EAI ELECTRONIC ASSOCIATES, INC. ■ LONG BRANCH, NEW JERSEY

QUARTER - SQUARE MULTIPLIER MODEL 7.096

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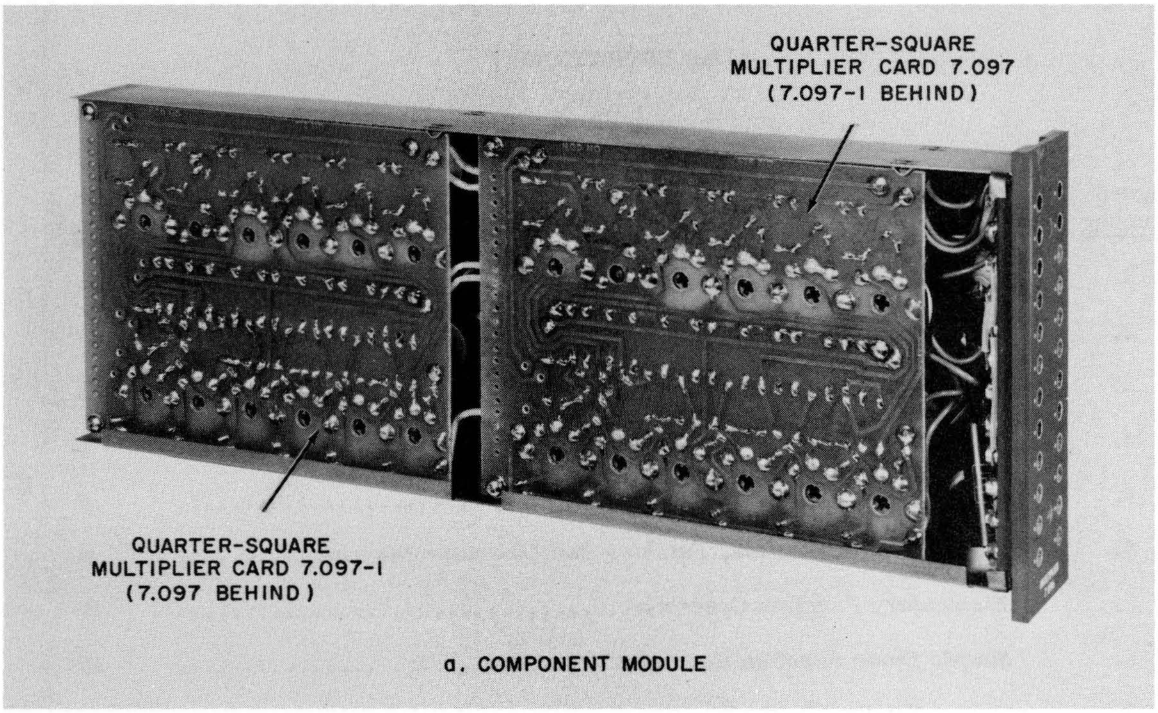
NOTICE

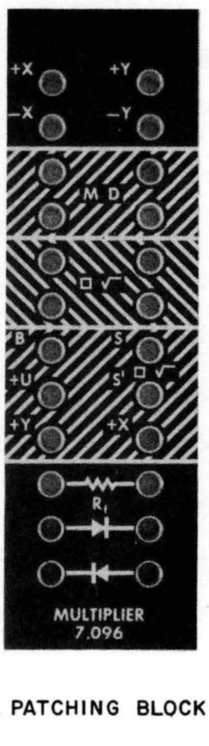
Page 12, Figure 10b: Change the $\frac{R_1 + R_2}{2}$ notation over the 20K input resistor to $\frac{R_1 = R_2}{2}$.

CONTENTS

ILLUSTRATIONS



a. COMPONENT MODULE



b. PATCHING BLOCK

NOTE:

THE 7.097 AND 7.097-1 ARE IDENTICAL EXCEPT THAT THE DIODES (CR1 THROUGH CR13) ARE REVERSED. (SEE D007 097 OS)

Figure 1. Quarter-Square Multiplier, Model 7.096

1. GENERAL DESCRIPTION

The Model 7.096 Quarter-Square Multiplier (Figure 1), is a wide bandwidth, low noise, high accuracy unit designed and manufactured by EAI (Electronic Associates, Inc.) for use in the TR-48 General Purpose Analog Computer. The unit is designed for use with a DC amplifier such as the TR-48 Model 6.514 or 6.614 to produce a four quadrant product of two variables, X and Y. In addition to multiplication the 7.096 is capable of division (two quadrant), squaring or extracting the square root of a variable input.

The 7.096 Multiplier utilizes the quarter-square multiplication technique to produce the product of two variables as illustrated by the equation:

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

This equation reduces multiplication essentially to the operations of summation and squaring. The squaring operations are performed by the quarter-square multiplier and the summation by an external DC amplifier.

The 7.096 is housed in a plug-in module to facilitate installation in the TR-48 Computer. It is interchangeable with the standard 7.099 Multiplier and may be used in any of the modular areas of the TR-48 allocated for multiplier installation. The use of conservatively-rated, precision, solid state components insures long-term accuracy and stability, long-life, and trouble-free operation.

2. TECHNICAL DATA

a. Power Requirements

+10 volts (computer reference)

-10 volts (computer reference)

3 milliamperes nominal reference drain per products from each reference source

b. 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, square root) .... -10 to +10 volts

c. Bandwidth

When used with 6.514 Amplifier; essentially that of the amplifier.

d. Normal Operating Temperature Range

50° to 100°F

The following specifications include errors of inverting amplifiers for a 7.096 programmed in a standard multiplication configuration within the normal operating temperature range.

e. Static Error

±0.1% of full scale - absolute maximum

±0.05% of full scale - typical maximum

When the sum of the inputs ≤9 (i.e., $|X|+|Y|\leq 9.0$) the *absolute maximum* static error is ±0.06% of full scale.

f. Zero Error

Either input zero	±0.05% of full scale - maximum
	±0.025% of full scale - typical
Both inputs zero	±0.005% of full scale - maximum

g. Total Instantaneous Dynamic Error at 1000 CPS

0.35% of output - maximum

h. Phase Shift at 1000 CPS

0.2° maximum

0.15° typical

3. INSTALLATION AND ADJUSTMENTS

a. Installation

The Model 7.096 Quarter-Square Multiplier is designed specifically for installation in the TR-48 General Purpose Analog Computer. The precedure for installing this unit in the TR-48 is described in Section II, Paragraph 2*d.* of the *TR-48 Analog Computer Operator's Manual.*

b. Adjustments

The 7.096 Quarter-Square Multiplier is factory calibrated and adjusted prior to shipment; the unit is ready for use upon installation in the TR-48 Rack. If desired, a simple check may be performed by patching the unit in the multiplication configuration, inserting various values of X and Y and noting the product output (-XY/10) on the computer DVM. This simple check will generally indicate if the factory adjustments have been affected by possible rough handling in shipment.

4. OPERATING INSTRUCTIONS

All patching connections for the 7.096 Quarter-Square Multiplier are accomplished via the patching block in the Pre-Patch Panel. Figure 2 shows the outline of the multiplier patching block and a simplified schematic of the terminations and their connections to the four multiplier cards. The four cards permit four-quadrant multiplication; only two of the cards will conduct at any one given time.

On Figure 2 the two +Y terminations of the simplified schematic are distinguished from each other by the subscripts T and B; $+Y_T$ denotes the +Y termination at the top and right-hand side of the patching block and the $+Y_B$ indicates the +Y termination in the lower left-hand corner of the bottom cross hatched area. These two terminations are not common to each other until a jumper is placed horizontally between the top two terminations of the □ $\sqrt{\ }$ cross-hatched area.

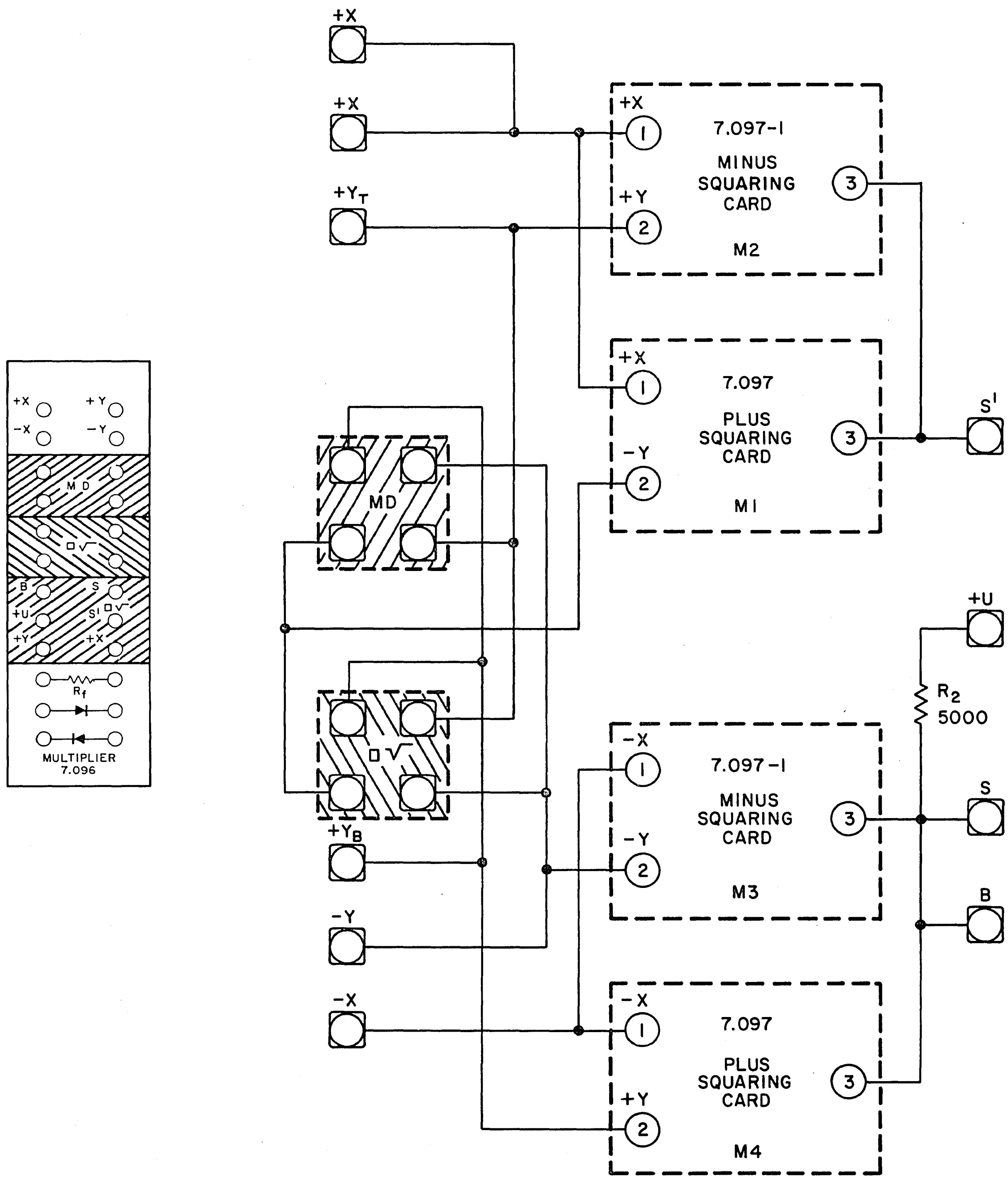


Figure 2. Patching Block and Simplified Schematic

In addition to the required patching terminations of the Quarter-Square Multiplier, the patching block also provides two diodes and a 5000 ohm precision resistor between the six bottom terminations. The diodes permit limiting the polarity of the inputs to the multiplier and are available for use in other programmed circuits. The resistor provides a second feedback resistor thus permitting the multiplier to be patched to produce two squaring or square root circuits, or it can be used as an input resistor to the multiplier summer to provide an output of -XY/10 +Z.

The patching block of the quarter-square multiplier is designed for ease of patching with maximum flexibility. Note in the cross hatched areas there are two overall sections labeled MD and □√; also in the third crosshatched area there is a □√ symbol between S and S'. These areas are marked so that for the function to be performed by the multiplier, the corresponding letter or symbol is left exposed after the patching is completed. For example, whenever the multiplier is to be used for multiplication or division, a four-connector bottle plug is placed in □√ area, and a patch cord is connected between S and S'. The □√ symbol is covered and the MD letters left exposed. Thus, at a glance the operator can tell the multiplier is being used either for multiplication or division. To perform a squaring operation or extract the square root, therefore, the programmer would place a bottle plug in the MD area leaving the □√ symbols exposed. The following sub-paragraphs describe each of the four operating modes of the 7.096 Quarter-Square Multiplier.

a. Multiplication

Figure 3a illustrates the patching requirements to set up the 7.096 Multiplier for four-quadrant multiplication. The b portion of the diagram illustrates the suggested configuration to be used by the programmer in generating a computer diagram. In the square denoting the multiplier a number may also be assigned, such as 01, to indicate the amplifier providing the product output; thus in Figure 3 the multiplier could be designated M01. Any system can be used that will aid the operator in readily locating the actual physical position of the multiplier in the computer from the computer diagram. The computer diagram shows all patching connections except the four connector bottle plug in the □√ area and the patch cord between S and S'. Since these connections must be made, and cover the □√ symbols (for multiplication or division), they are eliminated from the computer diagram for simplicity.

The patching configuration shown in Figure 3 produces the product -XY/10; if the product +XY/10 is desired it may be obtained by interchanging the +X and -X inputs *or* the +Y and -Y inputs. This procedure eliminates the requirement of an additional inverting amplifier.

The impedance of a given multiplier input is a function of the magnitude and polarity of the other input signal. Thus, the quantities X and Y should be obtained from the output of an amplifier and not directly from the wiper of a potentiometer.

b. Division

The patching configuration of the Quarter-Square Multiplier for division is shown in Figure 4. As in the case of multiplication, the computer diagram (Figure 4b) shows all the required patching except that required to cover the □√ symbols. Note that both -10 U/X and +10 U/X are available as outputs of the division circuit.

There are limitations to the division circuit in order to avoid positive feedback and also due to the inversion by amplifier 01. These limitations are:

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

(2) The divisor X must be positive*.

(3) The divisor X must not equal zero.

