TR-20/TR-48

COMPUTERS

Maintenance Series

7.117 AND 7.137
BI-POLAR MULTIPLIERS

EAI® TR-20/TR-48 COMPUTERS

Maintenance Series

7.117 AND 7.137
BI-POLAR MULTIPLIERS

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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.

Title	Publication Number
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
TR-48 Analog Computer Reference Handbook (RMC/EMC)	00 800.2008-1
Transport Delay Simulator, Type 2.448	00 800.2009-0
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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.

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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.

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CONTENTS

ILLUSTRATIONS

BI-POLAR MULTIPLIER, MODELS 7.117 AND 7.137

1. GENERAL DESCRIPTION

The Model 7.117 and 7.137 Bi-Polar Multipliers, shown in Figure 1, are wide bandwidth, low noise, high accuracy units designed and manufactured by EAI (Electronic Associates, Inc.,). The Model 7.117 Unit is used in the TR-48 General Purpose Analog Computer with a dc amplifier such as the Model 6.514 or 6.614. The Model 7.137 Unit is used in the TR-20 General Purpose Analog Computer with a dc amplifier such as the Model 6.712. Each unit, when used with an appropriate dc amplifier, may be patched to multiply two variables, divide two variables, square a variable, or extract the square root of a variable.

These units employ the quarter-square multiplication technique to produce the product of two variables. Equation 1 illustrates this technique.

$$XY = 1/4 \left[(X + Y)^2 - (X - Y)^2\right] \qquad \text{(Eq. 1)}$$

The equation reduces multiplication essentially to the operations of summation and squaring. The squaring operations are performed by the bi-polar multiplier, and the summation is performed by an external dc amplifier.

The 7.117 and 7.137 Units are electrically similar. The major difference between the two units is their physical layout (as shown on Figure 1). Unless otherwise noted, the information in this manual applies equally to both units.

2. TECHNICAL DATA

Where applicable, the following specifications include errors of the inverting and output amplifiers patched in a standard multiplication configuration.

2.1 Power Requirements

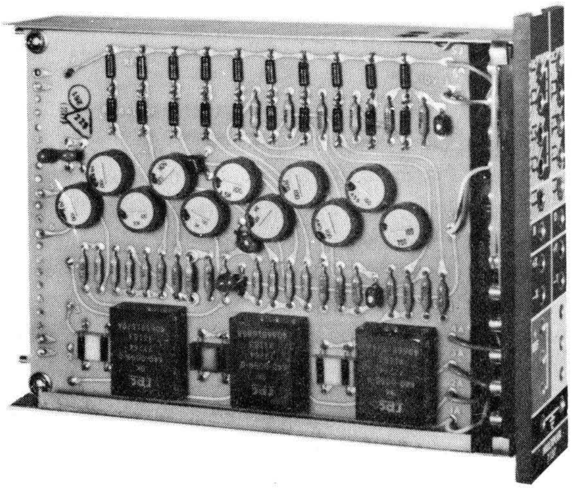
+10 Volts (Computer Reference)

-10 Volts (Computer Reference)

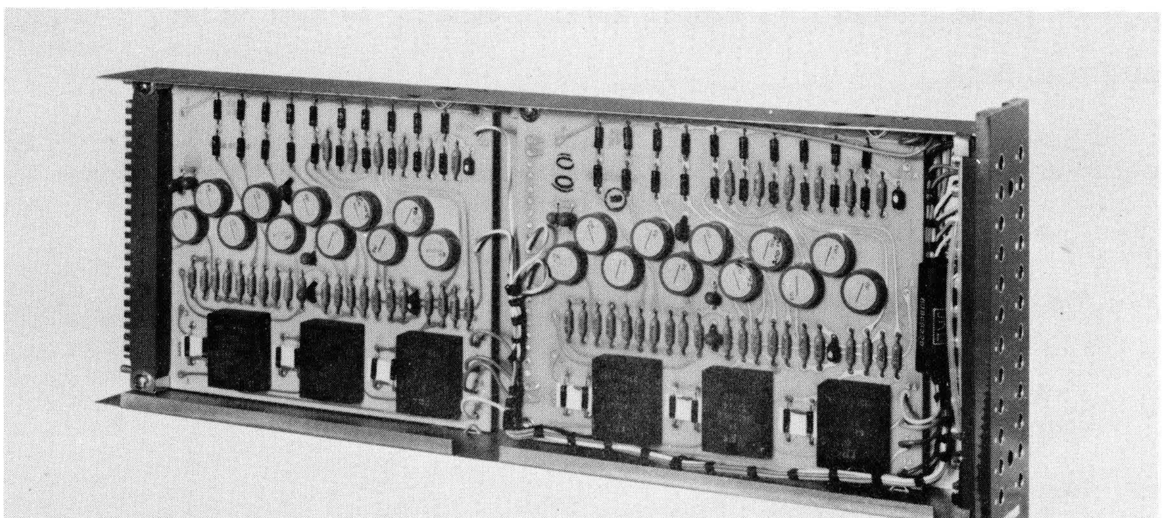
3 milliamperes nominal reference drain per product from each reference source.

2.2 Input Voltage Range

X (Multiplication, Squaring)	-10 to +10 Volts
X (Division)	0 to +10 Volts
Y (Multiplication, Squaring)	-10 to +10 Volts
U (Division)	-10 to +10 Volts
X (Square Root)	0 to -10 Volts
Y (Square Root)	0 to +10 Volts



(a) 7.137 Bi-Polar Multiplier (TR-20)



(b) 7.117 Bi-Polar Multiplier (TR-48)

Figure 1. Model 7.117 and 7.137 Bi-Polar Multipliers

2.3 Bandwidth

7.117 Unit Used With 6.514 Amplifier	190 KC
7.117 Unit Used With 6.614 Amplifier	250 KC
7.137 Unit Used With 6.282 or 6.712 Amplifier	190 KC

2.4 Normal Operation Temperature Range

60°F to 90°F

2.5 Static Error

When both inputs are in the normal operating range of -10 to +10 volts:

±0.07% of Full Scale	Absolute Maximum
±0.05% of Full Scale	Typical Maximum

2.6 Zero Error

With Either Input Zero	±0.03% of Full Scale, Maximum
	±0.020% of Full Scale, Typical
With Both Inputs Zero	±0.005% of Full Scale, Maximum

2.7 Total Instantaneous Dynamic Error at 1000 CPS

7.117 Unit Used With 6.514 or 6.614 Amplifier	0.20% of Full Scale, Maximum
	0.15% of Full Scale, Typical
7.137 Unit Used With the 6.282 or 6.712 Amplifier	0.20% of Full Scale, Maximum
	0.15% of Full Scale, Typical

2.8 Phase Shift at 1000 CPS

7.117 Unit Used With 6.514 Amplifier	0.15 Degrees, Maximum
	0.10 Degrees, Typical
7.117 Unit Used With 6.614 Amplifier	0.09 Degrees, Maximum
	0.06 Degrees, Typical
7.137 Unit Used With the 6.282 or 6.712 Amplifier	0.15 Degrees, Maximum
	0.10 Degrees, Typical

2.9 Temperature Coefficient

Within ±10° of Set-up Temperature (Set-up Temperature 80° to 85°F)...........	±1.0 MV/°F, Typical

3. INSTALLATION AND ADJUSTMENTS

3.1 Installation

The Model 7.117 Bi-Polar Multiplier is designed specifically for installation in the TR-48 General Purpose Analog Computer. The procedure for installing the unit is described in Section II, Paragraph 2d of the TR-48 Analog Computer Reference Handbook, (Publ. No. 00 800.2008-1).

The Model 7.137 Bi-Polar Multiplier is designed specifically for installation in the TR-20 General Purpose Analog Computer. Installation data for this unit is provided in Chapter I, Paragraphs 2, 5, and 6 of the TR-20 Maintenance Manual, (Publ. No. 00 800.2006-0).

3.2 Adjustments

The bi-polar multipliers are factory calibrated and adjusted prior to shipment; the units are ready for use upon installation in the appropriate computer. If desired, a simple check may be performed by patching the unit to multiply, inserting several values of X and Y, and observing the product output. This check generally indicates whether factory adjustments have been disturbed during shipping or handling.

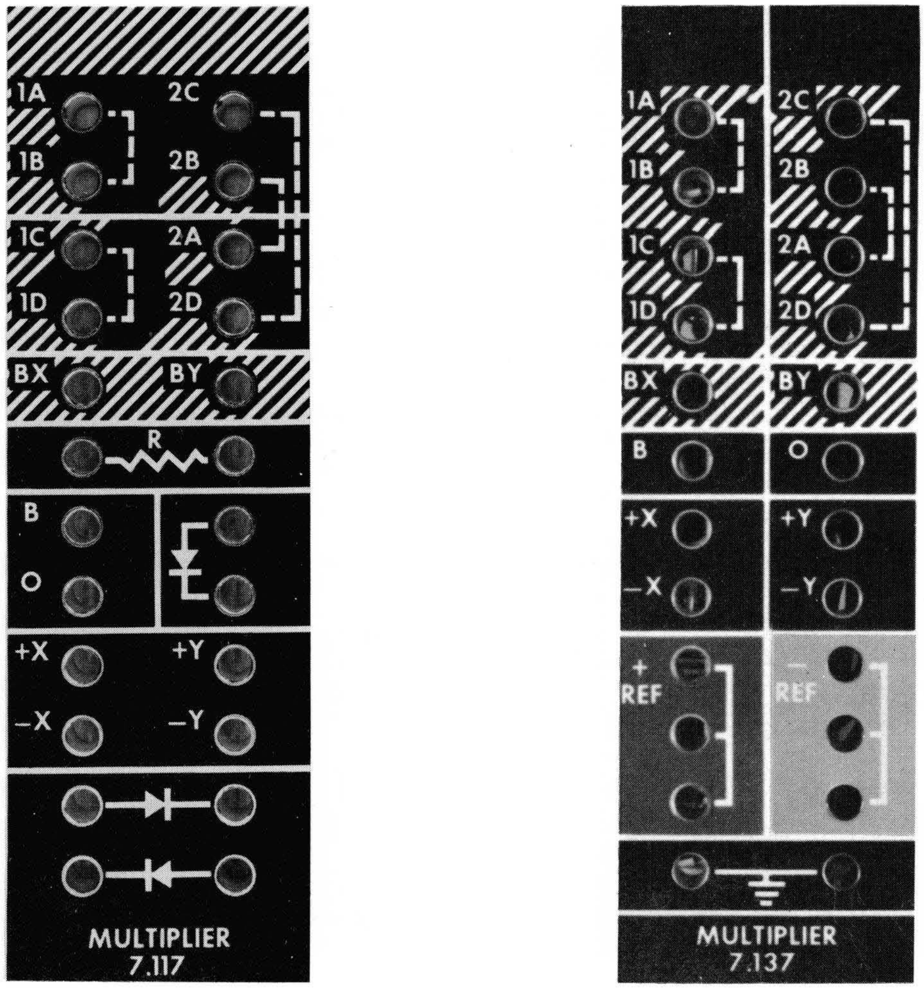
4. OPERATING INSTRUCTIONS

This section describes the patching configuration used to perform the various functions with the bi-polar multiplier. Figure 2 shows the patching block layout for both the 7.117 and 7.137 Units. Note that the two patching blocks are similar; the 7.117 Unit has several additional terminals which provide three diodes and a resistor which may be used for other programmed circuits. The diodes may be used to limit the polarity of inputs, and the resistor provides a second feedback resistor when the multiplier is patched to produce two squaring or square-root functions, or it may be used as an input resistor to the multiplier summer to provide an output of $-XY/10 + Z$. The 7.137 Unit may be patched to perform the same functions by using external components. Figure 3 is a simplified schematic of the bi-polar multiplier showing patch block connections.

The bi-polar multiplier patching block (Figure 2) is designed for ease of patching with maximum flexibility. Patching in the cross-hatched area determines the type of operation performed by the card. For multiplication and division, adjacent horizontal terminals in the cross-hatched area are jumpered. For squaring and square-root extraction, vertical jumpers are installed as indicated on the patching block. Each of the common patching modes is described in the following paragraphs. Although the 7.117 Unit patching block is shown in each case, patching for the 7.137 Unit is similar.

4.1 Multiplication

Figure 4a illustrates the patching for four quadrant multiplication. Figure 4b is a suggested method of illustrating the circuit on computer diagrams. The amplifier designations are arbitrary; any available amplifiers may be used, and any method of indicating their physical location which is convenient to the programmer may be employed. Patching in the cross-hatched area of the patch block is not normally indicated on the computer diagram. The simple rule of patching adjacent horizontal terminals in this area for multiplication and



