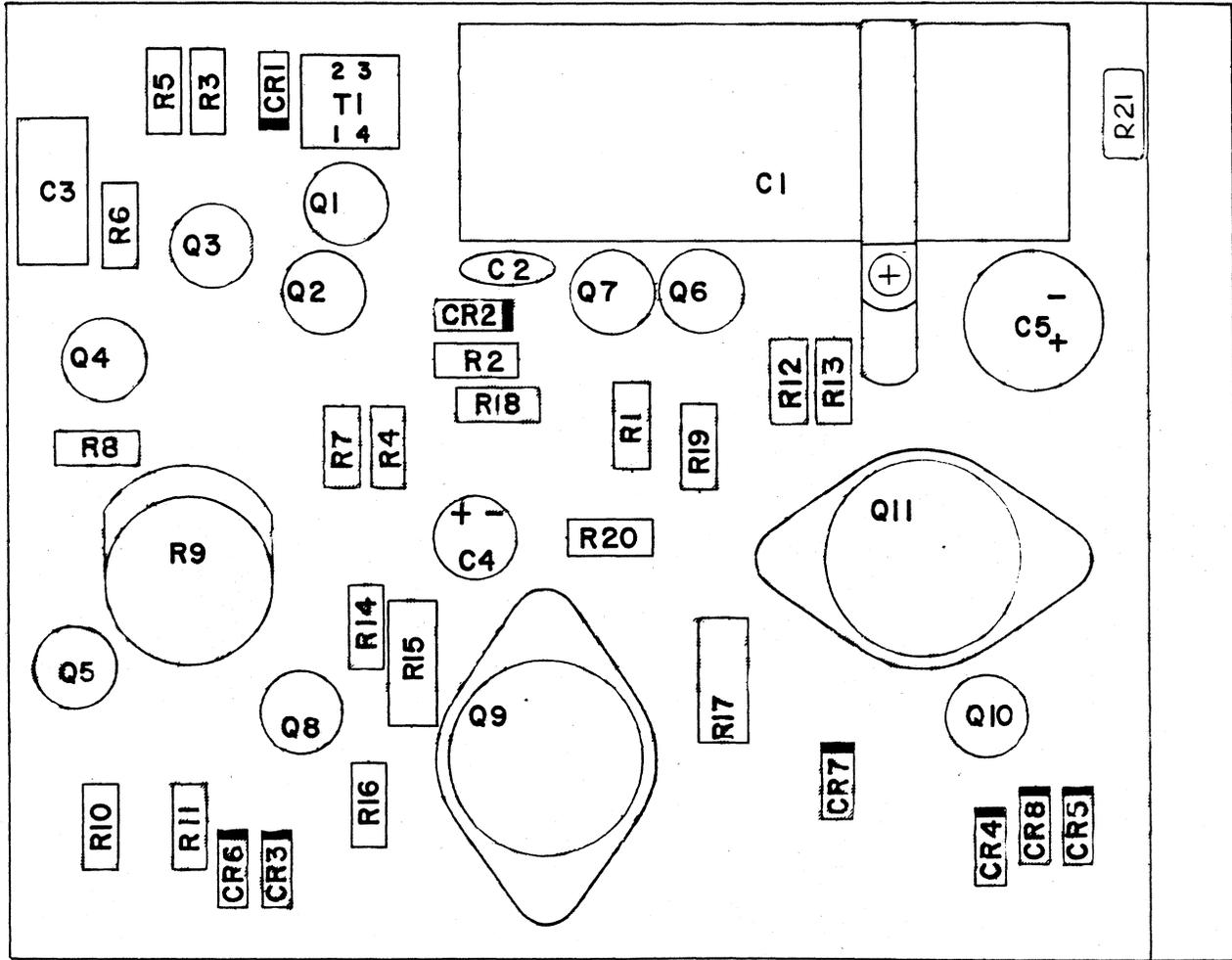
TOLERANCE ON

FRACTIONS DECIMALS ANGLES

± 1/64 ± .005 ±

*TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
SCHEMATIC OVERLOAD IND.	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19068	B020 919 0S
SHEET / OF / SHEETS	

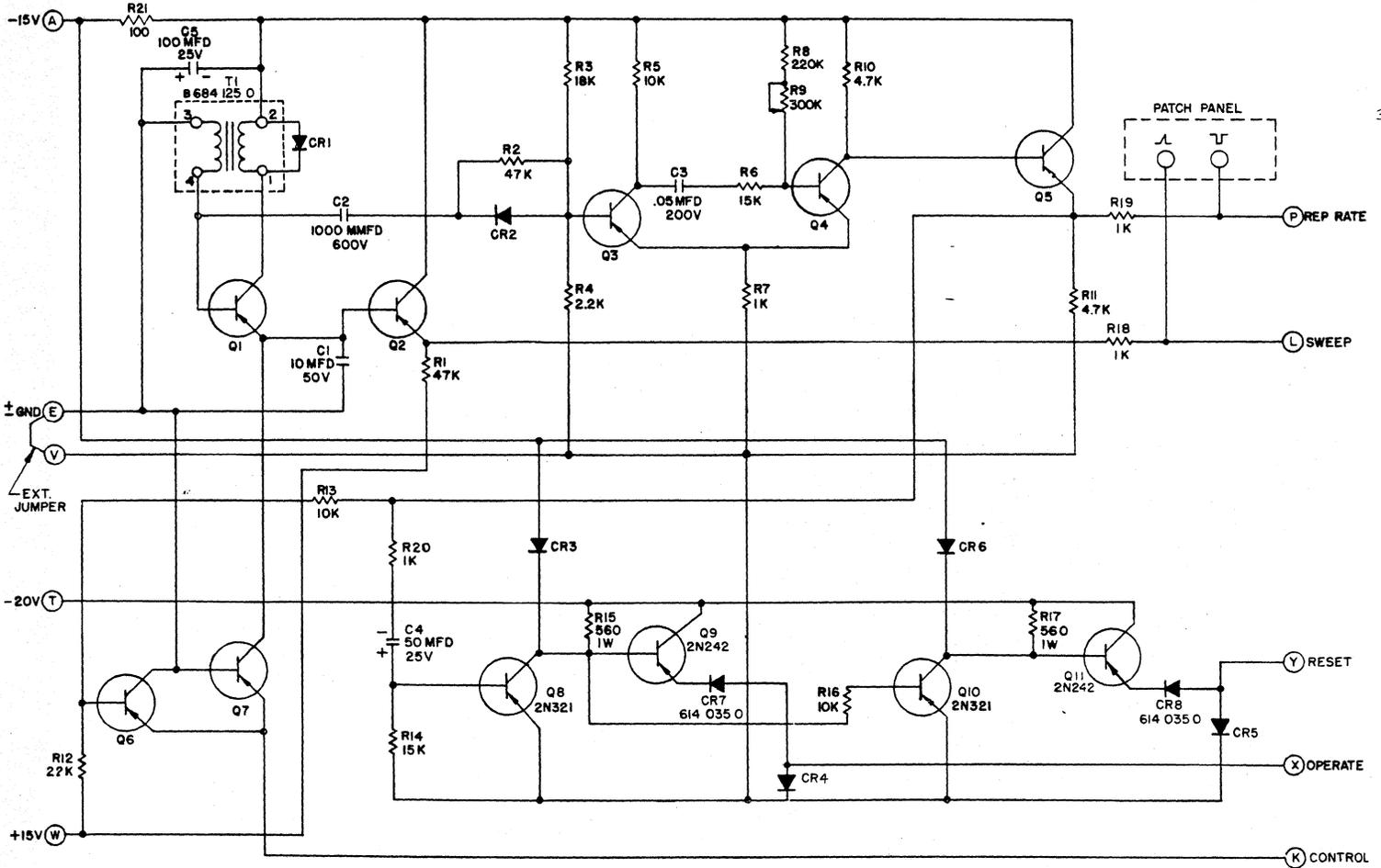


A

Z

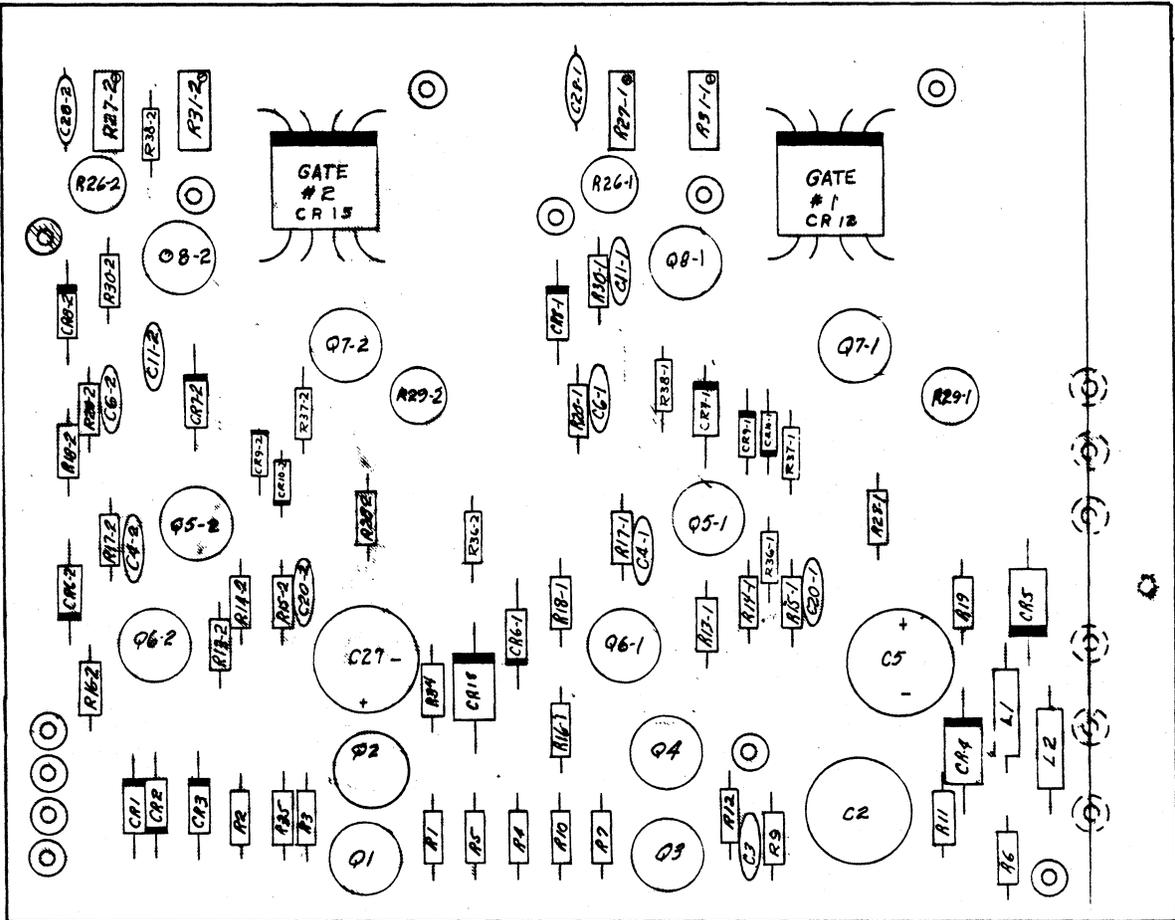
36.063 Timing Unit

- NOTES:
 1. ALL TRANSISTORS ARE 686 Q32 O UNLESS NOTED.
 2. ALL DIODES ARE 614 043 O UNLESS NOTED.
 3. ALL RESISTORS ARE $\pm 10\%$ TOLERANCE, 1/2 W. UNLESS OTHERWISE SPECIFIED.



UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON
 FRACTIONS DECIMALS ANGLES
 $\frac{1}{4}$ 1 2.00 2
 © VOL. OF MATERIAL SUPPLIED

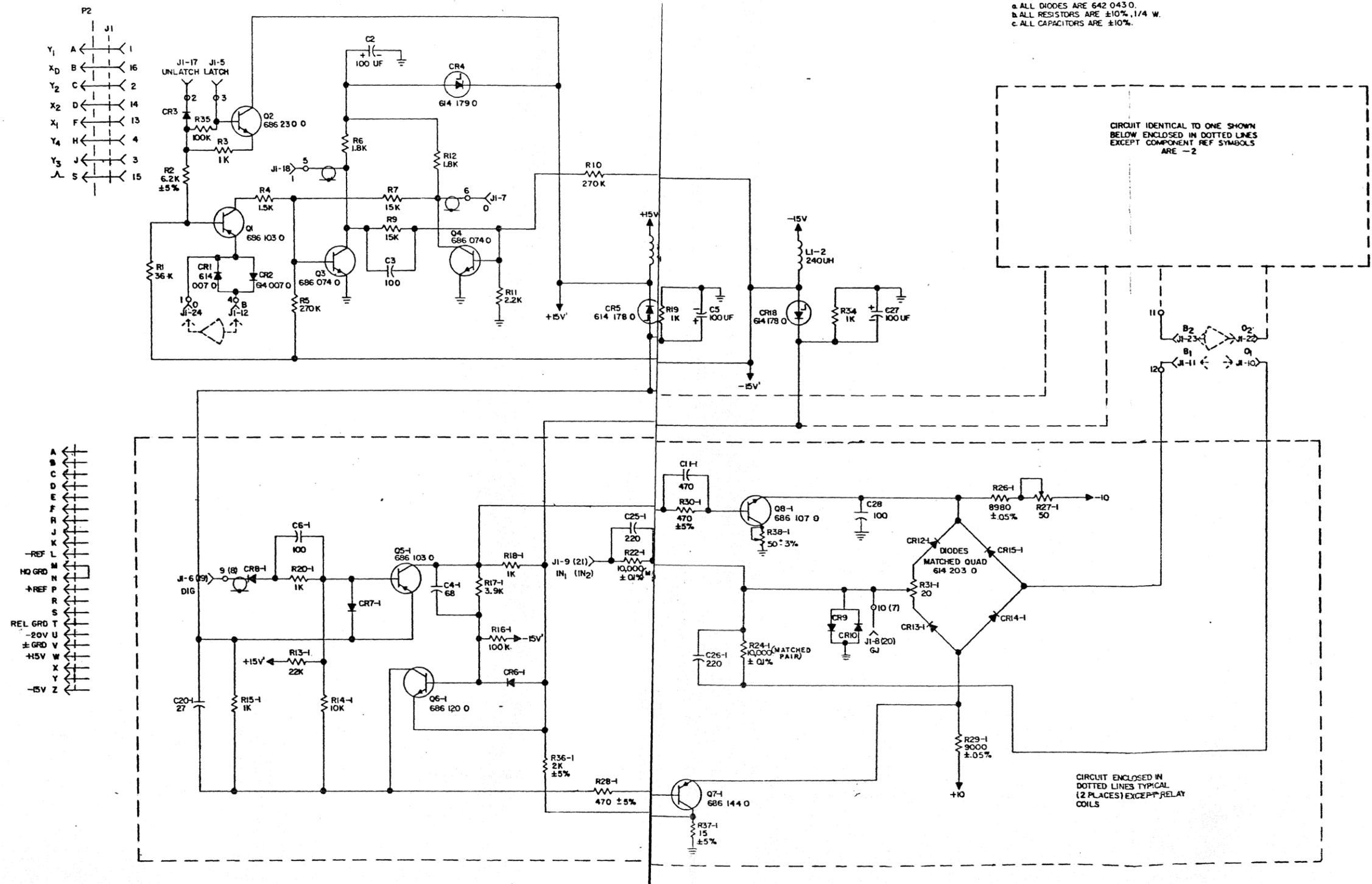
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC TIMING UNIT	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1991 C 036 082 05
SHEET	OF SHEETS



A

Z

40.493 Electronic Comparator Card



NOTES:
 1. UNLESS OTHERWISE SPECIFIED:
 a. ALL DIODES ARE 642 043 O.
 b. ALL RESISTORS ARE $\pm 10\%$, 1/4 W.
 c. ALL CAPACITORS ARE $\pm 10\%$.

CIRCUIT IDENTICAL TO ONE SHOWN
 BELOW ENCLOSED IN DOTTED LINES
 EXCEPT COMPONENT REF SYMBOLS
 ARE - 2

CIRCUIT ENCLOSED IN
 DOTTED LINES TYPICAL
 (2 PLACES) EXCEPT RELAY
 COILS

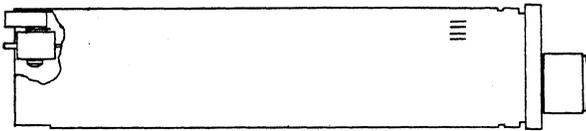
UNLESS OTHERWISE SPECIFIED			
RESISTANCE VALUES IN OHMS			
RESISTANCE IN K OHMS			
RESISTANCE IN M OHMS			
FRACTIONS	DECIMALS	INCHES	
$\frac{1}{2}$ 1/2	0.5	1/2	2
P.C. OF MATERIAL SUPPLIER			

ELECTRONIC ASSOCIATES, INC.
 LONG BRANCH, NEW JERSEY

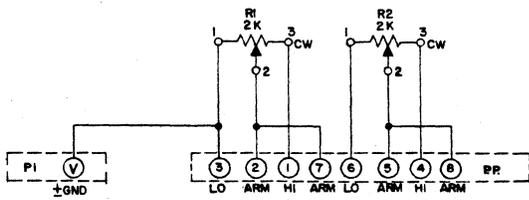
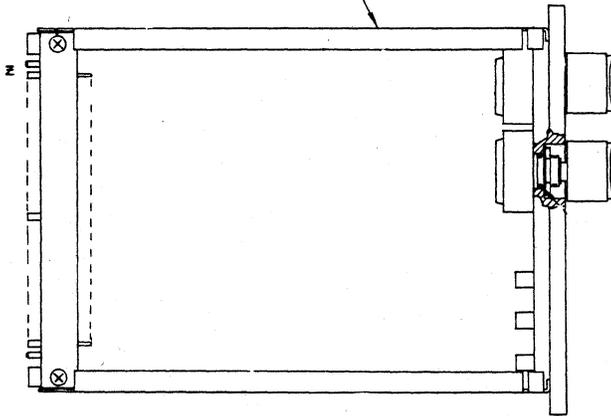
**ELECTRONIC
 COMPARATOR**

SHT. NO.	
SIZE	
REV. NO.	
PROJECT	D040 538 0 S
DATE	1/10/58

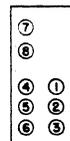
NOTES:
 ALL JUMPERS TO BE #22 PHU
 UNLESS OTHERWISE SPECIFIED.



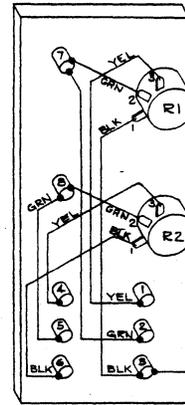
IDENTIFY 42.183



SCHEMATIC DIAGRAM



PATCH PANEL
 PIN LAYOUT
 (LOOKING
 FROM REAR)



REAR VIEW OF
 CONNECTOR BLOCK



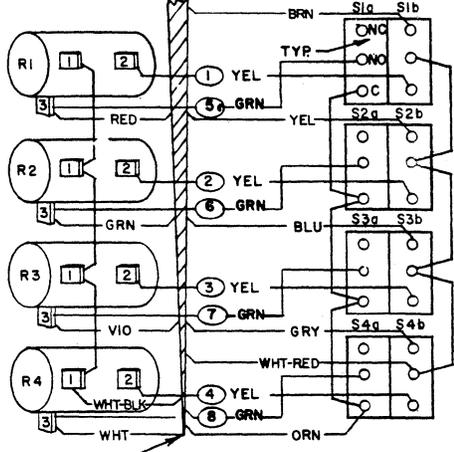
COVER THIS SOLDERED
 CONNECTION WITH TEFLON
 TUBING 3/16 LG
 FOR STRAIN RELIEF

WIRING DIAGRAM

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
ASSEMBLY ATTENUATORS	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1830 C 042 183 OA
SHEET OF SHEETS	

IDENTIFY 42.185

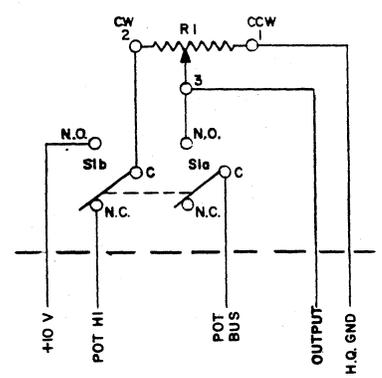
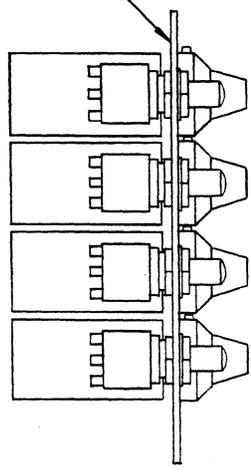
NOTE:
1. ALL JUMPERS TO BE
#20 SD-BUS COVERED
EXTRUDED PLASTIC TUBING.



WIRING DIAGRAM

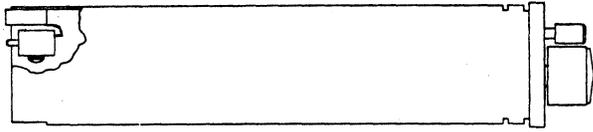
HARNESS #18260

NO.	COLOR	AWG.	TYPE	LENGTH
1	YEL	22	PHU	
2	YEL	22	PHU	
3	YEL	22	PHU	
4	YEL	22	PHU	
5	GRN	22	PHU	
6	GRN	22	PHU	
7	GRN	22	PHU	
8	GRN	22	PHU	

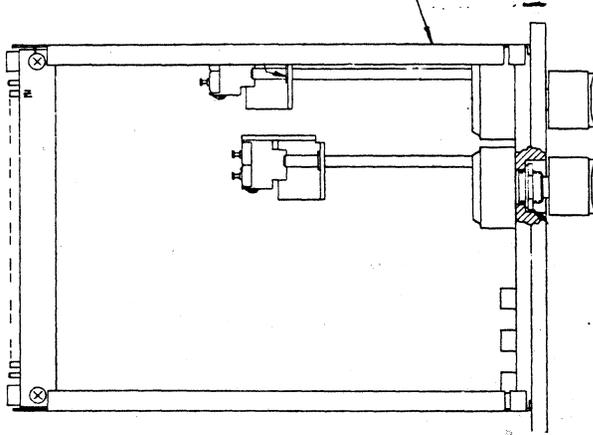


TYPICAL ATTEN SCHEMATIC

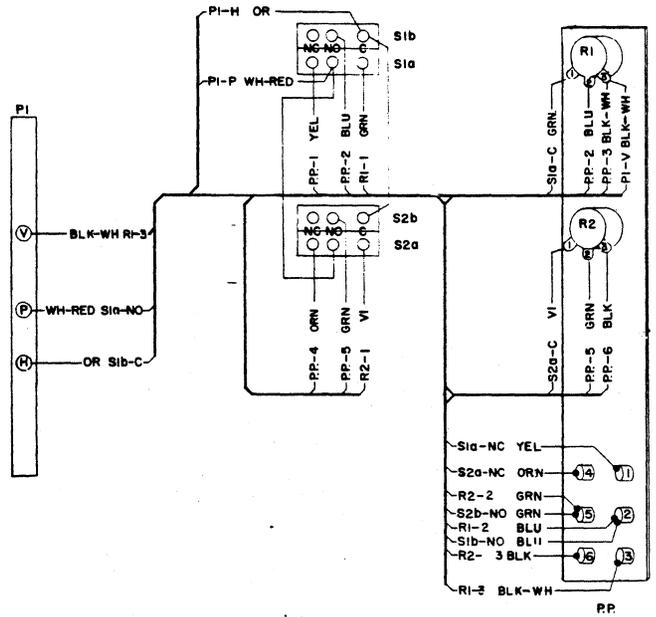
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY ATTENUATOR PANEL	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 1991	C042 185 0A
SHEET	OF SHEETS



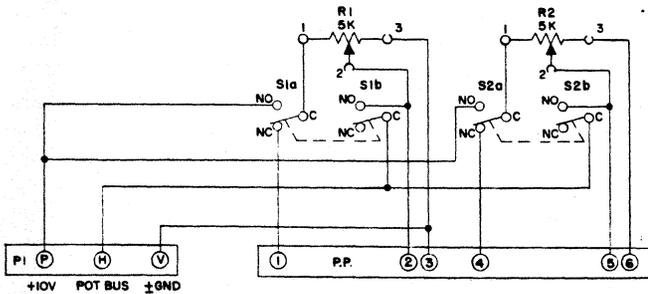
IDENTIFY 42.187



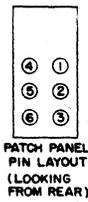
NOTE:
1. ALL JUMPERS TO BE #20 SD-BUS, COVERED WITH TEFLON TUBING.



