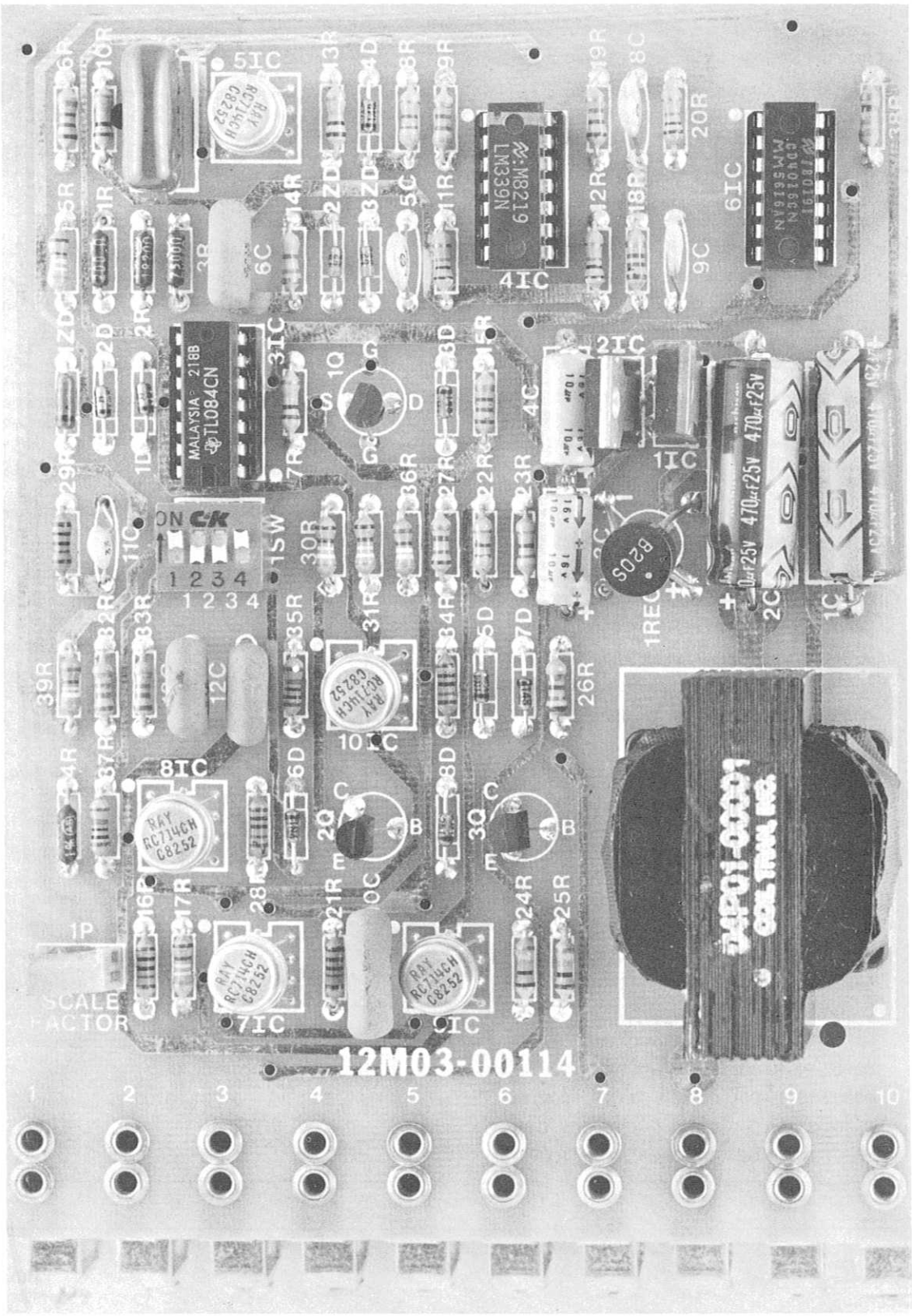
REFLEX®

Trouble-shooting Manual
MODEL 209
MULTIPLIER/DIVIDER
PART NUMBER 12M03-00114-01



REFLEX® MODEL 209 MULTIPLIER/DIVIDER

PART NUMBER 12M03-00114-01
SCHEMATIC DIAGRAM 12M03-00114-01

I. SPECIFICATIONS

SUPPLY
- 120 Volts AC ± 10%
- 50/60 Hz, single phase

AMBIENT TEMPERATURE
- 0° to 40°C (32° to 104°F)
- 50°C in cabinet

MULTIPLICATION: Four Quadrant (± X, ± Y inputs)
- INPUTS (X or Y): 0 to ± 10 volts into 10K ohms (± 1.0%) input resistance
  0 to ± 1 mA
- OUTPUT (Z): 0 to ± 10 volts @ 5 mA
  Z = XY/10 when X and Y inputs are both volts
  Z = XY when one input is in volts and the other in milliamperes
  Z = 10 XY when both inputs are in milliamperes
- SIGNAL LIMITATIONS:
  10 volts or 1 mA maximum
  no minimum limit for X or Y inputs

DIVISION: Two Quadrant (± X input, + Y input)
Square Root, Single Quadrant (+ X input)
- INPUTS (X): 0 to ± 10 volts into 10K ohms (± 1.0%) input resistance
  0 to ± 1 mA
  (Y): + 0.25 to + 10 volts or + 25 uA to + 1 mA (can operate as low as 0.1 volts or 10 uA with reduced accuracy)

DIVISION:
- OUTPUT (Z): 0 to ± 10 volts @ 5 mA