(a) 7.117 Unit

(b) 7.137 Unit

Figure 2. Bi-Polar Multiplier Patching Blocks

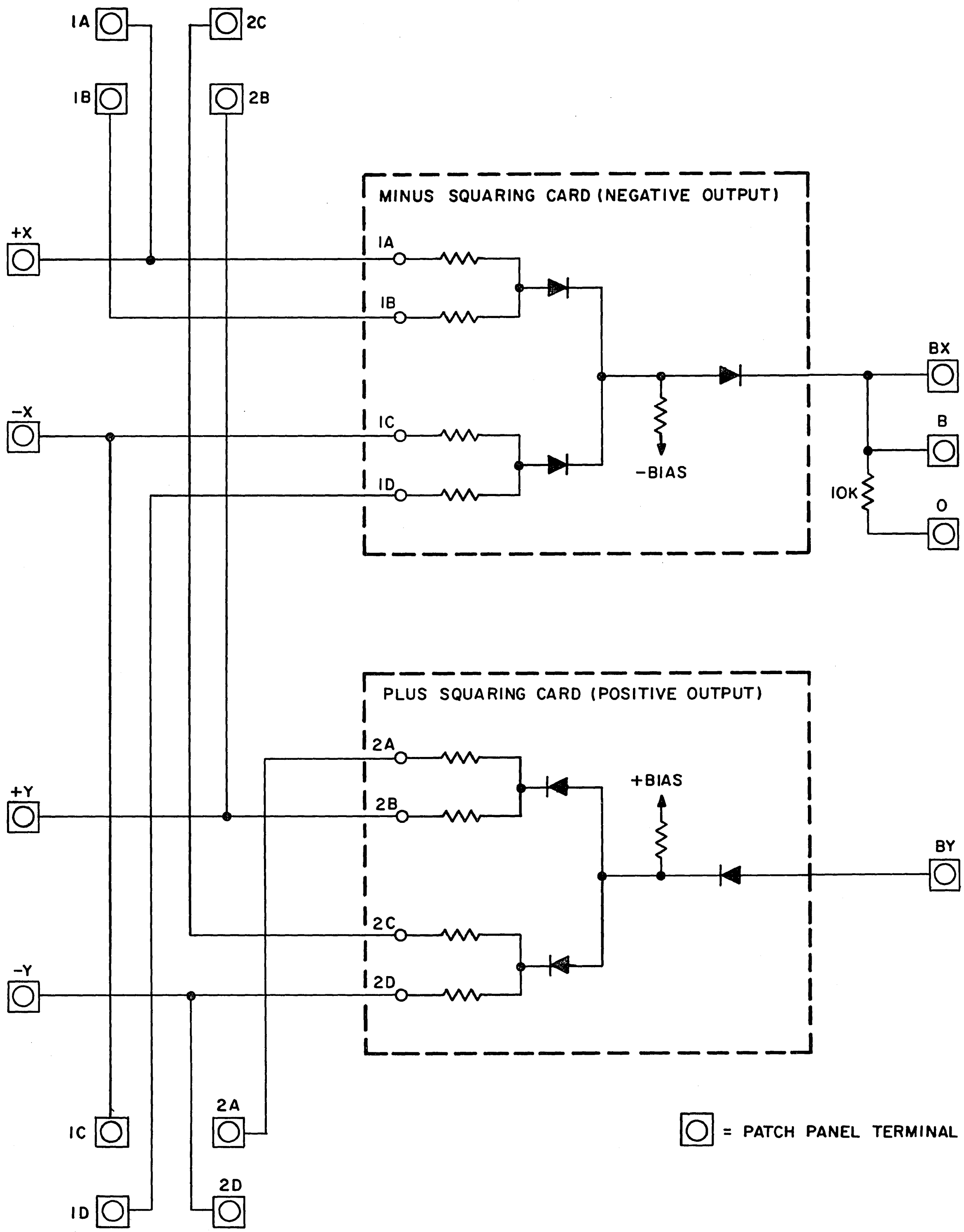
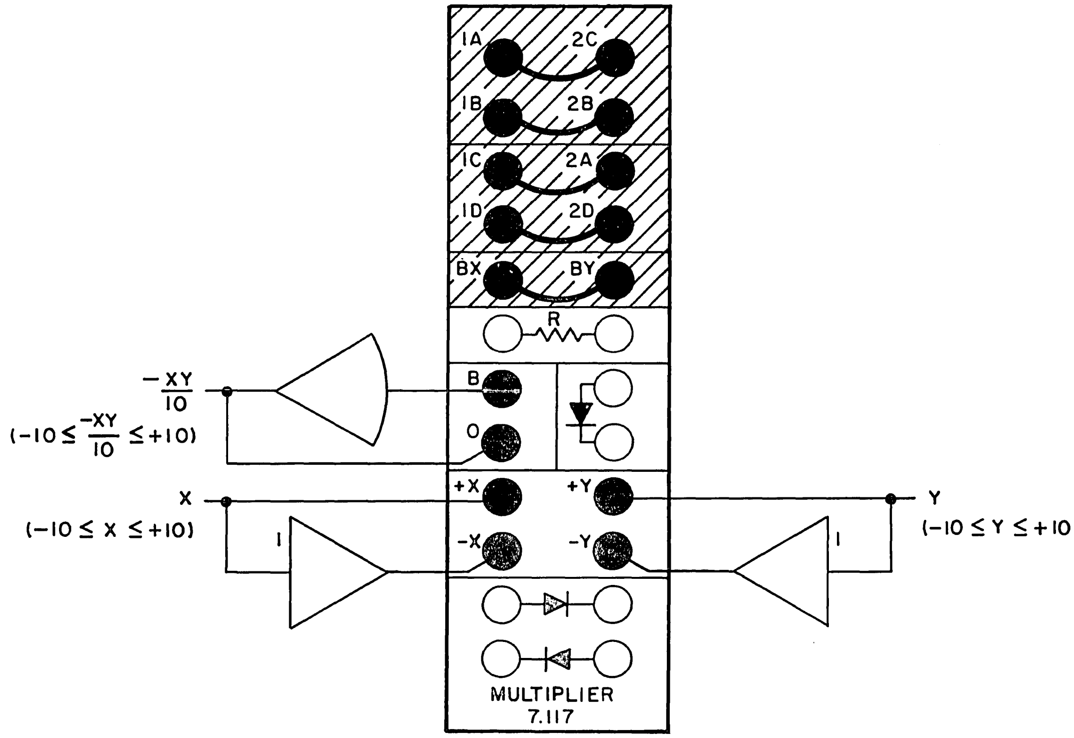
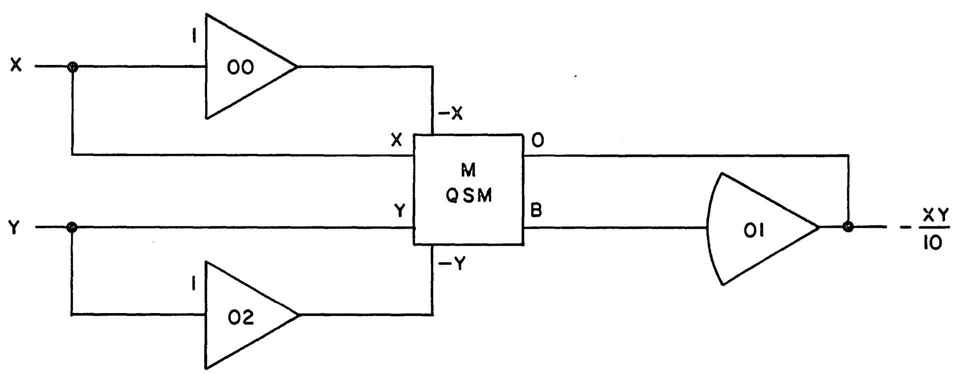


Figure 3. Bi-Polar Multiplier, Simplified Schematic Diagram (With Patching)



(a) Patching Diagram



(b) Computer Diagram

Figure 4. Multiplication Patching and Computer Diagrams

division, and making the indicated connections (1A to 1B, 1C to 1D, 2C to 2D and 2B to 2A) for squaring and square root extraction is quickly learned and normally not repeated on the computer diagram.

As indicated, the configuration shown in Figure 4 produces the product -XY/10. If the product +XY/10 is desired, it may be obtained by interchanging either the +X and -X <u>or</u> the +Y and -Y inputs. This method eliminates the need to use an additional inverting amplifier.

The impedance of a given multiplier input is a function of the magnitude of the other input signal. For this reason, the X and Y inputs should be obtained from an amplifier, rather than directly from the wiper of a potentiometer.

4.2 Division

The patching configuration for division is shown in Figure 5. Again, the computer diagram (Figure 5b) disregards the standard patching in the cross-hatched area. This circuit produces both -10 U/X and +10 U/X.

The following division circuit limitations must be imposed to avoid positive feedback:

1. The divisor (X) must be larger than, or equal to, the dividend (U).

2. The divisor (X) must be positive. If X is negative, the +X and -X inputs must be interchanged. The output from amplifier 01 then becomes +10 U/X while amplifier 02 produces -10 U/X.

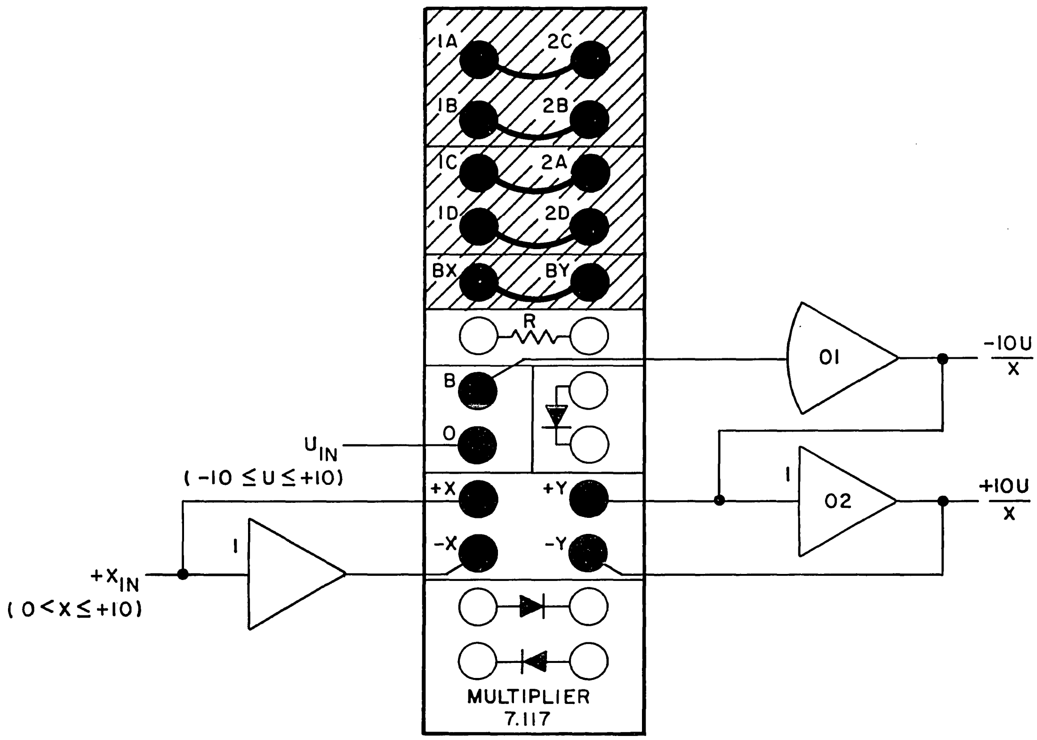
3. The divisor (X) must not equal zero.

4.3 Squaring

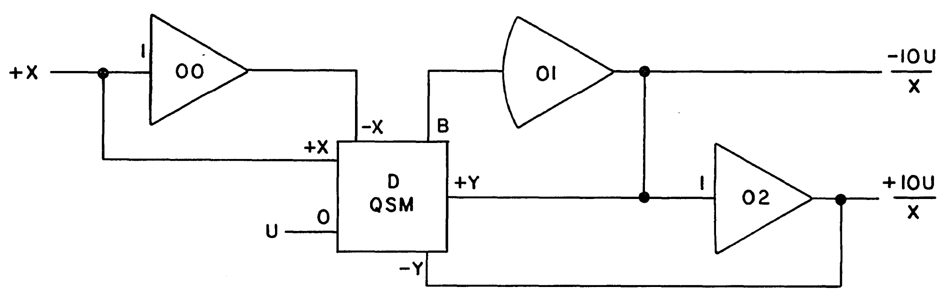
Figure 6 shows the patching to obtain the square of an input variable. Two squaring circuits may be patched from the bi-polar multiplier. To distinguish between the two circuits on Figure 6, the X^2 circuit is shown patched by solid lines while the Y^2 circuit is shown patched by dashed lines. The circuits are entirely independent of each other. If desired, one squaring and one square-root circuit may be patched from the same bi-polar multiplier. Patching in the cross-hatched area is the same for both squaring and square-root extraction. If the input to the squaring circuit is always positive, the input may be applied to +X, the inverting amplifier may be eliminated, and -X grounded. If the input is always negative, the input may be applied to +Y, the inverting amplifier eliminated, and -Y grounded. The circuit shown in Figure 6 generates the true square of the input variable. In some cases the programmer may wish to generate the function $X|X|$, where the output polarity is determined by the input polarity. Figure 7 illustrates patching to produce the output $-X|X|/10$. One circuit of this type may be patched from each bi-polar multiplier.

4.4 Square Root

Figure 8a shows the patching configuration for extracting the square root of an input variable. As with the squaring configuration, two independent square

