

INSTRUCTION MANUAL
MODEL 150
AND
MODEL 155
PROGRAMMABLE VOLTAGE
CONTROLLED GENERATORS

WAVETEK

8159 ENGINEER ROAD, SAN DIEGO, CALIFORNIA

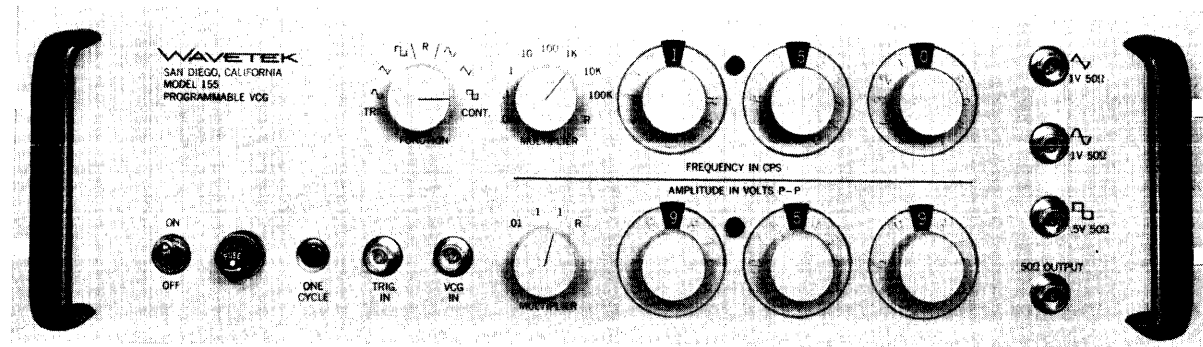
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WAVETEK MODEL 150 PROGRAMMABLE VOLTAGE-CONTROLLED GENERATOR



WAVETEK MODEL 155 PROGRAMMABLE VOLTAGE-CONTROLLED GENERATOR

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WARRANTY

WAVETEK warrants instruments manufactured by it to have met WAVETEK's published specifications at the time of shipment of such instruments, and agrees to repair within one year of shipment, such instruments or their components (excluding batteries), which under normal use are found to be defective as a result of our manufacturing. Our obligation under this warranty is limited solely to repairing any such instrument which in our sole opinion proves to be defective when returned to our factory. Transportation to the factory is to be prepaid by purchaser. Instruments returned to the factory will be accepted only when prior authorization has been given by a representative of WAVETEK.

This warranty does not apply to any of our products which have been repaired or altered by persons not authorized by WAVETEK, or not in accordance with instructions furnished by us. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

WAVETEK assumes no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. WAVETEK assumes no liability for secondary charges or consequential damages, and in any event, WAVETEK's liability for breach of warranty under any contract or otherwise, shall not exceed the purchase price of the specific instrument shipped and as to which a claim is made.

Any recommendations made by WAVETEK for the use of its products are based upon tests believed to be reliable, but WAVETEK makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, expressed or implied, and no representative or person is authorized to represent or assume for us any liability in connection with the sale of our products other than set forth herein.

SECTION I

INTRODUCTION AND GENERAL DESCRIPTION

SCOPE

This instruction manual provides instructions for operation, calibration, and maintenance of WAVETEK Series 150 Programmable Voltage-Controlled Generators.

GENERAL DESCRIPTION

The WAVETEK 150 Series Programmable Voltage-Controlled Generators are solid-state, multi-purpose function generators which produce sine, triangle and square wave outputs. The 150 Series includes the Model 150 and the Model 155. Both models are completely programmable, using binary-coded-decimal (BCD) control of frequency and amplitude. Frequency, waveform function, and signal amplitude are selected by remote contact closures or logic levels. Both models provide continuous and triggered operating modes. The Model 155 also includes local control by front panel digital switches which allow manual control of frequency, waveform function, amplitude, and range.

The programmed BNC output of the 150 Series instruments provides any one of the three waveform signals at any amplitude between 10 millivolts and 10 volts, peak to peak, into a 50 Ω load. The output frequency range is 0.01 Hz to 1 MHz, in eight ranges. An analog voltage input (VCG) will vary the frequency through each range to a maximum of 20:1.

Both models also provide simultaneous sine, triangle, and square wave outputs with constant amplitude over the entire frequency range of the instrument. The output impedance of all outputs is 50 Ω .

The output signals may be continuous or may be triggered by a 5 volt gate or pulse input. The trigger input may be specified for either polarity. In the triggered mode, at least one complete cycle is generated for each trigger pulse. The frequency of the cycle is determined by the programmed frequency and range. If a gate voltage is applied to the trigger input, numerous cycles at the programmed frequency are generated during the period of the gate. A trigger pulse of shorter duration than one cycle of the frequency being generated will produce one cycle.

Series 150 instrument are 5-1/4 inches high, 16 inches deep, and 19 inches wide, and are contained in an enclosure which fits a standard RETMA 19-inch relay rack. The solid-state electronic circuits are contained on plug-in glass-epoxy circuit boards, interconnected through a mother board. An extender board is included in each instrument, to allow circuit boards to be operated while extended outside the enclosure. The modular construction facilitates

calibration and maintenance to an extent not usually associated with complex electronic equipment.

MODEL 150 PROGRAMMABLE VOLTAGE-CONTROLLED GENERATOR

The Model 150 Programmable Voltage-Controlled Generator is operated by remote closures or logic levels in an 8-4-2-1 BCD code. Other input codes are available as indicated in Table 1. The AC power switch and fuse are located on the front panel. The remote programming and analog frequency sweep voltage inputs are located on the rear panel. The programmed output connector and the three simultaneous output connectors are also mounted on the rear panel. Controls and connectors are described on page 2-3.

MODEL 155 PROGRAMMABLE VOLTAGE-CONTROLLED GENERATOR

The Model 155 Programmable Voltage-Controlled Generator is similar to the Model 150; however, the Model 155 provides local control through manually operated switches on the front panel. Simultaneous and programmed outputs are available at both front and rear panels. The VCG sweep voltage input points are available on both the front and rear panels and a manually operated single cycle trigger switch is provided on the Model 155. Controls and connections for the Model 155 are described on page 2-3.

INTERFACE ACCESSORIES

Standard card sets are available to convert Models 150 and 155 to the proper interface for any code or control. Available card sets for the different codes and controls are listed in Table I. Control forms not listed will be built to customer order.

Table I

INTERFACE ACCESSORIES

OPTION	CODE	CONTROL	FORM
1	4221	Contact Closure	Not Applicable
2	8421	Logic Level	True = ± 5 to 20v dc False = $0v \pm 0.5v$
3	8421	Logic Level	True = $0v \pm 0.5v$ False = ± 5 to 20v dc
4	4221	Logic Level	True = ± 5 to 20v dc False = $0v \pm 0.5v$ dc
5	4221	Logic Level	True = $0v \pm 0.5v$ dc False = ± 5 to 20v dc
6	Decimal	Contact Closure	Not Applicable
7	Decimal	Logic Level	True = ± 5 to 20v dc False = $0v \pm 0.5v$ dc
8	Decimal	Logic Level	True = $0v \pm 0.5v$ dc False = ± 5 to 20v dc

SECTION II

SPECIFICATIONS

(Revised 12-66)

GENERAL

The WAVETEK Models 150-155 are broad band function generators capable of producing sine, triangle and square waves in a frequency band of 0.01 Hz to 1 MHz. Frequency, amplitude, and function are programmable from a remote (R) source by contact closures. The Model 155 has front panel controls in addition to the remote capability. The following specifications apply when this equipment works into a 50Ω coaxial cable terminated in a 50Ω load; the instrument has been turned on for at least one hour in an environmental temperature of $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$; and, relative humidity of less than 70 per cent. Terms marked with an asterisk are defined at the end of this specification under "Definitions."