  Z = 10X/Y when X and Y are both volts or both milliamperes
  Z = X/Y when X is in volts and Y is in milliamperes
  Z = 100X/Y when X is in milliamperes and Y is in volts
- SIGNAL LIMITATIONS:
  10 volts or 1 mA maximum
  Y input must be positive and not less than 0.1V or 10 uA
  Denominator (Y) should not be less than the numerator (X)

ACCURACY
- MULTIPLICATION: ± 0.25% of full scale
- DIVISION: Depends on the operating level
  Better than ± 2.0% if the numerator is 1 volt or greater

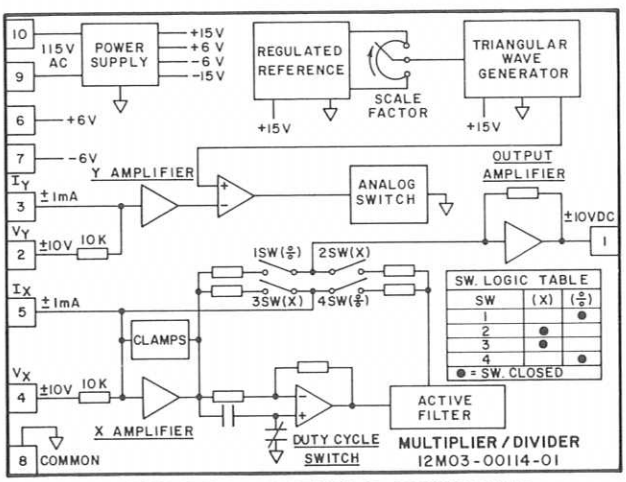


FIGURE 1. SIMPLIFIED SCHEMATIC

II. THEORY OF OPERATION

The REFLEX Model 209 Multiplier/Divider Assembly provides the means for obtaining the product or quotient (Z) of two signals (X and Y). The product is obtained by controlling the Amplitude (X) and Duty Cycle (Y) of a rectangular wave. The output is, therefore, proportional to the area (X times Y) of the rectangular wave.

The quotient is obtained by using the Y Amplifier to control the gain of the X Amplifier (if Y doubles, the output of the X Amplifier is halved). The Divide function may also be used to obtain the square root of the X input.