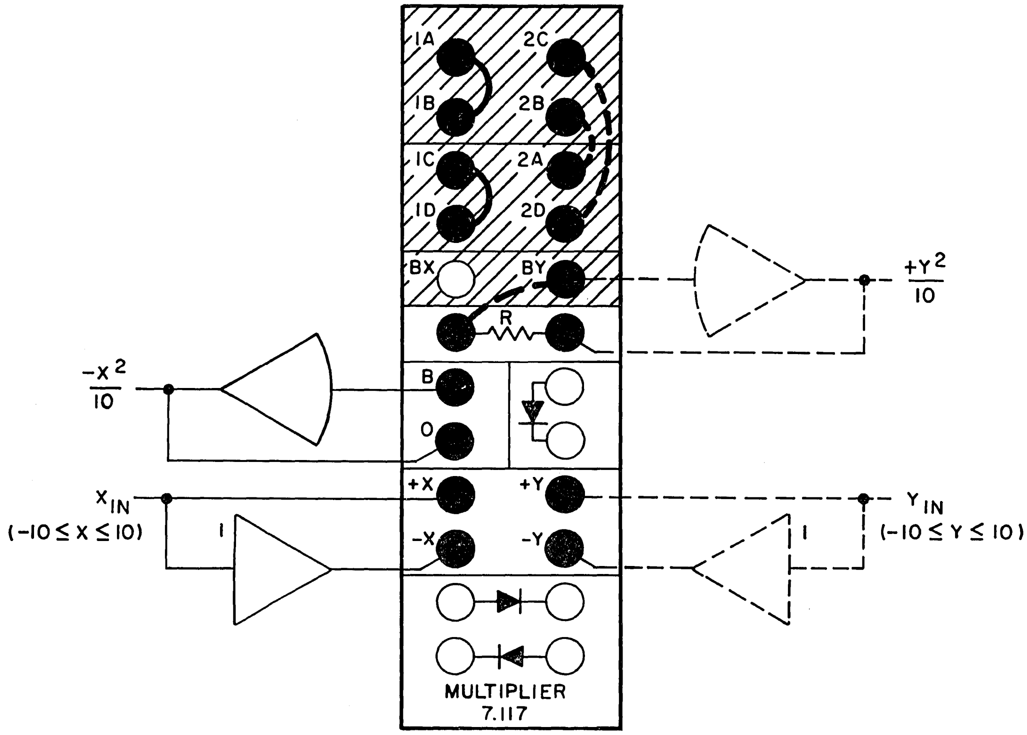


(a) Patching Diagram

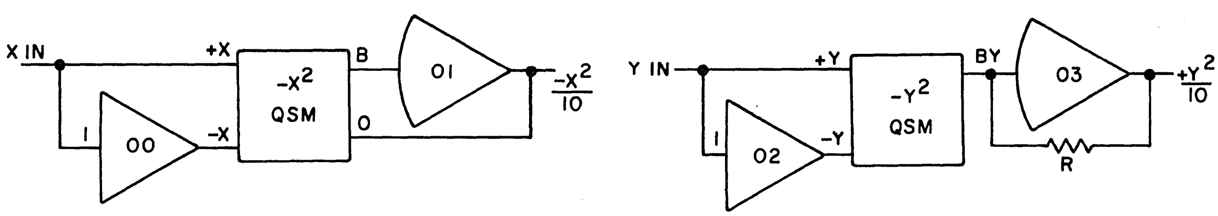


(b) Computer Diagram

Figure 5. Division Patching and Computer Diagrams



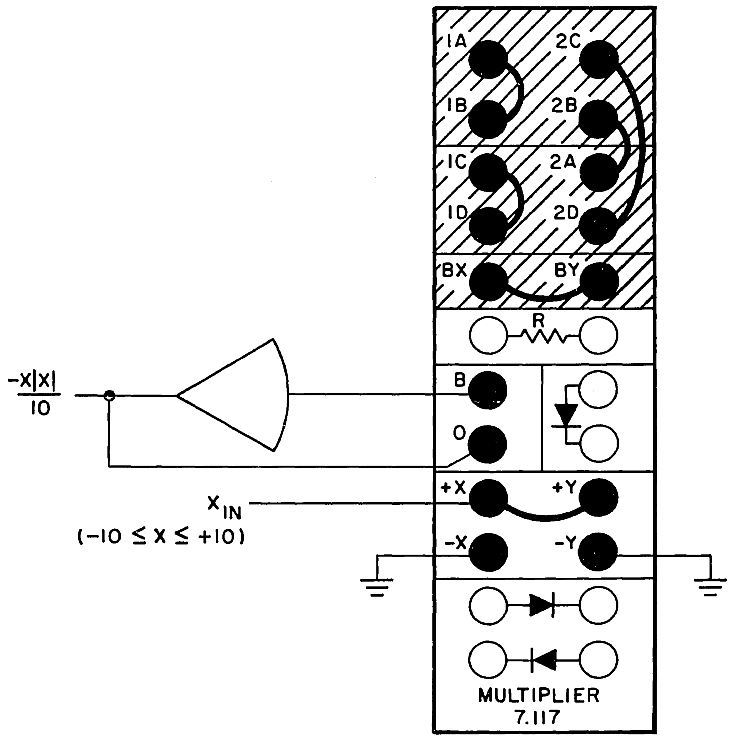
(a) Patching Diagram



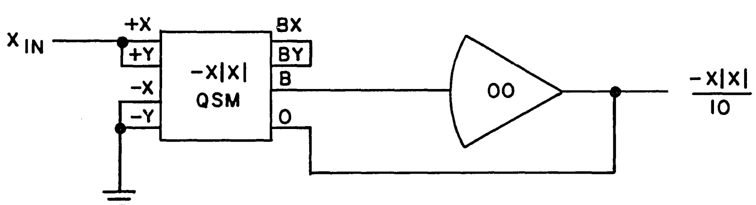
(b) Computer Diagram

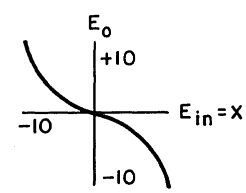
(c) E_o Versus E_{in}

Figure 6. X^2 Squaring Patching and Computer Diagrams



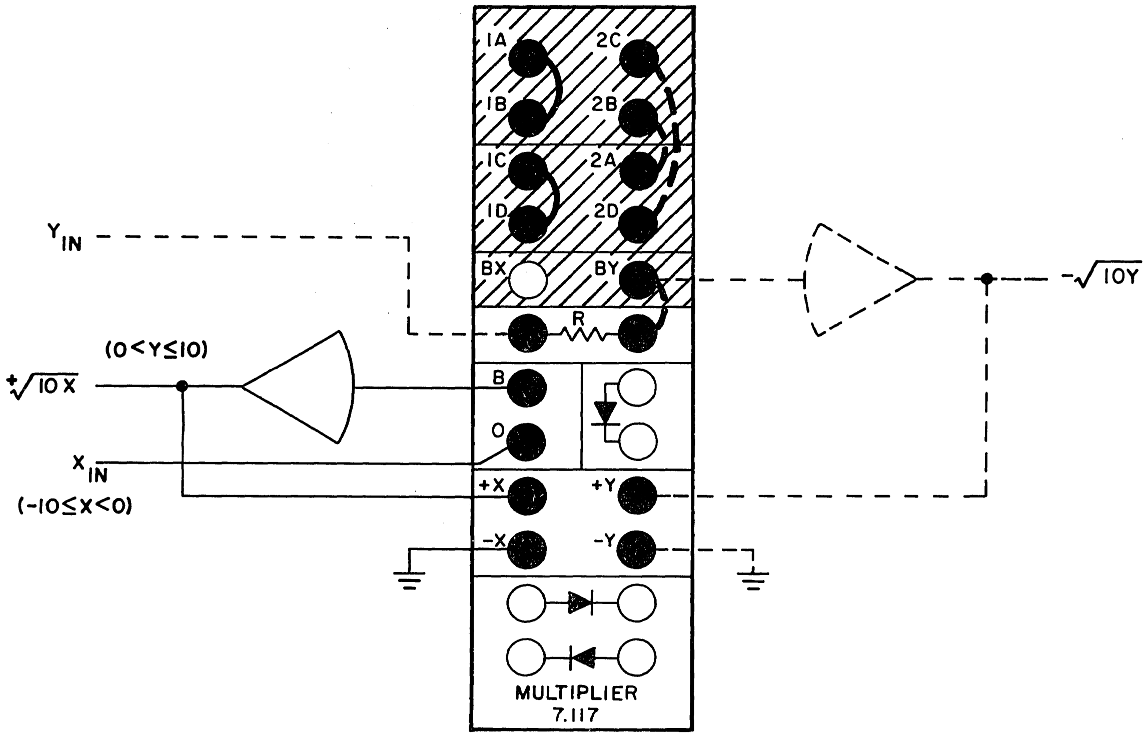
(a) Patching Diagram



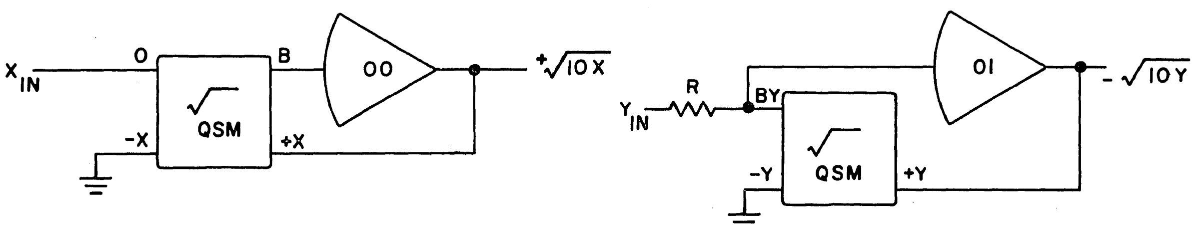


(b) Computer Diagram *(c) E_o Versus E_{in}*

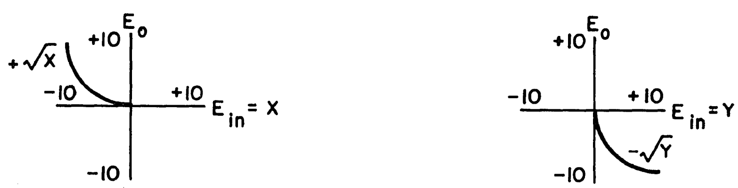
Figure 7. X/X/ Squaring Patching and Computer Diagrams



(a) Patching Diagram



(b) Computer Diagrams



(c) E_o Verses E_{in}

Figure 8. Square Root Extraction Patching and Computer Diagrams

root circuits are available. These circuits are shown with solid lines ($+\sqrt{10X}$) and dashed lines ($-\sqrt{10Y}$) on Figure 8. As mentioned previously, one square root and one squaring circuit may be patched from the same bi-polar multiplier.

5. BASIC DIODE FUNCTION GENERATORS

This paragraph is intended as a brief review of diode function generator fundamentals to assist personnel unfamiliar with these units. The Theory of Operation of the 7.117 and 7.137 Bi-Polar Multipliers is covered in Paragraph 6.

Figure 9 illustrates an elementary function generator. By varying the wiper position of the potentiometer R, such that R decreases as the input voltage increases, the gain of the amplifier increases and a function similar to that of Figure 9b can be generated (in an operational amplifier $E_o = E_{in} R_f/R$). Using this method of function generation leads to difficulty since an elaborate control system for R is required to reproduce a function with even a minimum amount of accuracy; accurate reproduction by manually operating the pot is, for practical purposes, impossible.

A more practical method of varying the input impedance (R) is to switch in different input resistors by means of diodes. The switching action of the diode can be directly controlled by the input voltage magnitude, thus assuring the reproduction of a function.

An <u>ideal</u> diode can be regarded as a voltage-sensitive on-off switch; for this discussion it will also be assumed the diode has an infinite resistance when reverse biased (cut off by a more negative potential applied to the anode than to the cathode) and a zero resistance when forward biased (conducting). Assume such an ideal diode is placed between the input resistor R and the summing junction of an operational amplifier, and reverse biased from a negative source (Figure 10). As long as the positive input voltage remains less than a given level, say 2 volts, the diode acts as an open switch and the amplifier output remains at zero. However, when the positive input reaches 2 volts the diode "switch" is closed and the diode conducts (this point is defined as the diode breakpoint). As the input increases in magnitude the output (solid lines) increases directly in proportion to the ratio of R_f/R (Figure 10b)*. In the example illustrated a 20K input resistor is assumed; if a 10K input resistor is used the output would follow the dashed line in Figure 10b. Note that the breakpoint is dependent on the value of the bias voltage on the diode, while the slope of the output, after the breakpoint is reached, is dependent on the ratio R_f/R. Although the function generated in Figure 10 is very simple, it is readily reproduced with extremely high accuracy.

More complex functions may be generated by paralleling biased diode networks. Figure 11 illustrates a simple DFG with three paralleled diode networks. Assuming each diode is reverse biased at the potentials listed within the squares, no conduction will take place until E_{in} reaches +1 volt. At this time CR1 conducts and R_1 becomes the input resistor; the ratio of $R_f/R_1 = 1/2$ and this will be the gain of the amplifier until CR2 conducts (E_{in} reaches +3 volts). The input impedance is now determined by the paralleled resistance value of R_1

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*It is assumed for simplicity that $R_1 \gg R$ in Figure 10a and therefore the output slope of the amplifier may be assumed to equal R_f/R.

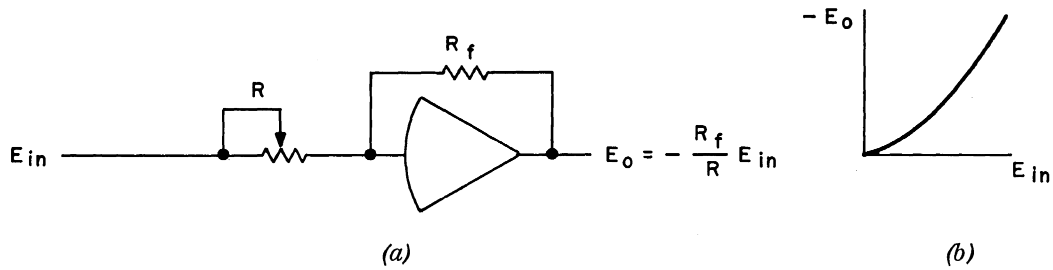


Figure 9. Elementary Function Generator

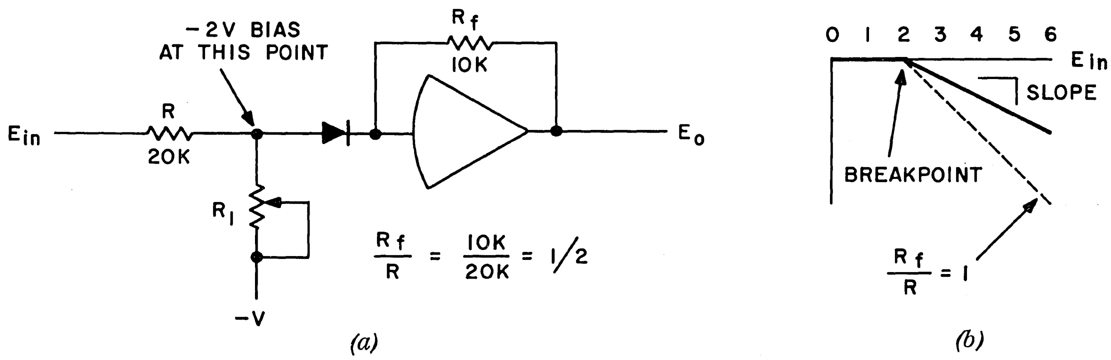


Figure 10. Simple Diode Function Generator

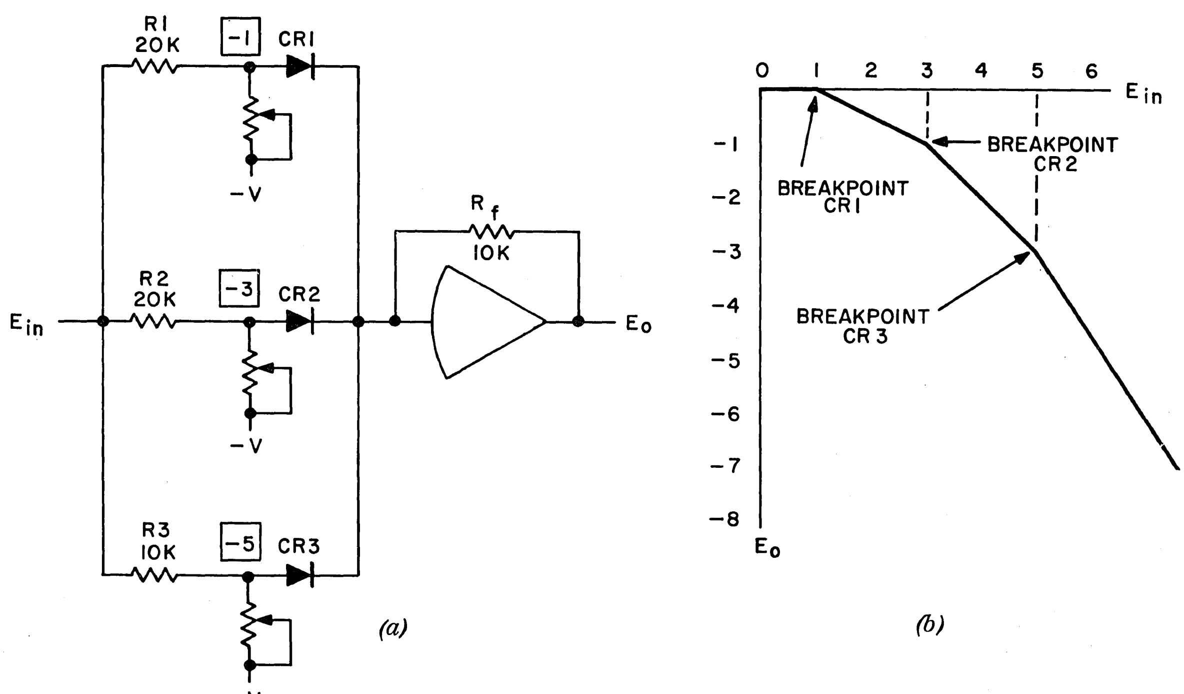


Figure 11. Three-Network Diode Function Generator

and R_2 (10K); the amplifier gain equals one. When CR3 conducts the amplifier gain becomes 2 since the paralleled impedance of the three input resistors equals 5K ohms.