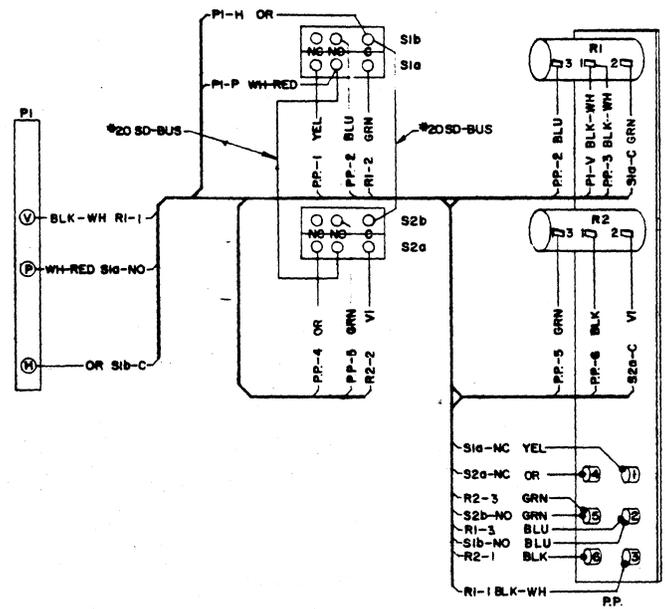
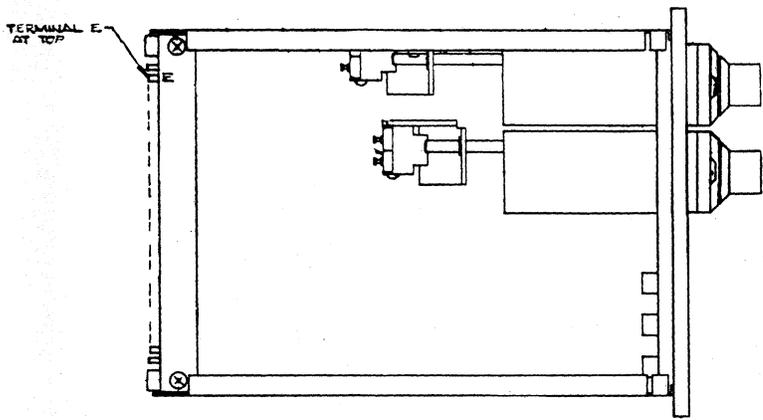
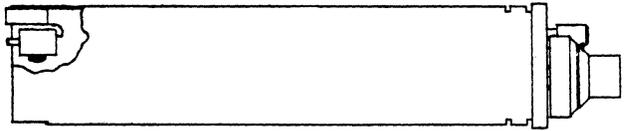
WIRING DIAGRAM



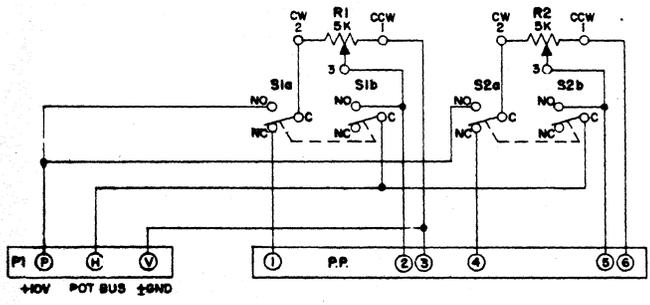
SCHEMATIC DIAGRAM



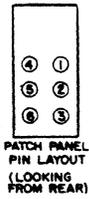
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY ATTENUATORS	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1991 C 042 187 OA
SHEET OF SHEETS	



WIRING DIAGRAM



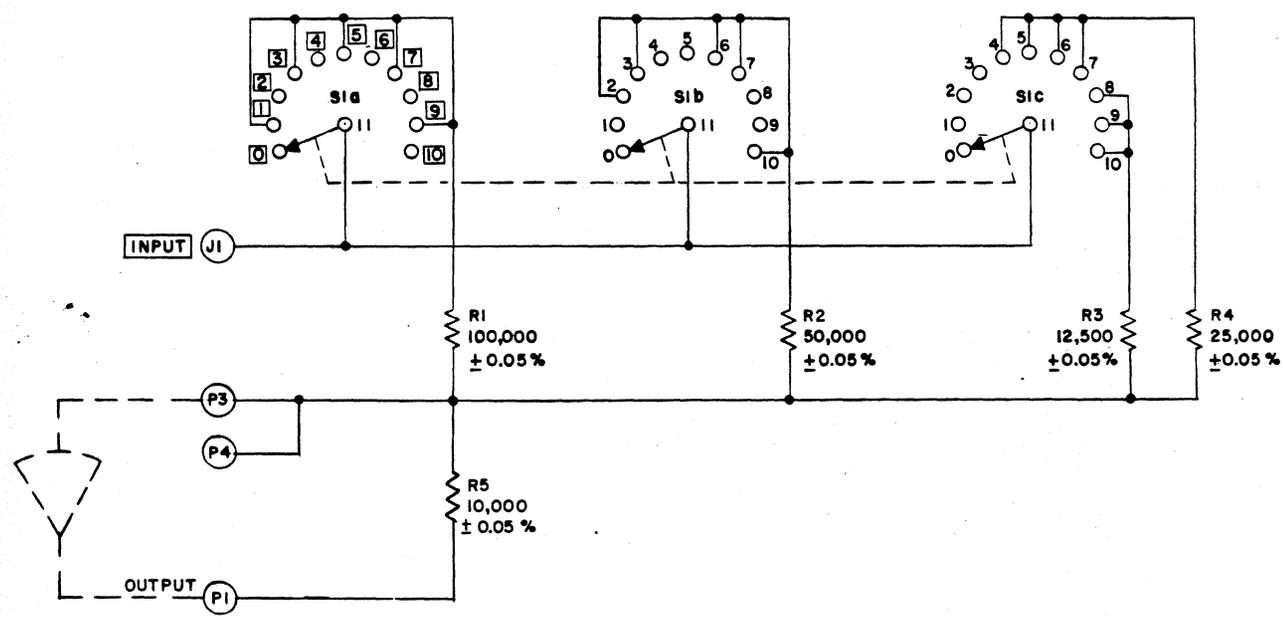
SCHEMATIC DIAGRAM



42.188-1	042 188 1A	042 188 1A	AS SHOWN - SHEET 2
42.188	042 188 0A	042 188 0A	AS SHOWN - SHEET 1
UNIT NUMBER	ASSEMBLY NUMBER	PARTS LIST & NEXT ASSEMBLY	DESCRIPTION
TABLE OF UNIT NUMBERS			

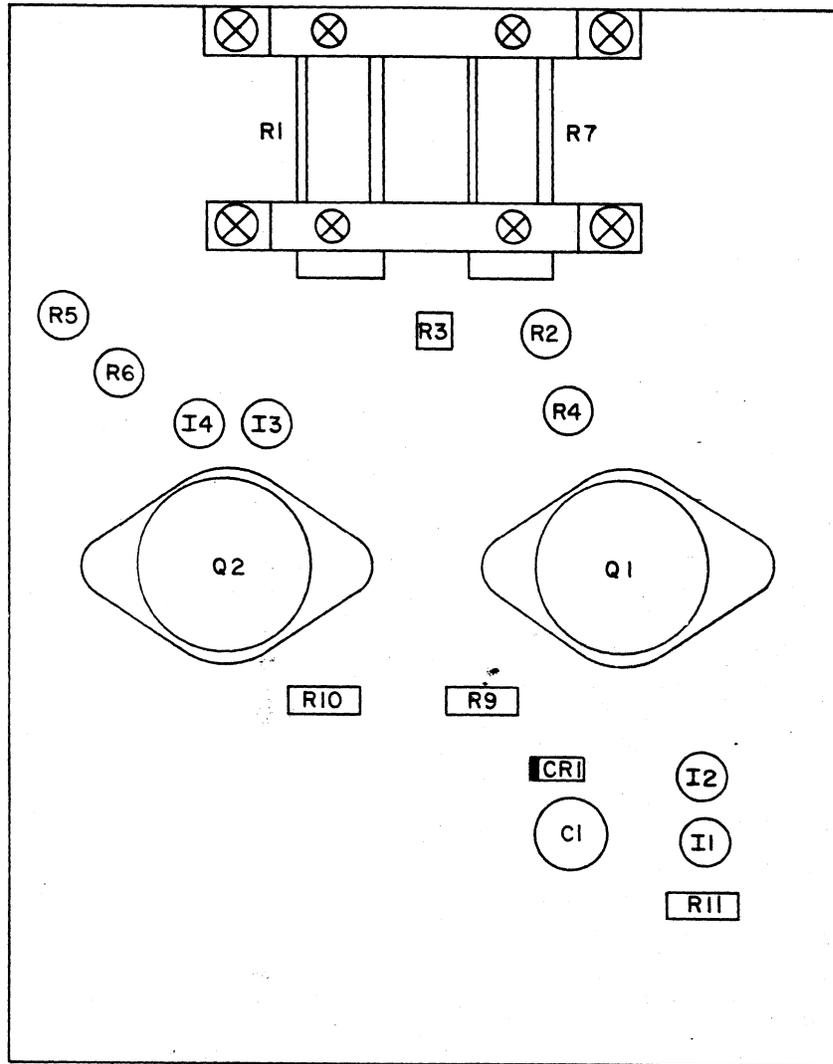
ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
ASSEMBLY ATTENUATORS	
UNIT NO.	Z
SIZE	C
REV. NO.	1
PROJECT	1991 C 042 188 0A

NOTE:
 1. RESISTORS R1 THRU R5 ARE A MATCHED SET
 AS PER DWG. B640 006 0.



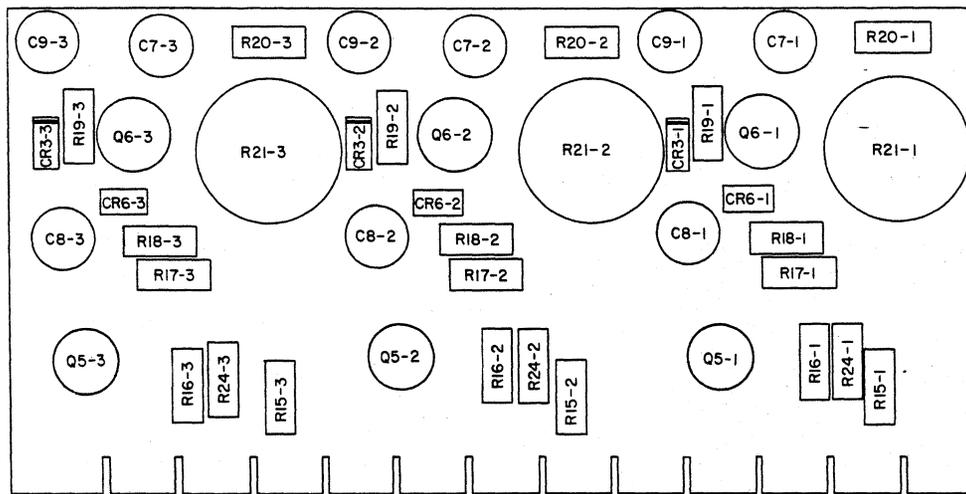
UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON
 FRACTIONS DECIMALS ANGLES
 2/64 0.005 1/2
 & TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC ATTENUATOR	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	1991 B 042 243 OS
SHEET OF SHEETS	