The circuit consists of the following elements as shown in the Simplified Schematic Diagram (Figure 1).

1. Power Supply
2. Regulated Reference
3. Triangular Wave Generator
4. Y Amplifier
5. X Amplifier
6. Duty Cycle Switch
7. Active Filter
8. Output Amplifier

1. **Power Supply** – The Power Supply uses a center-tapped transformer with 10 volts on each side of center together with a bridge rectifier and two 470 MF filter capacitors to provide a nominal positive and negative unregulated 15 volts DC with respect to the transformer center tap, which is connected to circuit common.

   Additionally, a positive and negative 6 volt regulated voltage is obtained from the positive and negative 15 volt supplies, using regulators 1IC and 2IC each with a 10MF filter capacitor.

2. **Regulated Reference** – The regulated reference uses a temperature compensated zener diode (1ZD) in a bridge configuration where the Op-Amp (3IC(C)) becomes an active part of the bridge to keep the current through the zener diode at a constant current necessary for temperature compensation.

   The output can be varied by the "Scale Factor" adjustment (1P) to obtain an output from the assembly of 10 volts for 10 volts (or 1 mA) on each input. A slightly different setting may be required for "Multiply" or "Divide" functions.

3. **Triangular Wave Generator** – This section generates a triangular wave having a nominal level of ± 5 volts peak and a nominal frequency of 5 to 8K Hz.

   The positive and negative points of the Triangular Wave are determined by the switching action of comparator 4IC(B) to be a nominal ± 5 volts. The signals are zener regulated at the output of the comparator to insure that the slopes of the triangular wave are linear.

   The two inputs of the comparator 4IC(B) are (1) the Triangular Wave and (2) a Reference Voltage which is selected by its output state through the action of a switching FET (1Q).

   Integrating Amplifier 3IC(B) generates the Triangular Wave. When integrator 3IC(B) is integrating in a positive direction towards the positive peak of the Triangular Wave, the reference voltage for comparator 4IC(B) comes from the Regulated Reference. As soon as the Triangular Wave has reached this reference voltage the comparator changes state, reversing the direction of integration and simultaneously switching the reference voltage for the comparator 4IC(B) to the output of long-term integrating amplifier 5IC.

   This amplifier (5IC) adjusts its output as required to keep the average value of the Triangular Wave to exactly zero. In this way the negative and positive peaks of the Triangular Wave are exactly equal and the time periods between crossing zero in the positive direction and the negative direction are also exactly equal.

4. **Y Amplifier** – The Y Amplifier 7IC has two inputs: terminal 2, a voltage input with 10K ohms (± 1%) input impedance requiring 10 volts DC maximum, and terminal 3, a current input that requires 1 mA full scale. Its output is 5 volts with rated input. The input signal must be positive in the "DIVIDE" mode.

   The output of the Y Amplifier is fed to comparator 4IC(C) together with the Triangular Wave. The output of the comparator is a square wave with a perfectly symmetrical duty cycle if the output of the Y Amplifier is zero.

   If the output of the Y Amplifier is negative, the duty cycle is positive for a longer period of time than it is negative. Conversely, if the output of the Y Amplifier is positive, the duty cycle is negative for a longer period of time than it is positive.

5. **X Amplifier** – The X Amplifier 9IC has two inputs identical to the Y Amplifier. Terminal 4, a voltage input with 10K ohms (± 1%) input impedance requiring ± 10 volts DC maximum, and terminal 5, a current input that requires ± 1 mA full scale.

   It differs from the Y Amplifier in two respects:

   1. Its feedback is changed for multiplication or division. For multiplication its feedback is a 4.99K resistor 30R from its output, producing 5 volts output at rated input.

      For division, a selector switch transfers feedback from the 4.99K resistor to the output of the Active Filter as described below.