**If X is negative the +X and -X inputs must be interchanged. The output of amplifier 01 becomes +10 U/X and 02 produces -10 U/X.*

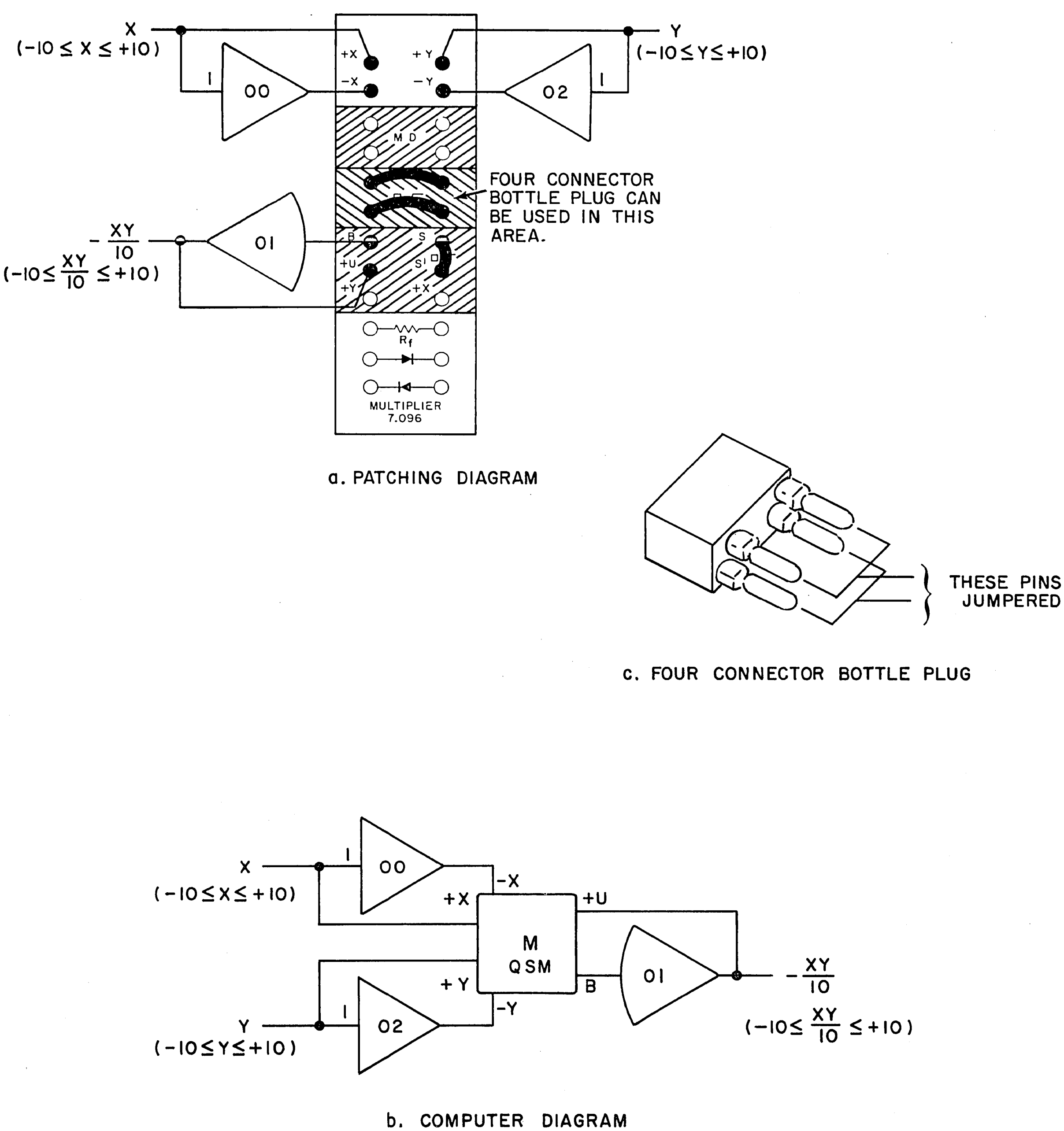
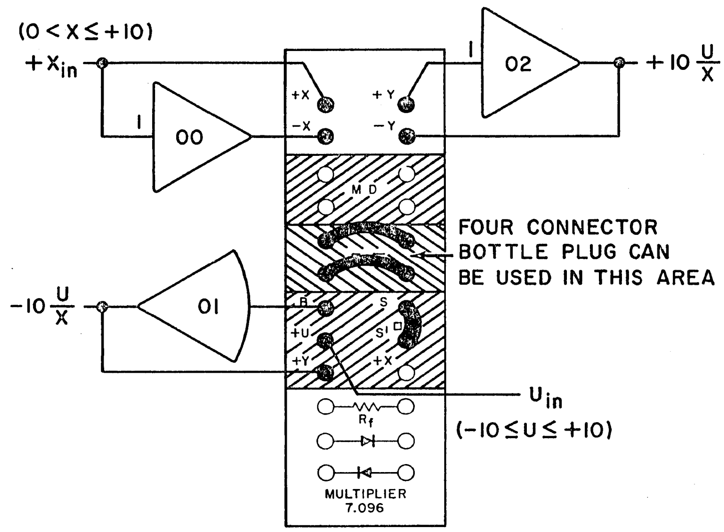


Figure 3. Multiplier Patching and Computer Diagram



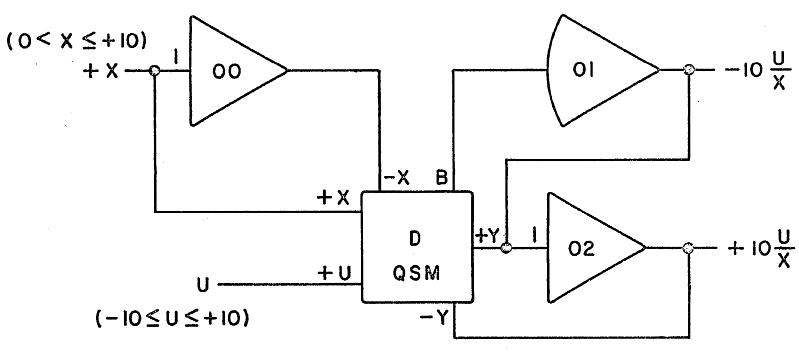
a. PATCHING DIAGRAM

DIVISION CIRCUIT RESTRICTIONS

1. $\frac{U}{X} \leq 1.0$ $(X \geq U)$

2. X MUST BE POSITIVE (IF X IS NEGATIVE INTERCHANGE +X AND −X)

3. $X \neq 0$



b. COMPUTER DIAGRAM

Figure 4. Division Patching and Computer Diagram

c. Squaring

Figure 5a shows the patching configuration to obtain the square of an input variable. The patching provides two squaring circuits and are distinguished from each other on Figure 5a by solid and dashed lines. Thus, if a single squaring circuit is required, only the dashed or solid connections need be made. However, if four-connector bottle plugs are used as suggested on Figure 5a the presence of the essentally "extra pair" of jumpers will not effect the circuit operation since the two squaring circuits are completely independent. For example, if the solid line squaring circuit is connected, and four-connector bottle plugs are used, the connections between the top terminations in the MD area and between +X and +Y are made (shown dashed) although not required; they will not effect the solid line circuit operation (and vice versa). If the operator therefore, automatically places the four connector plugs in place, whether two circuits are required or not, the computer diagram can be simplified (as shown in Figure 5b) by eliminating the connections made by these bottle plugs. As described in the succeeding paragraph, these connections made by the bottle plugs are also required for extracting the square root; thus, one squaring circuit may be combined with a square root circuit.

Note in this configuration none of the patching covers the $\square\sqrt{\ }$ symbols but a bottle plug covers the MD area. The exposed $\square\sqrt{\ }$ symbols immediately indicates the two possible modes of operation of the multiplier. The outputs of either of these circuits is actually the variable times the absolute value of the variable; thus, the "square" output changes polarity with a change in the input polarity.

d. Square Root

Figure 6a shows the patching configuration for extracting the square root of an input signal. As in the case of the squaring configuration, two independent square root circuits are available; the two circuits are distinguished from each other by the solid and dashed lines. Both of the circuits produce the square root of 10 times the *absolute* value of the input signal; the output polarity changes sign when the input polarity changes. As in the case of squaring, if the operator places four-connector bottle plugs in the MD and the +X, -X, +Y, -Y area directly above it whenever desiring to extract the square root the simplified computer diagrams shown in Figure 6b can be used.

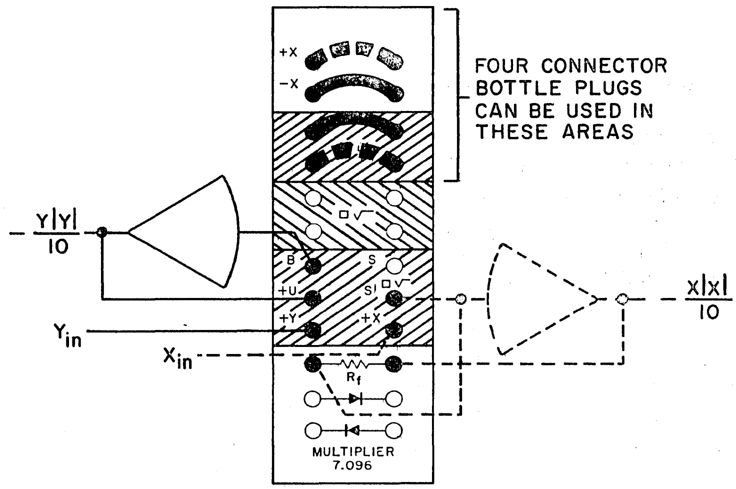
5. BASIC DIODE FUNCTION GENERATORS

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 7.096 Quarter-Square Multiplier is covered in Paragraph 6.

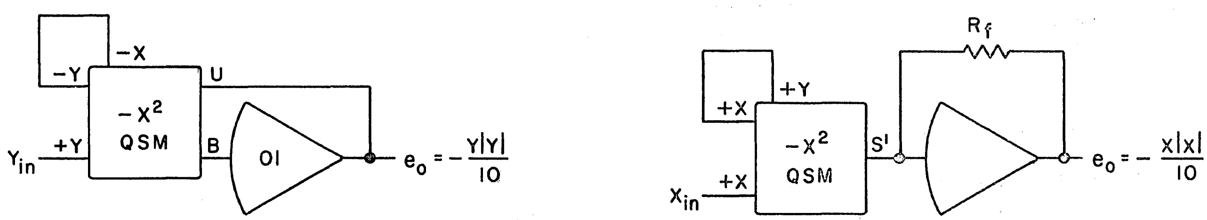
Figure 7 illustrates an elementary function generator. By varying the wiper position of the potentiometer R, such that R decreases as the input voltage increases, the gain of the amplifier will increase and a function similar to that of Figure 7b can be generated (in an operational amplifier $E_o = E_{in} R_f/R$). 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 for practical purposes is 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 *ideal* 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 then to the cathode) and a zero resistance when forward biased (conducting).



a. PATCHING DIAGRAM



WHEN $-10 \leq Y \leq 0$, $e_o = +\frac{Y^2}{10}$

WHEN $0 \leq Y \leq +10$, $e_o = -\frac{Y^2}{10}$

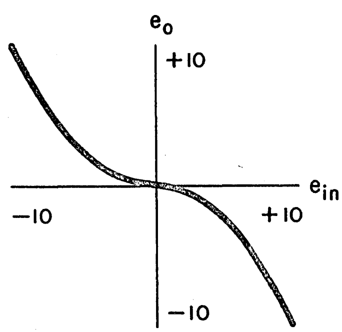
(SEE e_o Vs. e_{in} PLOT)

WHEN $-10 \leq X \leq 0$, $e_o = +\frac{X^2}{10}$

WHEN $0 \leq X \leq +10$, $e_o = -\frac{X^2}{10}$

(SEE e_o Vs. e_{in} PLOT)

b. COMPUTER DIAGRAMS



c. e_o Vs. e_{in} PLOT

NOTE:
SOLID LINES DENOTE PATCHING FOR Y^2 CIRCUIT, DASHED LINES FOR X^2 CIRCUIT.

Figure 5. Squaring Patching and Computer Diagram

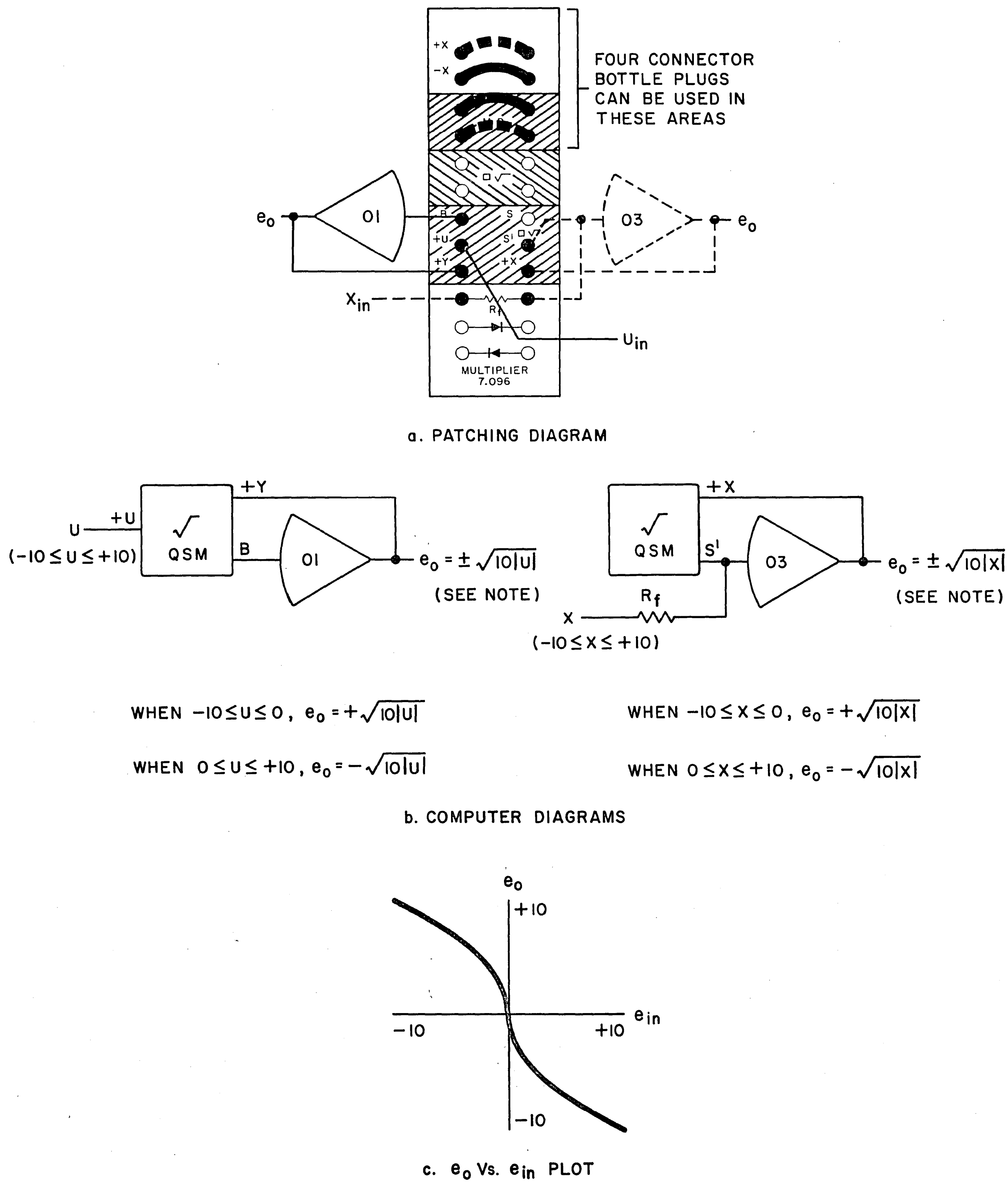


Figure 6. Square Root Extraction, Patching and Computer Diagram

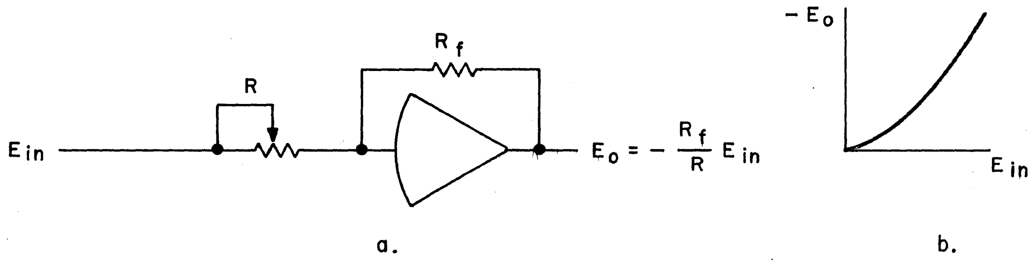


Figure 7. Elementary Function Generator

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 8). 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 8b)*. 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 8b. 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 8 is very simple it is readily reproduced with extremely high accuracy.