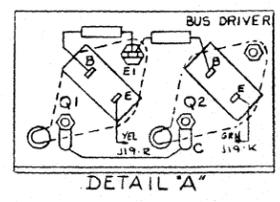
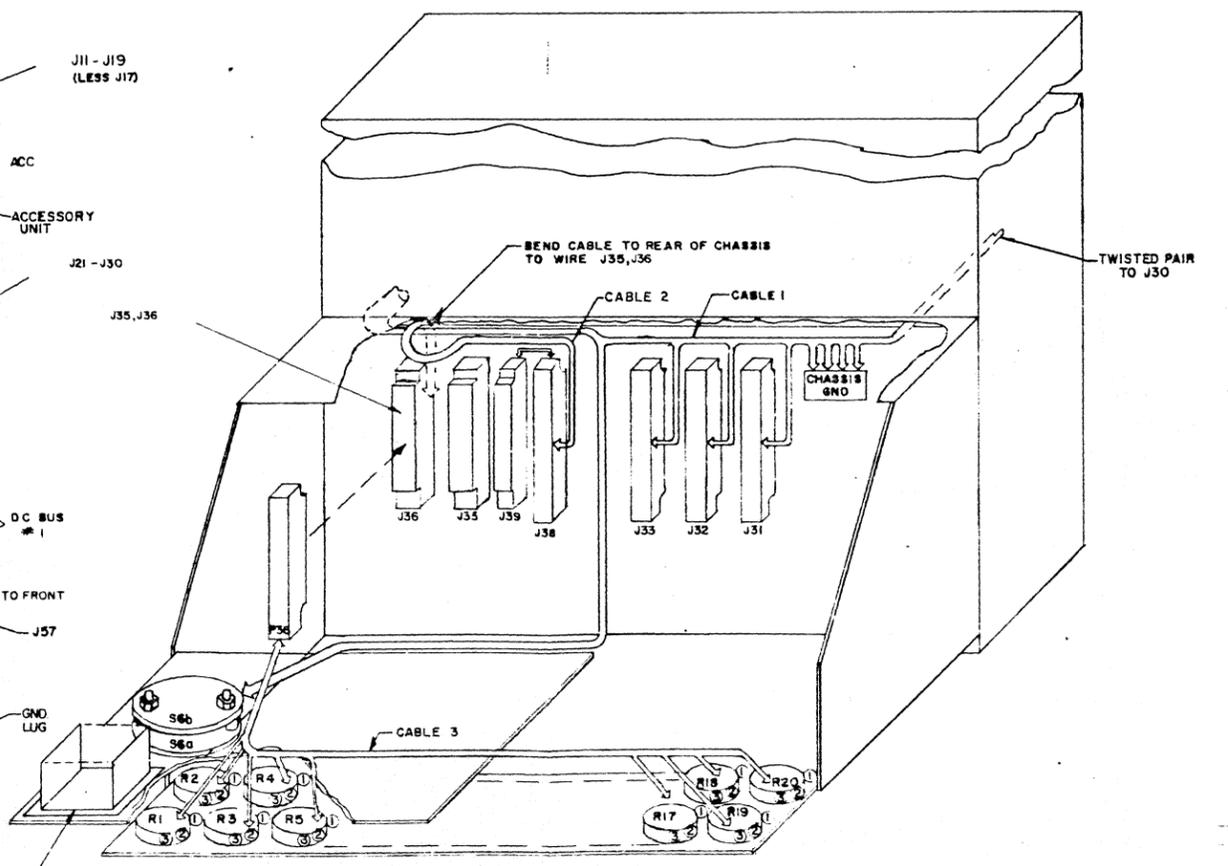
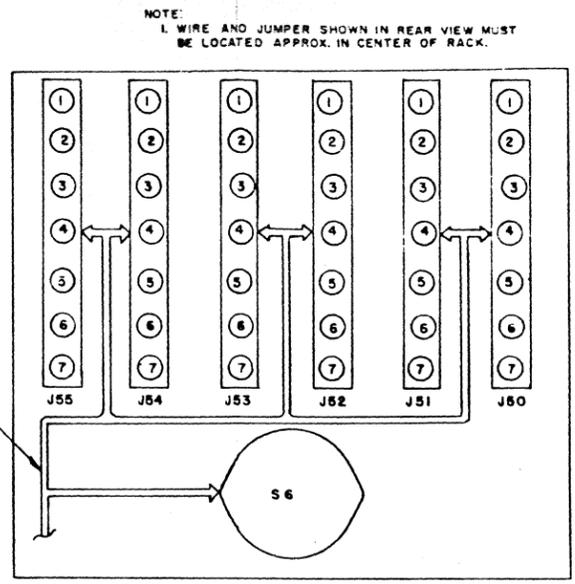
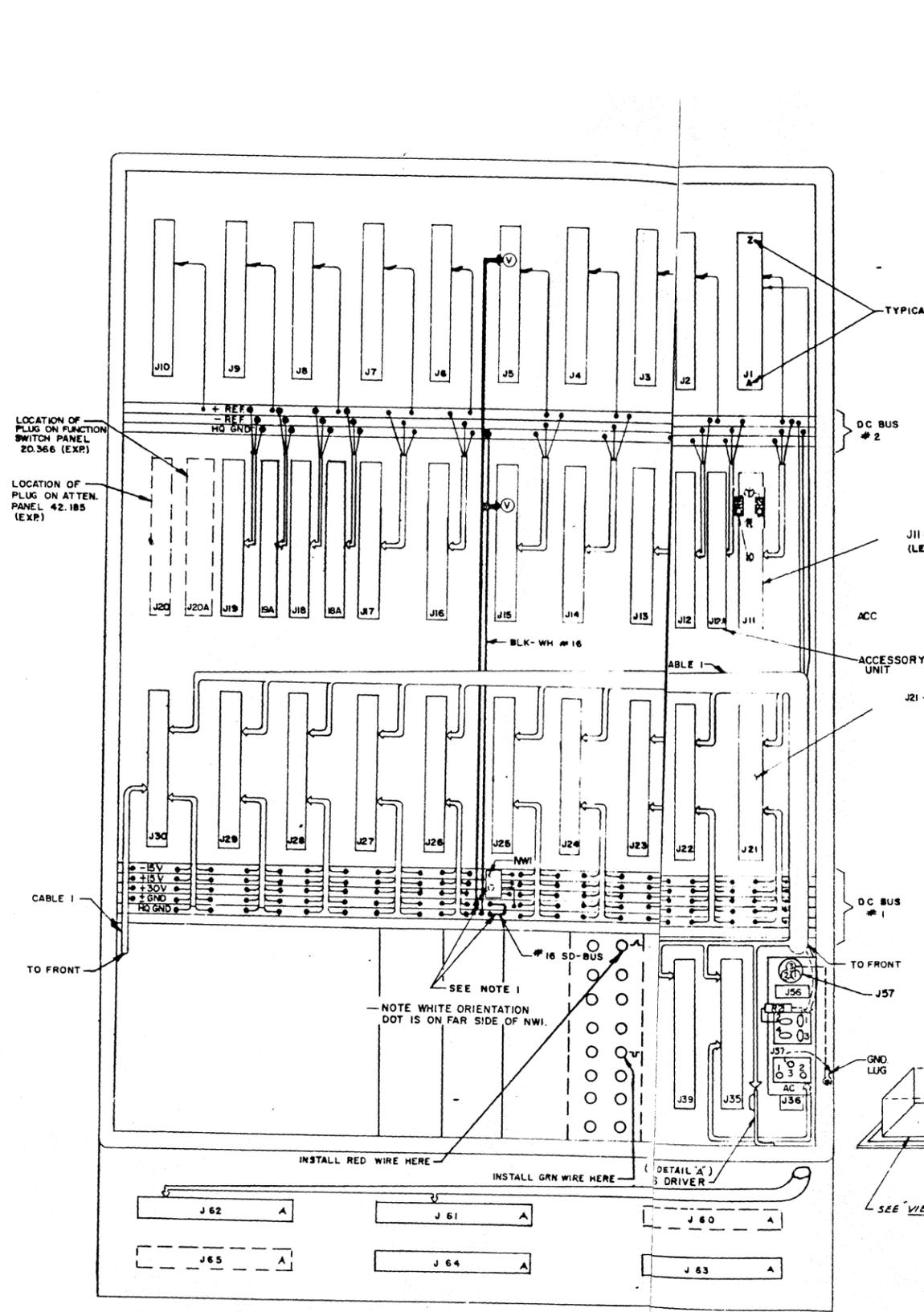
PLUG-IN END OF CARD

43.038 Ref. Regulator



PLUG-IN END OF CARD

43.107 Power Supply Regulator



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
WIRING TR-20 COMPUTER	
SMT. NO.	
SIZE	
REV. NO.	
PROJECT	19098D045 078 0W
SHEET 2 OF 2 SHEETS	

"AC" AND "CHASSIS GRD"						
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2	
			DESTINATION	WIRE	DESTINATION	WIRE
	AC-1	115V AC Com	J35-Y	WHT 20TP	J57-2	WHT #20
	AC-2	115V AC	J35-Z	WHT-GRY 20TP		
	AC-3	Chassis Grd	Grd Lug	SD-BUS 18		
	Chassis					
	Grd-1	Chassis Grd	J36-A	BLK		
	-2		J35-J	BLK-WHT		
	-3		J55-4	BLK		
	-4					
	-5		J33-V	BLK		
	-6		J32-E	BLK		
	-7		J32-M	BLK-WHT		
	-8		J32-N	BLK-WHT		
	-9		J32-V	BLK		
	-10		J31-D to H	Grd Strap		
	-11		J19-T	BLK		
	-12		J31-C	BLK #20		
	-13		* Grd-1	BLK 18	SEE NOTE 1	
	-14	Chassis Grd	*Grd-1	BLK 18		
	Chassis					
	Grd-15	Chassis Grd	J37-1	BLK 18		
	XDS1-1	6.3V AC	J32-F	BRN 22 TP		
	XDS1-2	6.3V AC	J32-H	WHT-BRN 22 TP		

NOTES:

1. Leads from chassis ground-13 and 14 must be installed on opposite ends of Bus Bar.

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(AC and Chassis Grd)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	B 045 078 OW
SHEET 3 OF SHEETS	

J1 and J2								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J1-A							
	J1-B							
	J1-C							
	J1-D							
	J1-E							
	J1-F							
	J1-H	Pot Bus	J2-H	SD-BUS				
	J1-J							
	J1-K							
	J1-L							
	J1-M							
	J1-N							
	J1-P	+10V Ref	+10V-2	WH-RED				
	J1-R							
	J1-S							
	J1-T							
	J1-U							
	J1-V	+Gnd	J2-V	SD-BUS				
	J1-W							
	J1-X							
	J1-Y							
	J1-Z							
	J2-A							
	J2-B							
	J2-C							
	J2-D							
	J2-E							
	J2-F							
	J2-H	Pot Bus	J1-H	SD-BUS	J3-H	SD-BUS		
	J2-J							
	J2-K							
	J2-L							
	J2-M							
	J2-N							
	J2-P	+10V Ref	+10V-2	WH-RED				
	J2-R							
	J2-S							
	J2-T							
	J2-U							
	J2-V	+Gnd	J1-V	SD-BUS	J3-V	SD-BUS		
	J2-W							
	J2-X							
	J2-Y							
	J2-Z							

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J1 and J2)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 E 045 078 OW
SHEET 4 OF SHEETS	

J3 and J4								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J3-A							
	J3-B							
	J3-C							
	J3-D							
	J3-E							
	J3-F	Pot Bus	J2-H	SD-BUS	J4-H	SD-BUS		
	J3-H							
	J3-K							
	J3-L							
	J3-M							
	J3-N							
	J3-P	+10V Ref	+10V-2	WH-RED				
	J3-R							
	J3-S							
	J3-U							
	J3-V	+Gnd	J2-V	SD-BUS	J4-V	SD-BUS		
	J3-W							
	J3-X							
	J3-Y							
	J3-Z							
	J4-A							
	J4-B							
	J4-C							
	J4-D							
	J4-E							
	J4-F	Pot Bus	J3-H	SD-BUS	J5-H	SD-BUS		
	J4-H							
	J4-J							
	J4-K							
	J4-L							
	J4-M							
	J4-N							
	J4-P	+10V Ref	+10V-2	WH-RED				
	J4-R							
	J4-S							
	J4-T							
	J4-U							
	J4-V	+Gnd	J3-V	SD-BUS	J5-V	SD-BUS		
	J4-W							
	J4-X							
	J4-Y							
	J4-Z							

ELECTRONIC ASSOCIATES, INC.									
LONG BRANCH, NEW JERSEY									
(J3 AND J4)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19098	B	045	078	0W				
SHEET 5 OF SHEETS									