   2. Transistor clamps limit its output to approximately ± 5.5 volts to protect the Analog Switches in 6IC.

6. **Duty Cycle Switch** – Amplifier 3IC(D) uses the form C contact configuration from Analog Switch 6IC to change its action from inverting to non-inverting, each with unity gain, to produce a rectangular wave with precisely equal negative and positive amplitudes.

   The amplitude will be the same as the magnitude of the output of the X Amplifier, and the duty cycle is a linear function of the output of the Y Amplifier.

   The average value of the output of amplifier 3IC(D) is, therefore, directly proportional to the product of the outputs of both the X and Y Amplifiers. Mathematically this may be expressed as:

   $$Z = K \text{ (X Amp out) (Y Amp out)}$$

7. **Active Filter** – The AC component of the rectangular wave is removed by a two-pole, low-pass filter having a nominal 250 Hz crossover frequency.

   In the "Multiply" Mode the output of the Active Filter is switched directly to the Output Amplifier.

   In the "Divide" Mode the output of the Active Filter is fed back to the input of the X Amplifier. Therefore, the X Amplifier attempts to regulate the output of the Active Filter. This places the Y "Multiply" function in the output of the X Amplifier so that the percentage of feedback from the X Amplifier back to its input is controlled by the signal from the Y Amplifier (from zero to 100% feedback).

   For example: If the Y Amplifier is at rated output (5 volts) the feedback causes the X Amplifier to have unity gain and its output is equal to the input.

   If the Y input is reduced to 50%, then the X Amplifier receives only one half as much feedback so its output increases to twice the input. If the Y input is reduced to zero then no feedback is available for the X Amplifier and it will saturate attempting to produce an infinite output.

   This suggests several rules necessary for proper use of the "Divide" function:

   1. Since the feedback from output to input of the X Amplifier must always be negative, the polarity of the Y signal must always be positive. This means that the "Divide" function is two quadrant with the denominator always positive.

2. The magnitude of the denominator can never be less than the magnitude of the numerator because if the numerator is larger than the denominator the circuit will saturate attempting to produce an output in excess of the 10 volt maximum.

   NOTE: Because of these constraints, careful attention is required in scaling the inputs.

3. The Y input (denominator) must never be allowed to go to zero since the output then becomes indeterminate both in regard to magnitude and polarity.

8. Output Amplifier – The output Amplifier 8IC has a gain of 2 to 1 to provide an output of 0 to ± 10 volts DC @ 5mA.

VOLTAGE CHECK

1. The primary voltage of 1T, leads 1 and 2 (terminals 10 and 9), should be 120V AC.
2. The secondary voltage of 1T, leads 3 to 4 and leads 5 to 6 should be 10V AC. These can be measured between circuit common, terminal 8 (leads 4 and 5), and each AC input to the bridge rectifier 1 REC (leads 3 and 6). Voltage at the AC input to the bridge rectifier 1 REC (leads 3 to 6) should be 20V AC.
3. +15V DC nominal between the positive end of capacitor 1C and terminal 8.
4. –15V DC nominal between the negative end of capacitor 2C and terminal 8.
5. +6V DC nominal (5.5 to 6.5 volts) between terminal 6 and terminal 8.
6. –6V DC nominal (5.5 to 6.5 volts) between terminal 7 and terminal 8.