Note that the straight-line segments on the graph (Figure 11b) approximate a smooth curve. If additional network segments are added to the amplifier circuit which shorten each of the existing line segments, the approximation of the smooth curve becomes more accurate. Thus, by properly selecting component values and using a sufficient number of line segments, a DFG can accurately approximate a function such as an X^2 curve. Should a DFG be used to generate a true X^2 curve, when the input X = 10 volts the output (X^2) = 100 volts. In the case of a 10 volt reference computer this output is well beyond the limitations of the amplifier. However, by scaling the DFG components so the output is actually $X^2/10$, the maximum output is 10 volts which is well within the operating tolerance of the amplifier.

The 7.117 and 7.137 Bi-Polar Multipliers use the X^2 DFG principle; however, these squaring circuits must produce outputs proportional to $\left[(X + Y)/2\right]^2$ and $-\left[(X - Y)/2\right]^2$. This can be accomplished by modifying the basic DFG circuit shown in Figure 10 to the configuration shown in Figure 12a. Figure 12b is an equivalent circuit of 12a and clearly shows the similarity to Figure 10.

The circuit shown in Figure 12 is useful only when the sum of X and Y is positive. Additional dual input networks must be added to cover all possible combinations of X and Y. Figure 13 is a simplified diagram of the circuit used by the 7.117 and 7.137 Units. Note that the diode designations shown are to aid this description, they have no other significance. The minus squaring card produces a current i_1 which is proportional to $\left[(X + Y)/2\right]^2$ while the plus squaring card produces a current i_2 which is proportional to $-\left[(X - Y)/2\right]^2$. Table 1 lists all combinations of X and Y, and the diode which conducts in each case.

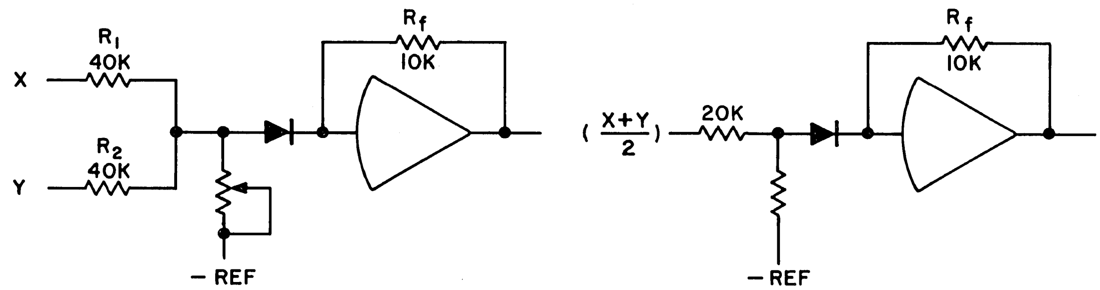
Diodes CR1, 2, 4, and 5 are simply gating diodes; diodes CR3 and CR6 on the simplified schematic represent the DFG segment diodes.

6. CIRCUIT DESCRIPTION

The 7.117 and 7.137 Bi-Polar Multipliers use the quarter-square multiplication technique to produce the product of two variables. The following equation illustrates this technique:

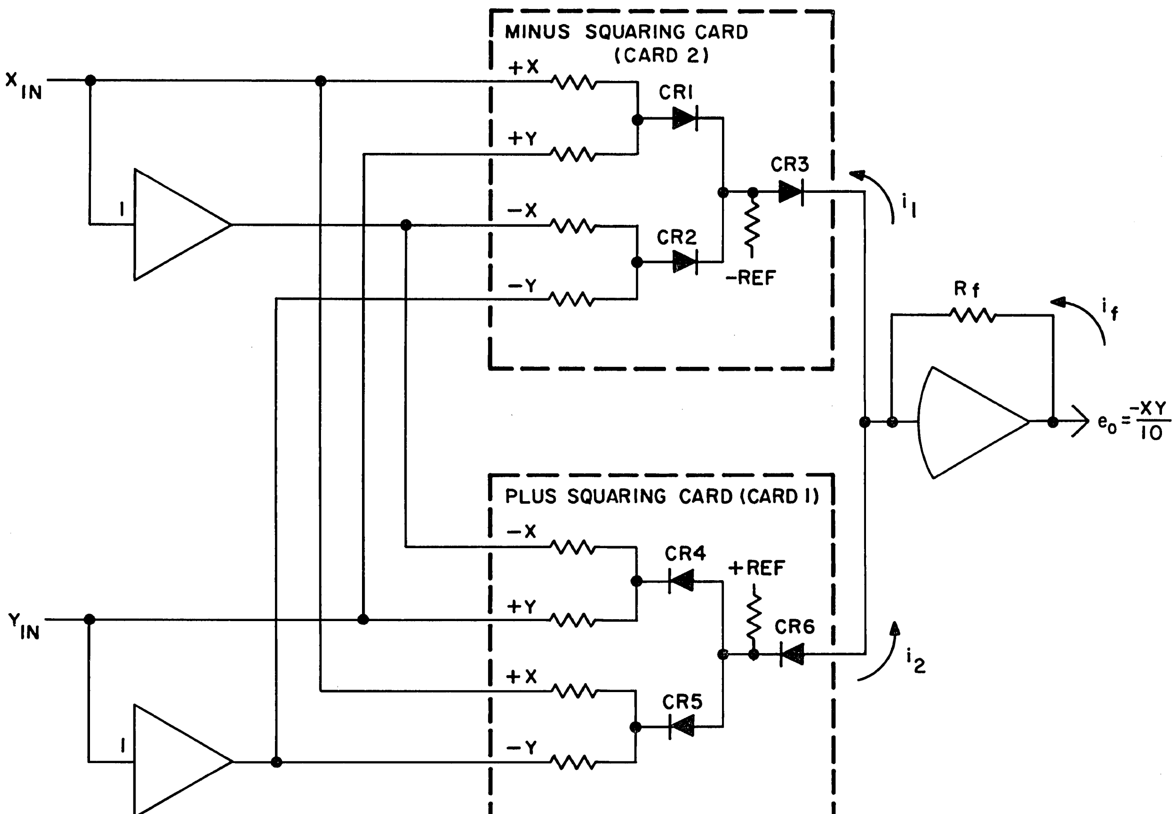
$$-1/10 \left[\left(\frac{X + Y}{2}\right)^2 - \left(\frac{X - Y}{2}\right)^2\right] = -\frac{XY}{10} \qquad \text{(Eq. 2)}$$

The negative sign is a result of inversion by the summing amplifier. The 1/10 scale factor is obtained by selection of resistor values, and assures that the multiplier output does not exceed the 10 volt computer reference for maximum values of both X and Y.



(a) Dual Input Network *(b) Equivalent Circuit for Dual Input*

Figure 12. Simplified Quarter-Square Multiplier DFG Network



NOTES:

1. THE PLUS AND MINUS SQUARING CARD DESIGNATIONS ARE DETERMINED BY THE AMPLIFIER OUTPUT POLARITY WHEN THE CARD CONDUCTS.
2. ALL PATCH CONNECTIONS ARE OMITTED FOR CLARITY.

Figure 13. Bi-Polar Multiplier Circuit, Simplified Schematic Diagram

Table 1. X and Y Combinations With Conducting Diodes

X and Y Characteristics	Conducting Diodes
$X > 0$, $Y > 0$, $X > Y$	CR1, CR4
$X > 0$, $Y > 0$, $X < Y$	CR1, CR5
$X < 0$, $Y < 0$, $X > Y$	CR2, CR5
$X < 0$, $Y < 0$, $X < Y$	CR2, CR4
$X < 0$, $Y > 0$, $X > Y$	CR2, CR5
$X < 0$, $Y > 0$, $X < Y$	CR1, CR5
$X > 0$, $Y < 0$, $X > Y$	CR1, CR4
$X > 0$, $Y < 0$, $X < Y$	CR2, CR4
$X > 0$, $Y > 0$, $X = Y$	CR1 Only
$X < 0$, $Y < 0$, $X = Y$	CR2 Only
$X > 0$, $Y < 0$, $X = Y$	CR4 Only
$X < 0$, $Y > 0$, $X = Y$	CR5 Only

As explained previously in Section 5, each bi-polar multiplier consists of two squaring cards. Each card produces an output equal to $1/10 \left[(X - Y)/2 \right]^2$ or $-1/10 \left[(X + Y)/2 \right]^2$ depending upon the input polarities and levels. Both cards conduct to provide the two terms of Equation 2, except when X and Y are equal. When X and Y are equal, one term of the equation (depending upon polarity) is eliminated.

Drawing D007 117 0S in Appendix 2 is a schematic of a typical bi-polar multiplier card. The card shown is the minus squaring card. The positive squaring card is similar except that all diode and reference voltage polarities are reversed. Again, the plus and minus card designations include the inverting amplifier which follows the card. The plus card therefore accepts negative inputs, while the minus card accepts positive inputs. Ten-segment squaring cards are employed in these multipliers. Each segment contains two diodes in series. This arrangement permits a closer approximation of the square curve due to the diode characteristics. The segments are divided into one group of two segments, one group of three segments, and one group of five segments. The inputs to each group are applied through separate encapsulated sets of matched input resistors. All segments except the first are reverse biased so that as the sum of the inputs becomes more positive, additional segments start to conduct. The first segment (CR7 and CR8) is forward biased near the point of conduction to assure that it conducts when the sum of the inputs is positive by a value less than the combined diode breakdown voltage. Note that all biasing networks contain thermistors which compensate for changes in the ambient temperature of the multiplier. The breakpoint for each segment is set by a separate potentiometer. The rheostats for segments 3 and 6 (numbered from the left) affect the adjustments for other segments in those groups, and are therefore set first. Voltage drops of the input diodes (CR1 and CR2, CR3 and CR4, and CR5 and CR6) are matched in pairs to within 1 millivolt over their operating current range.

7. MAINTENANCE

The 7.117 and 7.137 Bi-Polar Multipliers require very little maintenance. All adjustments are very stable and normally the unit is tested, as part of preventive maintenance, only to ensure the operator's faith in its performance. For this reason, Paragraph 7.2 provides an error test to indicate the unit accuracy. If the error test produces a faulty indication, refer to the Trouble Analysis paragraph later in this section for troubleshooting data.

7.1 Preliminary Adjustments

The following adjustments must be made on the computer and associated amplifiers prior to maintenance checks, troubleshooting, or calibration of the multiplier. The exact procedures for accomplishing these checks are contained in the TR-48 and TR-20 Maintenance Handbooks.

1. Check that the +10 volt reference voltage is 10 volts ±5 millivolts.

2. Balance the computer reference voltages to within one millivolt.

3. Balance all amplifiers to be used with multiplier tests or adjustments.

7.2 Error Test

1. Set up the test circuit shown in Figure 14. The assigned amplifier, attenuator, and function switch designations are arbitrary and do not necessarily indicate the best patching configuration.

2. The following setup conditions must be satisfied to assure the accuracy of the test results:

   (1) The input and feedback resistors for inverters 00, 02 and 03 should be selected so that with a 10 volt input, the output is 10 volts with less than 0.1 millivolt maximum error. (See Paragraph 7.3.)

   (2) The two input resistors to summing amplifier 04 should be selected so that equal magnitude inputs provide equal outputs with less than 0.1 millivolts maximum error. (See Paragraph 7.3.)