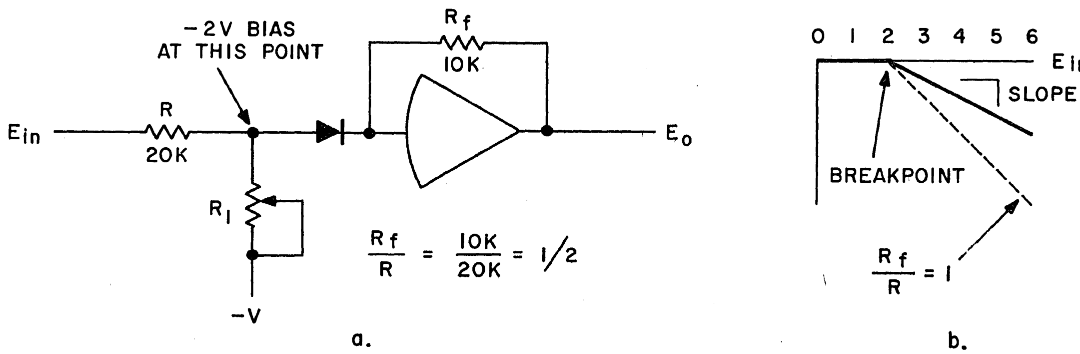


Figure 8. Simple Diode Function Generator

More complex functions may be generated by paralleling biased diode networks. Figure 9 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 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.

**It is assumed for simplicity that $R_1 \gg R$ in Figure 8a and therefore the output slope of the amplifier may be assumed to equal R_f/R.*

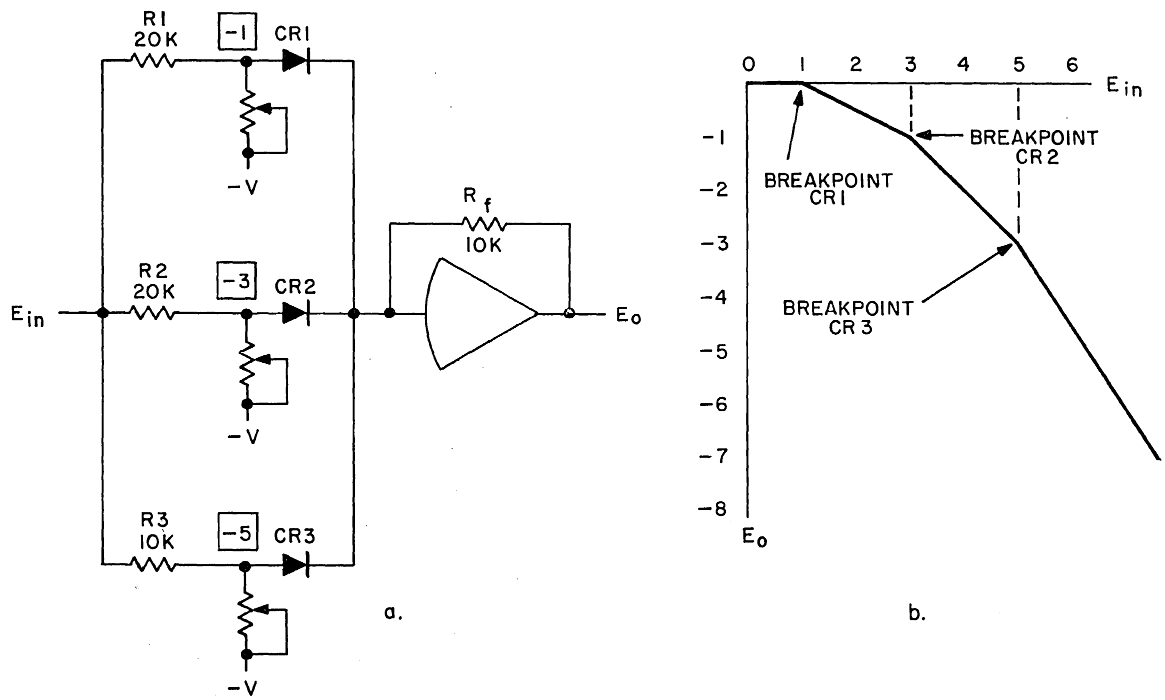


Figure 9. Three-Network Diode Function Generator

Note that the straight-line segments on the graph (Figure 9b) 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 7.096 Quarter-Square Multiplier utilizes the X^2 DFG principle; however, these squaring circuits must produce outputs proportional to $[(X + Y)/2]^2$ and $-[(X - Y)/2]^2$. This can be accomplished by modifying the basic DFG circuit shown in Figure 8 to the configuration shown in Figure 10a. Figure 10b is an equivalent circuit of 10a and clearly shows the similarity to Figure 8.

By paralleling several of the dual input networks, ratioed to the feedback resister of an amplifier, an amplifier output of $1/10\ [(X + Y)/2]^2$ can be obtained. To obtain $-1/10\ [(X - Y)/2]^2$ a series of parallel networks are required that have the diodes *reversed* and biased from a *positive* voltage source. The X input to this network must be negative, however, and must always be larger than Y*.

**The second network as described produces* $1/10\ [(-X + Y)/2]^2$ *which equals* $1/10\ [(X - Y)/2]^2$.

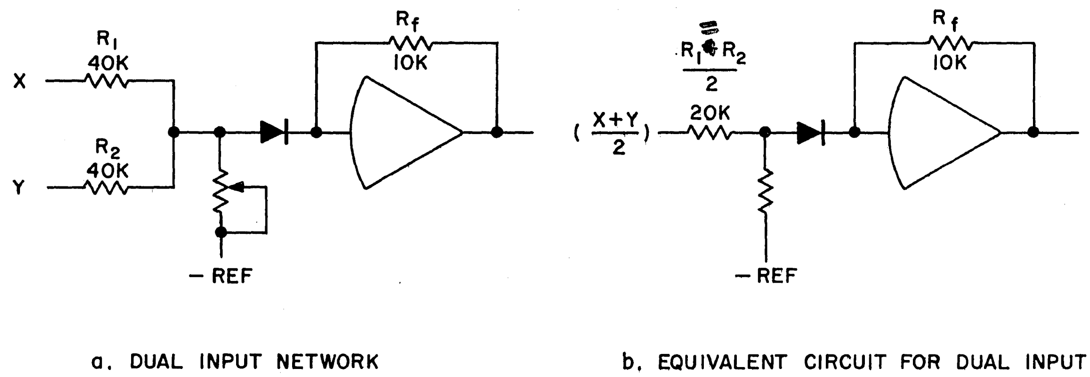


Figure 10. Simplified Quarter-Square Multiplier DFG Network

Figure 11 is a simplified schematic of a Quarter-Square Multiplier using two input squaring networks as described in the previous paragraph. As each diode conducts (or reaches its breakpoint) the resistors of a network that are common to the X input are paralleled, as are those of the Y input resistors; R1, R2, R3, and R4 therefore represent the equivalent resistance of these parallel groups. Also shown on this diagram is the direction of the input and feedback currents (electron flow) when an input of +X and +Y is applied and where X is larger than Y.

This same arrangement can be used when X is negative, Y is positive, and Y is larger than X. In this case the $(X + Y)^2$ function is obtained from the bottom network and the $(X - Y)^2$ function from the top network. If both X and Y are positive and *equal* in magnitude only the top card conducts and the $[(X + Y)/2]^2$ function essentially becomes $[(2X)/2]^2$. Only the bottom card conducts when X = Y and X is negative and Y positive.

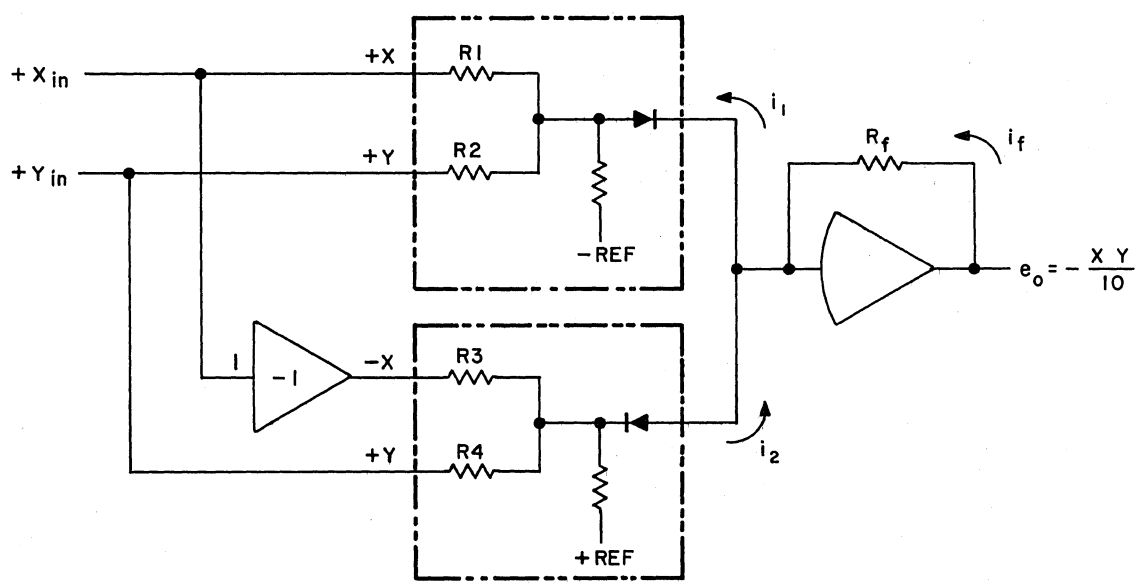
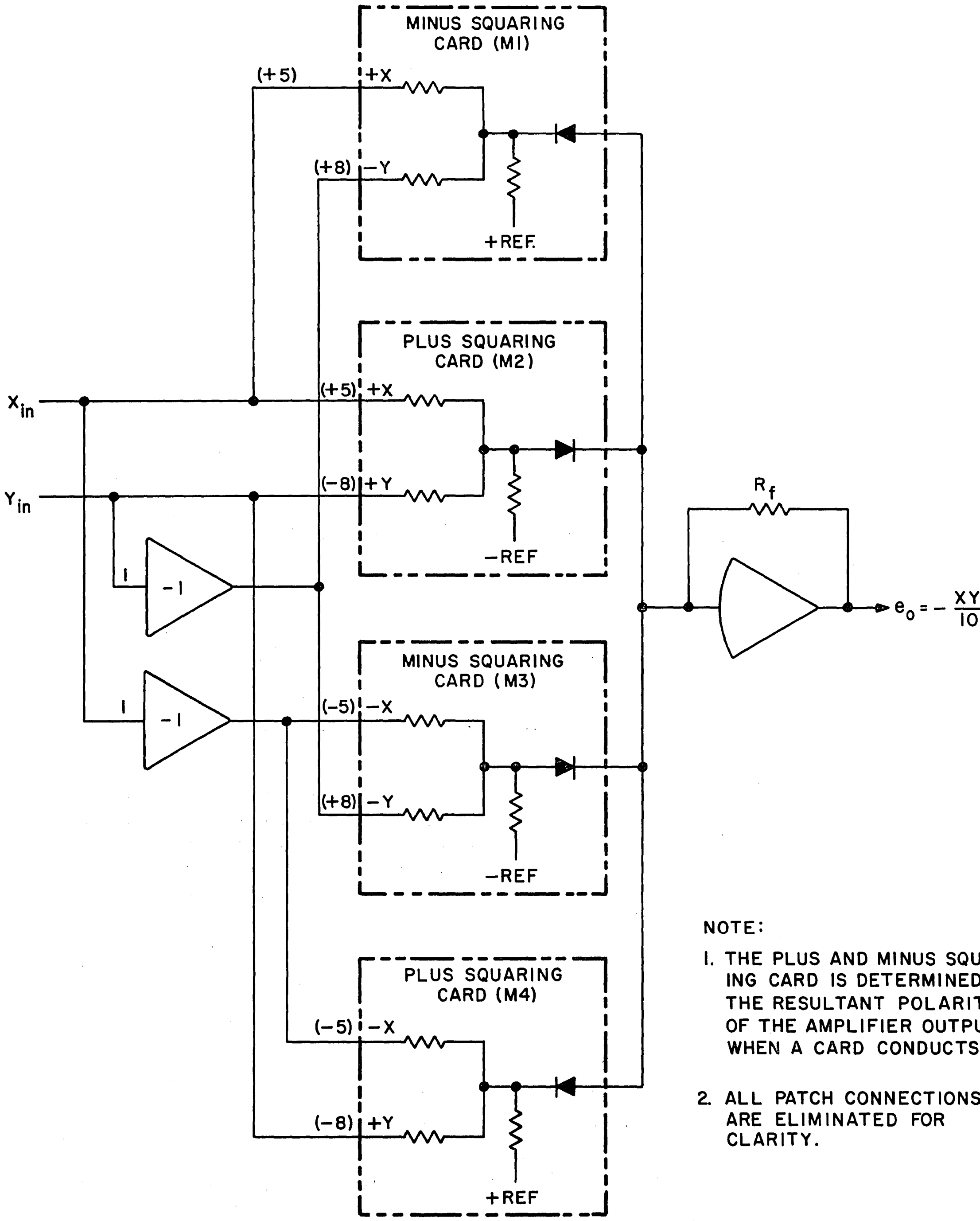


Figure 11. Two-Network Quarter-Square Multiplier, Simplified Schematic

Thus the two-network multiplier will handle four possible combinations of X and Y inputs with regard to magnitude and polarity. There are actually 12 possible combinations; by adding two more networks and one more inverting amplifier (as shown in Figure 12) all 12 combinations can be handled. The multiplier as shown in Figure 12 is essentially a simplified schematic of the 7.096 Quarter-Square Multiplier.



NOTE:

1. THE PLUS AND MINUS SQUARING CARD IS DETERMINED BY THE RESULTANT POLARITY OF THE AMPLIFIER OUTPUT WHEN A CARD CONDUCTS.

2. ALL PATCH CONNECTIONS ARE ELIMINATED FOR CLARITY.

Figure 12. Four Quadrant Quarter-Square Multiplier, Simplified Schematic

6. 7.096 MULTIPLIER CIRCUIT DESCRIPTION

The 7.096 Quarter-Square Multiplier utilizes the quarter-square multiplication technique to produce product of two variables as illustrated by the equation:

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

The negative sign is a result of the inversion by the summing amplifier. The scale factor of 1/10 is obtained by selection of resistance values; the scale factor prevents exceeding the computer 10 volt reference level for maximum values of both X and Y.

As indicated in Paragraph 5 the 7.096 Multiplier contains four squaring cards each capable of generating an output equal to $1/10\left[(X+Y)/2\right]^2$ or $1/10\left[(X-Y)/2\right]^2$ depending on the input levels and polarities. The unit is designed so that no more than two of the cards can conduct at any one time thus providing the two terms of Equation (1).

The schematic diagram of each of the squaring cards of the multiplier is given on D007 096 0S in Appendix II of this manual. The schematic shows a plus squaring card configuration; however, by reversing all the diodes and reversing the bias inputs between pins 4 and 6, the unit becomes a minus squaring card.