COMPONENT LIST - ASSEMBLY #12MO3-00114-01

Symbol	Part #	Description (Acceptable Substitute)*
1T	04P01-00001	Transformer–120V AC PRI, two 10V SEC @ 220mA (Signal-PC20-220)
1REC	05P01-00003	Rectifier Bridge–50V, 1A (EDI-PF50)
1-8D	05P02-00001	Diode–Signal, 50 mA, 200 PIV (1N4148)
1ZD	05P03-00004	Zener Diode–6.2V @ 7.5 mA (1N5244B)
2, 3ZD	05P03-00005	Zener Diode-6.8V, 500mW, 10% (1N5235B)
1Q	05P05-00001	Transistor-N Channel JFET (2N4093)
2Q	05P04-00002	Transistor-NPN, Small Signal (2N3392)
3Q	05P04-00001	Transistor-PNP, Small Signal (2N3638A)
1IC	05P08-00006	+6 Volt Regulator (7806)
2IC	05P08-00007	–6 Volt Regulator (7906)
3IC	05P08-00002	Quad Op-Amp (TI-TL084)
4IC	05P08-00004	Quad Comparator (National-LM339)
5, 7, 8, 9, 10IC	05P08-00005	Precision Op-Amp (Fairchild 714)
6IC	05P09-00008	Quad Analog Switch (4016 or 4066)
1P	02P04-10201-00	Potentiometer–1K, ½W (Beckman 72XR1K)
1, 2C	03P01-47102-01	Capacitor-470MF, 25V, Electrolytic
3, 4C	03P01-10001-00	Capacitor–10MF, 15V, Electrolytic
5, 8, 9C	03P06-50005-00	Capacitor–50PF, 50V, Ceramic
6C	03P07-10210-00	Capacitor–0.001MF, Film
7C	03P07-10510-00	Capacitor-1.0MF, 100V, Film
10C	03P07-10410-00	Capacitor-0.1MF, 100V, Film
11C	03P06-33005-00	Capacitor-33PF, 50V, Ceramic
12, 13C	03P07-10310-00	Capacitor-0.01MF, 100V, Film
14C	03P06-10205-00	Capacitor-0.001MF, 50V, Ceramic
1R	01P02-20001-01	Resistor-200 Ohm, ½W, 1%
2R	01P02-18211-01	Resistor-1820 Ohm, ½W, 1%
3R	01P02-75011-01	Resistor-7.50K, ½W, 1%
4R	01P02-20011-01	Resistor-2.0K, ½W, 1%
5, 17, 30, 31R	01P02-49911-01	Resistor-4.99K, ½W, 1%
6, 15, 18R	01P01-22200-02	Resistor-2.2K, ¼W, 5%
7, 10, 13 24, 25R	01P01-10400-02	Resistor-100K, ¼W, 5%
8, 9 22, 23R	01P01-47200-02	Resistor-4.7K, ¼W, 5%
11, 12, 20R	01P01-10300-02	Resistor-10K, ¼W, 5%
14R	01P01-47300-02	Resistor-47K, ¼W, 5%
16, 21, 34R	01P02-10021-01	Resistor-10.0K, ½W, 1%
19R	01P01-22300-02	Resistor-22K, ¼W, 5%
26, 27R	01P01-15200-02	Resistor-1.5K, ¼W, 5%
28, 29R	01P02-10021-00	Resistor-10K, ½W, 0.1%
32, 33R	01P01-68300-02	Resistor-68K, ¼W, 5%
35, 37R	01P02-10031-01	Resistor-100K, ½W, 1%
36, 39R	01P02-49921-01	Resistor-49.9K, ½W, 1%
38R	01P01-33200-02	Resistor-3.3K, ¼W, 5%

*OR EQUAL

BENCH TEST

NOTE: This test is not intended as a test to determine the accuracy of the multiplier or divider. It is meant only to determine the functionality of this board.

TEST MATERIAL REQUIRED:

- 2 - Power supplies capable of producing 1 to 10 volts DC, or two 1.5V C or D cells and two 9 volt transistor radio batteries.
- 1 - 120V AC line cord with plug
- 1 - Digital Voltmeter (Beckman HD-110 or equal)
- 4 - Clip leads