J5 and J6								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J5-A							
	-B							
	-C							
	-D							
	-E							
	-F							
	-H	Pot Bus	J4-H	SD-BUS	J6-H	SD-BUS		
	-J							
	-K							
	-L							
	-M							
	-N							
	-P	+10V Ref	+10V-2	WH-RED				
	-R							
	-S							
	-T							
	-U							
	-V	+Gnd	J4-V	SD-BUS	J6-V	SD-BUS	+ GND-1	BLK 16
	-W							
	-X							
	-Y							
	J5-Z							
	J6-A							
	-B							
	-C							
	-D							
	-E							
	-F							
	-H	Pot Bus	J5-H	SD-BUS	J7-H	SD-BUS		
	-J							
	-K							
	-L							
	-M							
	-N							
	-P	+10V Ref	+10V-2	WH-RED				
	-R							
	-S							
	-T							
	-U							
	-V	+Gnd	J5-V	SD-BUS	J7-V	SD-BUS		
	-W							
	-X							
	-Y							
	J6-Z							

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(J5 and J6)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19098	B 045 078 0W
SHEET 6 OF SHEETS	

J7 and J8								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J7-A							
	-B							
	-C							
	-D							
	-E							
	-F							
	-H	Pot. Bus	J6-H	SD-BUS	J8-H	SD-BUS		
	-J							
	-K							
	-L							
	-M							
	-N							
	-P	+10V Ref	+10V-2	WH-RED				
	-R							
	-S							
	-T							
	-U							
	-V	+Gnd	J6-V	SD-BUS	J8-V	SD-BUS		
	-W							
	-X							
	-Y							
	-Z							
	J8-A							
	-B							
	-C							
	-D							
	-E							
	-F							
	-H	Pot. Bus	J7-H	SD-BUS	J8-H	SD-BUS		
	-J							
	-K							
	-L							
	-M							
	-N							
	-P	+10V Ref	+10V-2	WH-RED				
	-R							
	-S							
	-T							
	-U							
	-V	+Gnd	J7-V	SD-BUS	J8-V	SD-BUS		
	-W							
	-X							
	-Y							
	-Z							

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(J7 and J8)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	B 045 078 OW
SHEET 7 OF SHEETS	

J9 and J10								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J9-A							
	B							
	C							
	D							
	E							
	F							
	H	Pot Bus	J8-H	SD-Bus	J10-H	SD-Bus		
	J							
	K							
	L							
	M							
	N							
	P	+10V Ref	+10V-2	Wh-Red				
	R							
	S							
	T							
	U							
	V	+ Gnd	J8-V	SD-Bus	J10-V	SD-Bus		
	W							
	X							
	Y							
	J9-Z							
	J10-A							
	B							
	C							
	D							
	E							
	F							
	H	Pot Bus	J9-H	SD-Bus	J35-P	OR		
	J							
	K							
	L							
	M							
	N							
	P	+10V Ref	+10V-2	Wh-Red				
	R							
	S							
	T							
	U							
	V							
	W	+ Gnd	J9-V	SD-Bus				
	X							
	Y							
	J10-Z							

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J9 and J10)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 B 045 078 OW
SHEET 8 OF SHEETS	

J11, J12 and J12A								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J11-D							
	B							
	C							
	D							
	E	REF OP	J12A-E	SD-BUS				
	F							
	M							
	J							
18.543	K	Operate	J12A-K	SD-Bus				
	L	-10V Ref	-10V-2	Wh-V1				
18.543	M	HQ Cnd	HQ-Cnd-2	Blk-Wh				
18.543	N							
	P	+10V Ref	+10V-2	Wh-Red				
	R	Reset	J12A-R	SD-Bus				
	S							
	T	Relay Com	J12A-T	SD-Bus				
	U							
	V	± Grd	J12A-V	SD-Bus				
	W							
	X							
	Y							
	J11-E							
18.646	J12-A	B1	J64-A	BRN				
18.646	B	B2	J64-B	RED				
18.646	C	In	J64-C	ORN				
	D							
	E	REF OP	J12A-E	SD-BUS	J13-E	SD-BUS		
	F							
	M							
	J							
18.543	K	Operate	J12A-K	SD-Bus	J13-K	SD-Bus		
	L	-10V Ref	-10V-2	Wh-V1	J64-L	WHT-V10		
18.543	M	HQ-Cnd	HQ-Cnd-2	Blk-Wh				
18.543	N							
	P	+10V Ref	+10V-2	Wh-Red	J64-P	WHT-RED		
	R	Reset	J12A-R	SD-Bus	J13-R	SD-Bus		
	S							
	T	Relay Com	J12A-T	SD-Bus	J13-T	SD-Bus		
	U							
	V	± Grd	J12A-V	SD-Bus	J13-V	SD-Bus		
	W							
	X							
	Y							
	J12-E							
18.646	J12A-A	B1	J63-A	BRN				
18.646	B	B2	J63-B	RED				
18.646	C	IN	J63-C	ORN				
	D							
	E	REF OP	J11-E	SD-BUS	J12-E	SD-BUS		
	F							
	H							
	J							
18.543	K	Operate	J11-K	SD-BUS	J12-K	SD-BUS		
	L	-10V	-10V-2	WHT-V10	J63-L	WHT-V10		
18.543	M	HQ Grd	HQ Grd 2	BLK-WHT				
18.543	N							
	P	+10V	+10V-2	WHT-RED	J63-P	WHT-RED		
	R	Reset	J11-R	SD-BUS	J12-R	SD-BUS		
	S							
	T	Relay Com	J11-T	SD-BUS	J12-T	SD-BUS		
	U							
	J12A-V	± Grd	J11-V	SD-BUS	J12-V	SD-BUS		

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J11, J12 & J12A)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	B 045 078 DW
SHEET 9 OF SHEETS	

J13 and J14								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J13-A							
	B							
	C							
	D							
	E	REP OP	J12-E	SD-BUS	J14-E	SD-BUS		
	F							
	H							
	J							
18.543	K	Operate	J12-K	SD-Bus	J14-K	SD-Bus		
	L	-10V Ref	-10V-2	Wh-V1				
18.543	M	HQ Gnd	HQ-Gnd-2	Blk-Wk				
18.543	N							
	P	+10V Ref	+10V	Wh-Red				
	R	Reset	J12-R	SD-Bus	J14-R	SD-Bus		
	S							
	T	Relay Com	J12-T	SD-Bus	J14-T	SD-Bus		
	U							
	V	± Gnd	J12-V	SD-Bus	J14-V	SD-Bus		
	W							
	X							
	Y							
	J13-Z							
	J14-A							
	B							
	C							
	D							
	E	REP OP	J13-E	SD-BUS	J15-E	SD-BUS		
	F							
	H							
	J							
18.543	K	Operate	J13-K	SD-Bus	J15-K	SD-Bus		
	L	-10V Ref	-10V-2	Wh-V1				
18.543	M	HQ-Gnd	HQ-Gnd-2	Blk-Wk				
18.543	N							
	P	+10V Ref	+10V-2	Wh-Red				
	R	Reset	J13-R	SD-Bus	J15-R	SD-Bus		
	S							
	T	Relay Com	J13-T	SD-Bus	J15-T	SD-Bus		
	U							
	V	± Gnd	J13-V	SD-Bus	J15-V	SD-Bus		
	W							
	X							
	Y							
	J14-Z							

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J13 and J14)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 B 045 078 OW
SHEET 10 OF SHEETS	

J15 and J16								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J15-A							
	B							
	C							
	D							
	E	REP OP	J14-E	SD-BUS	J16-E	SD-BUS		
	F							
	H							
	J							
18.543	K	Operate	J14-K	SD-Bus	J16-K	SD-Bus		
	L	-10V Ref	-10V-2	Wh-V1				
18.543	M	HQ-Gnd	HQ-Gnd-2	Blk-Wh				
18.543	N	+10V Ref	+10V-2	Wh-Red				
	P	Reset	J14-R	SD-Bus	J16-R	SD-Bus		
	R							
	S							
	T	Relay Com	J14-T	SD-Bus	J16-T	SD-Bus		
	U							
	V	± Gnd	J14-V	SD-Bus	J16-V	SD-Bus	± GND-1	BLK 16
	W							
	X							
	Y							
	J15-Z							
	J16-A							
	B							
	C							
	D							
	E	REP OP	J15-E	SD-BUS	J17-E	SD-Bus		
	F							
	H							
	J							
18.543	K	Operate	J15-K	SD-Bus	J17-K	SD-Bus		
	L	-10V Ref	-10V-2	Wh-V1				
18.543	M	HQ-Gnd	HQ-Gnd-2	Blk-Wh				
18.543	N	+10V Ref	+10V-2	Wh-Red				
	P	Reset	J15-R	SD-Bus	J17-R	SD-Bus		
	R							
	S							
	T	Relay Com	J15-T	SD-Bus	J17-T	SD-Bus		
	U							
	V	± Gnd	J15-V	SD-Bus	J17-V	SD-Bus		
	W							
	X							
	Y							
	J16-Z							

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY									
(J15 and J16)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19 098 E 045 078 0W								
SHEET 11 OF SHEETS									

J17 & J18A						
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2	
			DESTINATION	WIRE	DESTINATION	WIRE
	J17-A					
	B					
	C					
	D					
	E	Rep Op	J16-E	SD-Bus	J18A-E	SD-Bus
	F					
	H					
	J					
18.543-1	K	Operate	J16-K	SD-Bus	J18A-K	SD-Bus
	L	-10V Ref	J16-2	WHT-VIO		
18.543-1	M	HQ Grd	HQ Grd-2	BLK-WHT		
18.543-1	N					
	P	+10V Ref	+10V-2	WHT-RED		
	R	Reset	J16-R	SD-Bus	J18A-R	SD-Bus
	S					
	T	Relay Com	J16-T	SD-BUS	J18A-T	SD-Bus
	U					
18.543-1	V	± Grd	J16-V	SD-Bus	J18A-V	SD-Bus
	W	+15V	DC Bus #1 (+15)	ORN		
	X					
18.543-1	Y					
	Z	-15V	DC Bus #1 (-15)	VIO		
18.646	J18A-A	B ₁	J61-A	BRN		
18.646	B	B ₂	J61-B	RED		
18.646	C	In	J61-C	ORN		
	D					
	E	Rep Op	J17-E	SD-Bus	J18-E	SD-Bus
	F					
	H					
	J					
18.543 18.646	K	Operate	J17-K	SD-Bus	J18-K	SD-Bus
	L	-10V Ref	J17-2	WHT-VIO	J61-L	WHT-VIO
18.543	M	HQ Grd	HQ Grd-2	BLK-WHT		
18.543 18.646	N					
	P	+10V Ref	+10V-2	WHT-RED	J61-P	WHT-RED
	R	Reset	J17-R	SD-Bus	J18-R	SD-Bus
	S					
	T	Relay Com	J17-T	SD-Bus	J18-T	SD-Bus
	U					
	V	± Grd	J17-V	SD-Bus	J18-V	SD-Bus
	W					
	X					
	Y					
	Z					

ELECTRONIC ASSOCIATES, INC.											
LONG BRANCH, NEW JERSEY											
(J17 & J18A)											
SHT. NO.											
SIZE											
REV. NO.											
PROJECT	19098	B	045	078	OW						
SHEET 12 OF SHEETS											

J18 & J19A						
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2	
			DESTINATION	WIRE	DESTINATION	WIRE
18.646	J18-A	B1	J62-A	BRN		
18.646	B	B2	J62-B	RED		
18.646	C	In	J62-C	ORN		
	D					
	E	Rep Opr	J18A-E	SD-Bus	J19-E	SD-Bus
	F					
	H					
	J					
	K	Operate	J18A-K	SD-Bus	J19-K	SD-Bus
18.543 18.646	L	-10V Ref	-10V-2	WHT-VIO	J62-L	WHT-VIO
18.543 18.646	M	HQ Grd	HQ Grd-2	BLK-WHT		
18.543 18.646	P	+10V Ref	+10V-2	WHT-RED	J62-P	WHT-RED
	R	Reset	J18A-R	SD-Bus	J19-R	SD-Bus
	S					
	T	Relay Com	J18A-T	SD-Bus	J19-T	SD-Bus
	U					
	V	± Grd	J18A-V	SD-Bus	J19-V	SD-Bus
	W					
	X					
	Y					
	Z					
18.646	J19A-A	Y1	J56-5	BRN		
	B	X0 (Ω)	J56-19	RED		
	C		J56-13	RED		
18.646	D	Y2	J56-7	BLU		
	E	Rep Op	J18-E	SD-Bus	J19-E	SD-Bus
18.646	F	X1	J56-11	GRN		
18.646	H	Y4	J56-15	YEL		
18.646	J	Y3	J56-14	ORN		
	K	Operate	J18-K	SD-Bus	J19-K	SD-Bus
18.543 18.646	L	- Ref	-10V-2	WHT-VIO 20	J56-9	WHT-VIO 20
18.543 18.646	M	HQ Grd	HQ Grd-2	BLK-WHT 20	J56-3	BLK-WHT 20
18.646	N	HQ Grd	HQ Grd-2	BLK WHT 20	J56-4	BLK-WHT 20
18.543 18.646	P	+ Ref	+10V-2	WHT-RED 20	J56-6	WHT-RED 20
	R	Reset	J18-R	SD-Bus	J19-R	SD-Bus
18.646	S	Sweep (Ω)	TU-Ω	RED		
	T	Relay Com	J18-T	SD-Bus	J19-T	SD-Bus
	U					
	V	± Grd	J18-V	SD-Bus	J19-V	SD-Bus
18.646	V	± Grd	J56-10	BLK 20		
	W					
	X					
	Y					
	Z					