The terms plus and minus squaring cards indicate the polarity of the output summing amplifier signal when a given card conducts with the 7.096 patched for multiplication. Due to the inversion of the summing amplifier therefore, a plus squaring card accepts negative inputs, and a minus squaring card accepts positive inputs.

Figure 13 is a simplified schematic of a plus squaring card of the 7.096 Multiplier. Note that all of the diodes except CR1 are reverse biased from the computer positive reference source. Thus as the sum of the inputs X and Y becomes more and more negative, more of the diodes reach their break-point, conduct and produce an output proportional to the square of the sum of the inputs.

As shown, diode CR1 is not biased via the positive computer reference, but is biased from the minus reference. The bias level on the diode is adjusted so CR1 is at the threshold of conduction when both X and Y are zero. This feature eliminates the requirement that the input sum reach a finite value before CR1 conducts and thus eliminates the large error frequently encountered with low level inputs to a DFG.

As an example of the operation of the multiplier, assume the unit is patched for multiplication and inputs of $X = +5$ volts and $Y = -8$ volts are applied. Referring to Figure 12, which is essentially a simplified schematic of this multiplier when patched for multiplication, the following inputs are applied to M1 through M4:

M1 $+X = +5$ volts, $-Y = +8$ volts (inverted Y input)

M2 $+X = +5$ volts, $+Y = -8$ volts

M3 $-X = -5$ volts (inverted X input), $-Y = +8$ volts (inverted Y input)

M4 $-X = -5$ volts (inverted X input), $+Y = -8$ volts

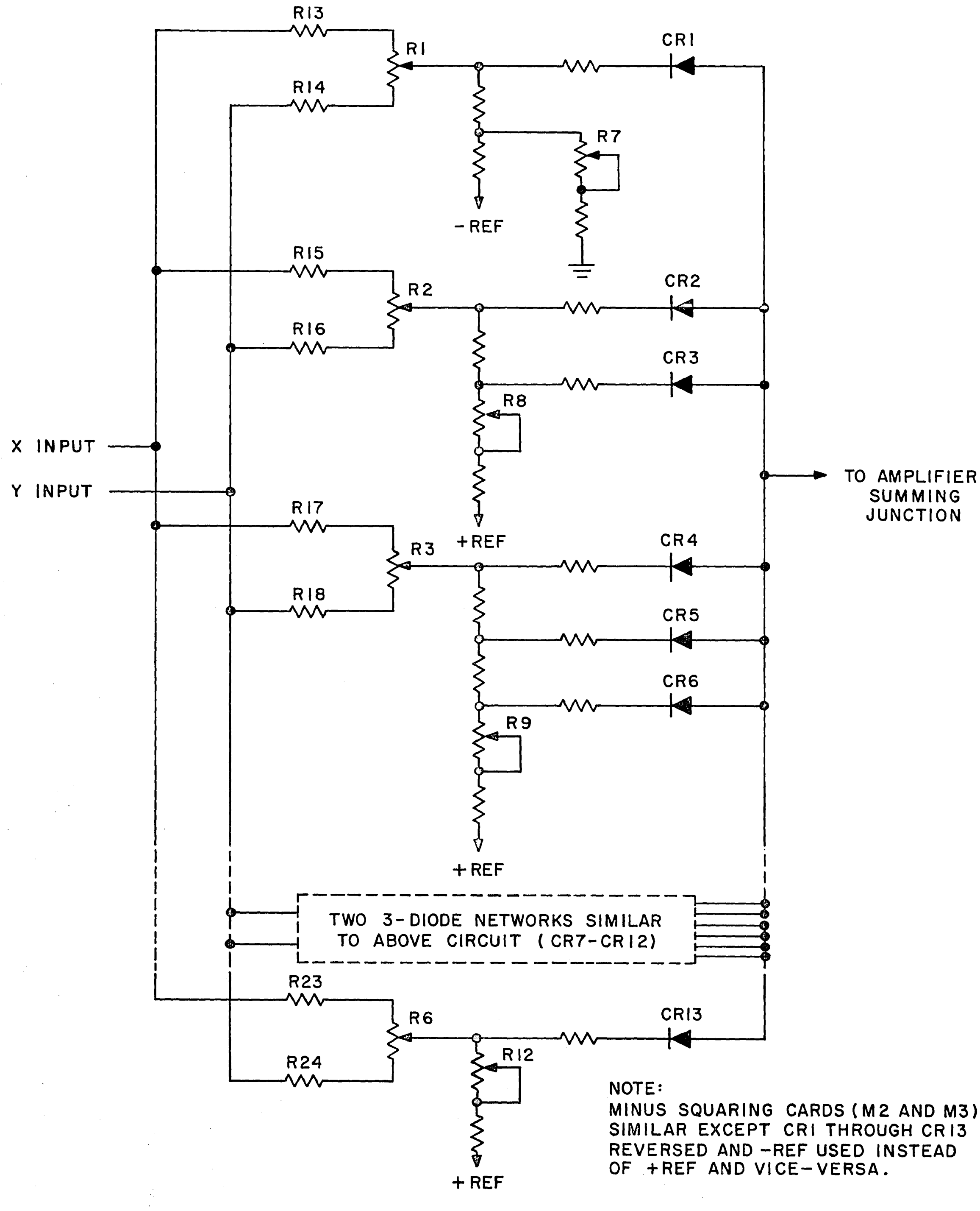


Figure 13. Plus Squaring Card, Model 7.097-0, Simplified Schematic

Since the inputs to card M1 are both additive to the reverse bias, the diodes of M1 do not conduct. The diodes of card M2 are also cut off since the algebraic sum of X and Y (-3 volts) is also additive to the diode reverse bias. For cards M3 and M4, however, the algebraic sum of the X and Y inputs (+3 volts for M3 and -13 volts for M4) tend to forward bias the diodes and cause them to conduct.

The current through M3 is proportional to $-1/10\left[(-5+8)/2\right]^2$; the negative sign is assigned since this current will tend to cause the amplifier output to swing negative. The current through M4 is proportional to $+1/10\left[(-5-8)/2)\right]^2$.

Substituting these values in Equation (1):

$$-\frac{1}{10}\left(\frac{-5+8}{2}\right)^2+\frac{1}{10}\left(\frac{-5-8}{2}\right)^2=-\frac{1}{10}\left[\left(\frac{-3}{2}\right)^2-\left(\frac{-13}{2}\right)^2\right]=-\frac{XY}{10} \qquad (2)$$

$$-\frac{1}{10}\left[\frac{9}{4}-\frac{169}{4}\right]=-\frac{1}{40}(-160)=\frac{-160}{-40}=4 \text{ volts} \qquad (3)$$

This agrees with $-XY/10$ or $-(5)(-8)/10 = +4$ volts. For other input voltage levels and polarities different cards conduct to provide the proper output product. Note, however, no more than two cards will conduct at any given time.

The operation of the multiplier when patched as a division, square root, or squaring circuit may be analyzed in a similar manner. Note that the actual polarity of the input signal as applied to a card must be considered to determine if a card conducts. These signal polarities may or may not agree with the sign of the patch panel input termination.

7. MAINTENANCE

The Quarter-Square Multiplier, Model 7.096 requires very little maintenance. The 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 Sub-Paragraph *b*. provides an error test to indicate the unit accuracy; should this test indicate a faulty multiplier the subsequent paragraphs should help isolate the problem.

a. Preliminary Adjustments

Prior to performing maintenance checks or troubleshooting the multiplier, the following adjustments must be accomplished on the computer and the associated amplifiers. The method of accomplishing these procedures is covered in the TR-48 Analog Computer handbook.

(1) Be sure that the level of the computer +10 reference supply is 10 volts ±2 millivolts. (This is the specification that the TR-48 +10 volt reference supply must meet when shipped; however, if the reference supply is 10 volts ±5 millivolts it is within sufficient tolerance to check and calibrate the multiplier.)

(2) Balance the computer reference voltages to within one millivolt maximum difference in magnitude.

(3) Carefully balance all amplifiers to be used in conjunction with multiplier tests or adjustments.

b. Error Test

(1) Set up the test circuit shown in Figure 14. This drawing shows the test circuit with the patching block outline to show all connections (Figure 14a) and also the same test circuit in computer diagram form (Figure 14b). The symbols used are those shown in Appendix I of the TR-48 Analog Computer Operators Manual. The assigned amplifier attenuator and function switch designations are arbitrary and not necessarily indicative of the best patching configuration.

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

(a) The input and feedback resistors of inverters 00 and 01 should be selected so that with a 10 volt input the output is 10 volts with less than 0.5 millivolt maximum error. (See Paragraph 7*c*.)

(b) The two input resistors of summing amplifier 02 should be selected so that equal magnitude inputs provide equal outputs with less than 0.5 millivolt maximum error. (See Paragraph 7*c*.)

(c) Attenuator 00 and the combination of 01 and 02 should be adjusted to provide the same multiplication factor. (See Paragraph 7*c*.)

(3) Adjust attenuator 03 at the input of integrator 01 to provide a reasonable sweep rate of the plotter arm.

(4) Place function switch F1 to the right and apply minus reference to attenuator 00 (function switch F2 to the left). Record the resultant error curve.

(5) Place F1 to the left and F2 to the right. Record the resultant error curve.

(6) Interchange the +X and +Y leads and the -X and -Y leads of the multiplier. Repeat Step (4) above and record the resultant error curve.

(7) Repeat Step (5) and record the resultant error curve.

Figure 15 illustrates two typical error plots similar to those generally obtained from Steps (4) through (6) of this procedure. Should the unit error exceed 20 millivolts (maximum allowable error) at any point, and the associated equipment is known to be functioning properly, it indicates one or more of the cards require adjustment. The procedures given in Sub-Paragraph *d.* will permit isolation of the faulty card or cards. These procedures also illustrate how the error curve can indicate the most likely card causing the apparent error.

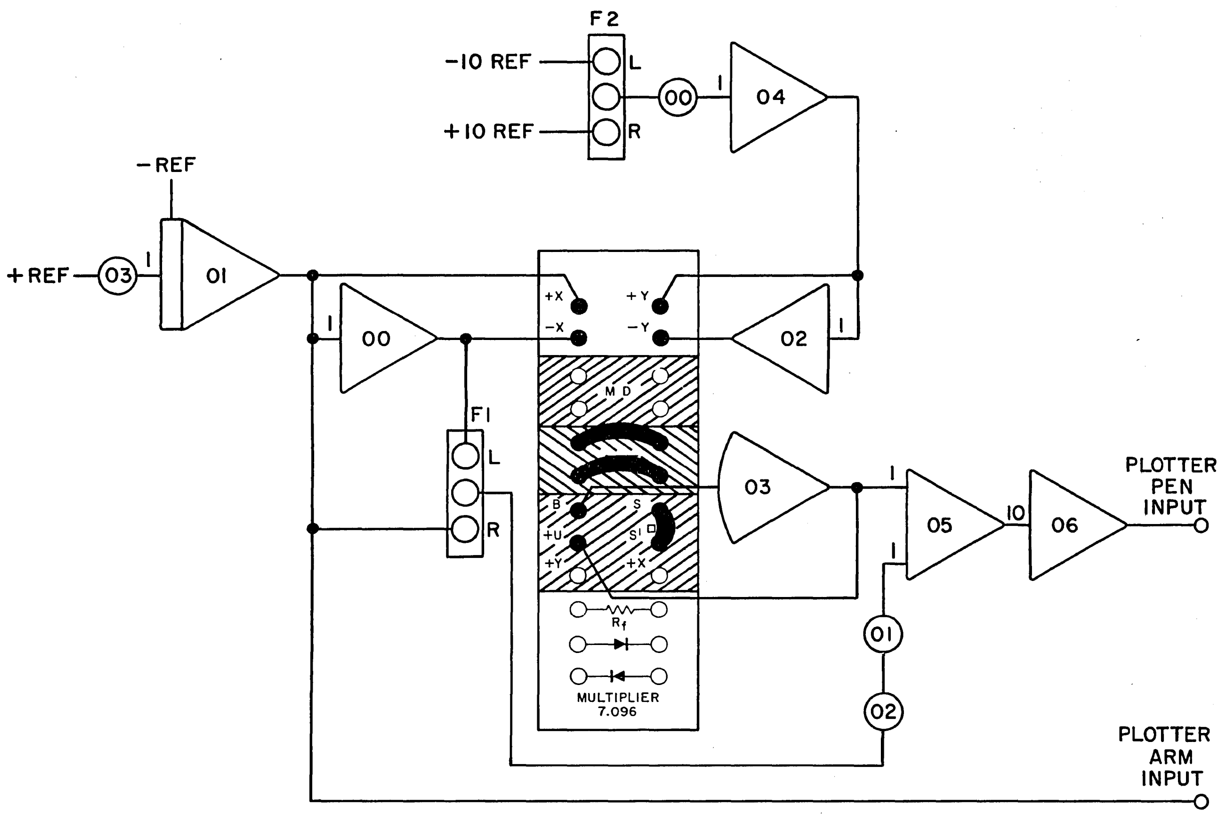
c. Matching Error-Test Circuit Components

The following procedures assume that the amplifiers are balanced and meet the specifications given in the TR-48 Maintenance manual.