1. Configure the DIP switch on the assembly as follows: DIP switch positions 1 and 4 off and positions 2 and 3 on.
2. Connect power supply or 9 volt battery negatives to terminal 8 and the positive ends to terminals 2 and 4 of the assembly.
3. Apply 120 volt AC power to terminals 9 and 10.
4. Measure and adjust the power supplies to 10.00 volts DC (9 volts using batteries).
5. Measure and adjust "SCALE FACTOR" for 10.00 volts at terminal 1 (8.0 volts DC for batteries).
6. Refer to figure 1 for power supplies or figure 2 for batteries, and complete test by applying appropriate voltages and comparing output results to the respective tables.
7. Reconfigure the DIP switch positions as follows: Positions 2 and 3 off and positions 1 and 4 on.
8. Using either the 9 volt transistor batteries or the power supplies, set to 10.00 volts DC, apply the positive terminals to assembly terminals 2 and 4, and the negative terminals to terminal 8. Adjust "SCALE FACTOR" to obtain 10.00 volts DC.
9. Using figures 3 and 4, apply voltage to terminals 2 and 4 of the assembly as indicated. Corresponding outputs should fall within the two voltage readings on the chart. (Measured at terminal 1 of the assembly.)

MULTIPLIER MODE TEST
USING POWER SUPPLY

Input Y Term 2	INPUT X TERMINAL 4				
	10	1	0	-1	-10
10	9.8 to 10.2	0.9 to 1.1	±0.05	-0.9 to 1.1	-9.8 to -10.2
1	0.9 to 1.1	0.05 to 0.15	±0.05	-0.05 to -0.15	-0.9 to -1.1
0	±0.05	±0.05	±0.05	±0.05	±0.05
-1	-0.9 to -1.1	-0.05 to -0.15	±0.05	0.05 to 0.15	0.9 to 1.1
-10	-9.8 to - 10.2	-0.9 to -1.1	±0.05	0.9 to 1.1	9.8 to 10.2

FIGURE 1

USING BATTERY

Input Y Term 2	INPUT X TERMINAL 4				
	9	1.5	0	-1.5	-9
9	7.95 to 8.25	1.25 to 1.45	± .05	-1.25 to -1.45	-7.95 to -8.25
1.5	1.25 to 1.45	.22 to .23	± .05	-.22 to -.23	-1.25 to -1.45
0	±.05	±.05	± .05	±.05	±.05
-1.5	-1.25 to -1.45	- .22 to - .23	± .05	.22 to .23	1.25 to 1.45
-9	-7.95 to -8.25	-1.25 to -1.45	± .05	1.25 to 1.45	7.95 to 8.25