STARTING CHARACTERISTIC

The generator may take up to a minute to start its normal operation after the power is turned on.

OUTPUTS

There are three fixed amplitude outputs and a programmable amplitude output; all are BNC connectors and produce their respective signals at the programmed frequency. All have an output impedance of $50\Omega \pm 5\%$. Each output is calibrated into precisely 50Ω . Amplitude specifications apply only when outputs are terminated in precisely 50Ω . The location of these connectors is on the rear panel of the Model 150 and duplicate connectors on the front and rear panel of the Model 155. Connection may be made to the front or rear connector of a given function, but not both.

FREQUENCY

The frequency of the signal at all outputs is identical. It is equal to the programmed frequency $\pm 1\%$ plus one digit on all ranges with the following exceptions:

X.01 range:	$\pm 2\%$ plus one digit
X100K range:	$\pm 5\%$ plus one digit

FIXED AMPLITUDE SINE

The following are specifications applicable to the fixed amplitude sine output:

Output Amplitude:	1 volt peak to peak ± 20 mv to 99.9 KHz and ± 50 mv to 1 MHz.
*Amplitude Asymmetry:	Less than 1% to 99.9 KHz and 2% to 1 MHz.
*Transient Aberrations:	
Period:	Less than 250 nsec.
Amplitude:	Less than 20 mv peak to peak.
Total Harmonic Distortion:	Less than 1% between 1 Hz and 99.9 KHz and less than 2% between 100 KHz and 500 KHz.

FIXED AMPLITUDE TRIANGLE

The following are specifications applicable to the fixed amplitude triangle output:

Output Amplitude:	1 volt peak to peak ± 10 mv to 99.9 KHz and ± 50 mv to 1 MHz.
*Amplitude Asymmetry:	Less than 1% to 99.9 KHz and 2% to 1 MHz.
*Transient Aberrations:	
Period:	Less than 250 nsec.
Amplitude:	Less than 50 mv peak to peak.
Triangle Linearity:	Triangle slopes between switch points are constant $\pm 1\%$ to 100 KHz.

FIXED AMPLITUDE SQUARE

The following are specifications applicable to the fixed amplitude square wave output:

Output Amplitude:	0.5 volt peak to peak ± 20 mv.
*Amplitude Asymmetry:	Less than 1%.

10% to 90% Rise and
Fall Time:

Less than 10 nsec.

Overshoot and Ringing:

Less than ± 25 mv in respect
to *settled value.

Settling Time:

To within 10 mv of *settled
value within 200 nsec. from
an axis crossing.

*Time Asymmetry:

X.01 range:

Less than $10/P\%$

X.1 range:

Less than $2/P\%$

X100K range:

Less than $(1 + 0.1P)\%$

All other ranges:

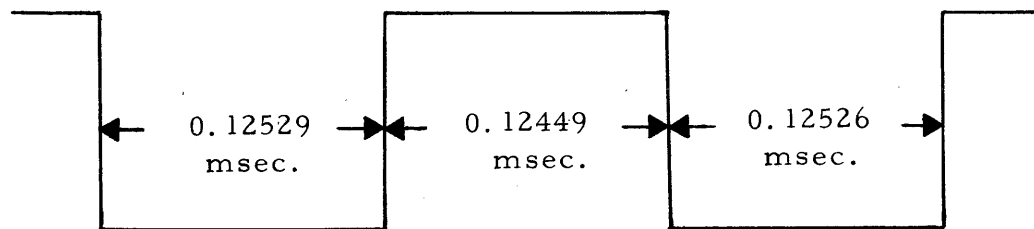
Less than $1/P\%$

(Where P equals the frequency
program, not including the fre-
quency range, X.XX; i.e.,
1.00 to 9.99)

*Cycle to Cycle Time
Jitter:

Less than 0.1% divided by P.

Example:



Frequency Program = 4.00 X 1K

$$\begin{aligned} \text{*Time Asymmetry} &= \frac{0.5(0.12529 - 0.12449)}{0.250} = \frac{0.0004}{0.250} \\ &= 0.0016 = \underline{\underline{0.16\%}} \end{aligned}$$

$$\text{Spec.} = \frac{1\%}{4.00} = \underline{\underline{0.25\%}}$$

$$\begin{aligned} \text{*Cycle to Cycle Time Jitter} &= \frac{0.12529 - 0.12526}{0.250} \\ &= \frac{0.00003}{0.250} = 0.00012 = \underline{\underline{0.012\%}} \end{aligned}$$

$$\text{Spec.} = \frac{0.1\%}{4.00} = \underline{\underline{0.025\%}}$$

PROGRAMMABLE AMPLITUDE OUTPUT

Signal from this output is selectable in function, frequency and amplitude. The frequency of signal at this output is the same as that of the fixed amplitude outputs. The function and amplitude are selected by switches on the Model 155 or by remote closure program in the Models 150 and 155. The following are specifications applicable to the programmable amplitude output:

Amplitude:	Equal to the programmed peak to peak amplitude $\pm 1\%$ plus one digit to 99.9 KHz and $\pm 5\%$ plus one digit to 1 MHz.
*Amplitude Asymmetry:	Less than 1% plus 1 mv to 99.9 KHz and 2% plus 1 mv to 1 MHz.

SINE FUNCTION

Total Harmonic Distortion:	Same as fixed amplitude sine for amplitudes greater than 1 volt peak to peak.
*Transient Aberrations:	
Period:	Less than 250 nsec.
Amplitude:	Less than 5% of programmed peak to peak amplitude plus 20 mv.

TRIANGLE FUNCTION

Triangle Linearity:	Same as fixed amplitude triangle.
*Transient Aberrations:	
Period:	Less than 250 nsec.
Amplitude:	Less than 5% of programmed peak to peak amplitude plus 20 mv.

SQUARE FUNCTION

10% to 90% Rise and Fall Time:	Less than 150 nsec.
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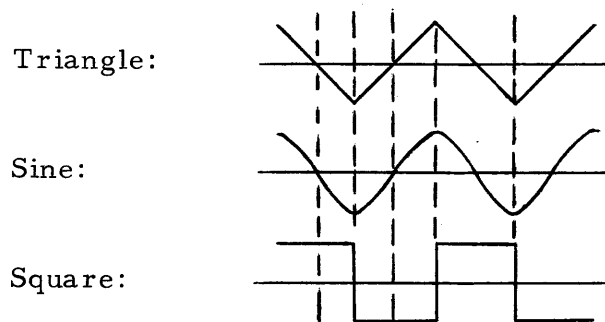
Overshoot and Ringing: Less than 5% of programmed peak to peak amplitude plus 10 mv.