3. Plot the error curve produced with the unit patched as shown in Figure 14. (See Figure 15, Curve 1.)

4. Patch -REF to the +Y input and set F1 left. Plot the resultant error curve. (See Figure 15, Curve 2.)

5. Interchange the +X and +Y inputs, and the -X and -Y inputs. Plot the resultant error curve. (See Figure 15, Curve 3.)

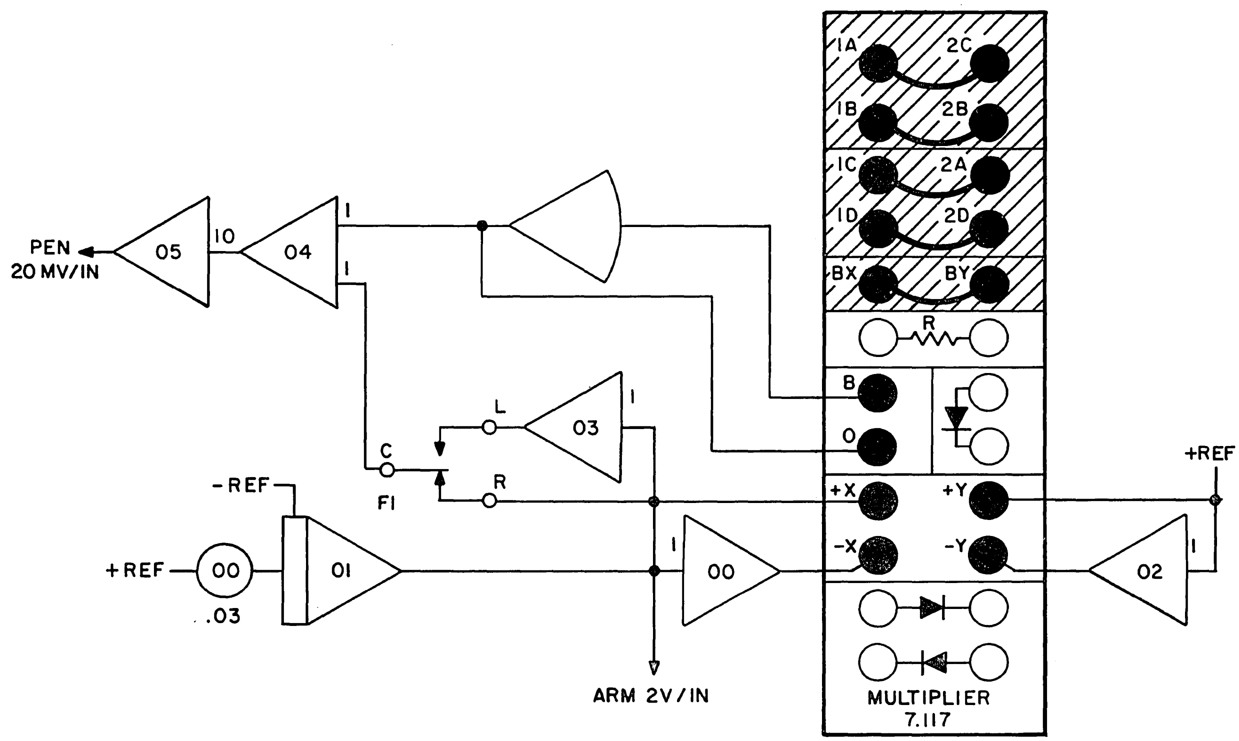


Figure 14. Error Test Patching

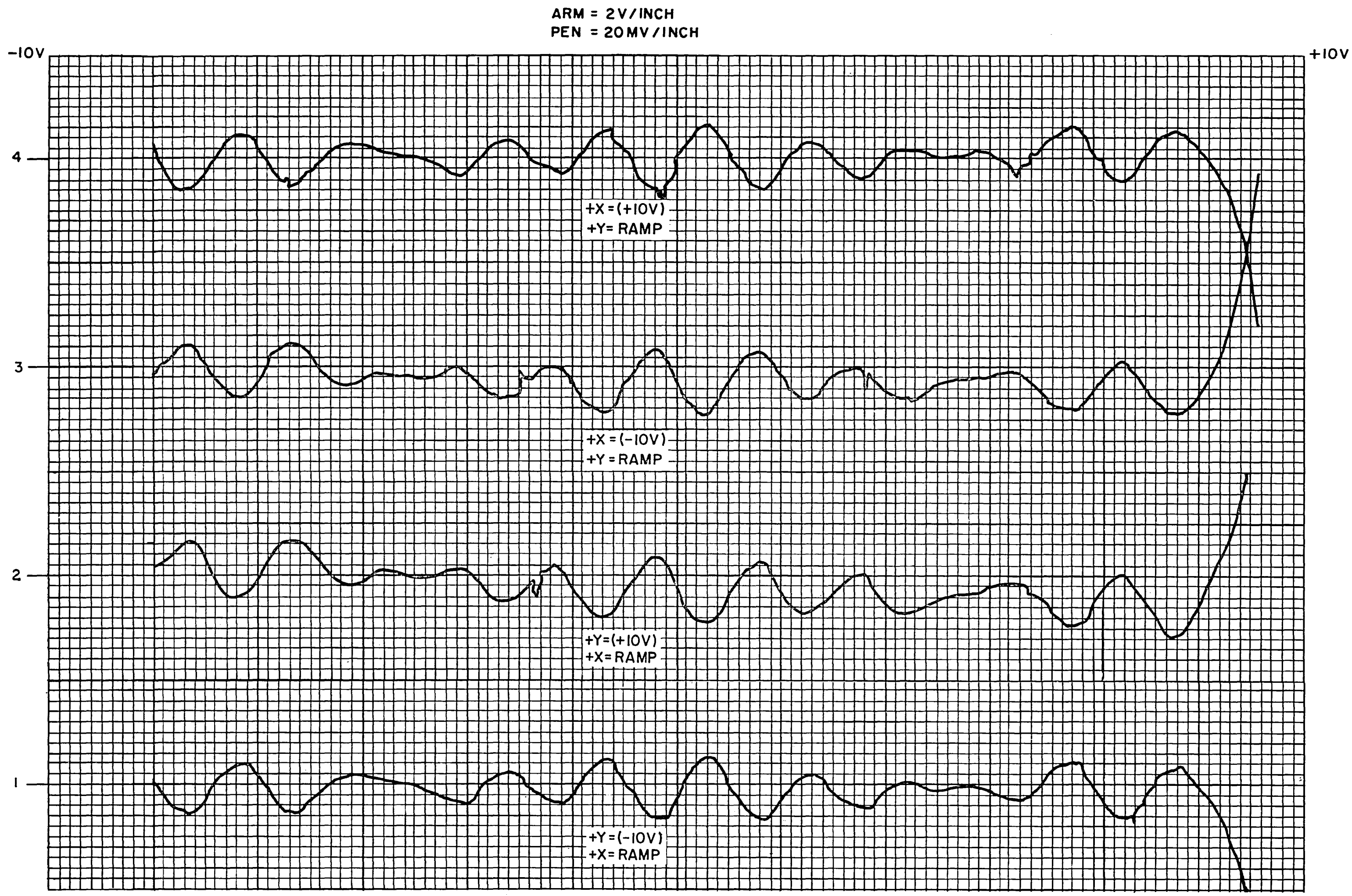


Figure 15. Typical Bi-Polar Multiplier Error Curves

6. Patch +REF to the +Y input and set F1 right. Plot the resultant error curve. (See Figure 15, Curve 4.)

Figure 15 illustrates typical plots similar to those generally obtained from a functional multiplier during Steps (3) through (6). If the error exceeds 20 millivolts at any point, and the associated equipment is known to be operating correctly, one or both cards require adjustment or repair. Paragraph 7.4 provides trouble analysis data on these units.

7.3 Matching Error-Test Circuit Components

Use the following procedure to select matched resistors for error test setup.

1. Set up the test circuit shown in Figure 16. The amplifier designated A is the one for which the matched resistors are being selected.

2. Ground both inputs to amplifier A. The DVM reading is the test circuit zero reference point; record this reading. (If desired, an attenuator may be connected as shown by the dotted lines on the diagram. This attenuator may then be set to apply sufficient input to the last amplifier to cause the DVM to read 0000. The reference polarity must be the same as the DVM polarity reading.)

3. Apply +10 volts reference to one input and -10 volts reference to the other input to amplifier A; note the DVM reading. Record the difference between this reading and the test circuit zero reference point.

4. Interchange the two inputs to amplifier A and note the DVM reading. Record the difference between this reading and the test circuit zero reference point.

5. If the difference between the readings recorded in Step (3) and (4) is equal to; or greater than, 0.1 millivolt, try different combinations of input resistors to amplifier A until the difference is less than 0.1 millivolt. (It may be necessary to try another amplifier.) Resistors matched to this 0.1 millivolt tolerance may be used as input and feedback resistors for amplifiers 00, 02, 03, and 04 in the error test setup.

7.4 Trouble Analysis

The error test outlined in Section 7.2 should be performed prior to trouble shooting the multiplier. The error curves may then be analyzed to help isolate the faulty card. Figure 17 shows the sequence in which the various cards conduct when performing the error test. If an excessive error is noted during the error test, it may often be isolated by comparing the error plots to Figure 17.

Figure 18 shows patching arrangements for checking each input network on each card individually. In each case the output should equal $X^2/10$ where X is considered the input. Figure 18 references both the card and the input gating diodes which conduct with each input. Refer to the schematic in Appendix 2 for the associated input resistors.

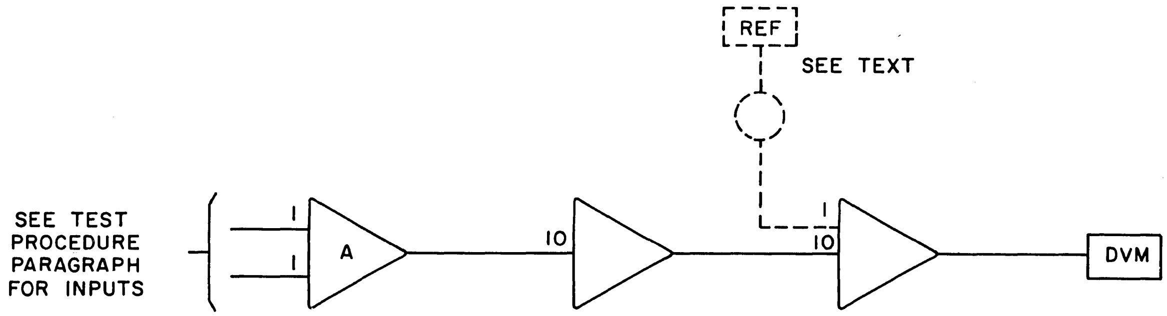
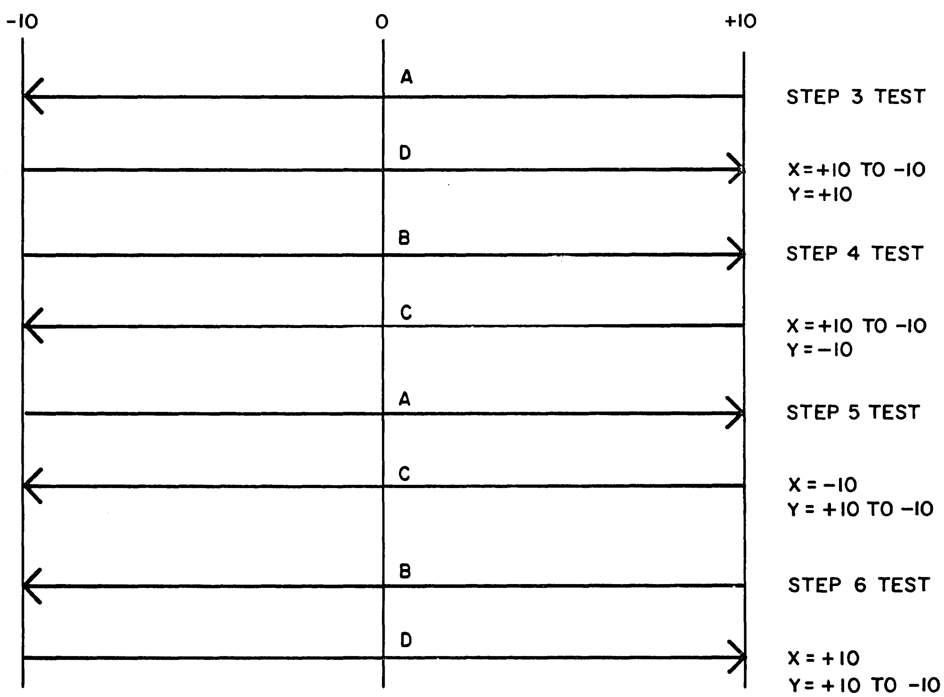


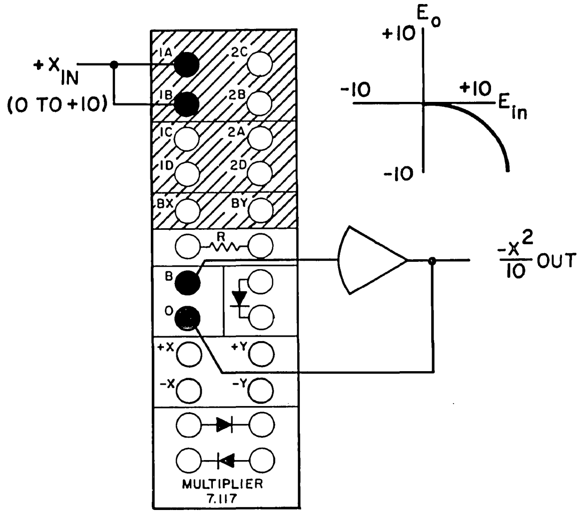
Figure 16. Resistor Matching Test Setup



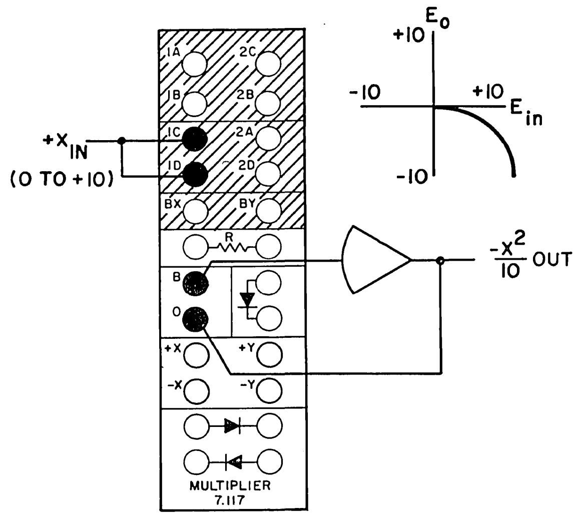
A = CARD 1 (+CARD) - DIODES CR1, CR3 AND CR5
B = CARD 1 (+CARD) - DIODES CR2, CR4 AND CR6
C = CARD 2 (-CARD) - DIODES CR1, CR3 AND CR5
D = CARD 2 (-CARD) - DIODES CR2, CR4 AND CR6

NOTES: 1. DIODE DESIGNATIONS ABOVE ARE FROM SCHEMATIC IN APPENDIX II.
2. ARROWS INDICATE DIRECTION OF INCREASING INPUT VOLTAGE.

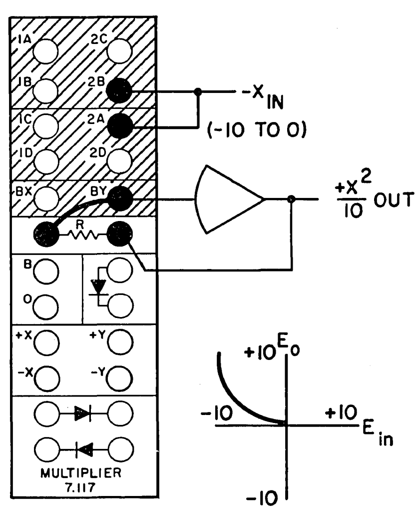
Figure 17. Error Test Circuit Operation Sequence



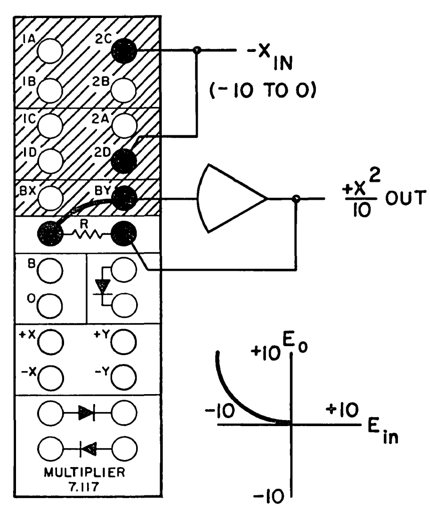
(a) Card 1 - Diodes CR2, CR4, and CR6



(b) Card 1 - Diodes CR1, CR3, and CR5



(c) Card 2 - Diodes CR2, CR4, and CR6



(d) Card 2 - Diodes CR1, CR2, and CR5

Figure 18. Patching For Individual Circuit Testing

Once the faulty card is isolated, if the calibration procedures are performed and do not correct the error, the faulty component is usually located in the group of components associated with the adjustment which cannot meet the calibration requirements. The faulty component may then be isolated by a simple resistance check. Note, however, that some resistors must be lifted at one end to avoid erroneous readings due to parallel paths.

To further assist the maintenance technician Table 2 lists various combinations (with respect to polarity and magnitude) of X and Y inputs, and indicates the card and gating diode which conducts under a given set of conditions.

8. CALIBRATION

The 7.117 and 7.137 Bi-Polar Multipliers employ high-quality, conservatively-rated components to insure long-life, trouble-free operation. The unit is calibrated at the time of manufacture; recalibration should not be attempted unless definitely indicated after a thorough check of the multiplier and associated equipment.

Prior to starting the calibration procedures, the adjustments outlined in Paragraph 7.1 must be performed. The ambient temperature during the following procedures must be between 75°F and 80°F. The actual ambient temperature should not vary more than ±0.3°F during the procedures.

There are 11 adjustments on each of the two cards in a 7.117 or 7.137 Unit. The cards are designated simply as Card 1 (the + card) and Card 2 (the - card). Each card is adjusted separately, Figure 19 shows the location of the adjustments on each unit.