ELECTRONIC ASSOCIATES, INC.									
LONG BRANCH, NEW JERSEY									
(J18 & J19A)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19098	B	045	078	OW				
SHEET 13 OF SHEETS									

J19						
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2	
			DESTINATION	WIRE	DESTINATION	WIRE
	J19-A					
	B					
	C					
	D					
	E	Rep Op	J19A-E	SD-Bus	J35-T	BLU
	F					
	H					
	J					
	K	Operate	J19A-K	SD-Bus	Q2-E	GRN
18.543	L	- Ref	-10V-2	WHT-VIO		
18.543	M	HQ Grd	HQ Grd-2	BLK-WHT		
	N	HQ Grd	HQ Grd-2	BLK-WHT		
18.543	P	+ Ref	+10V-2	WHT-RED		
	R	Reset	J19A-R	SD-Bus	Q1-E	YEL
	S					
	T	Rel Grd	J19A-T	SD-Bus	J31-T	BLK
	U	-20V	J31-u	GRY		
	V	± Grd	J19A-V	SD-Bus		
	W	+15V	J31-K	ORN		
	X					
	Y					
	Z	-15V	-15V-1	VIO		

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J19)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098
	B 045 078 OW
SHEET 14 OF SHEETS	

J21 and J22								
CABLE	TERMINAL	FUNCTION	DESTINATION #1	WIRE #1	DESTINATION #2	WIRE #2	DESTINATION #3	WIRE #3
	J21-A	-15V	-15V-1	V1				
	B	Output #2	S6a-2	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	± Gnd-1	Blk				
	F	6.3V AC	J22-F	SD-Bus				
	H	6.3V AC	J22-H	SD-Bus				
	J	+30V	+30V-1	Red				
	K	Bal Pot #2	J36-Y	Yel				
	L	Stab #2	S6b-2	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	P	Stab #1	S6b-1	Grn				
	R	Bal Pot #1	J36-Z	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	± Gnd-1	Blk				
	W	+ 15V	+15V-1	Or				
	X							
	Y	Output #1	S6a-1	Blu				
	J21-Z	-15V	-15V-1	V1				
	J22-A	-15V	-15V-1	V1				
	B	Output #4	S6a-4	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	± Gnd-1	Blk				
	F	6.3V AC	J21-F	SD-Bus	J23-F	SD-Bus		
	H	6.3V AC	J21-H	SD-Bus	J23-H	SD-Bus		
	J	+ 30V	+ 30V-1	Red				
	K	Bal Pot #4	J36-W	Yel				
	L	Stab. #4	S6b-4	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	P	Stab. #3	S6b-3	Grn				
	R	Bal Pot #3	J36-X	Yel				
	S	+ 30V	+ 30V-1	Red				
	T							
	U							
	V	± Gnd	± Gnd-1	Blk				
	W	+ 15V	+15V-1	Or				
	X							
	Y	Output #3	S6 -3	Blu				
	J22-Z	- 15V	-15V-1	V1				

ELECTRONIC ASSOCIATES, INC.									
LONG BRANCH, NEW JERSEY									
(J21 and J22)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19098	B	045	078	OW				
SHEET 75 OF SHEETS									

J23 and J24								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	J23-A	-15V	-15V-1	V1				
	B	Output #6	S6a-6	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	±Gnd-1	Blk				
	F	6.3V AC	J22-F	SD-Bus	J24-F	SD-Bus		
	H	6.3V AC	J22-H	SD-Bus	J24-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal. Pot #6	J36-U	Yel				
	L	Stab. #6	S6b-6	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	P	Stab. #5	S6b-5	Grn				
	R	Bal. Pot #5	J36-V	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	± Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #5	S6c-5	Blu				
	J23-Z	-15V	-15V-1	V1				
	J24-A	-15V	-15V-1	V1				
	B	Output #8	S6c-8	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	±Gnd-1	Blk				
	F	6.3V AC	J23-F	SD-Bus	J25-F	SD-Bus		
	H	6.3V AC	J23-H	SD-Bus	J25-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal. Pot #8	J36-5	Yel				
	L	Stab. #8	S6b-8	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-wh				
	P	Stab. #7	S6b-7	Grn				
	R	Bal. Pot #7	J36-T	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	±Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #7	S6a-7	Blu				
	J24-Z	-15V	-15V-1	V1				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY									
(J23 and J24)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19098 B 045 078 OW								
SHEET 16 OF SHEETS									

J25 and J26								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
			#1	#1	#2	#2	#3	#3
	J25-A	-15V	-15V-1	Vi				
	B	Output #10	S6a-10	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	±Gnd-1	Blk				
	F	6.3V AC	J24-F	SD-Bus	J26-F	SD-Bus		
	H	6.3V AC	J24-H	SD-Bus	J26-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal Pot #10	J36-P	Yel				
	L	Stab. #10	S6b-10	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	P	Stab. #9	S6b-9	Grn				
	R	Bal Pot #9	J36-R	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	±Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #9	S6b-9	Blu				
	J25-Z	-15V	-15V-1	Vi				
	J26-A	-15V	-15V-1	Vi				
	B	Output #12	S6a-12	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	±Gnd	±Gnd-1	Blk				
	F	6.3V AC	J25-F	SD-Bus	J27-F	SD-Bus		
	H	6.3V AC	J25-H	SD-Bus	J27-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal Pot #12	J36-M	Yel				
	L	Stab. #12	S6b-12	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	P	Stab. #11	S6b-11	Grn				
	R	Bal Pot #11	J36-N	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	±Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #11	S6b-11	Blu				
	J26-Z	-15V	-15V-1	Vi				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(J25 and J26)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 B 645 078 DW
SHEET 17 OF SHEETS	

J27 and J28								
CABLE	TERMINAL	FUNCTION	DESTINATION #1	WIRE #1	DESTINATION #2	WIRE #2	DESTINATION #3	WIRE #3
	J27-A	-15V	-15V-1	V1				
	B	Output #14	S6a-14	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	±Gnd	±Gnd-1	Blk				
	F	6.3V AC	J26-F	SD-Bus	J28-F	SD-Bus		
	H	6.3V AC	J26-H	SD-Bus	J28-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal Pot #14	J36-K	Yel				
	L	Stab #14	S6b-14	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-WH				
	N	HQ-Gnd	HQ-Gnd-1	Blk-WH				
	P	Stab #13	S6b-13	Grn				
	R	Bal Pot #13	J36-L	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	±Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #13	S6a-13	Blu				
	J27-Z	-15V	-15V-1	V1				
	J28-A	-15V	-15V-1	V1				
	B	Output #16	S6a-16	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	± Gnd	±Gnd-1	Blk				
	F	6.3V AC	J27-F	SD-Bus	J29-F	SD-Bus		
	H	6.3V AC	J27-H	SD-Bus	J29-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal Pot #16	J36-H	Yel				
	L	Stab #16	S6b-16	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-WH				
	N	HQ-Gnd	HQ-Gnd-1	Blk-WH				
	P	Stab #15	S6b-15	Grn				
	R	Bal Pot #15	J36-J	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	± Gnd	±Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #15	S6a-15	Blu				
	J28-Z	-15V	-15V-1	V1				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY			
(J27 and J28)			
SHT. NO.			
SIZE			
REV. NO.			
PROJECT	19098	B	045-078 GW
SHEET 18 OF SHEETS			

J29 and J30								
CABLE	TERMINAL	FUNCTION	DESTINATION #1	WIRE #1	DESTINATION #2	WIRE #2	DESTINATION #3	WIRE #3
	J29-A	-15V	-15V-1	V1				
	B	Output #18	S6a-18	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	+Gnd	+Gnd-1	Blk				
	F	6.3V AC	J28-F	SD-Bus	J30-F	SD-Bus		
	H	6.3V AC	J28-H	SD-Bus	J30-H	SD-Bus		
	J	+30V	+30V-1	Red				
	K	Bal Pot #18	J36-E	Yel				
	L	Stab #18	S6b-18	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	P	Stab #17	S6b-17	Grn				
	R	Bal Pot #17	J36-F	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	+Gnd	+Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #17	S6a-17	Blu				
	J29-Z	-15V	-15V-1	V1				
	J30-A	-15V	-15V-1	V1				
	B	Output #20	S6a-20	Blu				
	C							
	D	+15V	+15V-1	Or				
	E	+Gnd	+Gnd-1	Blk				
	F	6.3V AC	J29-F	SD-Bus	J31-W	Brn #18 TP		
	H	6.3V AC	J29-H	SD-Bus	J31-V	Wh-Brn #18 TP		
	J	+30V	+30V-1	Red				
	K	Bal Pot #20	J36-C	Yel				
	L	Stab #20	S6b-20	Grn				
	M	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	N	HQ-Gnd	HQ-Gnd-1	Blk-Wh				
	P	Stab #19	S6b-19	Grn				
	R	Bal Pot #19	J36-D	Yel				
	S	+30V	+30V-1	Red				
	T							
	U							
	V	+Gnd	+Gnd-1	Blk				
	W	+15V	+15V-1	Or				
	X							
	Y	Output #19	S6a-19	Blu				
	J30-Z	-15V	-15V-1	V1				

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J29 and J30)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19 098 B 045 078 OW
SHEET 15 OF SHEETS	

J31 and J32								
CABLE	TERMINAL	FUNCTION	DESTINATION #1	WIRE #1	DESTINATION #2	WIRE #2	DESTINATION #3	WIRE #3
	J31-A	-15V	-15V-1	V1 #16	J19-Z	V1	J32-A	SD-Bus
	B	-15V	J35-B	V1	J32-Z	V1		
	C	+ Gnd	Chas. Gnd-12	BLK #20				
	D	-15V Com		SD-Bus				
	E	-15V Com		SD-Bus	Chassis Gnd-10	Gnd Strap		
	F	+15V Com		SD-Bus				
	H	+15V Com		SD-Bus				
	J	6V DC	J50-2	WHT-BRN				
	K	+15V	J32-W	Or	J19-W	Or		
	L	+15V	J32-D	Or	J31-M	SD-Bus		
	M	+30 Com	J35-C	Or	J31-L	SD-Bus		
	N	+30 Com	+15V-1	Or #18				
	P	6V DC Com	J50-4	BLK				
	R	+30V	J35-D	Red	J32-J	Red		
	S	+30V	+30V-1	Red #16	J32-S	SD-Bus		
	T	-Relay Com	J37-2	Blk	J19-T	BLK		
	U	-Relay	J35-E	Gy	J19-U	Gy		
	V	6.3V AC	J30-H	Wh-Brn 18	J32-H	Wh-Brn 20 TP		
	W	6.3V AC	J30-F	Brn #18	J32-F	Brn #20 TP		
	X							
	Y	115V AC Com	J35-Y	Wh #20				
	J31-Z	115V AC SW	J35-X	Wh-Gy #20				
	J32-A	-15V	J31-A	SD-Bus	J33-A	SD-Bus		
	B	Output						
	C							
	D	+15V	J31-L	Or	J33-W	SD-Bus		
	E	+ Gnd	Chassis Gnd-6	Blk				
	F	6.3V AC	J31-W	Brn #20	TPXDS1-1	BRN TP		
	H	6.3V AC	J31-V	Wh-Brn 20	TPXDS1-2	WHT-BRN TP		
	J	+30V	J31-R	Red				
	K	Bal Pot #22	J33-K	SD-Bus				
	L	Stab. #22	S6-22	Grn				
	M	HQ-Gnd	Chassis Gnd-7	Blk-Wh				
	N	HQ-Gnd	Chassis Gnd-8	Blk-Wh				
	P	Stab #21	S6-21	Grn				
	R	Bal Pot #21	J33-R	SD-Bus				
	S	+30V	J31-S	SD-Bus				
	T							
	U							
	V	+ Gnd	Chassis Gnd-9	Blk				
	W	+15V	J31-K	Or				
	X							
	Y	Output						
	J32-Z	-15V	J31-B	V1				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(J31 and J32)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 B 045 078 OW
SHEET 20 OF SHEETS	