*Time Asymmetry: Same as fixed amplitude square wave.

Cycle to Cycle Time Jitter: Same as fixed amplitude square wave.

PHASE RELATIONSHIP OF OUTPUTS

The nominal phase relationship of the fixed amplitude outputs follows:



The programmable amplitude output waveforms are nominally in phase with the corresponding fixed amplitude outputs. Phase errors of less than 50 nsec. are not regarded as violations of this specification.

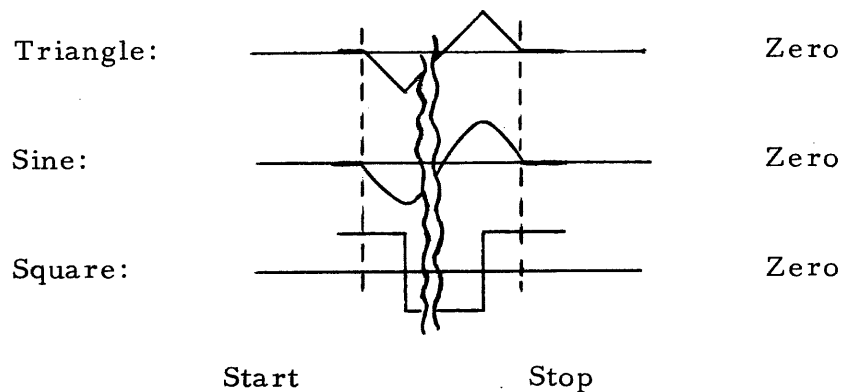
CONTACT CLOSURES

The remote program is applied to the generator by means of contact closures. Each group of input lines close only to the appropriate return as shown in the Control Connector Wiring Data at the conclusion of this section. The current drawn by any programming contact closure will not exceed 50 ma. The voltage across any contact closure regarded as closed must not exceed 200 mv. The current drawn by any contact closure regarded as open must not exceed 1 μ a. The time required for the generator to respond to a new program will not exceed 5 msec.

TRIGGER

The trigger input is a BNC connector on the rear panel of the Model 150 and duplicate connectors on the front and rear panel of the Model 155. If the generator is programmed for triggered operation, a positive input of more

than 5 volts on this input will cause the generator to produce an output signal on all outputs simultaneously. Less than 0.5 volts on this input will cause the generator to stop producing a signal on the outputs. On the removal of the trigger input voltage, the generator will stop only after the completion of the cycle in which the trigger input was removed. The start and stop points of the waveforms are nominally as follows:



To put it another way, a trigger input of any duration will produce an integer number of cycles. The input impedance at this connector will not be less than 1 K Ω . The quiescent state of the triggered sine and triangle will be less than 1% of the programmed peak to peak amplitude ± 1 mv. The quiescent state of the square wave will be within 1% of the programmed positive peak value ± 1 mv. Amplitude of the transient at the stop point discontinuity of the sine and triangle will be less than 1% of the programmed peak to peak value ± 1 mv. On the fixed amplitude sine and triangle outputs, it will be less than 10 mv.

On the front panel of the Model 155, there is a single cycle pushbutton which produces a brief gating signal when the generator is in the triggered mode. The pushbutton will produce a single cycle on all outputs. The start and stop points are the same as the voltage triggered operation. The triggered operation is not specified above 200 KHz.

ANALOG VOLTAGE CONTROL INPUT (VCG)

This input is a BNC connector on the rear panel of the Model 150 and duplicate connectors on the front and rear panels of the Model 155. This analog voltage control can be used to trim or otherwise modify the existing program by putting in a dc level, or it can be used to frequency modulate the outputs of the generator. In any case, it must be remembered that the analog voltage control input adds to or subtracts from the existing closure program, depending on the polarity of the input signal. Positive polarity adds to the existing closure program and negative subtracts. Operation above 11 times the

frequency multiplier or below 0.5 times the frequency multiplier, is not specified.

Sensitivity = 2 Hz/v X Frequency Multiplier $\pm$ 2%.

Input Impedance = 10 K Ω $\pm$ 1%.

VCG Linearity: Frequency deviation from the best straight line shall not exceed $\pm$ 0.2% of the frequency bandwidth to 100 KHz.

Response Rate: The generator will follow VCG input signals to meet its other specifications at a rate of at least 50 Kv/sec.

VCG input will accept $\pm$ 100 volts d-c without permanent damage.

POWER REQUIREMENT

115 volts a-c $\pm$ 10%, power consumed will not exceed 20 watts. Optional power input is 230 volts a-c $\pm$ 10%.

DIMENSIONS

Height:	Not more than 5 and 1/4 inches (not including bench mount feet).
Depth:	Not more than 16 and 1/4 inches from back of front panel (not including mating connectors).
Width:	Not more than 17 and 1/2 inches except front panel which is standard 5 and 1/4 inches by 19 inches for rack mount.
Weight:	Net shipping weight is approximately 20 pounds.

DEFINITIONS

For purposes of this specification, the following are definitions of some of the terms:

AMPLITUDE ASYMMETRY:	Is the ratio of half of the algebraic sum of the plus and minus *peak values of a waveform to the *peak to peak value of the waveform.
CYCLE TO CYCLE TIME JITTER:	Is the ratio of the time difference between any two adjacent half cycles of the same polarity to the indicated cycle length.
PEAK TO PEAK VALUE	Of a waveform is the arithmetical sum of the plus and minus *peak values.
SETTLED VALUE:	Of a square wave is the mean value taken over the final half of the half cycle disregarding the final 100 nsec. before an axis crossing.
TIME ASYMMETRY:	Is one-half of the time difference between any two adjacent half cycles divided by the indicated cycle length.
TRANSIENT ABERRATIONS:	Are momentary voltage deviations from the apparent ideal behavior of a sine or triangle waveform. *Peak values and triangle linearity are measured exclusive of *transient aberrations within the stated limits.

CONTROL CONNECTOR WIRING DATA
for
WAVETEK MODEL 150 & 155 PROGRAMMABLE FUNCTION GENERATORS
(Amp, 50 Pin, Type M Connector)

IMPORTANT

NOTE: There are ten independent returns which may be tied together externally on the Model 150. The returns on the Model 155 may be tied together, but unless all front panel controls are in the remote position (R), there will be some interaction between external and front panel controls.