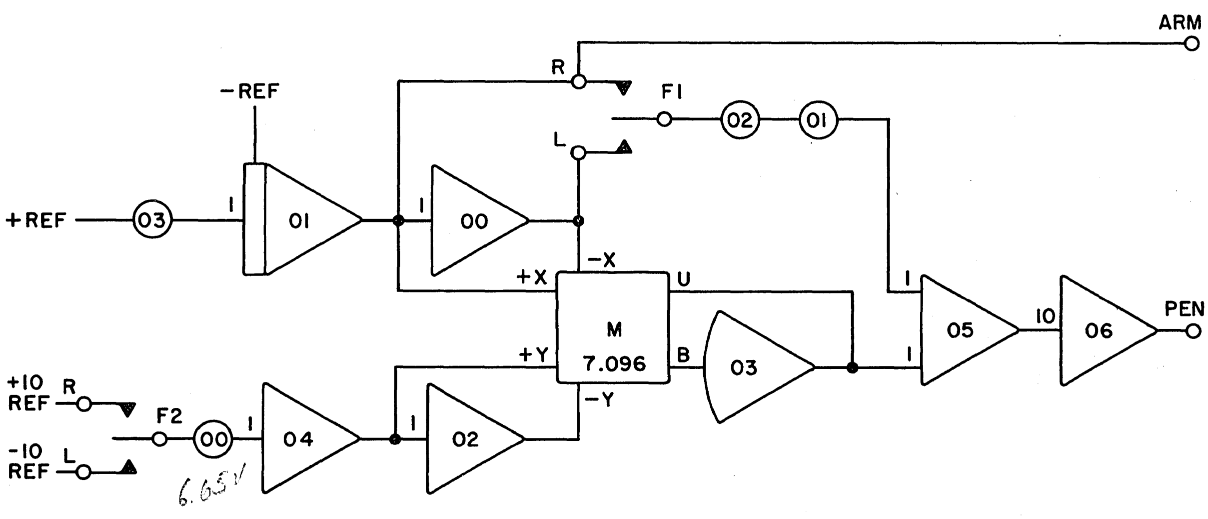
(1) *Selecting Matched Resistor Sets*

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

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

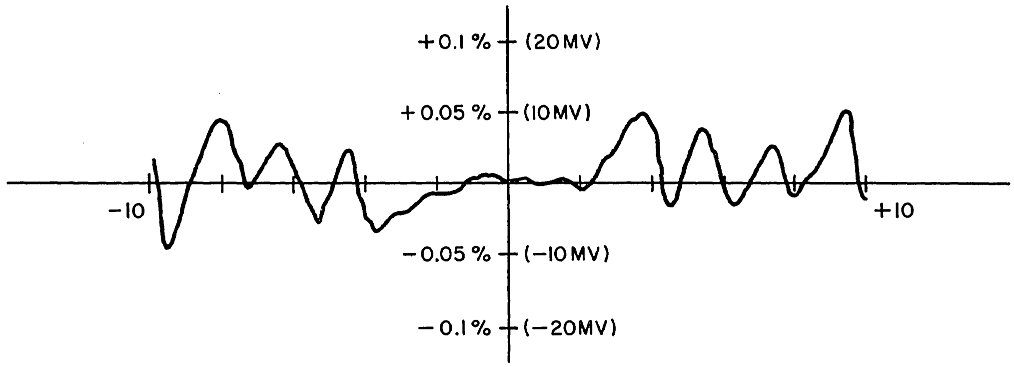


a. TEST SETUP SHOWING MULTIPLIER PATCH BLOCK

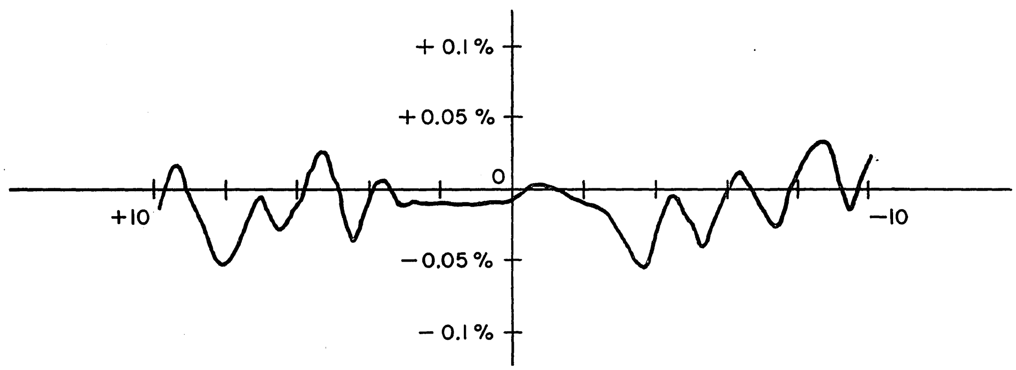


b. TEST CIRCUIT IN COMPUTER DIAGRAM FORM

Figure 14. Error Test Setup



a. TYPICAL ERROR CURVE FOR Y = +RAMP, X = +6.65 VOLTS

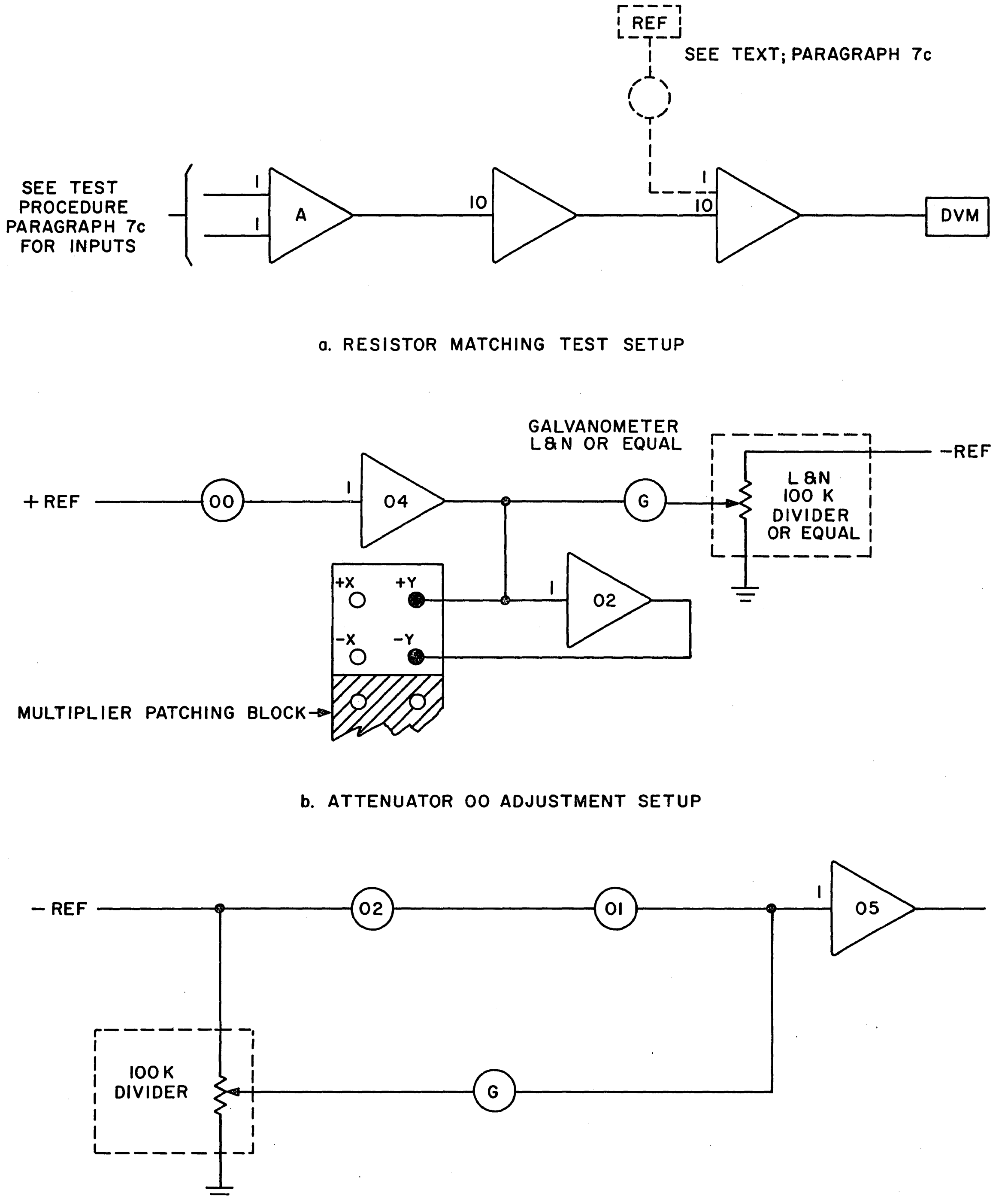


b. TYPICAL ERROR CURVE FOR Y = −RAMP, X = −6.65 VOLTS

NOTES:

1. + RAMP STARTS AT −10 VOLTS AND GOES TO +10 VOLTS.
2. − RAMP STARTS AT +10 VOLTS AND GOES TO −10 VOLTS.

Figure 15. Two Typical Error Curves for 7.096 Multiplier



a. RESISTOR MATCHING TEST SETUP

b. ATTENUATOR 00 ADJUSTMENT SETUP

c. ATTENUATORS 01 AND 02 ADJUSTMENT SETUP

Figure 16. Component Matching Setup Circuits

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

(d) Interchange the two input leads to amplifier A and note the DVM reading. Record the difference between this reading and the test circuit zero point.

(e) If the difference between the recorded readings of Steps *(c)* and *(d)* are equal to or greater than 0.05 volts try a different combination of input resistor to amplifier A until the difference is less than 0.05. If necessary try another amplifier.

(f) When a matched pair of resistors is found, they will be used as the input and feedback resistors for the amplifier used as 00 or 02 of Figure 14 or the two input resistors of amplifier 05.

(2) *Matching Attenuator Settings (00 to 01, 02)*

(a) Connect the output of amplifier 04 to an L & N 100K Null Voltage Test Set (or equal) as shown in Figure 16b. Set attenuator 00 for an output from amplifier 04 as close as possible to -6.65 volts.

(b) Set up the circuit shown in Figure 16c, with the L & N Divider at the same setting as used in *(a)* above.

(c) Adjust the attenuators 01 and 02 to provide the same voltage level as set for amplifier 04 in Step *(a)* to within ±0.1 millivolt.

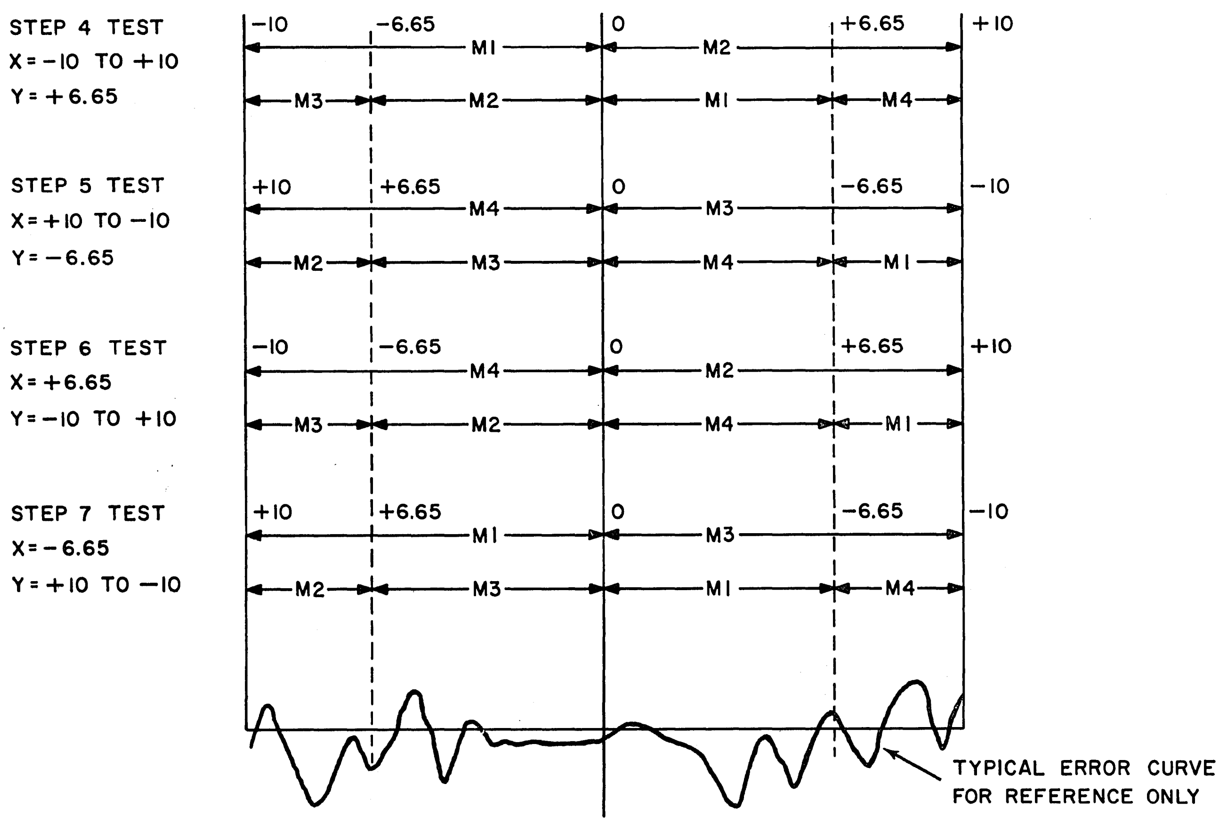


Figure 17. Error-Test Card Operation Sequence

c. Trouble Analysis

The error test as outlined in Sub-Paragraph *b.* should be performed prior to trouble shooting 7.096. The error curves obtained help isolate the faulty card. Figure 17 shows the sequence in which the various cards conduct when performing the error tests outlined in Sub-Paragraph *b.* If during a test excessive error is encountered in a given area of the plot, by referring to Figure 17 the trouble can frequently be isolated to a particular card.

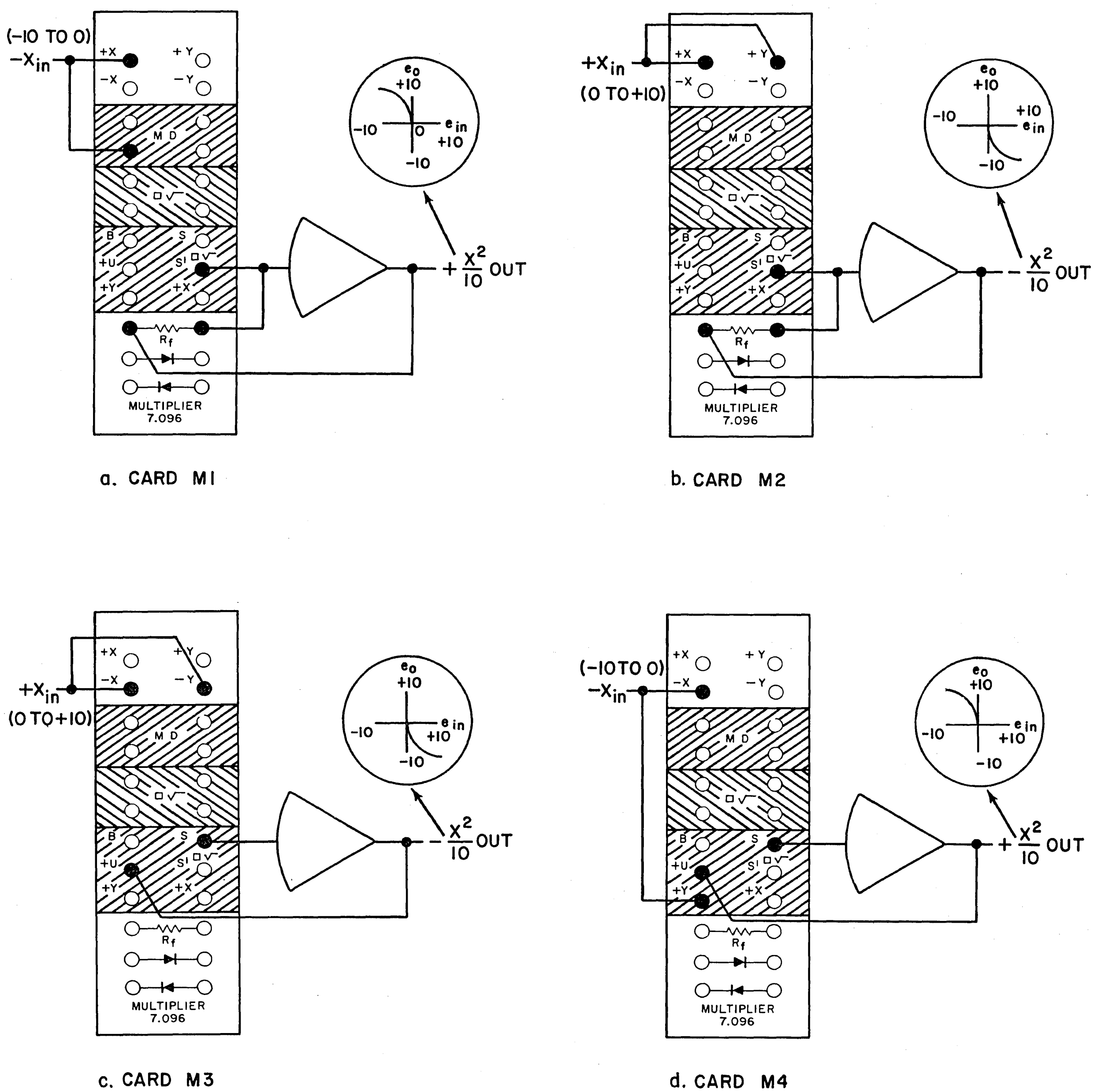


Figure 18. Patching for Individual Card Testing

Figure 18 shows patching arrangements for checking each card individually. In each case the output should equal $X^2/10$ where X is considered the input. Figure 19 is a simplified schematic of the 7.096 Multiplier showing the relationship between the patching terminations and the unit cards.