8.1 Calibration Procedure

1. Patch the configuration shown in Figure 20.

2. Set all potentiometers on both cards fully clockwise.

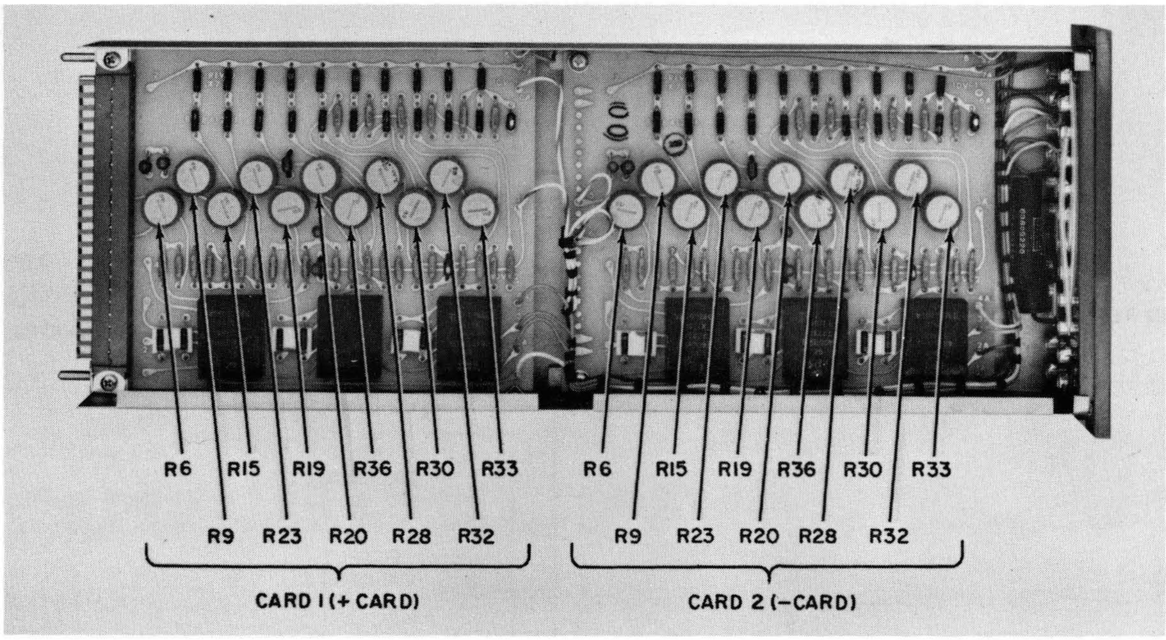
3. Set switch S1 to the -REF position.

4. Set switch S3 to the +REF position.

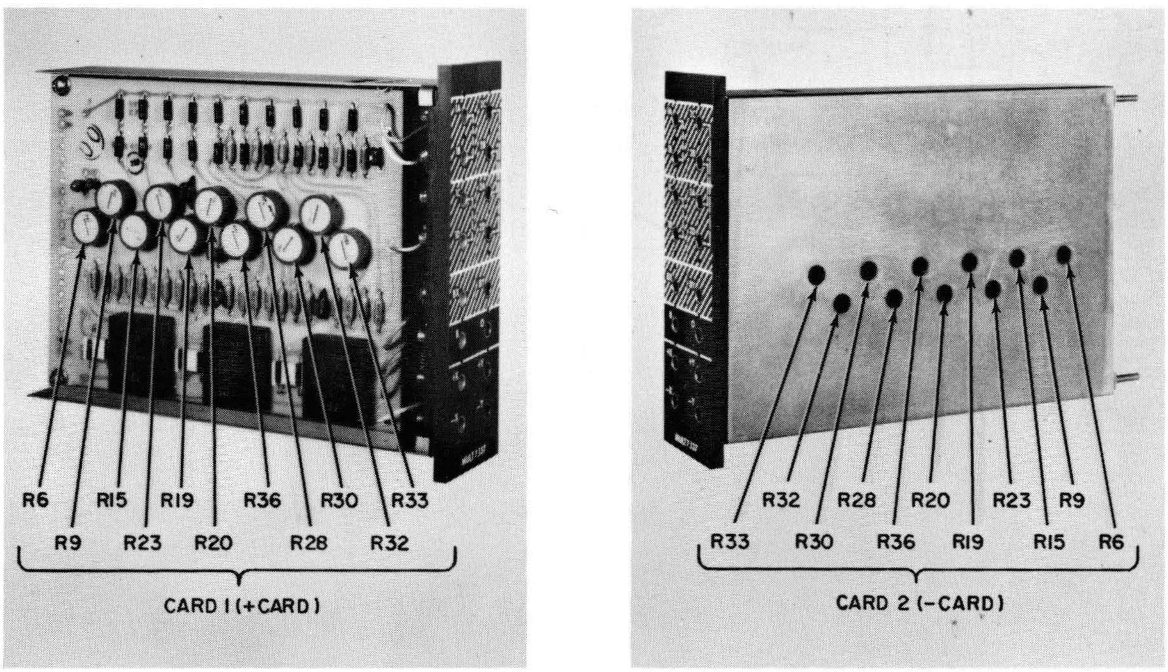
5. Set S2 to the input calibrate positions.

6. Set S4-S5 to the + input position.

7. Referring to Table 3, set the voltage divider to the E_{in} value listed, then adjust the two potentiometers for a null on the galvanometer. Set switch S2 to the output calibrate position and set the potentiometer on Card 1 indicated in Table 3 for the E_{out} value given. Repeat this procedure for each of the 11 steps listed. Note that S4-S5 is switched to the - input position for Step 2 (on Table 3), and then returned to the + input position for the remaining steps.



(a) 7.117 Unit



(b) 7.137 Unit

Figure 19. Multiplier Card Adjustment Locations

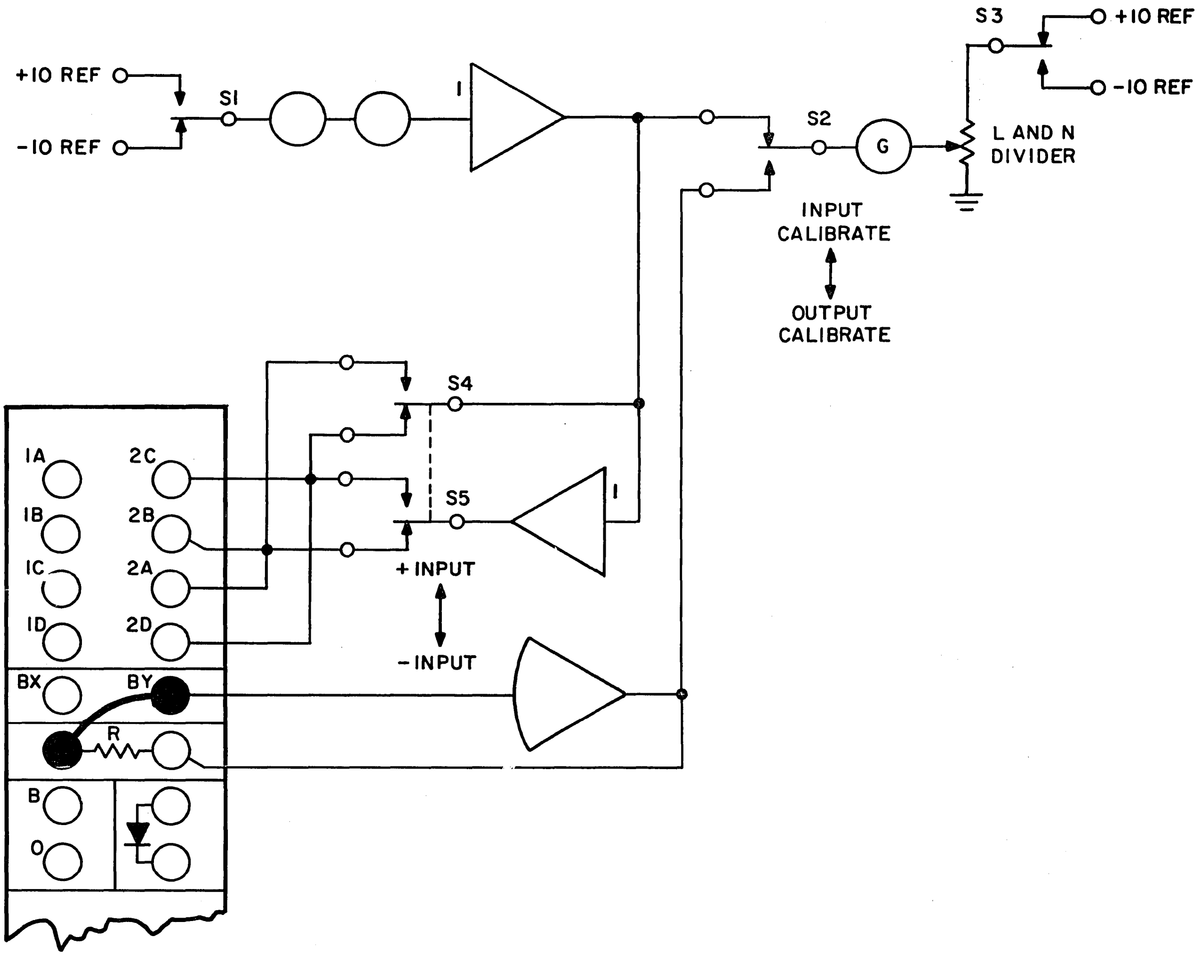


Figure 20. Card 1 Calibration Patching Diagram

Table 2. Input Signal versus Conducting Card Relationship

Input Signal Polarity		Magnitude Relationship	Conducting Cards and Diodes (Card 1 = +Card, Card 2 = -Card)
X	Y		
+	+	X > Y	Card 1 - CR2, CR4, and CR6 Card 2 - CR2, CR4, and CR6
+	+	X < Y	Card 1 - CR1, CR3, and CR5 Card 2 - CR2, CR4, and CR6
+	+	X = Y	Card 2 - CR2, CR4, and CR6
+	-	X > Y	Card 1 - CR2, CR4, and CR6 Card 2 - CR2, CR4, and CR6
+	-	X < Y	Card 1 - CR2, CR4, and CR6 Card 2 - CR1, CR3, and CR5
+	-	X = Y	Card 1 - CR2, CR4, and CR6
-	+	X > Y	Card 1 - CR1, CR3, and CR5 Card 2 - CR1, CR3, and CR5
-	+	X < Y	Card 1 - CR1, CR3, and CR5 Card 2 - CR2, CR4, and CR6
-	+	X = Y	Card 1 - CR1, CR3, and CR5
-	-	X > Y	Card 1 - CR1, CR3, and CR5 Card 2 - CR1, CR3, and CR5
-	-	X < Y	Card 1 - CR2, CR4, and CR6 Card 2 - CR1, CR3, and CR5
-	-	X = Y	Card 2 - CR1, CR3, and CR5

Table 3. Multiplier Calibrate Data

Step	E_{in}	Adjustment	E_{out}
1	0.7792	R6	0.0639
2*	0.7792	R9	0.0639
3	1.6859	R15	0.2872
4	2.5440	R23	0.6502
5	3.4417	R19	1.1875
6	4.3990	R20	1.9381
7	5.3640	R36	2.8804
8	6.3650	R28	4.0544
9	7.3580	R30	5.4171
10	8.5187	R32	7.2597
11	9.6304	R33	9.2785

*Reverse S4-S5 for this step only.

8. Patch the configuration shown in Figure 21.
9. Set S1 to the +REF position.
10. Set S3 to the -REF position.
11. Set S4-S5 to the - Input position.
12. Repeat Step 7, adjusting potentiometers on Card 2.

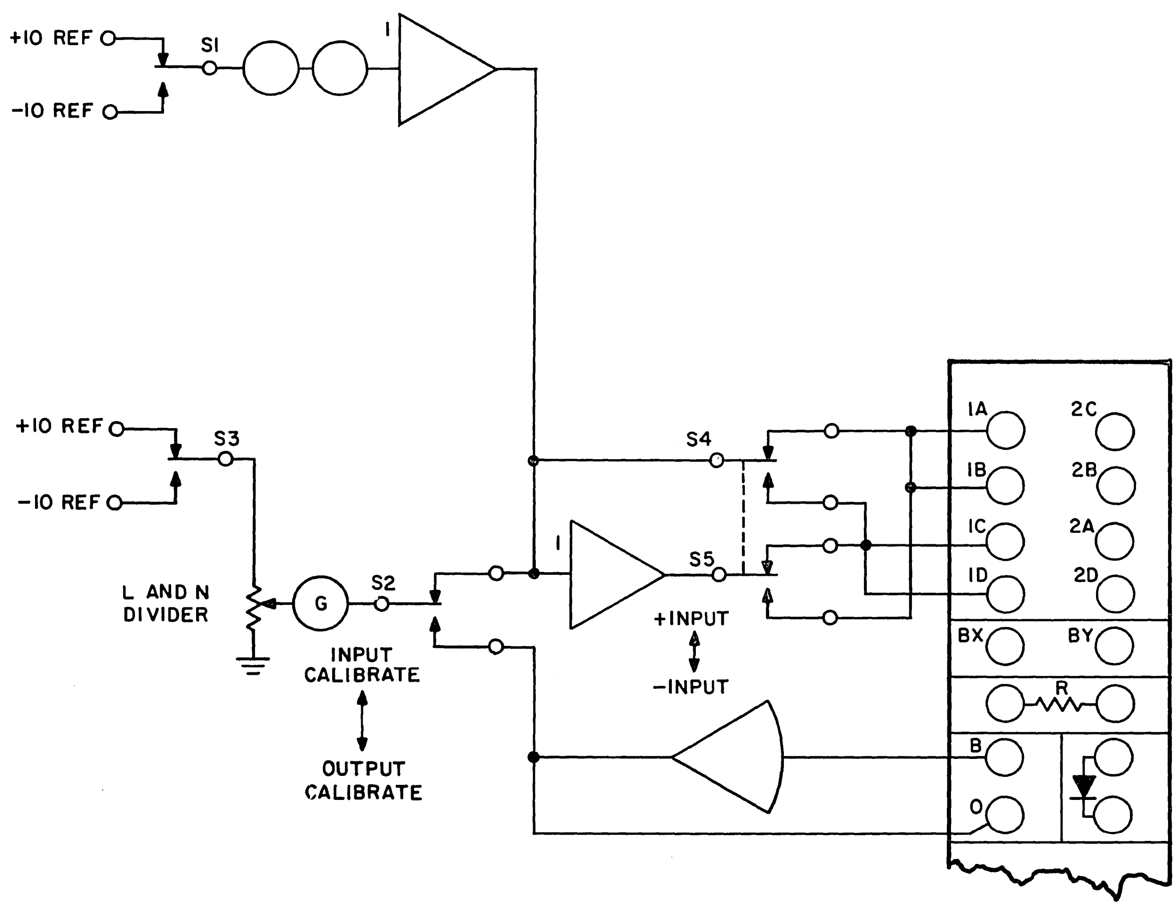


Figure 21. Card 2 Calibration Patching Diagram

APPENDIX 1

REPLACEABLE PARTS LISTS

BI-MULTIPLIER, MODELS 7.117 AND 7.137

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

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2,3	Diode	00 614.0007-0	B
2	J1	Connector Block: Lettered (MUTLIPLIER 7.117)	00 542.1326-1	B
3	P1	Connector, Plug: 22 Contacts; Male	00 542.0488-0	B
4	R1,2	Resistor, Fixed, Wirewound, Precision: 10K ohms ±0.0025%	00 638.0922-0	B
5		Patching Block: Lettered (MULTIPLIER 7.117)	00 542.1326-0	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.