Nomenclature					Pin No.
Frequency	Most Significant Decade			1	A
"	"	"	"	2	B
"	"	"	"	4	C
"	"	"	"	8	D
"	"	"	"	Return	E
" 2nd	"	"	"	1	F
" "	"	"	"	2	H
" "	"	"	"	4	J
" "	"	"	"	8	K
" "	"	"	"	Return	L
"	Least	"	"	1	M
"	"	"	"	2	N
"	"	"	"	4	P
"	"	"	"	8	R
"	"	"	"	Return	S
Frequency Range Multiplier				X.01	T
"	"	"	"	X.1	U
"	"	"	"	X1	V
"	"	"	"	X10	W
"	"	"	"	X100	X
"	"	"	"	X1K	Y
"	"	"	"	X10K	Z
"	"	"	"	X100K	a
"	"	"	"	Return	b
Amplitude	Most Significant Decade			1	c
"	"	"	"	2	d
"	"	"	"	4	e
"	"	"	"	8	f
"	"	"	"	Return	h
" 2nd	"	"	"	1	j
" "	"	"	"	2	k
" "	"	"	"	4	m
" "	"	"	"	8	n
" "	"	"	"	Return	p

Nomenclature					Pin No.
Amplitude	Least	Significant	Decade	1	r
"	"	"	"	2	s
"	"	"	"	4	t
"	"	"	"	8	u
"	"	"	"	Return	v
Circuit Gnd. (not used)					w
Amplitude Range Multiplier			X.01		x
"	"	"	X.1		y
"	"	"	X1		z
"	"	"	Return		AA
Function Sine Wave					BB
"	Triangle Wave				CC
"	Square Wave				DD
"			Return		EE
Continuous Trigger					FF
"	"		Return		HH

To program the three frequency decades and three amplitude decades, contact closures must be made for those bits desired and an open programmed for those bits not wanted.

To program Frequency Range Multiplier, Amplitude Range Multiplier and Function, short the appropriate return to the position desired.

To program Continuous Trigger, short pins FF to HH for Continuous operation.

SECTION III

OPERATION PROCEDURE

GENERAL

This section of the handbook contains procedures for operating either the Model 150 or Model 155 instrument.

OPERATION PROCEDURES

1. Remove generator from packing box. Plug power cord into rear power connector of the generator. For the Model 150, wire programmed mating connector according to the Control Connector Wiring Data Table (refer to Section II).
2. Connect the generator to a power source that meets the voltage and frequency requirements of the instruments.
3. Plug in the external program connector.
4. Turn front panel power switch to ON position.
5. Turn FUNCTION switch on Model 155 to CONT, , , or  depending on the desired output from the 50 Ω output. On the Model 150, program the desired function.
6. Turn the frequency MULTIPLIER switch on the Model 155 to the desired frequency range and turn the FREQUENCY IN Hz dials to the desired frequency. On the Model 150, program the desired frequency range and decade.
7. Turn the amplitude MULTIPLIER to desired amplitude range, and the AMPLITUDE IN VOLTS P-P dials to desired amplitude on the Model 155. On the Model 150, program the desired amplitude range multiplier and amplitude decades.
8. The 1v, 50 Ω triangle; 1v, 50 Ω sine; and the 0.5v, 50 Ω outputs are fixed amplitude and their frequency depends only on the dial setting or programmed frequency. For the Model 150, all outputs are found on the rear of the instrument. For the Model 155, outputs are found on both the front and rear panels of the instrument.
9. The 50 Ω output waveform depends on the selected waveform on the FUNCTION switch of the Model 155. On the Model 150, the output depends on the programmed function.

10. The 50 Ω output amplitude depends on the amplitude MULTIPLIER and dial setting. On the Model 150, the amplitude depends on the programmed amplitude.
11. The frequency of the 50 Ω output waveform depends on the frequency MULTIPLIER and FREQUENCY IN Hz dial settings on the Model 155. On the Model 150, the frequency depends on the programmed amplitude multiplier and decades.
12. For triggered operation turn the FUNCTION switch on the Model 155 to the desired waveform or TRIG. For the Model 150, program the desired trigger waveform. All outputs will yield the triggered waveform.
13. The instrument may be triggered by either the ONE CYCLE pushbutton or the TRIG IN from an external signal generator. All outputs will be triggered at the same time. The ONE CYCLE pushbutton is found on the front panel of the Model 155 only. The TRIG IN is found on the Model 155 front and rear panel. On the Model 150, it is on the rear panel only.
14. For the VCG input mode, the FUNCTION switch of the Model 155 must be turned to CONT. For the Model 150, the continuous function must be programmed.
15. For VCG operation the VCG signal is applied to the VCG IN from an external generator. For the Model 155, VCG IN is on the front and rear panel; and on the Model 150 it is on the rear panel only.
16. The Model 155 may be programmed externally in exactly the same manner as the Model 150. The Model 155 may be totally programmed externally or any one of the controls may be programmed separately. To program externally, turn the desired MULTIPLIER control on the front panel to the remote (R) position.

SECTION IV

THEORY OF OPERATION

MODEL 150 and 155. Figure 4-1 is a block diagram of the Model 150 and 155 Function Generator.

A square wave is applied to the input of the integrator (operational amplifier). This integrator is composed of a wide band high gain DC amplifier and integrating resistor R and integrating capacitor C . The output of the integrator (a triangle waveform) is fed into the Hysteresis and output switches. The Hysteresis and output switch function like a Schmitt trigger with the limit points set wide apart. As a result they fire when the triangle wave reaches $+2.5$ volts and -2.5 volts. The firing of the Hysteresis and the output switches reverses the square wave voltage fed into the integrator and the triangle wave then reverses direction. The result is simultaneous generation of a square wave and triangle wave of the same frequency with the positive half cycle of the square wave coincident with the negative going portion of the triangle wave.

The frequency of oscillation is determined by two conditions. The first condition is the values of the resistance and capacitance selected with the frequency range switch. The second condition is the amplitude of the square wave fed to the input of the integrator. Unique circuitry is provided whereby the amplitude of the square wave fed to the integrator is controlled by an analog voltage. The integrating resistor R is also connect to a PNP and NPN transistor switch. The bases of these transistor switches are driven from the output square wave. Negative square waves cause conduction of the PNP transistor, and positive square waves cause conduction of the NPN. These transistors are connected in an inverted configuration and when in the conduction mode, have in the vicinity of 10 mv drop between their emitter and collector.

The VCG input and the binary coded decimal switches both drive two operational amplifiers in cascade whose final output is proportional to, but inverted from, the sum of the input voltages. The first operational amplifier drives the second. As a result, a positive voltage appearing on the input of the first amplifier causes a negative voltage at the output of the first amplifier and a positive voltage at the output of the second amplifier. A negative square wave to the PNP, NPN transistor switch thus causes integrating resistor R to be shorted to the negative voltage output of the first amplifier. A positive square wave voltage causes resistor R to be shorted to the positive voltage output of the second amplifier.