J33						
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2	
			DESTINATION	WIRE	DESTINATION	WIRE
	J33-A	-15V	J32-A	SD-BUS		
	B	-Ref	-10V-2	Wh-VI #16		
	C	-Ref	J35-F	Wh-VI	S6a-22	Blu
	D					
	E					
	F					
	H					
	J					
	K	Bal Pot #22	J32-K	SD-Bus		
	L					
	M					
	N					
	P					
	R	Bal Pot #21	J32-R	SD-Bus		
	S					
	T					
	U					
	V	± Gnd	Chassis	Blk		
	W	+15V	Gnd-5			
	X	+ Ref	J32-D	SD-Bus		
			+10V-2	Wh-Red #16		
	Y	+ Ref	J35-H	Wh-Red	S6a-21	Blu
	J33-Z					
<p>For J34 Wiring (Audio Overload Alarm Connector) See Expansion Dwg. BOO2 415 OA.</p>						

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(J33 and J34)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19098	B 045 078 OW
21	

HARN/CABLE		TERMINAL	FUNCTION	DESTINATION	COLUMN 1 WIRE	DESTINATION	COLUMN 2 WIRE
		J35-A	+ Grd	+ Grd	BLK #18	R1 (Bus Driver)	BLK #20
		-B	-15V	J36-B	VIO	J31-B	VIO
		-H	-15V	J39-B	VIO		
		-C	+15V	J31-M	ORN	J39-W	ORN
		-D	+30V	J31-R	RED		
		-E	-Relay V	J31-U	GY	J39-F	GY
		-F	-Relay V	Q2-C	GY		
		-H	-Ref	J33-C	WHT-VIO		
		-I	+Ref	J33-Y	WHT-RED		
18.646		-J	HQ-GRD	Chassis Grd-2	BLK-WHT		
18.646		-K	Operate	J56-1	GY		
		-L	-24V	J56-2	VIO		
18.646		-M	Reset	J56-8	BLU		
		-N					
		-P	Pot Bus	J10-H	ORN		
		-R	Stab Out	S6b-W	GRN		
		-S	Amp Out	S6a-W	BLU		
		-T	Rep. Op.	J19-B	BLU	J39-S	BLU
		-U	Operate	Q2-B	GRN	J37-3	GRN
		-V	Operate	J39-X	GRN		
		-W	Reset	Q1-B	YEL	J37-4	YEL
		-Y	Reset	J39-Y	YEL		
		-Z					
		-I	115V AC SW	J31-Z	WHT-GY #20	J57-1	WHT-GY #16
		-Y	115V AC Com	J31-Y	WHT #20	AC-1	WHT #20
		J35-Z	115V AC	AC-2	WHT-GY #20		
		J36-A	+ Grd	J39-E	BLK #20	Chassis Grd-1	BLK #20
		-B	-15V	J35-B	VIO		
		-C	Bal Pot #20	J30-K	YEL		
		-D	Bal Pot #19	J30-R	YEL		
		-E	Bal Pot #18	J29-K	YEL		
		-F	Bal Pot #17	J29-R	YEL		
		-H	Bal Pot #16	J28-K	YEL		
		-J	Bal Pot #15	J28-R	YEL		
		-K	Bal Pot #14	J27-K	YEL		
		-L	Bal Pot #13	J27-R	YEL		
		-M	Bal Pot #12	J26-K	YEL		
		-N	Bal Pot #11	J26-R	YEL		
		-P	Bal Pot #10	J25-K	YEL		
		-R	Bal Pot #9	J25-R	YEL		
		-S	Bal Pot #8	J24-K	Yel		
		-T	Bal Pot #7	J24-R	YEL		
		-U	Bal Pot #6	J23-K	YEL		
		-V	Bal Pot #5	J23-R	YEL		
		-W	Bal Pot #4	J22-K	YEL		
		-X	Bal Pot #3	J22-R	YEL		
		-Y	Bal Pot #2	J21-K	YEL		
		J36-Z	Bal Pot #1	J21-R	YEL		
		J37-1	Chas. Grd (Slave)	Chas. Grd-15	BLK 18	R21-1	See Sht. 2
		-2	Rly Com (Slave)	J31-T	BLK	R21-2	
		-3	Operate (Slave)	J35-U	GRN		
		J37-4	Reset (Slave)	J35-V	YEL		

FOR WIRING OF J38 and J39 SEE SHEET 26.

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J35 thru J37)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19098 B 045 078 OW
SHEET 22 OF SHEETS	

F36								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	F36-A	± Gnd	R2-1	Blk #18				
	B	-19V	R1-3	Vi #18				
	C	Bal Pot #20	R20-2	Yel				
	D	#19	R19-2					
	E	#18	R18-2					
	F	#17	R17-2					
	H	#16	R16-2					
	J	#15	R15-2					
	K	#14	R14-2					
	L	#13	R13-2					
	M	#12	R12-2					
	N	#11	R11-2					
	P	#10	R10-2					
	R	#9	R9-2					
	S	#8	R8-2					
	T	#7	R7-2					
	U	#6	R6-2					
	V	#5	R5-2					
	W	#4	R4-2					
	X	#3	R3-2					
	Y	#2	R2-2					
	F36-Z	Bal Pot #1	R1-2	Yel				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
(F36)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19098	B 045 078 OW
SHEET 23 OF SHEETS	

R1 to R20								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	R1-1	+Gnd	R3-1	SD-BUS	+ Gnd-1	Blk #16	R2-1	SD-BUS
	R1-2	Bal Pot #1	P36-2	Yel				
	R1-3	-15V	R3-3	SD-BUS	P36-B	V1	R2-3	SD-BUS
	R2-1	+Gnd	R4-1	SD-BUS	R1-1	SD-BUS	P36-A	Blk #18
	R2-2	Bal Pot #2	P36-Y	Yel				
	R2-3	-15V	R4-3	SD-BUS	R1-3	SD-BUS		
	R3-1	+Gnd	R1-1	SD-BUS	R5-1	SD-BUS		
	R3-2	Bal Pot #3	P36-X	Yel				
	R3-3	-15V	R1-3	SD-BUS	R5-3	SD-BUS		
	R4-1	+Gnd	R2-1	SD-BUS	R6-1	SD-BUS		
	R4-2	Bal Pot #4	P36-W	Yel				
	R4-3	-15V	R2-3	SD-BUS	R6-3	SD-BUS		
	R5-1	+Gnd	R3-1	SD-BUS	R7-1	SD-BUS		
	R5-2	Bal Pot #5	P36-V	Yel				
	R5-3	-15V	R3-3	SD-BUS	R7-3	SD-BUS		
	R6-1	+Gnd	R4-1	SD-BUS	R8-1	SD-BUS		
	R6-2	Bal Pot #6	P36-U	Yel				
	R6-3	-15V	R4-3	SD-BUS	R8-3	SD-BUS		
	R7-1	+Gnd	R5-1	SD-BUS	R9-1	SD-BUS		
	R7-2	Bal Pot #7	P36-T	Yel				
	R7-3	-15V	R5-3	SD-BUS	R9-3	SD-BUS		
	R8-1	+Gnd	R6-1	SD-BUS	R10-1	SD-BUS		
	R8-2	Bal Pot #8	P36-S	Yel				
	R8-3	-15V	R6-3	SD-BUS	R10-3	SD-BUS		
	R9-1	+Gnd	R7-1	SD-BUS	R11-1	SD-BUS		
	R9-2	Bal Pot #9	P36-R	Yel				
	R9-3	-15V	R7-3	SD-BUS	R11-3	SD-BUS		
	R10-1	+Gnd	R8-1	SD-BUS	R12-1	SD-BUS		
	R10-2	Bal Pot #10	P36-P	Yel				
	R10-3	-15V	R8-3	SD-BUS	R12-3	SD-BUS		
	R11-1	+Gnd	R9-1	SD-BUS	R13-1	SD-BUS		
	R11-2	Bal Pot #11	P36-N	Yel				
	R11-3	-15V	R9-3	SD-BUS	R13-3	SD-BUS		
	R12-1	+Gnd	R10-1	SD-BUS	R14-1	SD-BUS		
	R12-2	Bal Pot #12	P36-M	Yel				
	R12-3	-15V	R10-3	SD-BUS	R14-3	SD-BUS		

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(R1 Thru R20)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19098	B 045 078 OW
SHEET 24 OF SHEETS	

R1 to R20								
CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE
	R13-1	+Gnd	R11-1	SD-BUS	R15-1	SD-BUS		
	R13-2	Bal Pot #13	P36-L	Yel				
	R13-3	-15V	R11-3	SD-BUS	R15-3	SD-BUS		
	R14-1	+Gnd	R12-1	SD-BUS	R16-1	SD-BUS		
	R14-2	Bal Pot #14	P36-K	Yel				
	R14-3	-15V	R12-3	SD-BUS	R16-3	SD-BUS		
	R15-1	+Gnd	R13-1	SD-BUS	R17-1	SD-BUS		
	R15-2	Bal Pot #15	P36-J	Yel				
	R15-3	-15V	R13-3	SD-BUS	R17-3	SD-BUS		
	R16-1	+Gnd	R14-1	SD-BUS	R18-1	SD-BUS		
	R16-2	Bal Pot #16	P36-H	Yel				
	R16-3	-15V	R14-3	SD-BUS	R18-3	SD-BUS		
	R17-1	+Gnd	R15-1	SD-BUS	R19-1	SD-BUS		
	R17-2	Bal Pot #17	P36-F	Yel				
	R17-3	-15V	R15-3	SD-BUS	R19-3	SD-BUS		
	R18-1	+Gnd	R16-1	SD-BUS	R20-1	SD-BUS		
	R18-2	Bal Pot #18	P36-E	Yel				
	R18-3	-15V	R16-3	SD-BUS	R20-3	SD-BUS		
	R19-1	+Gnd	R17-1	SD-BUS				
	R19-2	Bal Pot #19	P36-D	Yel				
	R19-3	-15V	R17-3	SD-BUS				
	R20-1	+Gnd	R18-1	SD-BUS				
	R20-2	Bal Pot #20	P36-C	Yel				
	R20-3	-15V	R18-3	SD-BUS				

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY									
(R1 thru R20)									
SHT. NO.									
SIZE									
REV. NO.									
PROJECT	19 098 B 045 078 0W								
SHEET 25 OF SHEETS									

CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE	DESTINATION	WIRE		
S6a-1	1	Output #1	J21-Y	BLU						
	2	#2	J21-B							
	3	#3	J22-Y							
	4	#4	J22-B							
	5	#5	J23-Y							
	6	#6	J23-B							
	7	#7	J24-Y							
	8	#8	J24-B							
	9	#9	J25-Y							
	10	#10	J25-B							
	11	#11	J26-Y							
	12	#12	J26-B							
	13	#13	J27-Y							
	14	#14	J27-B							
	15	#15	J28-Y							
	16	#16	J28-B							
	17	#17	J29-Y							
	18	#18	J29-B							
	19	#19	J30-Y							
	20	Output #20	J30-B							
S6a-22	-21	+Ref	J33-Y	BLU						
	-22	-Ref	J33-C							
	S6a-W	Output	J35-S							
S6b-1	1	Stab #1	J21-P	GRN	J50-1	BLK 26				
	2	#2	J21-L		J51-1	BRN				
	3	#3	J22-P		J52-1	RED				
	4	#4	J22-L		J53-1	ORN				
	5	#5	J23-P		J54-1	YEL				
	6	#6	J23-L		J55-1	GRN				
	7	#7	J24-P		J50-3	BLU				
	8	#8	J24-L		J51-3	VIO				
	9	#9	J25-P		J52-3	GY				
	10	#10	J25-L		J53-3	WHT				
	11	#11	J26-P		J54-3	WHT-RED				
	12	#12	J26-L		J55-3	BLK				
	13	#13	J27-P		J50-5	BRN				
	14	#14	J27-L		J51-5	RED				
	15	#15	J28-P		J52-5	ORN				
	16	#16	J28-L		J53-5	YEL				
	17	#17	J29-P		J54-5	GRN				
	18	#18	J29-L		J55-5	BLU				
	19	#19	J30-P		J51-71	VIO				
	20	#20	J30-L		J52-7	GY				
	S6b-w	-21	#21		J32-P	GRN	J53-7	WHT		
		-22	Stab #22		J32-L		J54-7	WHT-RED	26	
		Stab	J35-R							