DATE 9 /21 /66

UNIT TITLE

BI-POLAR MULTIPLIER

MODEL NO.

7.117 Sh. 1 of 1 Sh.

M446

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode: Matched Pair	00 614.0265-5	B
2	CR3,4	Diode: Matched Pair	00 614.0265-6	B
3	CR5,6	Diode: Matched Pair	00 614.0265-7	B
4	CR7 thru 26	Diode	00 614.0199-0	B
5	R1-(a,b,c,d) R2-(a,b,c,d) R3-(a,b,c,d)	Resistor, Fixed, Wirewound, Precision: (Matched Set) Four ea. 9K ohms ±0.5% Matched to 0.01%	00 640.0099-0	B
6	R4,7	Resistor, Fixed, Film: 20,490 ohms ±0.5%, 1/8W	00 634.0575-7	A
7	R6,9	Resistor, Variable, Wirewound: 20K ohms ±5%, 1W	00 642.0692-6	B
8	R5,8	Resistor, Fixed, Film: 140K ohms ±0.5%, 1/8W	00 634.0575-9	A
9	R10,11	Resistor, Fixed, Film: 50 ohms ±0.5%, 1/8W	00 634.0809-0	A
10	R12	Resistor, Fixed, Film: 31,314 ohms ±0.5%, 1/8W	00 634.0497-3	A
11	R13	Resistor, Fixed, Film: Value to be determined at time of manufacture	Order by Description	B
12	R14	Resistor, Fixed, Film: 51.5K ohms ±0.5%, 1/8W	00 634.0575-2	A
13	R15,23	Resistor, Variable, Wirewound: 50K ohms ±5%, 1W	00 642.0692-7	A
14	R16	Resistor, Fixed, Film: 43,230 ohms ±0.5%, 1/8W	00 634.0497-7	A
15	R17	Resistor, Fixed, Film: 1557 ohms ±0.5%, 1/8W	00 634.0496-4	A
16	R18	Resistor, Fixed, Film: 3.7K ohms ±0.5%, 1/8W	00 634.0496-6	A
17	R19	Resistor, Variable, Wirewound: 3K ohms ±5%, 1W	00 642.0692-4	B
18	R20	Resistor, Variable, Wirewound: 4.5K ohms ±5%, 1W	00 642.0692-5	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.

DATE 9 /21 /66

UNIT TITLE

BI-POLAR MULTIPLIER CARD

MODEL NO.

7.118-1 Sh. 1 of 3 Sh.

M446

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
19	R21	Resistor, Fixed, Film: 27,130 ohms ±0.5%, 1/8W	00 634.0575-8	A
20	R22	Resistor, Fixed, Film: 31.8K ohms ±0.5%, 1/8W	00 634.0575-1	A
21	R24	Resistor, Fixed, Film: 49,078 ohms ±0.5%, 1/8W	00 634.0497-8	A
22	R25	Resistor, Fixed, Film: 31,933 ohms ±0.5%, 1/8W	00 634.0497-4	A
23	R26	Resistor, Fixed, Film: 15,522 ohms ±0.5%, 1/8W	00 634.0496-9	A
24	R27	Resistor, Fixed, Film: 792 ohms ±0.5%, 1/8W	00 634.0496-3	A
25	R28	Resistor, Variable, Wirewound: 200 ohms ±5%, 1W	00 642.0692-0	B
26	R29	Resistor, Fixed, Film: 393 ohms ±0.5%, 1/8W	00 634.0496-2	A
27	R30	Resistor, Variable, Wirewound: 440 ohms ±5%, 1W	00 642.0692-1	B
28	R31	Resistor, Fixed, Film: 185 ohms ±0.5%, 1/8W	00 634.0496-1	A
29	R32	Resistor, Variable, Wirewound: 455 ohms ±5%, 1W	00 642.0692-2	B
30	R33	Resistor, Variable, Wirewound: 700 ohms ±5%, 1W	00 642.0692-3	B
31	R34	Resistor, Fixed, Film: 8942 ohms ±0.5%, 1/8W	00 634.0575-6	A
32	R35	Resistor, Fixed, Film: 1820 ohms ±0.5%, 1/8W	00 634.0575-0	A
33	R36	Resistor, Variable, Wirewound: 5K ohms ±5%, 1W	00 642.0670-0	B
34	R37	Resistor, Fixed, Film: 36,682 ohms ±0.5%, 1/8W	00 634.0497-5	A
35	R38	Resistor, Fixed, Film: 25,587 ohms ±0.5%, 1/8W	00 634.0497-2	A

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

UNIT TITLE
BI-POLAR MULTIPLIER CARD

MODEL NO.
7.118-1 Sh. 2 of 3 Sh.

DATE 9 /21 /66

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
36	R39	Resistor, Fixed, Film: 16,535 ohms ±0.5%, 1/8W	00 634.0497-0	A
37	R40	Resistor, Fixed, Film: 8887 ohms ±0.5%, 1/8W	00 634.0496-7	A
38	R41	Resistor, Fixed, Film: 3205 ohms ±0.5%, 1/8W	00 634.0496-5	A
39	RT1,2,3,4	Thermistor: 5K ohms ±20% @37.8°C	00 646.0089-0	B
40	RT5	Thermistor: 20.4K ohms ±5% @37.8°C	00 646.0078-0	B
41	RT6	Thermistor: 12.2K ohms ±5% @37.8°C	00 646.0079-0	B
42	RT7	Thermistor: 682 ohms ±5% @37.8°C	00 646.0080-0	B
		7.118-2 BI-POLAR MULTIPLIER CARD		
		Identical with 7.118-1 with the addition of a connector.		
43	P1	Connector, Plug: 22 Contacts; Male	00 542.0488-0	B

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

DATE 9 / 21 /66

UNIT TITLE
BI-POLAR MULTIPLIER CARD

MODEL NO.
7.118-1 Sh.3 of 3 Sh.

M446

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	J1	Connector Block: Lettered (Multiplier 7.137)	542.1399-6	B
2	R1	Resistor, Fixed, Wirewound, Precision: 10K ohms ±0.0025%	638.0922-0	B

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B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

DATE 7 / 21 / 65

UNIT TITLE

BI-POLAR MULTIPLIER

MODEL NO.

7.137 Sh. 1 of 1 Sh.

M446

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode: Matched Pair	614.0265-5	B
2	CR3,4	Diode: Matched Pair	614.0265-6	B
3	CR5,6	Diode: Matched Pair	614.0265-7	B
4	CR7 thru 26	Diode	614.0199-0	B
5	P1	Connector, Plug: 22 Contacts; Male	542.0692-0	B
6	R1-(a,b,c,d) R2-(a,b,c,d) R3-(a,b,c,d)	Resistor, Fixed, Wirewound, Precision (Matched Set): Four each 9K ohms ±0.5% Matched to 0.01%	640.0099-0	B
7	R4,7	Resistor, Fixed, Film: 20,490 ohms ±0.5%, 1/8W	634.0575-7	B
8	R6,9	Resistor, Variable, Wirewound: 20K ohms ±5%, 1W	642.0692-6	B
9	R5,8	Resistor, Fixed, Film: 140K ohms ±0.5%, 1/8W	634.0575-9	B
10	R10,11	Resistor, Fixed, Film: 50 ohms ±0.5%, 1/8W	634.0809-0	B
11	R12	Resistor, Fixed, Film: 31,314 ohms ±0.5%, 1/8W	634.0497-3	B
12	R13	Resistor, Fixed, Film: Value to be Determined at Time of Manufacture	Order by Description	B
13	R14	Resistor, Fixed, Film: 51.5K ohms ±0.5%, 1/8W	634.0575-2	B
14	R15,23	Resistor, Variable, Wirewound: 50K ohms ±5%, 1W	642.0692-7	B
15	R16	Resistor, Fixed, Film: 43,230 ohms ±0.5%, 1/8W	634.0497-7	B
16	R17	Resistor, Fixed, Film: 1557 ohms ±0.5%, 1/8W	634.0496-4	B
17	R18	Resistor, Fixed, Film: 3.7K ohms ±0.5%, 1/8W	634.0496-6	B
18	R19	Resistor, Variable, Wirewound: 3K ohms ±5%, 1W	642.0692-4	B
19	R20	Resistor, Variable, Wirewound: 4.5K ohms ±5%, 1W	642.0692-5	B

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B - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.

DATE 7 / 21 / 65

UNIT TITLE
BI-POLAR MULTIPLIER CARD

MODEL NO.
7.118 Sh. 1 of 3 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
20	R21	Resistor, Fixed, Film: 27,130 ohms ±0.5%, 1/8W	634.0575-8	B
21	R22	Resistor, Fixed, Film: 31.8K ohms ±0.5%, 1/8W	634.0575-1	B
22	R24	Resistor, Fixed, Film: 49,078 ohms ±0.5%, 1/8W	634.0497-8	B
23	R25	Resistor, Fixed, Film: 31,933 ohms ±0.5%, 1/8W	634.0497-4	B
24	R26	Resistor, Fixed, Film: 15,522 ohms ±0.5%, 1/8W	634.0496-9	B
25	R27	Resistor, Fixed, Film: 792 ohms ±0.5%, 1/8W	634.0496-3	B
26	R28	Resistor, Variable, Wirewound: 200 ohms ±5%, 1W	642.0692-0	B
27	R29	Resistor, Fixed, Film: 393 ohms ±0.5%, 1/8W	634.0496-2	B
28	R30	Resistor, Variable, Wirewound: 440 ohms ±5%, 1W	642.0692-1	B
29	R31	Resistor, Fixed, Film: 185 ohms ±0.5%, 1/8W	634.0496-1	B
30	R32	Resistor, Variable, Wirewound: 455 ohms ±5%, 1W	642.0692-2	B
31	R33	Resistor, Variable, Wirewound: 700 ohms ±5%, 1W	642.0692-3	A
32	R34	Resistor, Fixed, Film: 8942 ohms ±0.5%, 1/8W	634.0575-6	B
33	R35	Resistor, Fixed, Film: 1820 ohms ±5%, 1/8W	634.0575-0	B
34	R36	Resistor, Variable, Wirewound: 5K ohms ±5%, 1W	642.0670-0	B
35	R37	Resistor, Fixed, Film: 36,682 ohms ±0.5%, 1/8W	634.0497-5	B
36	R38	Resistor, Fixed, Film: 25,587 ohms ±0.5%, 1/8W	634.0497-2	B
37	R39	Resistor, Fixed, Film: 16,535 ohms ±0.5%, 1/8W	634.0497-0	B

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UNIT TITLE: BI-POLAR MULTIPLIER CARD

MODEL NO. 7.118 Sh. 2 of 3 Sh.

DATE 7 / 21 / 65

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
38	R40	Resistor, Fixed, Film: 8887 ohms ±0.5%, 1/8W	634.0496-7	B
39	R41	Resistor, Fixed, Film: 3205 ohms ±0.5%, 1/8W	634.0496-5	B
40	RT 1,2,3,4	Thermistor: 5K ohms ±20%, @37.8°C	646.0089-0	B
41	RT5	Thermistor: 20.4K ohms ±5%, @37.8°C	646.0078-0	B
42	RT6	Thermistor: 12.2K ohms ±5%, @37.8°C	646.0079-0	B
43	RT7	Thermistor: 682 ohms ±5%, @37.8°C	646.0080-0	B

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

DATE 7 /21 / 65

UNIT TITLE
BI-POLAR MULTIPLIER CARD

MODEL NO.
7.118 Sh.3 of 3 Sh.

APPENDIX 2

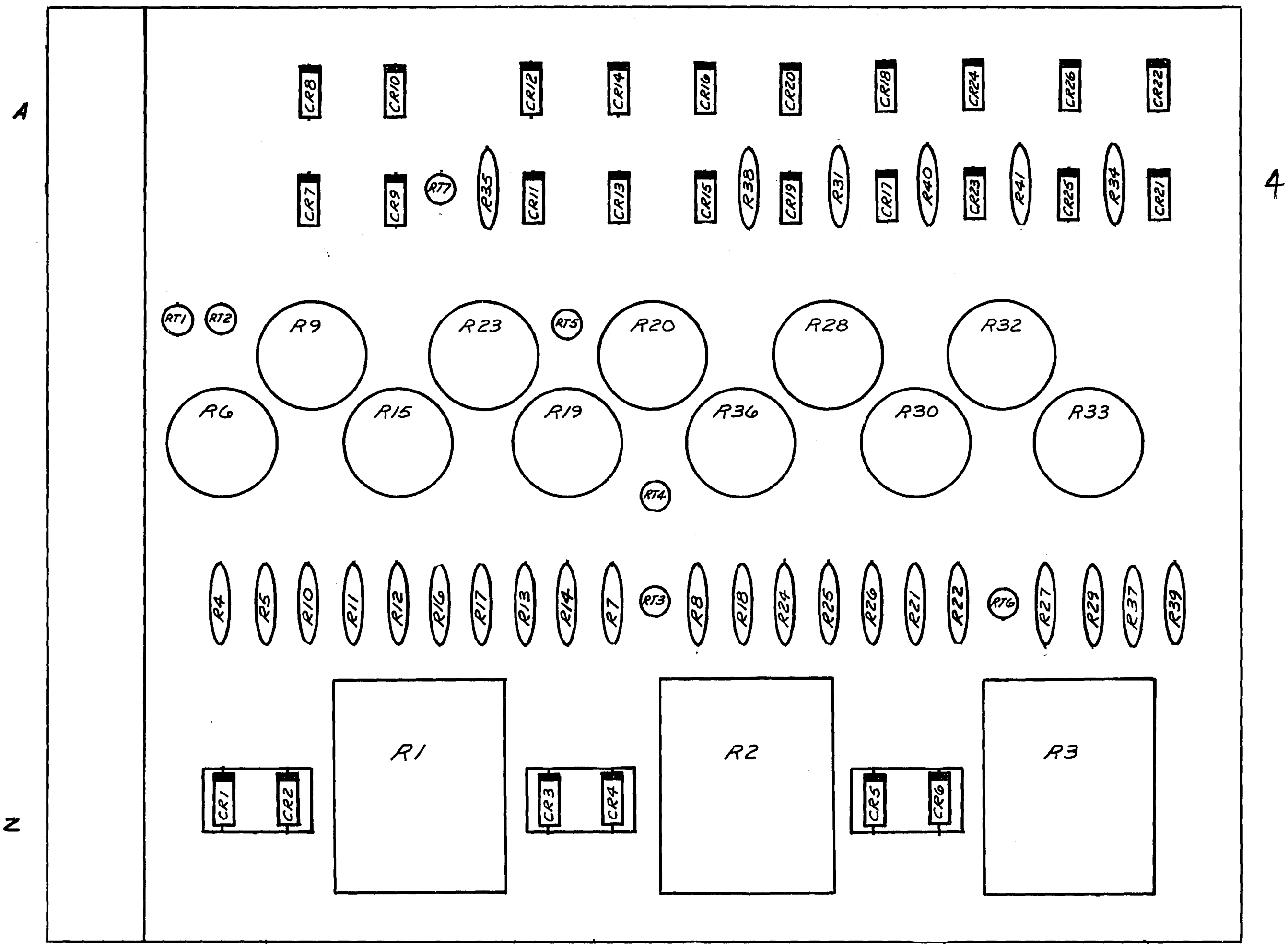
DRAWINGS

BI-POLAR MULTIPLIER, MODELS 7.117 AND 7.137

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.