The circuit would be complete and work accurately except for the small drop across the PNP, NPN switching transistors. This drop is compensated for by inserting a matching transistor in the feedback legs of the operational amplifiers. The drive to the compensating transistors is designed to equal the base drive to the switching transistors. The switching transistors and the operational

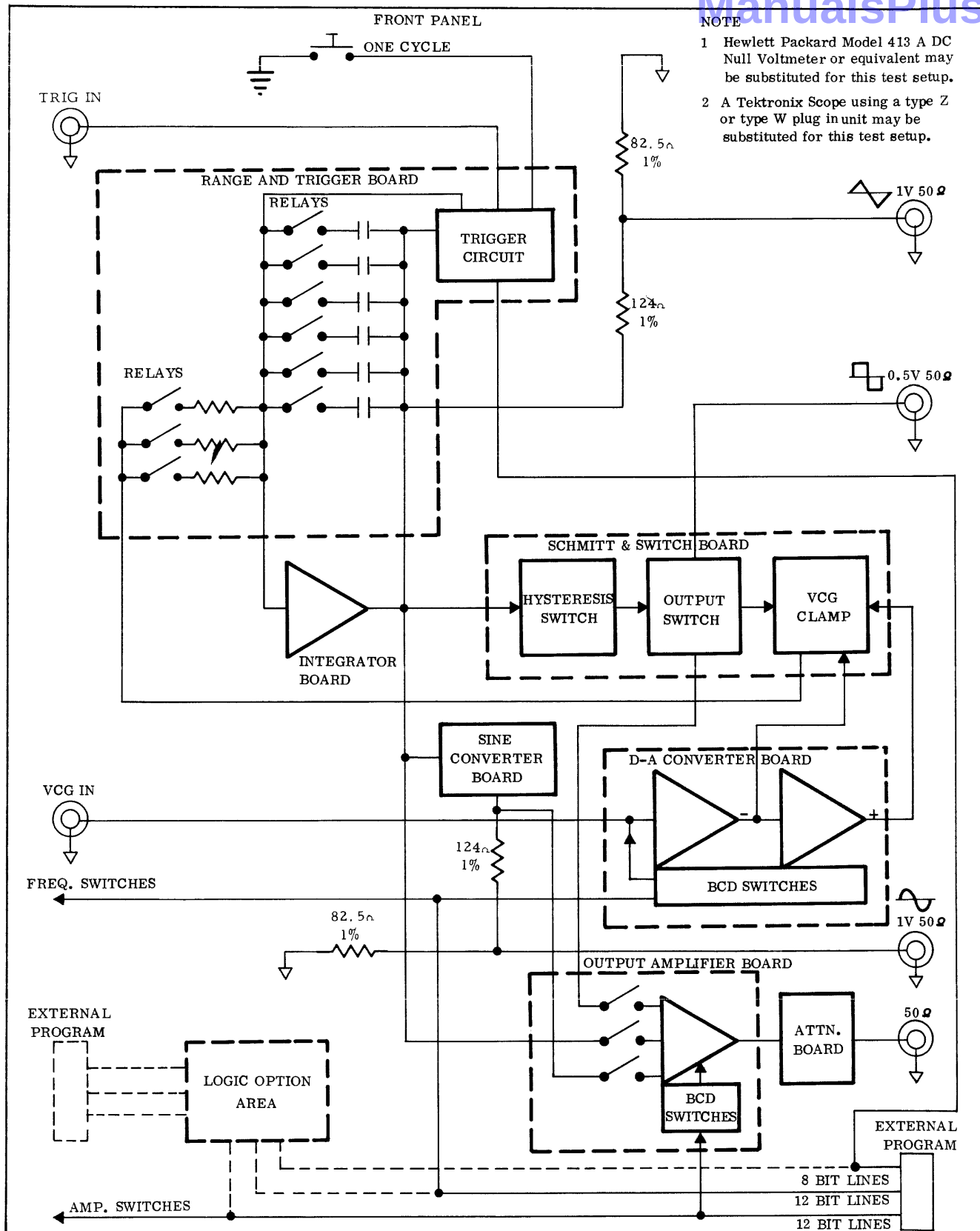


Figure 4 - 1. VCG Functional Block Diagram.

amplifiers must have good high frequency characteristics since square waves up to 1 MHz must be controlled. As a result, the basic circuitry is also capable of a wide band frequency modulation.

The sine wave is produced by shaping the triangle wave. The triangle wave is fed into a shaping network composed of resistors and diodes with transistor emitter follower biasing circuitry. As the triangle wave passes through zero, loading of the triangle wave is minimal and thus slope is maximum. As the triangle wave voltage increases successively, diodes with current limiting resistors conduct causing the slope of the output to be less. The resultant waveform resembles a sine wave but is pointed at the top. The diodes are biased by transistor emitter followers whose base emitter junctions are opposite in polarity from the diodes. This provides a first order compensation for drifts due to temperature variations. The increase in diode current at the peak of the triangle wave causes a pointed voltage pattern on the collectors of the emitter followers. This pointed waveform is combined out of phase with the somewhat pointed sine wave. The resultant waveform is an almost pure sine wave. The circuitry is completely symmetrical about ground using PNP transistors on one side and NPN transistors on the other. The sine wave produced by shaping is considerably less in amplitude than the triangle wave input and is thus amplified to be equal to the triangle wave.

The triangle wave, sine wave and square wave outputs are resistively divided down to provide fixed 1 volt peak to peak outputs into a 50Ω load. These same waveforms are selected by the amplitude multiplier and three dials.

The three waveforms (triangle, sine and square) are adjusted to appropriate relative amplitudes by resistive networks. One of these waveforms is selected by the function switch which connects it to the amplitude digital to analog converter through a buffer amplifier.

The amplitude D to A converter feeds signal current into the output amplifier summing mode to an extent determined by the digital program. The signal voltage out of the output amplifier is then proportional to the digital program.

The output amplifier output is connected to the output BNC connector through an attenuator which divides the amplifier output by 1, 10 or 100 depending on the amplitude range program.

The output attenuator is designed with a 50Ω output impedance so that when it is operated into a 50Ω load, the output will be the value indicated by the program. When operated into an open circuit, the output will be approximately twice the value indicated by the program.

SECTION V

CALIBRATION

GENERAL INSTRUCTIONS

1. When calibrating the Model 150 instrument (which has no front panel knob controls), and front panel controls are mentioned, disregard and program the Model 150 externally.
2. During instrument calibration, the board being tested is mounted on the extender board, and power is applied to the instrument.

TEST EQUIPMENT

Tektronix 533A with a type W plug-in, or equivalent.

Dekavider, or equivalent.

Four place DVM, or equivalent.

Frequency Counter 727D Computer Measurements Company, or equivalent.

POWER SUPPLY BOARD (Board No. 017-101-63)

IMPORTANT

1. Observe the plus output on pin 1 with a DVM or equivalent and adjust to +6.300 volts with R12.
2. Observe the negative output on pin 2 with a DVM or equivalent and adjust to -6.300 volts with R17.
3. Repeat Steps 2 and 3 several times due to a minor interaction between R12 and R17.

SCHMITT & SWITCH BOARD (Board No. 017-104-63)

1. Monitor the voltage output at pin 7 on the Integrator Board with a Tektronix type W plug-in. (Input attenuator X1 and straight through probe.)
2. Adjust the comparison knob on the W for 2.5 volts offset.
3. Switch the Vc range switch from + to - using the 11.1 range on the W and adjust the triangle waveform for a total of 5 volts peak to peak. R3 will adjust the positive portion of the waveform and R6 will adjust the negative portion.

4. R28 and R30 will be adjusted later in the calibration procedure.

INTEGRATOR AMPLIFIER BOARD (Board No. 017-105-62)

1. There are no adjustments on this board unless the input transistors Q1, Q2, Q3, and Q4 are replaced. Q1, Q4 and Q2, Q3 are matched pairs and should be matched to less than 1% for source current and V_{be} .
2. If these transistors are replaced, the zero offset is set with trim resistor R17 for less than 5 mv. To set zero offset, (1) remove Boards 017-104-63 and 017-106-62; (2) place a 3.3K, 10% resistor from pin 18 to pin 7 and a 0.1 μ f capacitor from pin 18 to ground (pin 11, 12, 13 or 14); (3) observe pin 7 with a DVM or equivalent and select a trim resistor R17 for an output of less than 5 mv.