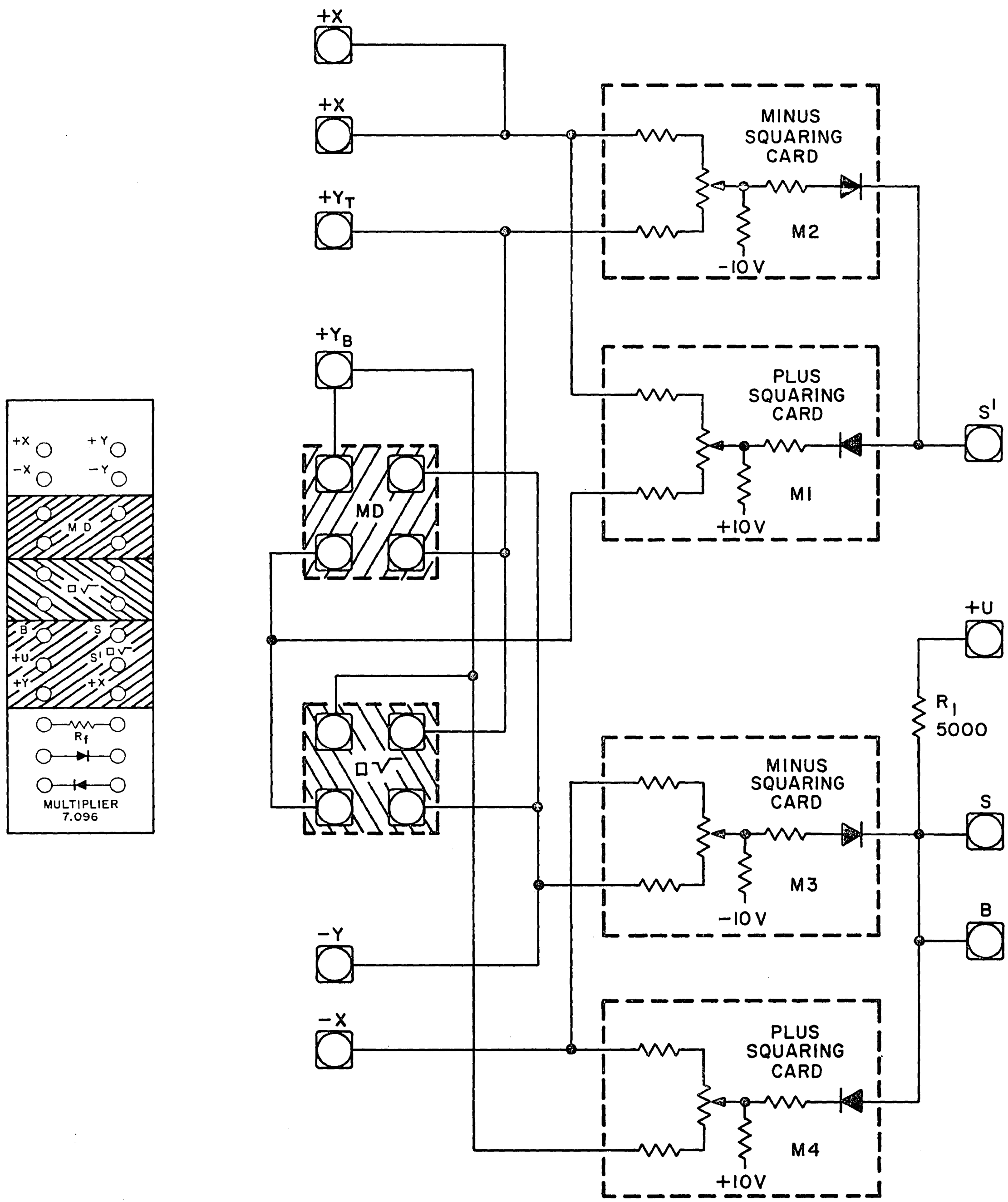


Figure 19. Quarter-Square Multiplier, Simplified Schematic and Patching Block

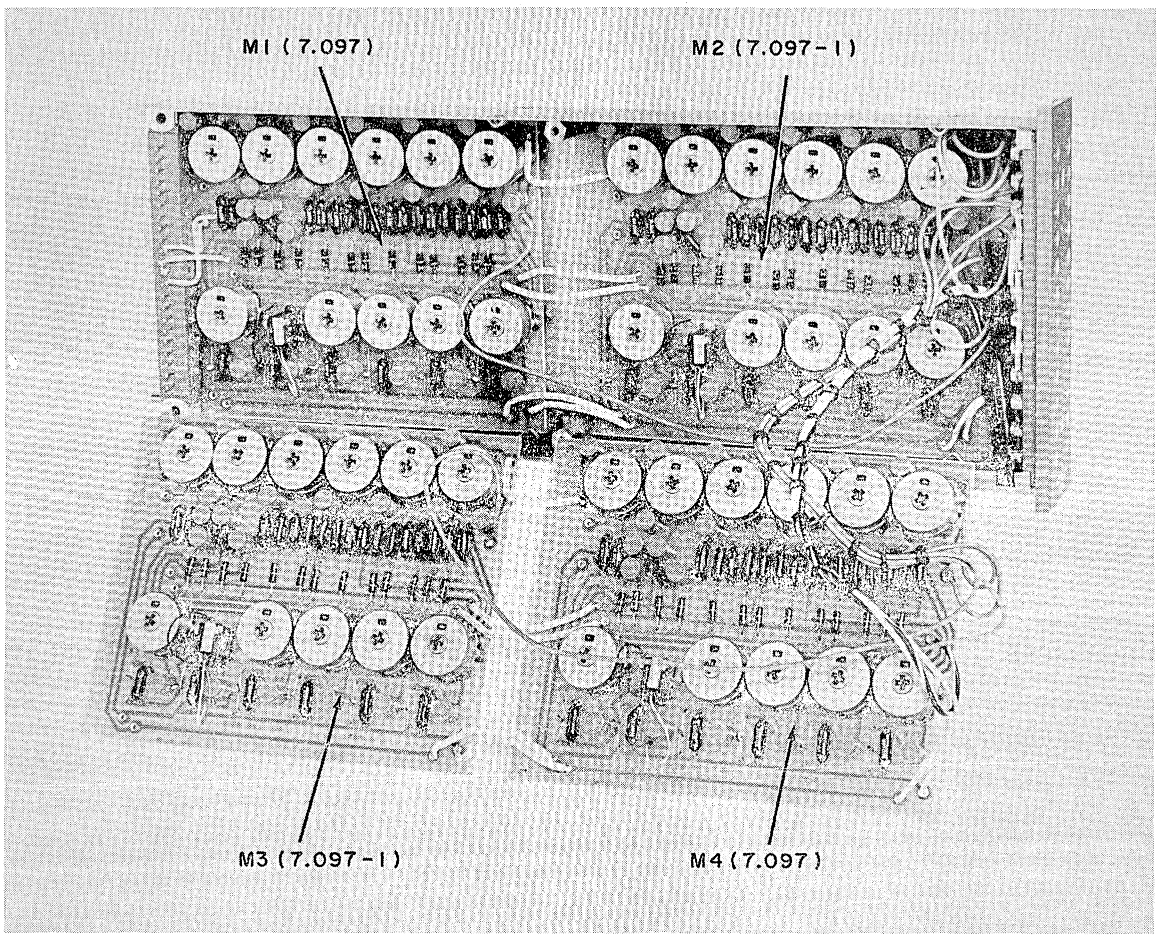


Figure 20. Multiplier With Card in Maintenance Position

Once the faulty card is isolated, if the calibration procedures are performed and do not correct the error (if caused by misadjustment error will be corrected), the faulty component is usually located in the group of components associated with the adjustment that cannot meet the calibration requirements.

The faulty component generally can then be isolated by a simple resistance check. Note, however, that the polarity of the meter probes should be known to prevent apparent erroneous readings that may be encountered should the meter battery cause a diode to conduct.

Figure 20 shows a multiplier with the top two cards swung out for access to the bottom two cards. This permits access to all components for maintenance of the 7.096 Multiplier.

To further assist the maintenance *technician,* Table 1 lists the various combinations of the X and Y inputs, with respect to polarity and magnitude, and indicates which of the squaring cards conducts under a given set of conditions.

TABLE 1. Input Signal to Card Conducting Sequence Relationship

Input Signal Polarity		Magnitude Relationship	Conducting Card(s)
X	Y		
+	+	X>Y	M2 & M4
+	+	X<Y	M1 & M2
+	+	X=Y	M2 only
+	-	X>Y	M2 & M4
+	-	X<Y	M3 & M4
+	-	X=Y	M4 only
-	+	X>Y	M1 & M3
-	+	X<Y	M1 & M2
-	+	X=Y	M1 only
-	-	X>Y	M1 & M3
-	-	X<Y	M3 & M4
-	-	X=Y	M3 only

8. CALIBRATION

The 7.096 Quarter-Square Multiplier utilizes 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 as necessary after thoroughly checking the multiplier and the associated equipment.

Prior to starting the calibration procedures the adjustments outlined in Paragraph 7*a*. must be accomplished. The ambient temperature when carrying out the procedures must be *between* 70° F and 85° F. The actual ambient temperature should not vary more than ±2° F during the procedure.

There are 12 adjustments necessary to calibrate each of the four squaring cards; the cards are designated M1 through M4. Adjustments 1 through 6 are the input balancing adjustments and 7 through 12 are the diode break point adjustments. Each of the four cards is adjusted separately; Figure 21 shows the location of the adjustments for each card.

a. Balance Adjustments

(1) Patch the multiplier test set-up as indicated in Figure 22 for the appropriate card to be adjusted.

(2) Place controls 9 through 12 in the full clockwise positions.

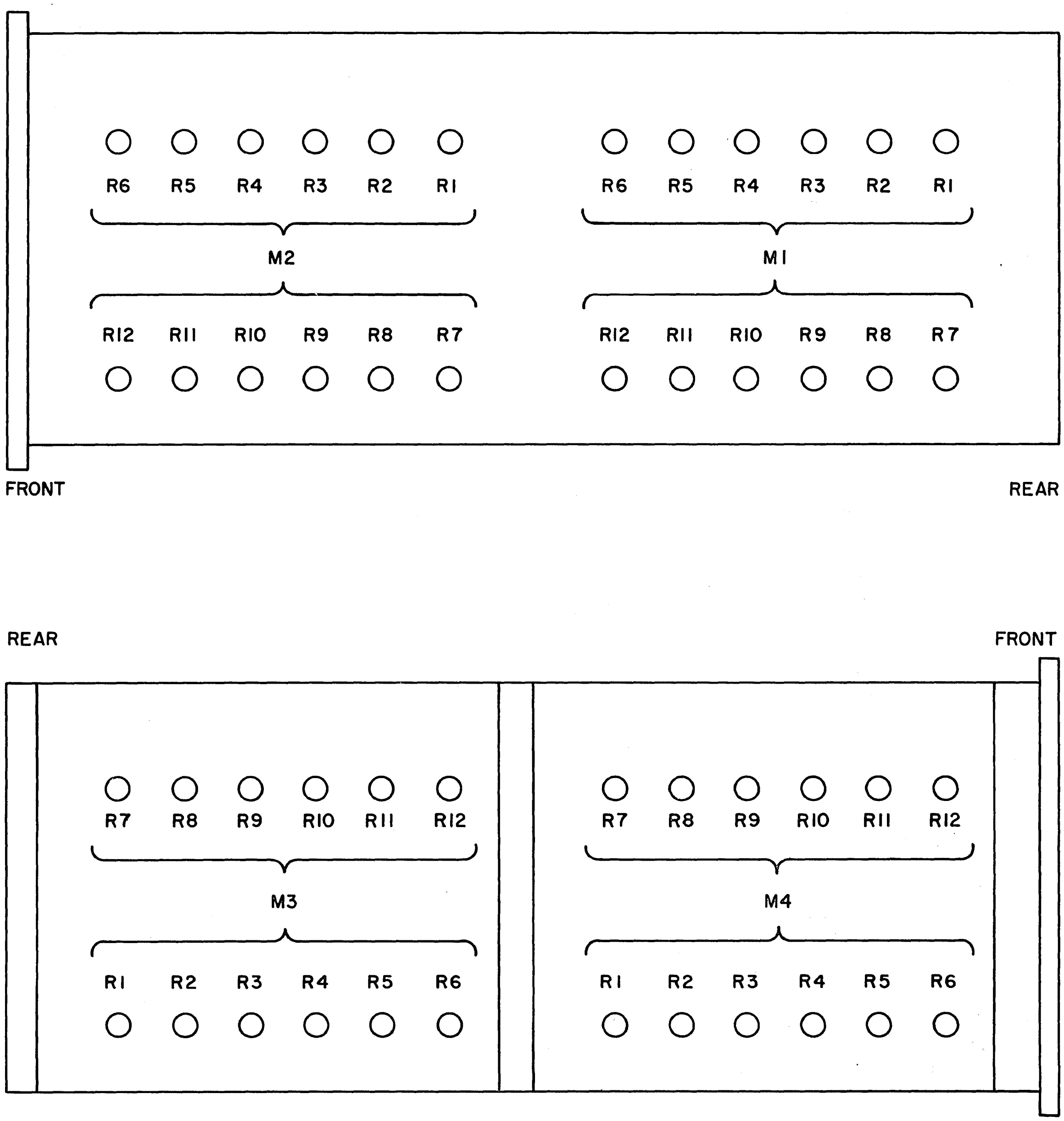
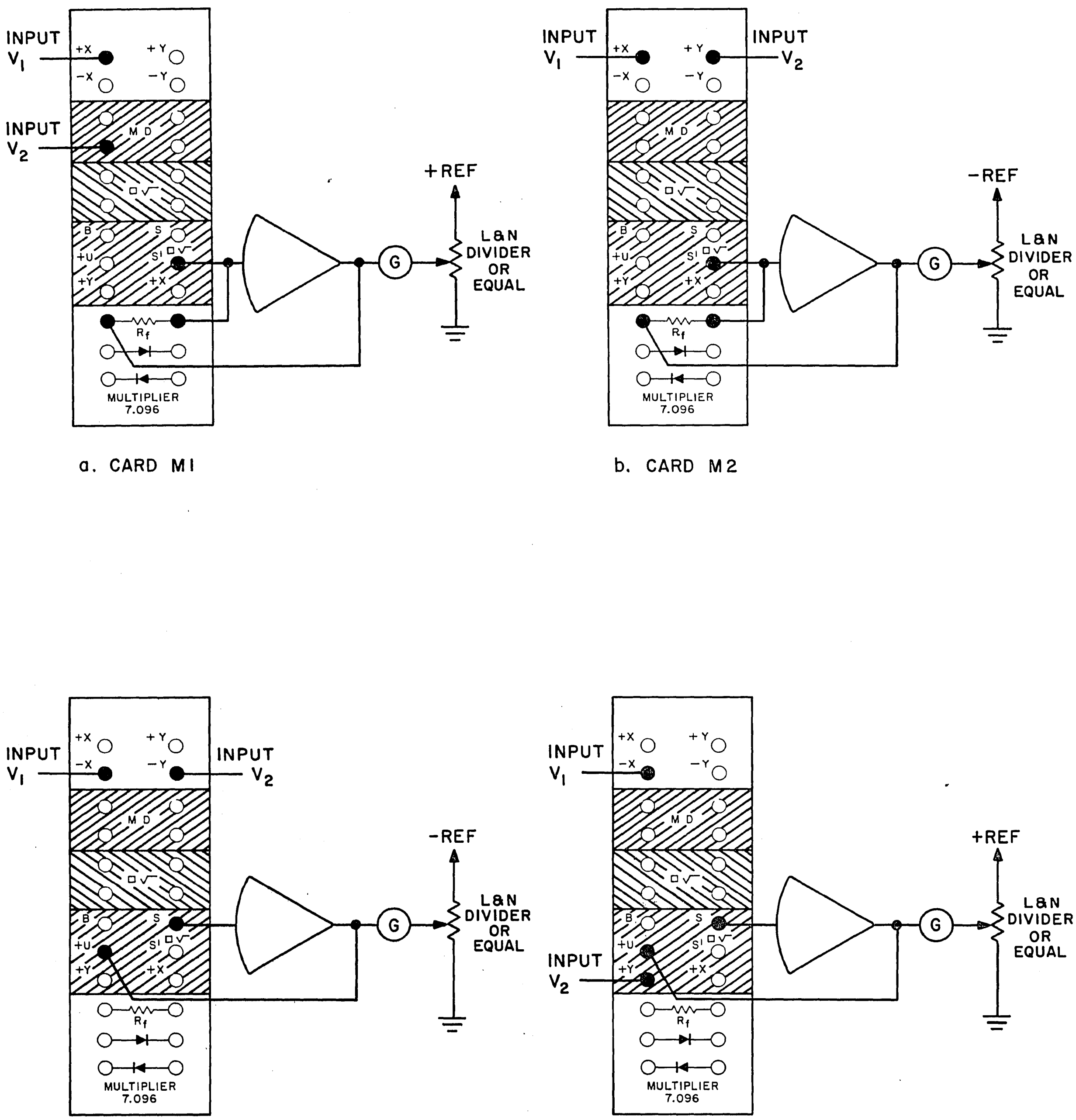


Figure 21. Multiplier Card Adjustment Locations

(3) Apply the first set of inputs indicated in Table 2 and measure the output using the L & N Divider (or equal). The proper polarity of the inputs for a given card is indicated in Table 3.