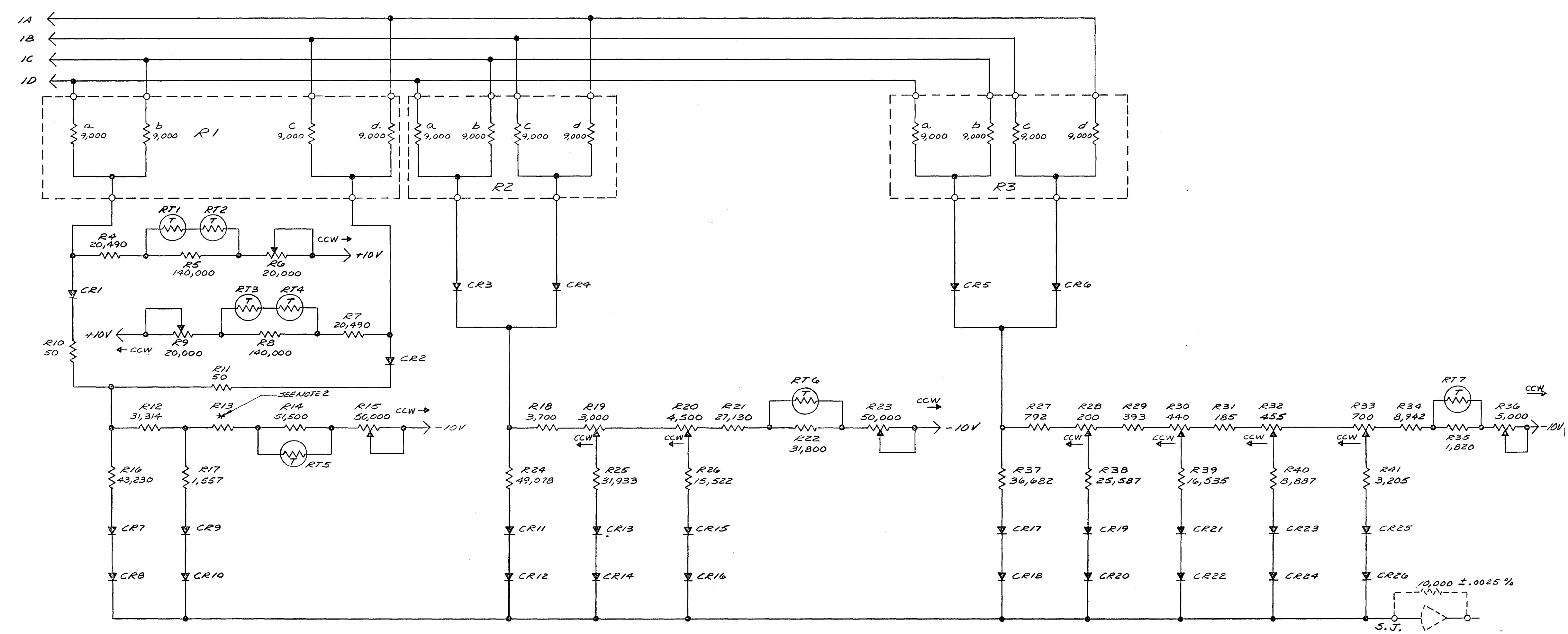
INDEX

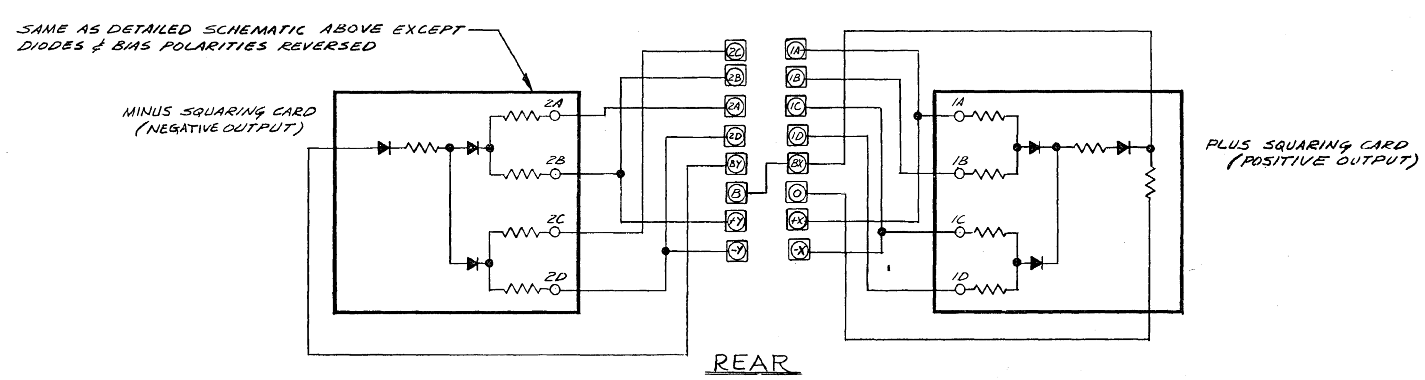


7.118 Bi-Polar Multiplier

NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   A. DIODES ARE C614 199 0
   B. RESISTORS ARE 1/8 W, ± .5%
2. VALUE OF R13 TO BE DETERMINED AT TIME OF MANUFACTURE

MIN	413,600 Ω		634 575-3
TYP	438,600 Ω	EAI#	634 575-4
MAX	463,600 Ω		634 575-5

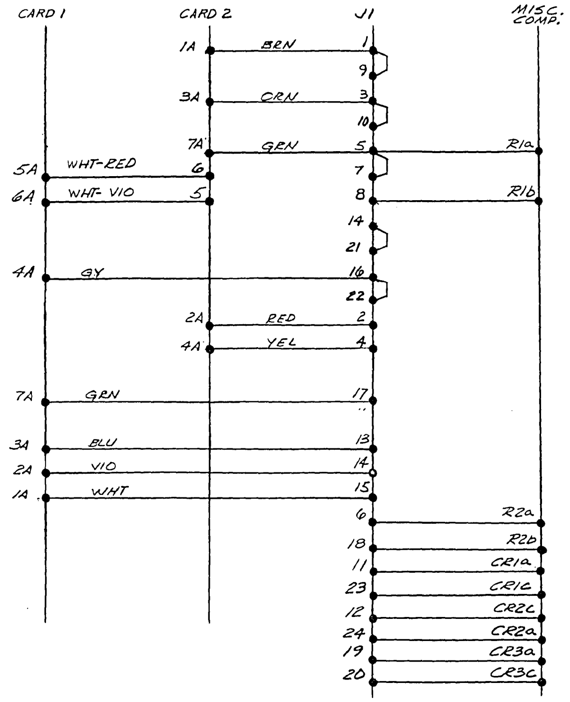


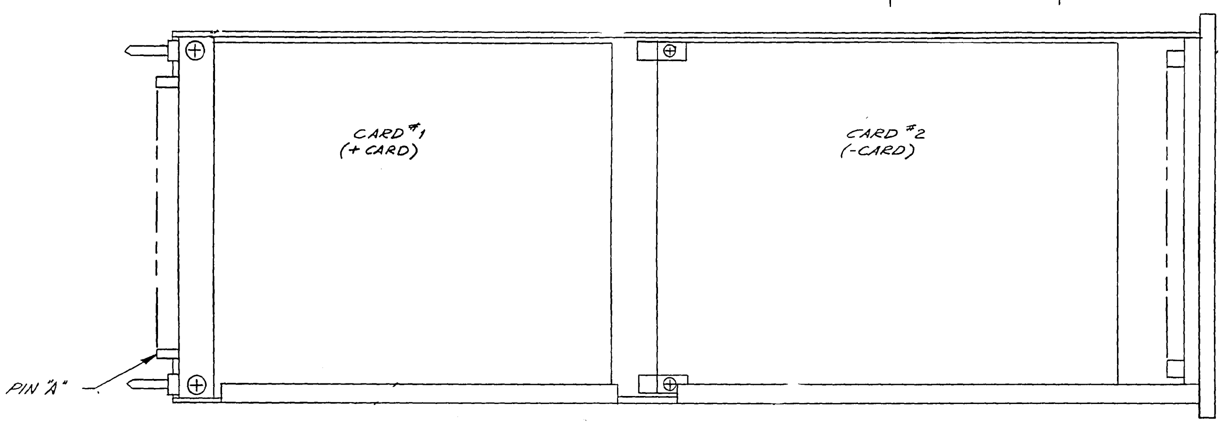


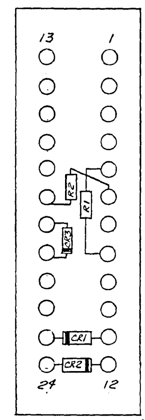
SIMPLIFIED SCHEMATIC
(SEE ABOVE FOR DETAIL)

UNLESS OTHERWISE SPECIFIED		
DIMENSIONS ARE IN INCHES		
CAPACITANCE IS IN pf		
RESISTANCE IS IN OHMS		
TOLERANCE OF:	.X = ± .03	.XX = ± .02
.XXX = ± .010	.XXXX = ± .005	∠ = ± 1°
* TOL. OF MATERIAL SUPPLIED		

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY	
SCHEMATIC BI-POLAR MULT.	
SHT. NO.	
SIZE	
REV. NO.	
PROJECT 19009	D007 117 05
SHEET 1 OF 1 SHEETS	





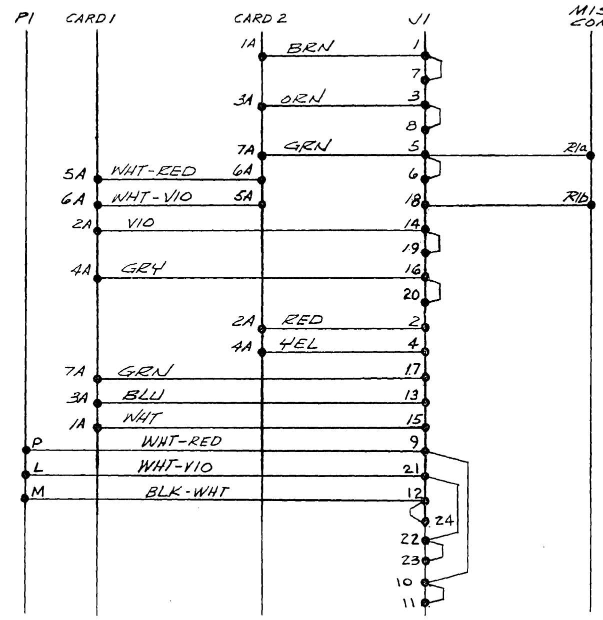


REAR VIEW

ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY
ASSEMBLY BI-POLAR MULT.
SHT. NO.
SIZE
REV. NO.
PROJECT 19009 — C 007 117 0A
SHEET 1 OF 1 SHEETS

NOTE:

1. LEAVE ALL WIRES LONG ENOUGH SO UNIT MAY BE SERVICED EASILY.
2. UNLESS OTHERWISE SPECIFIED:
   - A. WIRES ARE #22 PHU.
   - B. JUMPERS ARE #22 SD BUS COVERED WITH EXTRUDED PLASTIC TUBING WHERE NECCESSARY
3. WIRES FROM P1 TO RUN BETWEEN CARDS TO J1



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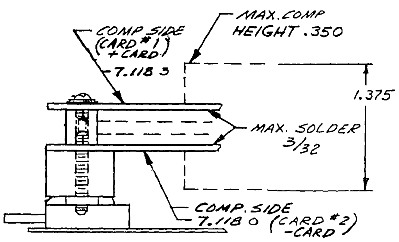
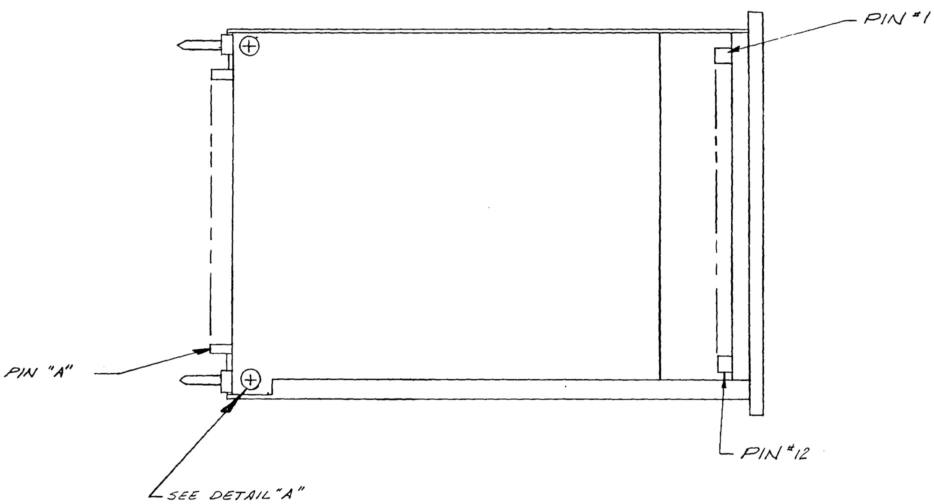


DETAIL "A"



ELECTRONIC ASSOCIATES, INC. LONG BRANCH, NEW JERSEY
ASSEMBLY BI-POLAR MULT.
SHT. NO.
SIZE
REV. NO.
PROJECT 19009 — C 007 137 0A
SHEET 1 OF 1 SHEETS

MANUAL COMMENT SHEET

Date ____________

From ____________

Company ____________

Address ____________

____

Title ____________

FOLD

Type of System ____________

FOLD

Manual Title ____________

EAI Project No. ____________ Publication No. ____________

CUT ALONG LINE

Check appropriate block and explain in space provided.

- ☐ Error (Page _____ or Drawing No.)
- ☐ Addition (Page _____, Drawing, Procedure, Etc.)
- ☐ Other

Explanation:

FOLD

FOLD

Fold, Staple, and Mail

No Postage Necessary if Mailed in U.S.A.