DIGITAL-TO-ANALOG BOARD (Board No. 017-102-63)

1. Turn the three frequency switches to the remote position. (In the Model 150, program a 000, equivalent to opening the 8-4-2-1 frequency control lines.)
2. With a voltmeter connected to the summing node of the minus amplifier (bussed terminals base of Q1), adjust lower right potentiometer for zero volts.
3. With a voltmeter connected to the top end of R21, adjust R1 to obtain a zero reading less than 1 mv.
4. Connect the voltmeter to the bottom of R21 and adjust lower left potentiometer for zero volts.
5. Connect the voltmeter to the bottom of R38 and adjust R25 for zero reading less than 1 mv.
6. Program a frequency of 900 Hz and adjust R37 so that the positive half cycle length equals the negative half cycle length to within 0.1%. This measurement is made with the counter connected to the 0.5 volt square wave output.
7. Without changing the range, program 090 Hz by turning the most significant decade to the remote (R) position and the other two decade switches to 90. Adjust R25 so that the positive half cycle length equals the negative half cycle. Adjust R15 for a total period of 11.11 msec.
8. Program a frequency of 100 Hz and adjust R46 to obtain a total cycle length of 10.00 msec.

9. Program a frequency of 200 Hz and adjust R51 to obtain a total cycle length of 5.000 msec.
10. Program a frequency of 400 Hz and adjust R55 to obtain a total cycle length of 2.500 msec.
11. Program a frequency of 800 Hz and adjust R59 to obtain a total cycle length of 1.250 msec.
12. Check the frequency decade calibration by programming and measuring various frequencies within one range.

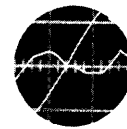
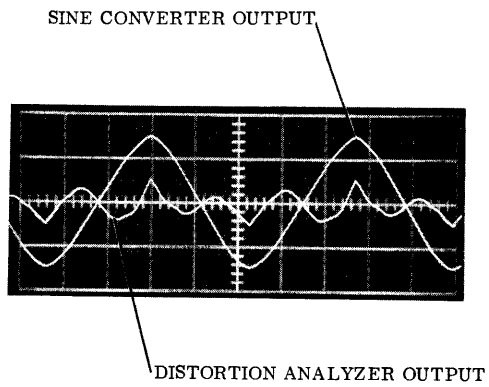
SINE CONVERTER BOARD (Board No. 017-103-61)

1. Set R30, R18 and R6 to the center of their rotation.
2. Set R25 fully CCW, R17 fully CW and R5 fully CW.
3. Set frequency to 9.99 and X100; see Figure 5-3 for waveform with oscilloscope on alternate sweep and external trigger.
4. Adjust R25 until a [?]burble near the axis crossing appears. Center the burble at the axis crossing with R30 (A, Figure 5-3).
5. Adjust R17 and R18 until waveform is as illustrated in A, Figure 5-4.
6. Adjust R5 and R6 until distortion analyzer null starts to flatten (See B, Figure 5-4).
7. Adjust R5 and R6 to smooth peaks.
8. If above steps were done correctly, the distortion should be less than 1%.
9. Tune distortion analyzer for best null and, finally, tune each potentiometer for minimum distortion.

OUTPUT AMPLIFIER BOARD (Board No. 017-119-61)

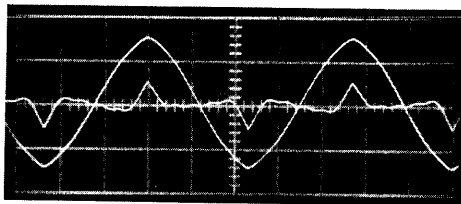
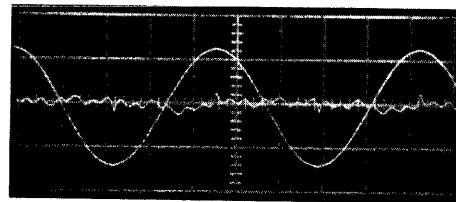
NOTE

In preparation for the adjustments on the output amplifier board, the following adjustments must be made on the Schmitt & Switch Board (017-104-63).

**A**

194-9

Figure 5-3. Sine Converter Board Output Wave Form

**A****B**

194-10

Figure 5-4. Optimum Wave for Sine Converter

1. With the Output Amplifier Board in place and the Schmitt & Switch Board on the extender, connect the probe of the scope with the W plug-in to the upper end of R2 on the Output Amplifier Board. Set the function switch to square wave and adjust R28 on the Schmitt & Switch Board for 5.00 volts peak to peak. Trim R31 for balance about ground.

NOTE

In preparation for the adjustments on the Output Amplifier Board, the following adjustments must be made on the Sine Converter Board (017-103-61).

2. With only the Sine Converter Board on the extender and other boards in place, connect the probe of the scope with the W plug-in to the upper end of R2 on the Output Amplifier Board. Set the function switch to sine wave and adjust R40 for balance about ground. Adjust R41 so that the sine amplitude equals the amplitude of the triangle wave. The two waveforms can be observed by switching the function between sine and triangle. Both waveforms should be 5 volts peak to peak.

NOTE

The remaining adjustments in this section are made with the Output Amplifier Board (017-119-61) on the extender and the other boards in place.

3. Connect an oscilloscope to the amplifier output BNC and terminate the scope end of the connection with a precise 50Ω load. Set the amplitude range to X1.
4. With the function switch on R and the frequency switch set to X.01 and 5.99, connect a voltmeter to the buffer amplifier summing node (TP1). Put enough resistance in series with the voltmeter so that no oscillations appear on the scope (about 5 to 10 K). Adjust R7 for zero volts $\pm 100 \mu\text{v}$.
5. Connect the voltmeter to the output of the buffer amplifier (TP2) and trim R3 or R4 for zero volts $\pm 1 \text{ mv}$. It should not be necessary to retrim R3 or R4 unless some transistors in the buffer amplifier are changed.
6. Place a voltmeter across the 50Ω termination. Set the three amplitude decade switches to remote (this programs a zero amplitude). Set the output amplifier zero potentiometer (R27) for zero on the voltmeter.

7. Program an amplitude of 8.00 and adjust the buffer amplifier zero potentiometer (R7) for zero output. Repeat the adjustment of these two potentiometers at the appropriate amplitude settings until the most significant amplitude switch can be turned through its range (1 through 9) keeping the output within ± 1 mv.
8. Set the function switch to triggered square wave. Set the amplitude decade switches to "R. 90." Check the scope or voltmeter to see that the output is approximately plus one-half volt. If it is approximately zero, turn the frequency range up and back to speed the starting process. If the output is approximately minus one-half volt, press the trigger button and wait for the output to get to the positive state. When the output is in the positive state, set the level to +0.450 volts ± 500 μ v with the buffer amplifier gain potentiometer, R19.
9. Program 1.00 and adjust R57 for +0.500 volt ± 500 μ v.
10. Program 2.00 and adjust R63 for 1.00 volt ± 1 mv.
11. Program 4.00 and adjust R69 for 2.00 volts ± 2 mv.
12. Program 8.00 and adjust R75 for 4.00 volts ± 4 mv.
13. Program an amplitude of 9.99 volts and a frequency of 999 KHz. Set the function switch to square wave and observe the waveform on the scope. Adjust damping capacitor C10 to the desired compromise between risetime and overshoot.