(4) Switch the V_1 and V_2 inputs and again measure the output.

(5) If the measurements of Steps (3) and (4) differ, adjust balance control number 1 (Figure 20) for the mean of this difference.



a. CARD M1

b. CARD M2

c. CARD M3

d. CARD M4

Figure 22. Input Balance Adjustment Test Setup

(6) Repeat Steps (3) through (5) until no difference occurs when the inputs are switched.

(7) Repeat Steps (3) through (6) using the appropriate inputs for the adjustment of controls 2 through 5.

(8) Turn control 12 fully counter-clockwise (achieves better sensitivity of card) and repeat Steps (3) through (6) for adjustment of control 6.

TABLE 2. Balance Control Adjustment Inputs

Input V_1	Input V_2	Control Adjustment
0	0.60	1
0	2.80	2
0	6.00	3
10.0	0	4
10.0	5.00	5
10.0	9.00	6 (Note Step 8 of procedure)

TABLE 3. Input Signal Polarity for Card Calibration

Card Number	Input Polarity
M1	-
M2	+
M3	+
M4	-

b. Breakpoint Adjustments

The balance adjustment of a card *must be completed* before attempting to adjust the card break points.

(1) Return control 12 fully clockwise (controls 7 through 11 should be in this state via balance adjustment procedure).

(2) Apply the input for adjustment 7 (as indicated by the designation E_{in} of Table 4) to *both* the V_1 and V_2 inputs of the appropriate portion of Figure 21 for the card being calibrated. The proper polarity of the input is indicated by Table 3.

(3) Adjust control 7 for the readout indicated by the designation E_o in Table 4.

(4) Repeat Steps (2) and (3) for adjustments 8 through 12 using the E_{in} and E_o values indicated in Table 4.

TABLE 4. Break Point Control Adjustment Inputs*

E_{in}	E_o	Control Adjustment
0.50795	0.02690	7
1.69545	0.28878	8
3.72462	1.38928	9
6.01000	3.61701	10
8.96540	8.03784	11
9.84195	9.68941	12

**Accuracy of input obtained using L & N Divider and Galvanometer.*

APPENDIX I

REPLACEABLE PARTS LISTS

QUARTER-SQUARE MULTIPLIER, MODEL 7.096

This appendix contains a Replaceable Parts List for the equipment described in this manual. In each case, a brief description of the part and a manufacturer's number are listed. Where applicable, a reference symbol (schematic designation) is included. To enable a particular sheet to be readily located, an index precedes the individual spare 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. The components 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 ordered from EAI.

The components in category B are items that can be obtained from EAI or any of the listed manufacturers. However, in most cases, EAI is in a position to offer the most rapid service on items in this category.

The parts in category C are custom-made components and proprietary items that are available only from EAI. When ordering items of this type, please specify the type number and serial number of the basic unit in which the part is located, as well as the part identification.

Where possible, sufficient information is given for category C items to permit an *electrically-similar* replacement part to be obtained locally. Thus, if desired, a temporary repair may be made while the *exact* replacement is being obtained from EAI. *Note, however, that EAI does not guarantee that the affected unit will operate within specifications when the specified category C part is not used.*

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.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
1	CR1,2	Diode, Germanium: Clevite CTP462	614 043 0	B
2	R1,2	Resistor, Fixed, Wirewound, Precision: 5000 ohms $\pm$.0025%; Julie Research Labs CH35 Type	B638 844 0	C
		7.097 $(1/4)^2$ Multiplier		
1	CR1-13	Diode, Silicon: Hughes Semiconductor 1N459	B614 007 0	B
2	R1	Resistor, Variable, Wirewound: 500 ohms $\pm$20%, Chicago Telephone Supply 115 Type	A642 569 3	C
3	R2-5	Resistor, Variable, Wirewound: 250 ohms $\pm$20%, Chicago Telephone Supply 115 Type	A642 569 4	C
4	R6,10,11	Resistor, Variable, Wirewound: 1K ohms $\pm$20%, Chicago Telephone Supply 115 Type	A642 569 0	C
5	R7	Resistor, Variable, Wirewound: 5K ohms $\pm$20%, Chicago Telephone Supply 115 Type	A642 569 2	C
6	R8	Resistor, Variable, Wirewound: 35K ohms $\pm$5%, 1W; Daystrom Pacific 300-64 Type	642 570 0	B
7	R9,12	Resistor, Variable, Wirewound: 2.5K ohms $\pm$20% Chicago Telephone Supply 115 Type	A642 569 1	C
8	R13,14	Resistor, Fixed, Wirewound, Precision: 24,750 ohms $\pm$1%, 1/4W; Resistance Products Co., PB Type	638 842 4	B
9	R15-22	Resistor, Fixed, Wirewound, Precision: 12,380 ohms $\pm$1%, 1/4W; Resistance Products Co. PB Type	638 842 8	B
10	R23,24	Resistor, Fixed, Wirewound, Precision: 49,500 ohms $\pm$1%, 1/4W; Resistance Products Co., PB Type	638 842 1	B
11	R25	Resistor, Fixed, Wirewound, Precision: 7,511 ohms $\pm$1%, 1/4W; Resistance Products Co., PB Type	638 843 0	B
12	R26	Resistor, Fixed, Film: 1,679 ohms $\pm$1%, 1/8W; Corning Glass Works N60 Type	634 457 4	B
13	R27	Resistor, Fixed, Film: 1,297 ohms $\pm$1%, 1/8W; Corning Glass Works N60 Type	634 457 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 CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS. DATE 1/ 10 / 63

UNIT TITLE $(1/4)^2$ Multiplier

MODEL NO. 7.096 Sh. 1 of 4 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
14	R28	Resistor, Fixed, Film: 654 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 458 0	B
15	R29	Resistor, Fixed, Film: 664.4 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 457 9	B
16	R30	Resistor, Fixed, Film: 454.4 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 458 1	B
17	R31	Resistor, Fixed, Film: 321.5 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 458 3	B
18	R32	Resistor, Fixed, Wirewound, Precision: 19,710 ohms ±1%, 1/4W; Resistance Products Co., PB Type	638 842 5	B
19	R33	Resistor, Fixed, Film: 16,260 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 5	B
20	R34	Resistor, Fixed, Wirewound, Precision: 35,100 ohms ±1%, 1/4W; Resistance Products Co., PB Type	638 842 2	B
21	R35	Resistor, Fixed, Film: 13,110 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 8	B
22	R36	Resistor, Fixed, Film: 28,420 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 2	B
23	R37	Resistor, Fixed, Film: 16,440 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 4	B
24	R38	Resistor, Fixed, Wirewound, Precision: 5,214 ohms ±1%, 1/4W; Resistance Products Co. PB Type	638 843 1	B
25	R39	Resistor, Fixed, Film: 25,630 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 3	B
26	R40	Resistor, Fixed, Film: 13,620 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 7	B
27	R41	Resistor, Fixed, Film: 3,454 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 457 1	B
28	R42	Resistor, Fixed, Film: 14,320 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 456 6	B
29	R43	Resistor, Fixed, Film: 5,426 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 457 0	B

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UNIT TITLE
$(1/4)^2$ Multiplier

MODEL NO.
7.096 Sh.2 of 4 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
30	R44	Resistor, Fixed, Film: 1,009 ohms ±1%, 1/8W Corning Glass Works N60 Type	634 457 6	B
31	R45	Resistor, Fixed, Film: 3,248 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 457 2	B
32	R46	Resistor, Fixed, Film: 94,030 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 456 0	B
33	R47	Resistor, Fixed, Wirewound, Precision: 1,260 ohms ±1%, 1/4W; Resistance Products Co. PB Type	638 843 2	B
34	R48	Resistor, Fixed, Wirewound, Precision: 134,400 ohms ±1%, 1/4W; Resistance Products Co. PB Type	C638 842 0	B
35	R49	Resistor, Fixed, Wirewound, Precision: 34,750 ohms ±1%, 1/4 W; Resistance Products Co. PB Type	638 842 2	B
36	R50	Resistor, Fixed, Wirewound, Precision: 15,960 ohms ±1%, 1/4W; Resistance Products Co. PB Type	638 842 7	B
37	R51	Resistor, Fixed, Wirewound, Precision: 9,537 ohms ±1%, 1/4W; Resistance Products Co. PB Type	638 842 9	B
38	R52	Resistor, Fixed, Wirewound, Precision: 27,700 ohms ±1%, .005% Stability; National Resistance Corp EU-2	A638 449 0	C
39	R53	Resistor, Fixed, Film: 11,000 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 456 9	B
40	R54	Resistor, Fixed, Film: 38,400 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 456 1	B
41	R55	Resistor, Fixed, Film: 3,190 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 457 3	B
42	R56	Resistor, Fixed, Film: 859 ohms ±1%, 1/8W; Corning Glass Works N60 Type	623 457 7	B
43	R57	Resistor, Fixed, Film: 383 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 458 2	B
44	R58	Resistor, Fixed, Film: 697 ohms ±1%, 1/8W; Corning Glass Works N60 Type	634 457 8	B

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B - INDICATES PARTS THAT CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS. DATE 1 / 9 / 63

UNIT TITLE
$(1/4)^2$ MULTIPLIER

MODEL NO.
7.096 Sh. 3 of 4 Sh.

ITEM	REF. DESIG.	DESCRIPTION	EAI NO.	*CAT.
45	R59	Thermistor: 5,050 ohms ± 10% @37.8 °C, .36W; Keystone Carbon Co RL20E1	646 049 0	B
46	R60	Thermistor: 20,600 ohms ±10% @37.8 °C, .36W; Keystone Carbon Co RL27E1	646 050 0	B
47	R61	Thermistor: 1930 ohms ±10% @37.8°C, .36W; Keystone Carbon Co RL14E1	646 048 0	B
48	R62	Thermistor: 718 ohms ±10% @37.8 °C, .36W; Keystone Carbon Co. RL8E1 Type	646 047 0	B
49	R63	Thermistor: 304 ohms ±10% @37.8°C, .36W; Keystone Carbon Co R13E1 Type	646 045 0	B
50	R64	Thermistor: 600 ohms ±10% @37.8 °C, .36W; Keystond Carbon Co. R17E1 Type	646 046 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 CAN BE PURCHASED LOCALLY OR FROM EAI.
C - INDICATES PARTS THAT SHOULD BE PURCHASED FROM EAI.
THE PROPER EAI PART SHOULD BE INSTALLED FOR CATEGORY C ITEMS. A COMPLETE DESCRIPTION IS GIVEN TO PROVIDE FOR TEMPORARY REPAIRS; HOWEVER, EAI WILL NOT BE RESPONSIBLE IF UNIT IS NOT WITHIN SPECIFICATIONS UNDER THESE CONDITIONS.

DATE 1 / 9 /63

UNIT TITLE

$(1/4)^2$ MULTIPLIER

MODEL NO.

7.096 Sh. 4 of 4 Sh.

APPENDIX II

DRAWINGS

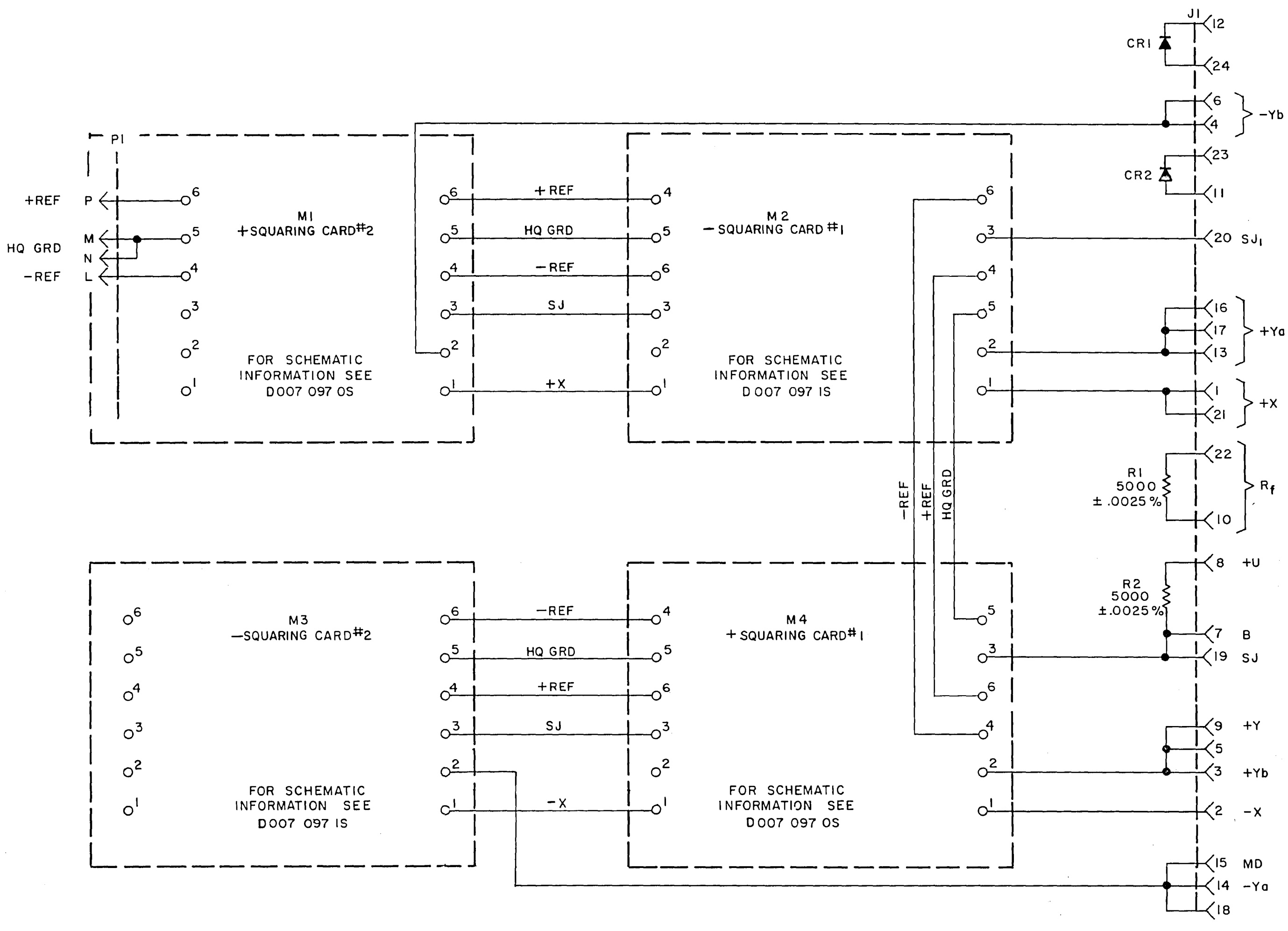
QUARTER-SQUARE MULTIPLIER, MODEL 7.096

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. Unless otherwise specified all resistance values are given in ohms and capacitance values in micro-micro farads (UUF).