FIGURE 2

DIVIDER MODE TEST
USING POWER SUPPLY

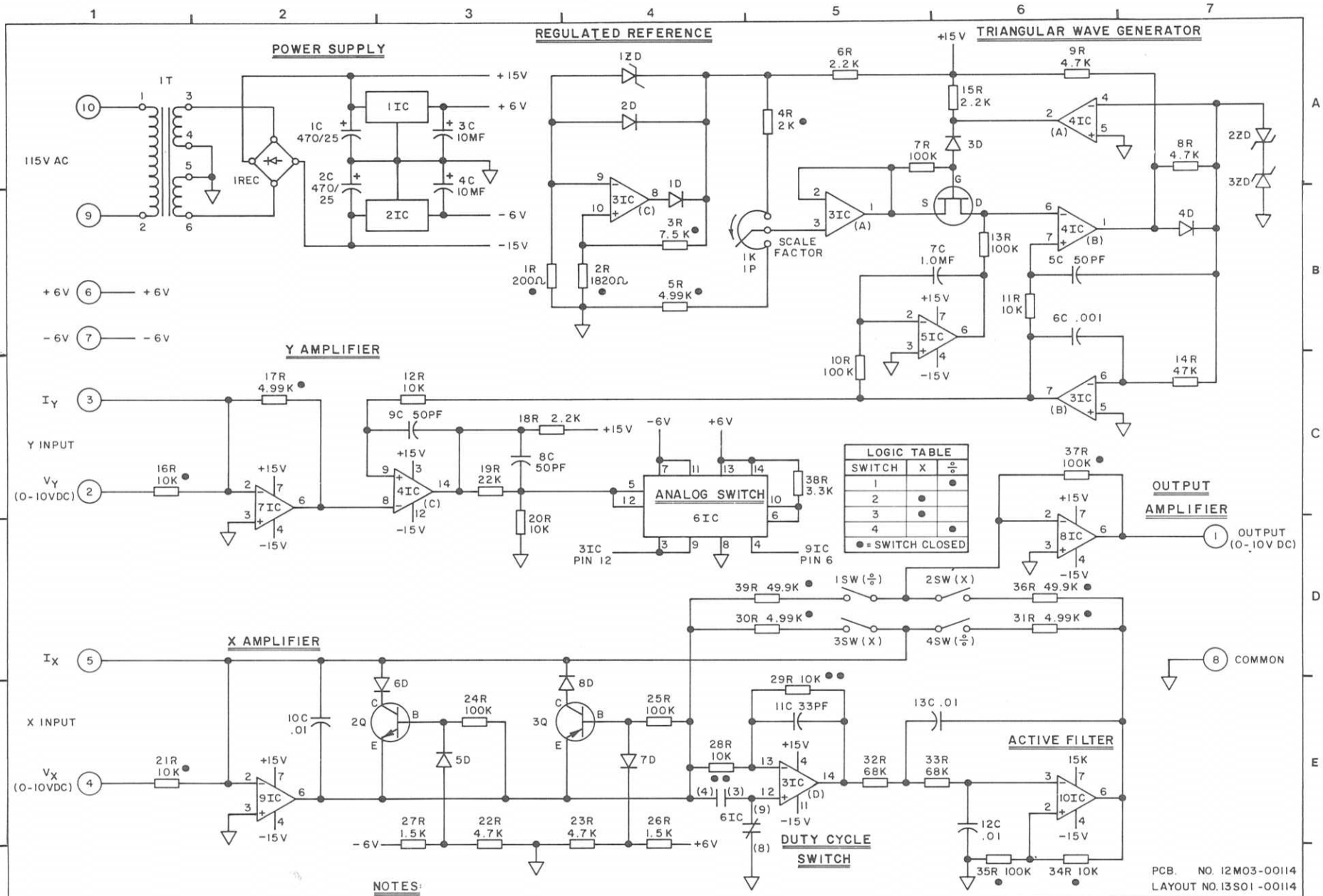
Input Y Term 2	INPUT X TERMINAL 4				
	10	1	0	-1	-10
10	9.8 to 10.2	.9 to 1.1	±.050	-.9 to 1.1	-9.8 to -10.2
1	X	9.0 to 11.0	±.050	-9.0 to -11.0	X
0	INDETERMINATE				

FIGURE 3

USING BATTERY

Input Y Term 2	INPUT X TERMINAL 4				
	9	1.5	0	-1.5	-9
9	9.8 to 10.2	1.56 to 1.76	±.05	-1.56 to 1.76	-9.8 to -10.2
1.5	X	9.0 to 11.0	±.05	-9.0 to -11.0	X
0	INDETERMINATE				

FIGURE 4



NOTES:
- ● - 1% RESISTOR
- ●● - 0.1% RESISTOR
1 - CLOSE 2 SW AND 3 SW FOR MULTIPLY
2 - CLOSE 1 SW AND 4 SW FOR DIVIDE

REV.	DESCRIPTION	DATE	INT.

REVISIONS

DR	CK'D	APP'D
MY		
DATE	SCALE	SHEET
11-12-82		OF

REFLEX INC.
CEDARBURG, WI

PRODUCT: MULTIPLIER/DIVIDER
REF (FILE No.): EX-209
CUSTOMER:
JOB No.:
TITLE: SCHEMATIC DIAGRAM
DWG No.: 12M03-00114-01

PCB NO. 12M03-00114
LAYOUT NO. 13S01-00114