SECTION VI

MAINTENANCE

GENERAL

This section contains maintenance and troubleshooting instructions for the Model 150 and Model 155 instruments. If the generator does not oscillate, perform the following procedures to isolate the cause.

1. Check main fuse.
2. Measure voltage at pins 1 and 2 of the power supply; it should be +6.300 volts and -6.300 volts. Observe that pins 24 and 25 are -24 volts. If proper voltages are not present, troubleshoot the power supply with the aid of the power supply schematic.
3. If the power supplies are normal, turn on generator and remove the Digital to Analog board. If the generator oscillates, then the problem is on the D-A board. If the generator does not oscillate, the problem is on the Schmitt & Switch board or the Integrator board. To troubleshoot the D-A board, remove the Schmitt and Switch board and place the D-A board on the extender board in its proper position in the generator. Turn power on the generator and apply a sine wave or triangle wave from an external generator to pin 20. If the input signal is 4 volts peak to peak, the output of Amplifier No. 1 should be approximately 2.4 volts peak to peak. If this output does not appear, Amplifier No. 1 is inoperative. If the proper output is present at the output of Amplifier No. 1, then check the output of Amplifier No. 2 (pin 4). The output of Amplifier No. 2 should be approximately 2.4 volts peak to peak. If the proper output is not present, the problem is in Amplifier No. 2. Use the D-A schematic diagram in the back of the manual to troubleshoot Amplifiers No. 1 and 2.
4. To troubleshoot the Schmitt and Switch board remove the D-A Board and the Integrator Board. Place the Schmitt and Switch board on the extender board in its proper position in the generator. Apply a 6 volt peak to peak triangle wave from an external generator to pin 7. Observe pin 10 with an oscilloscope. Pin 10 should have a 5 nsec. risetime square wave on it. If it has no output the problem is either in the Schmitt or the four-transistor switch. If there is a square wave present look at pin 9 which should have a 10 nsec. square wave on it. If there is no output, the problem is in the divider network. If there is a square wave on pin 9, apply +2 volts to pin 4 and -2 volts to pin 6 from ground from an external DC power supply. Observe pin 5 on the oscilloscope. Pin 5 should have 4 volts peak to peak square wave on it. If it does not have the proper output, the problem is in the clamp circuit made up of Q13 and Q14. Use the Schmitt and Switch schematic in the back of the manual for troubleshooting.

5. To troubleshoot the Integrator board, remove the Schmitt Board and Range and Trigger board. Jumper a 1K resistor from pin 7 to pin 18. Apply a 5 volt peak to peak triangle wave or a sine wave from an external generator through a 1K resistor to pin 18. This combination will yield an operational amplifier with a gain of one. Observe the output with an oscilloscope; it should be a 5 volt triangle wave. If there is no output, use the Integrator Amplifier schematic to troubleshoot the Amplifier.

NO OUTPUT FROM PROGRAMMED BNC CONNECTOR. (All other outputs performing properly.)

If the generator has the proper output on the fixed triangle, sine and square wave outputs, but no output on the 50 Ω variable output, check the following:

1. Make sure that the **FUNCTION** switch is set on CONT.
2. Make sure that the amplitude **MULTIPLIER** is not in the remote (R) position.
3. If there is still no output, the problem is on the Output Amplifier board. Place the Output Amplifier on the extender board and troubleshoot using the schematic diagram of the Output Amplifier in the back of the manual.

SECTION VII

PARTS LIST

GENERAL

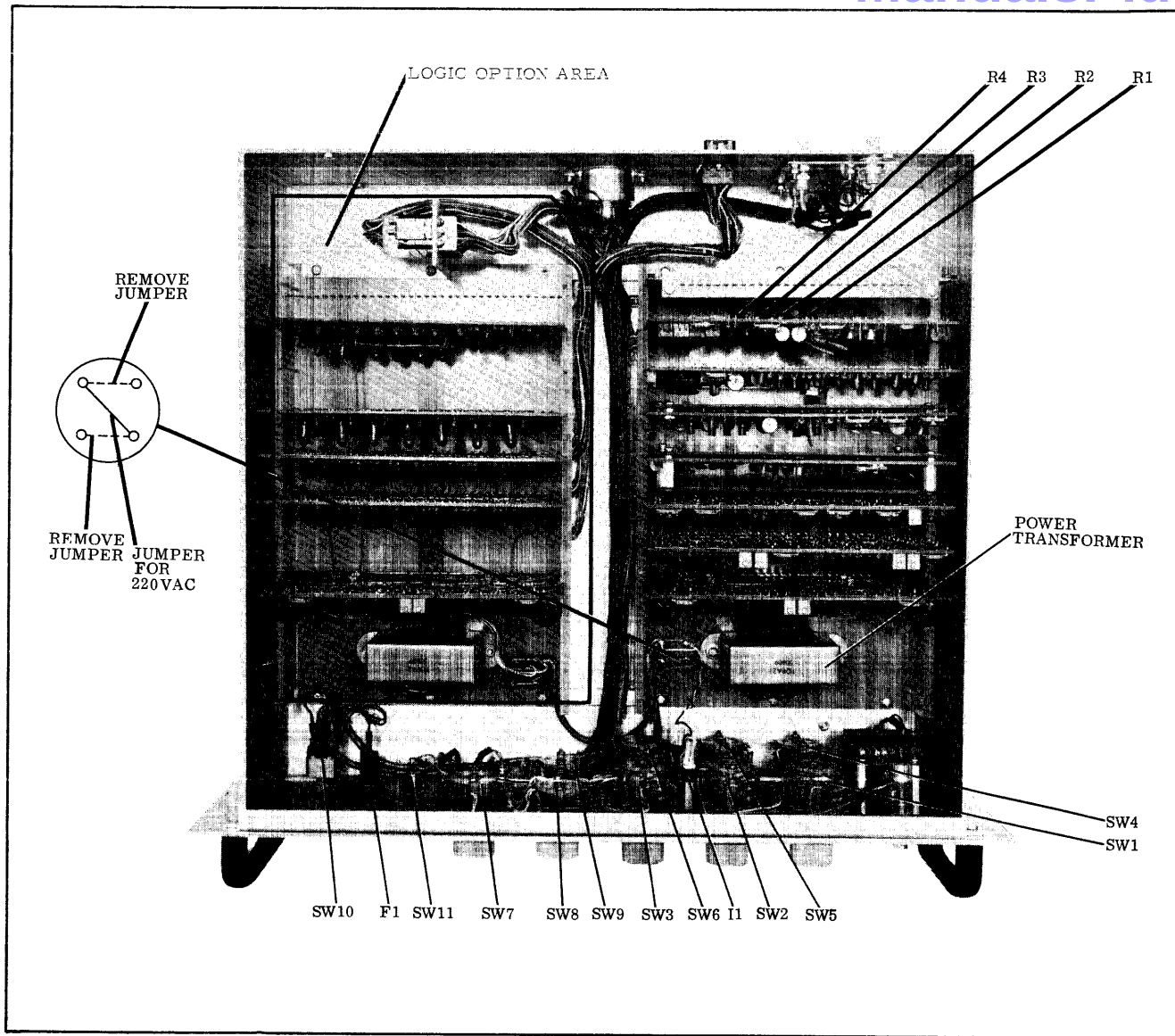
This section contains the list of replaceable electronic parts and assemblies in the equipment; structural items and hardware such as screws and nuts are not included.