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	19 096 B 045 078 OW
SHEET 26 OF 28	

J38 & J39									
CAB	TERMINAL	FUNCTION	DESTINATION #1	WIRE #1	DESTINATION #2	WIRE #2	DESTINATION #3	WIRE #3	
J38-A B C D E F H J K L M N P R S T U V W X Y J38-Z		-15V	J39-A	VI					
		± Gnd	J39-E	BLK 20		SD-BUS			
		Control Sweep	J39-K J39-L	BRN RED					
		-20V	J39-T	BLU					
		± Gnd +15V Operate	J39-V J39-W J39-X	BLK 20 OR GRN		SD-BUS			
		Reset	J39-Y	YEL					
	J39-A B C D E F H J K L M N P R S T U V W X Y J39-Z		-15V	J38-A	VI				
			-15V	J35-B	VI				
			± Gnd	J36-A	BLK 20	J38-E	BLK 20		
			- Relay V	J35-E	GY				
			Control Sweep	J38-K J38-L	BRN RED				
			± Gnd Rep. Op.	± Gnd Bus J35-T	BLK 20 BLU				
			-20V	J38-T	BLU				
		* Gnd +15V Operate	J38-V J38-W J38-X	BLK 20 OR GRN	J35-C J35-U	OR GRN			
		Reset	J38-Y	YEL	J35-V	YEL			

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J38 - J39)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19098	B 045 078 OW
SHEET 27 OF SHEETS	

J50-J55			COLUMN 1		COLUMN 2			
HARN/CABLE	TERMINAL	FUNCTION	DESTINATION	WIRE	DESTINATION	WIRE		
J50-1	2	Stab #1	S6b-1	BLK 26	J31-J	WHT-BRN		
	3	6V DC		WHT-BRN				
	4	Stab #7	S6b-7	BLU 26			J31-P	BLK
	5	6V Comm		BLK				
		Stab #13	S6b-13	BRN 26				
J50-7								
J51-1	2	Stab #2	S6b-2	BRN 26				
	3	6V DC		WHT-BRN				
	4	Stab #8	S6b-8	VIO 26				
	5	6V Comm		BLK				
	6	Stab #14	S6b-14	RED 26				
	J51-7		Stab #19	S6b-19			VIO 26	
J52-1	2	Stab #3	S6b-3	RED 26				
	3	6V DC		WHT-BRN				
	4	Stab #9	S6b-9	GY 26				
	5	6V Comm		BLK				
	6	Stab #15	S6b-15	GRN 26				
	J52-7		Stab #20	S6b-20			GRY 26	
J53-1	2	Stab #4	S6b-4	GRN 26				
	3	6V DC		WHT-BRN				
	4	Stab #10	S6b-10	WHT 26				
	5	6V Comm		BLK				
	6	Stab #16	S6b-16	YEL 26				
	J53-7		Stab #21	S6b-21			WHT 26	
J54-1	2	Stab #5	S6b-5	YEL 26				
	3	6V DC		WHT-BRN				
	4	Stab #11	S6b-11	WHT-RED 26				
	5	6V Comm		BLK				
	6	Stab #17	S6b-17	GRN 26				
	J54-7		Stab #22	S6b-22			WHT-RED 26	
J55-1	2	Stab #6	S6b-6	GRN 26	Chas. Grd-3	BLK		
	3	6V DC		WHT-BRN				
	4	Stab #12	S6b-12	BLK 26				
	5	6V Comm		BLK				
	J55-7		Stab #18	S6b-18			BLU 26	
Q1-B		Reset	J19R	YEL				
Q1-B		Reset	J35-V	YEL				
Q2-B		Operate	J19-K	GRN				
Q2-B		Operate	J35-U	GRN				
Q2-C		Relay Volts	J35-B	GRY				
E1		± GRD	J35-A	BLK #20				
		(See Note #2)						

NOTE:

1. All leads and jumpers coming to J50-J55 connector are to be terminated into edge connectors, Item #15.
2. E1 located on BUS Driver Assy which is in vicinity of J37.

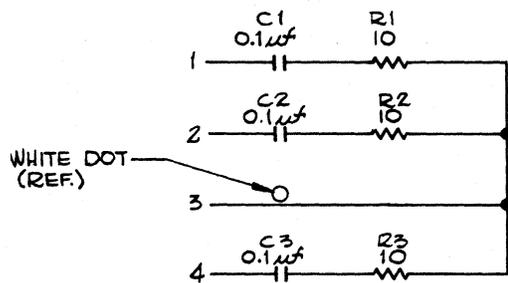
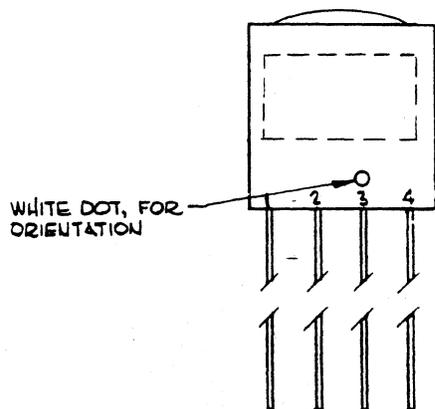
ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
(J50 thru J55)	
SMT. NO.	
SIZE	
REV. NO.	
PROJECT	B 045 078 OW
19098	
SHEET 28 OF SHEETS	

J56 & J57							
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2		
			DESTINATION	WIRE	DESTINATION	WIRE	
18.646	J56-1	Operate	J35-K	GY			
	2	Pen Lift (-24V)	J35-L	VIO			
	3	HO Grd	J19A-M	BLK-WHT 20			
	4	HQ Grd	J19A-N	BLK WHT 20			
	5	Y ₁	J19A-A	BRN			
	6	+10V	J19A-P	WHT-RED 20			
	7	X ₂	J19A-D	BLU			
	8	Reset	J35-M	BLU			
	9	-10V	J19A-L	WHT-VIO 20			
	10	= Grd	J19A-V	BLK #20			
	11	X ₁	J19A-F	GRN			
	12						
	13	Y ₂	J19A-C	RED			
	14	Y ₃	J19A-J	ORN			
	15	Y ₄	J19A-n	YEL			
	16						
	17	Unblanking	TU--	GRN			
	18						
	18.646	19	X ₀ (?)	J19A-B	RED		
		20					
	J57-1	115V AC SW	J35-X	WHT-GY #16			
	2	115V AC COM	AC-1	WHT			
	3	Chassis Grd	Grd Lug	SD-Bus #18			

ELECTRONIC ASSOCIATES, INC.					
LONG BRANCH, NEW JERSEY					
J56 & J57					
SHT. NO.					
SIZE					
REV. NO.					
PROJECT	19098	B	045	078	OW
SHEET 29 OF SHEETS					

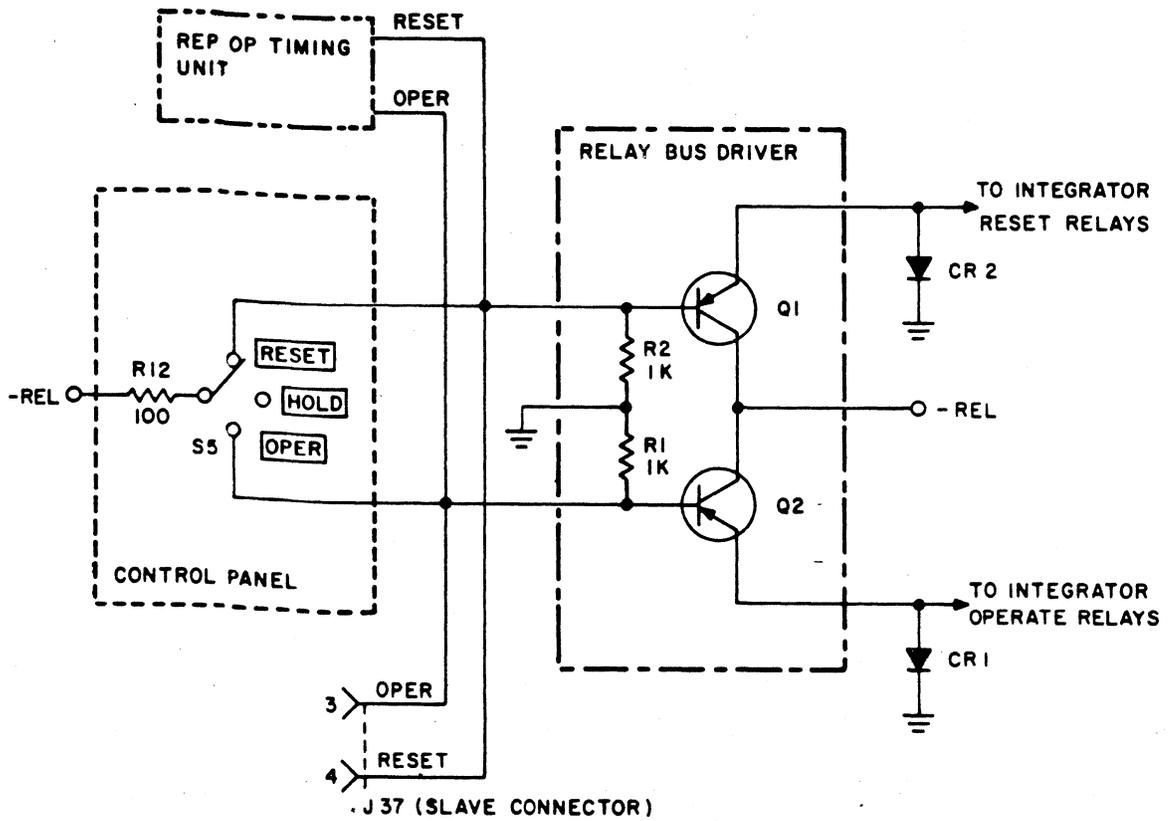
J62 & J61							
HARN/CABLE	TERMINAL	FUNCTION	COLUMN 1		COLUMN 2		
			DESTINATION	WIRE	DESTINATION	WIRE	
18.646	J62-A	B1	J18-A	BRN			
	B	B2	J18-B	RED			
	C	In	J18-C	ORN			
	D						
	E						
	F						
	H						
	J						
	K						
	L	-10V	J18-L	WHT-VIO			
	M	±Grd	±Grd-1	BLK 18			
	N						
	P	+10V	J18-P	WHT-RED			
	R						
	S						
	T						
	U						
	V						
	W						
	X						
	Y						
	Z						
	18.646	J61-A	B1	J18A-A	BRN		
		B	B2	J18A-B	RED		
		C	In	J18A-C	ORN		
		D					
E							
F							
H							
J							
K							
L		-10V	J18A-L	WHT-VIO			
M		±Grd	±Grd-1	BLK 18			
N							
P		+10V	J18A-P	WHT-RED			
R							
S							
T							
U							
V							
W							
X							
Y							
J61-Z							

ELECTRONIC ASSOCIATES, INC.	
LONG BRANCH, NEW JERSEY	
J62 & J61	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT	B 045 078 0W
SHEET 30 OF SHEETS	



UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES
 CAPACITANCE IS IN MMFD
 RESISTANCE IS IN OHMS
 TOLERANCE ON
 FRACTIONS DECIMALS ANGLES
 ±1/64 ±.005 ±
 * TOL. OF MATERIAL SUPPLIED

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
CIRCUIT MODULE RESISTOR CAPACITOR MODULE (IDENTIFICATION DWG)	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 1718	B 592 007 0
SHEET 1 OF 1 SHEETS	



Relay Bus Driver, Schematic

MANUAL COMMENT SHEET

Date _____

From _____

Company _____

Address _____

Title _____

Type of System _____

Manual Title _____

EAI Project No. _____ Publication No. _____

Check appropriate block and explain in space provided.

- Error (Page _____ or Drawing No. _____)
- Addition (Page _____, Drawing, Procedure, Etc.)
- Other

Explanation:

CUT ALONG LINE

FOLD

FOLD

FOLD

FOLD

Fold, Staple, and Mail

No Postage Necessary if Mailed in U. S. A.