INDEX

Unit or Component	Type of Drawing	Drawing Number
7.096 Quarter-Square Multiplier	Schematic	C007 096 0S
	Wiring	D007 096 0W
7.097 Squaring Card	Schematic	D007 097 0S

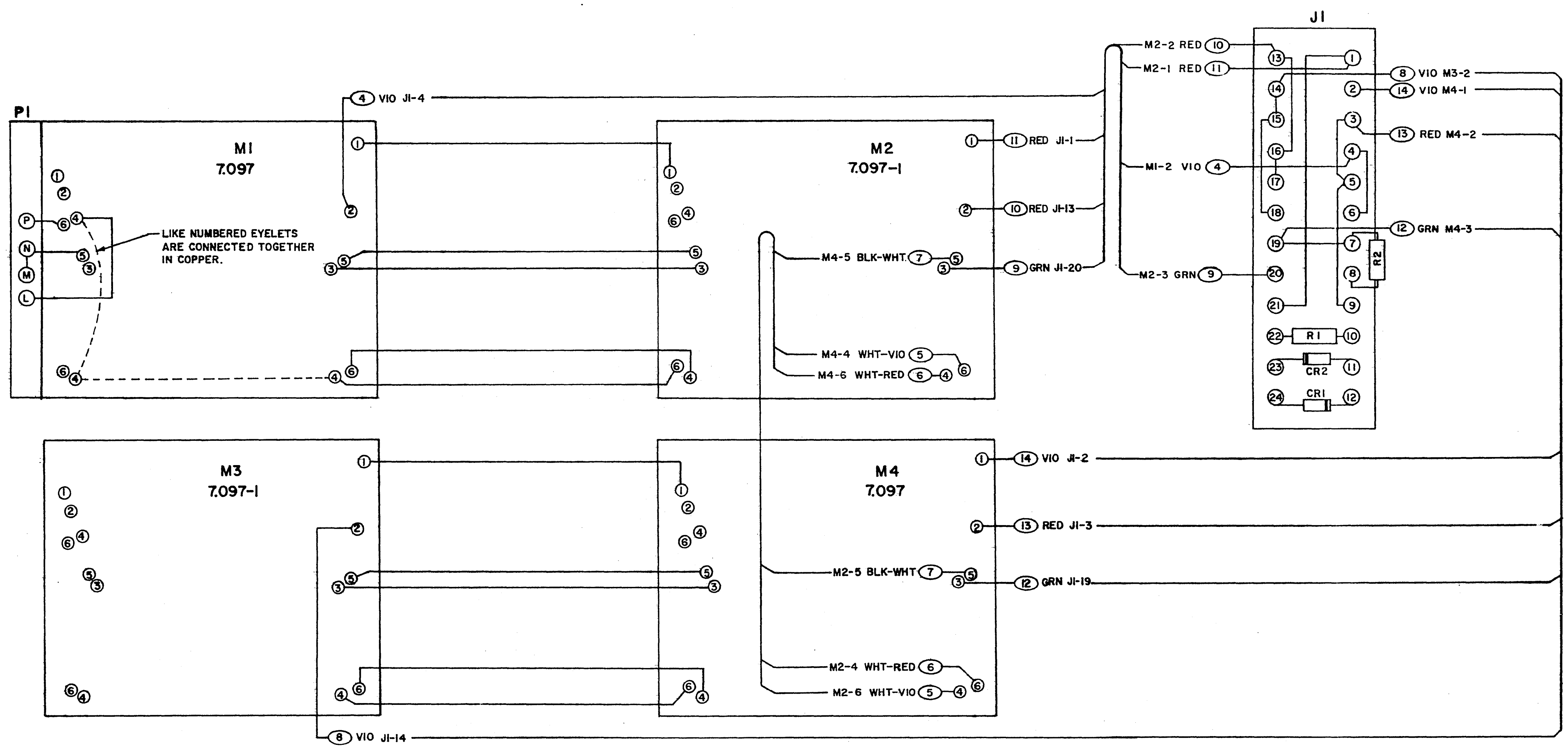


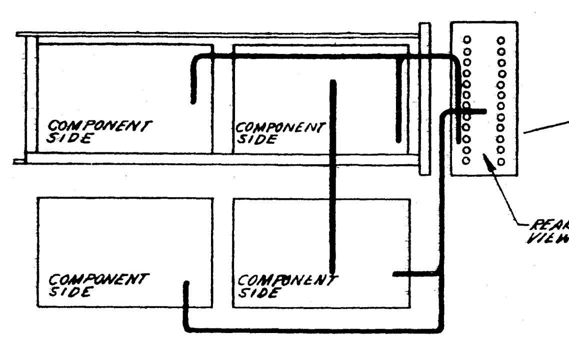
ELECTRONIC ASSOCIATES, INC.
LONG BRANCH, NEW JERSEY

SCHEMATIC
$(1/4)^2$ MULTIPLIER
(TR-48)

SHT. NO.	
SIZE	
REV. NO.	
PROJECT 1733	C007 096 0S
SHEET OF 1 SHEETS	

NOTES:
1 ALL PRINTED CIRCUIT CARDS VIEWED FROM COMPONENT SIDE.
2 ALL JUMPERS ARE 22 SD-BUS COVERED WITH EXTRUDED PLASTIC TUBING WHERE NECESSARY.





IMPORTANT: CABLE TO BE OF SUFFICIENT LENGTH SO THAT UNIT MAY BE SERVICED IN THIS MANNER.

NO.	COLOR	AWG	TYPE	LENGTH
	SD-BUS	22		
14	VIO	22	PHU	
13	RED			
12	GRN			
11	RED			
10	RED			
9	GRN			
8	VIO			
7	BLK-WHT			
6	WHT-RED			
5	WHT-VIO			
4	VIO	22	PHU	
3				
2				
1				

WIRE LEGEND

ELECTRONIC ASSOCIATES, INC.
LONG BRANCH, NEW JERSEY

WIRING
$(1/4)^2$ MULTIPLIER
(TR-48)

SHT. NO.
SIZE
REV. NO.
PROJECT 1733 D007 096 0W
SHEET OF SHEETS

NOTES:

1— UNLESS OTHERWISE SPECIFIED:

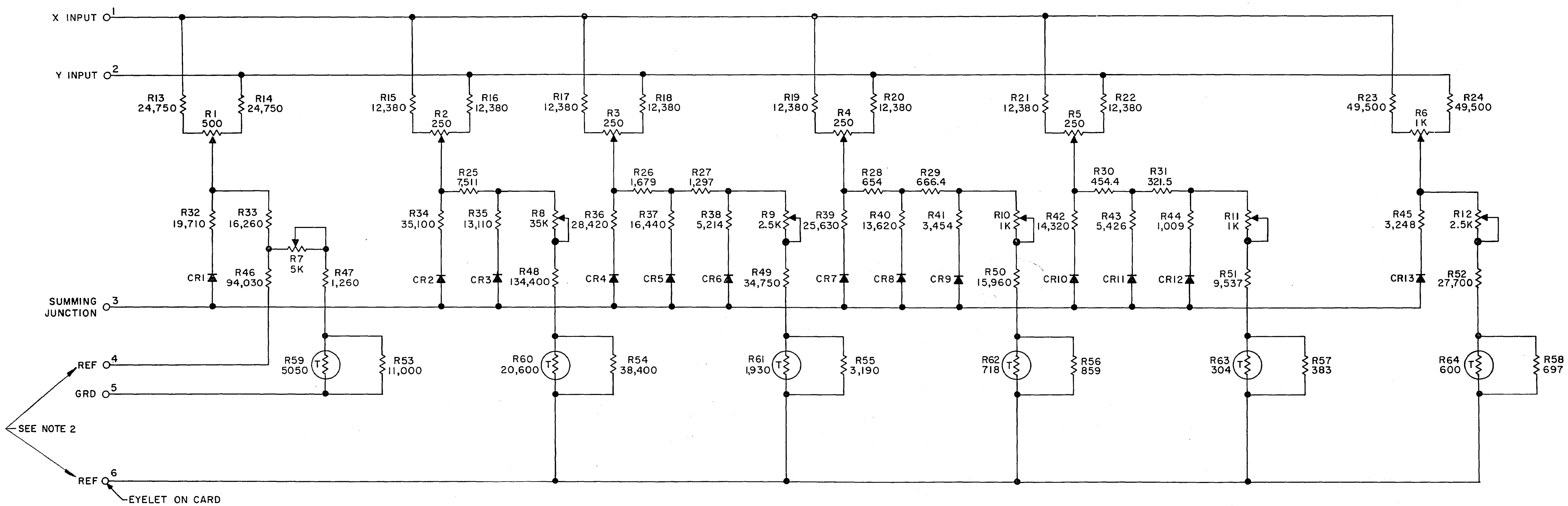
(a) ALL PRECISION RESISTORS ARE ±1%.

(b) ALL THERMISTORS ARE ±10%, 0.36W, AT 37.8°C.

(c) ALL DIODES ARE 1N459.

2— (a) ON PLUS CARD (7.097), EYELET NO. 4 IS −REF, EYELET NO. 6 IS +REF

(b) ON MINUS CARD (7.097-1), EYELET NO. 4 IS +REF, EYELET NO. 6 IS −REF.



7.097-1	007 097 IS	007 097 IP	CR1–CR13 REVERSED (−)	007 096 IP	1733
7.097	D007 097 0S	A007 097 0P	AS SHOWN (+)	A007 096 0P	1733
UNIT NUMBER	SCHEMATIC NUMBER	PARTS LIST & NEXT ASSY	DESCRIPTION	PARTS LIST USED ON:	PROJECT NUMBER

TABLE OF UNIT NUMBERS

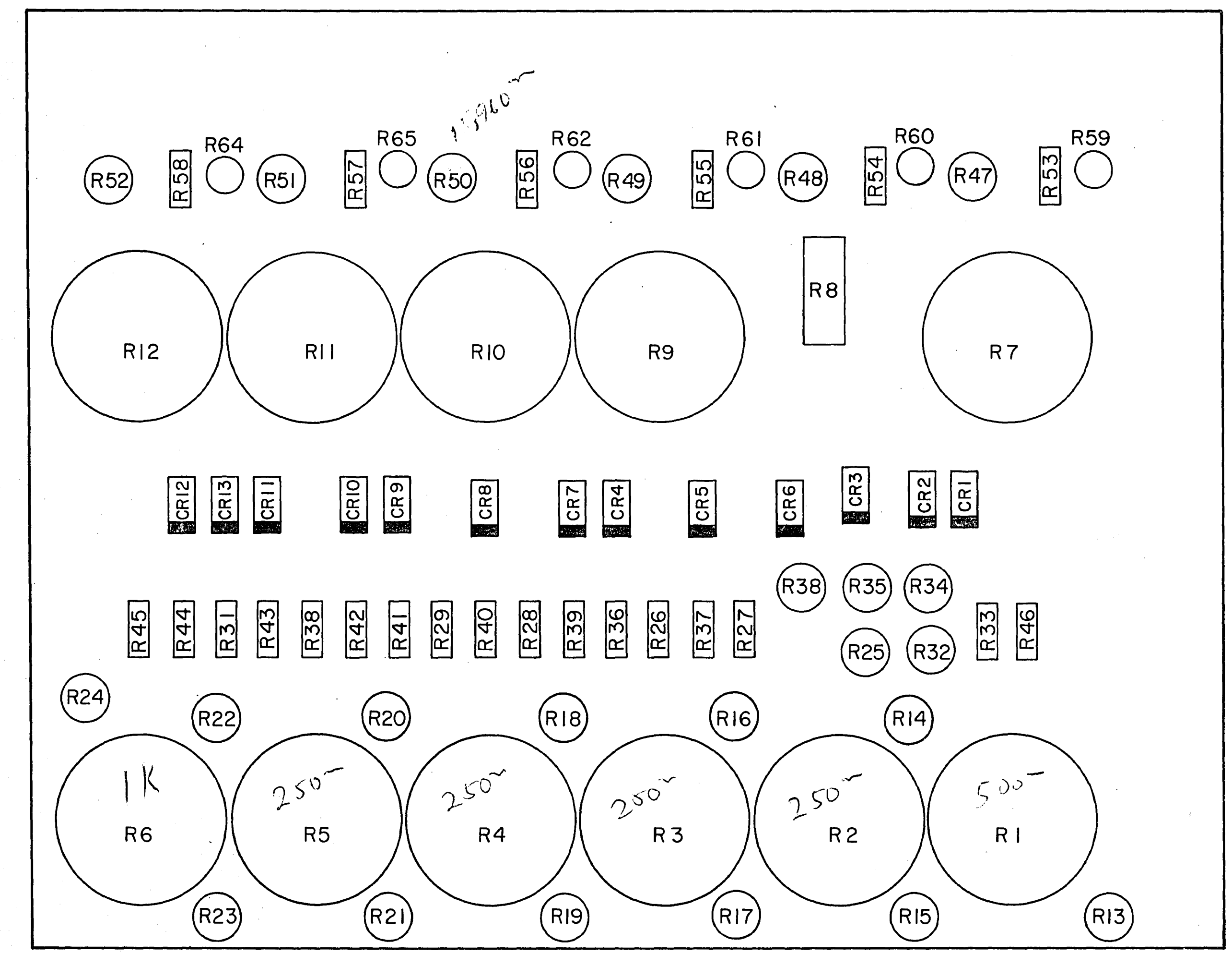
ELECTRONIC ASSOCIATES, INC.
LONG BRANCH, NEW JERSEY

SCHEMATIC
$(1/4)^2$ MULTIPLIER
(TR-48)

SHT. NO.										
SIZE										
REV. NO.										

PROJECT 1733 D007 097 0S

SHEET 1 OF 1 SHEETS



NOTE:
QUARTER-SQUARE MULTIPLIER CARD 7.097 AS SHOWN; CARD 7.097-1 SIMILAR, (DIODES CR1 THROUGH CR13 REVERSED)

Component Location Diagram, Quarter-Square Multiplier, Model 7.097