PARTS LIST ARRANGEMENT

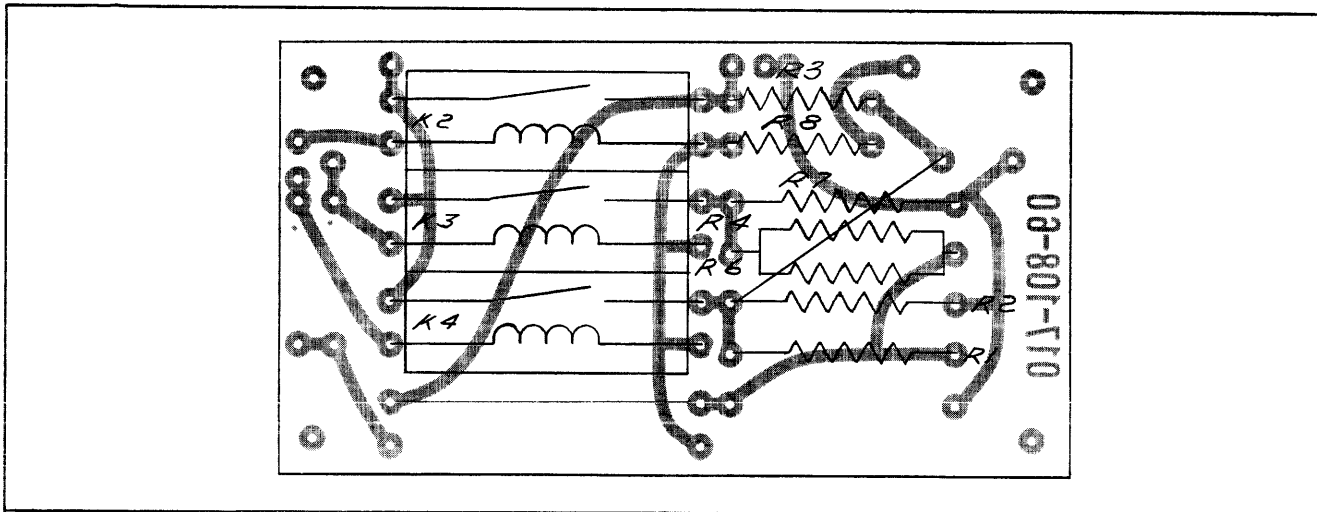
The parts list starts with the Chassis and Front Panel assembly as Figure 7-1 which is followed by Figure 7-2, the Mother Board assembly which, among other components calls out and locates the circuit board assemblies. The remaining illustrations are of circuit board assemblies, and the last illustration is the extender board, which does not have a parts list.

LIST OF MANUFACTURERS

Allen Bradley	Allen Bradley, Milwaukee, Wisconsin
Amphenol	Amphenol Connector Division, Chicago, Illinois
ARCO	Arco Electronics, Great Neck, L.I., New York
Beckman	Beckman Systems Division, Fullerton, California
CDE	Cornell-Dubilier Electronics Division, Newark, New Jersey
CH	Cutler-Hammer Incorporated, Milwaukee, Wisconsin
CRL	Centralab, Division of Globe Union, Milwaukee, Wisconsin
CTS	Chicago Telephone, Pasadena, California
Elco	Elco Corporation, W. Los Angeles, California
Eldema	Eldema Corporation, Compton, California
Electra	Electra Manufacturing Company, Independence, Kansas
Electro Cube	Electro Cube Incorporated, Pasadena, California
Electrol	Electrol Incorporated, Northridge, California
Elpac	Elpac Incorporated, Fullerton, California
Fairchild	Fairchild Semiconductor Corporation, Palo Alto, California
G. E.	General Electric Company, Semiconductor Division, Buffalo, New York
IRC	International Resistance Company, Philadelphia, Pennsylvania
Littelfuse	Littelfuse Incorporated, Des Plaines, Illinois
Miller	J. W. Miller Company, Los Angeles, California
Motorola	Motorola Semiconductor Products, Phoenix, Arizona
Nashville	Nashville Electronics Incorporated, Nashville, Tennessee
RCA	RCA, Semiconductor Division, Somerville, New Jersey
Sprague	Sprague Electric Company, North Adams, Massachusetts
Stackpole	Stackpole Carbon Company, Sant Mary's, Pennsylvania
Switchcraft	Switchcraft Incorporated, Chicago, Illinois
Topaz	Topaz Incorporated, San Diego, California
TRW	TRW Electronics Incorporated, El Segundo, California



Chassis and Front Panel Assembly



Output Attenuator Assembly

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
<u>OUTPUT ATTENUATOR</u>				
R8		RESISTOR, Carbon, 1/2w, 10% 390 Ω	1	Stackpole
R3		RESISTOR, Carbon, 1/2w, 10% 120,000 Ω	1	Stackpole
R4		RESISTOR, Carbon, 1/2w, 10% 4700 Ω	1	Stackpole
R2, R7		RESISTOR, Metal Film, 1/2w, 1% 49.9 Ω	2	IRC
R6		RESISTOR, Metal Film, 1/2w, 1% 499 Ω	1	IRC
R1		RESISTOR, Metal Film, 1/2w, 1% 4.99 Ω	1	IRC
K2, K3, K4	101-2	RELAY	3	Electrol
<u>CHASSIS AND FRONT PANEL</u>				
	017-100-00	MOTHER BOARD	1	Wavetek
	017-108-00	OUTPUT ATTENUATOR	1	Wavetek
	017-302-31	CHASSIS	1	Wavetek
	UG-657/U	BNC	12	Amphenol
	017-301-30	COVER, Bottom	1	Wavetek
	017-303-30	COVER, Top	1	Wavetek
	BH2085W/467	RUBBER FEET	4	Accurate
	UG-657/U	CONNECTOR	6	Amphenol
	CG3R-RCS- 2E-100	INDICATOR, Pilot Lamp	2	Eldema
	3AG3/4aU/L	FUSE, 3/4 amp	1	Littelfuse
	342012	FUSE HOLDER	1	Littelfuse
	017-305-30	KNOB, Main	3	Wavetek
	017-307-30	KNOB, Skirted	6	Wavetek
		RESISTOR, Metal Film, 1/4w, 1% 124 Ω	2	IRC

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
		RESISTOR, Metal Film, 1/4w, 1% 82.5 Ω	2	IRC
	150-SW1A	SWITCH	6	CTS
	150-SW2	SWITCH	1	CTS
	150-SW3	SWITCH	1	CTS
	150-SW4	SWITCH	1	CTS
	7565-K5	SWITCH, DPST	1	CH
	913	SWITCH, Momentary	1	Switchcraft
	50609	TRANSFORMER, Power	1	Topaz

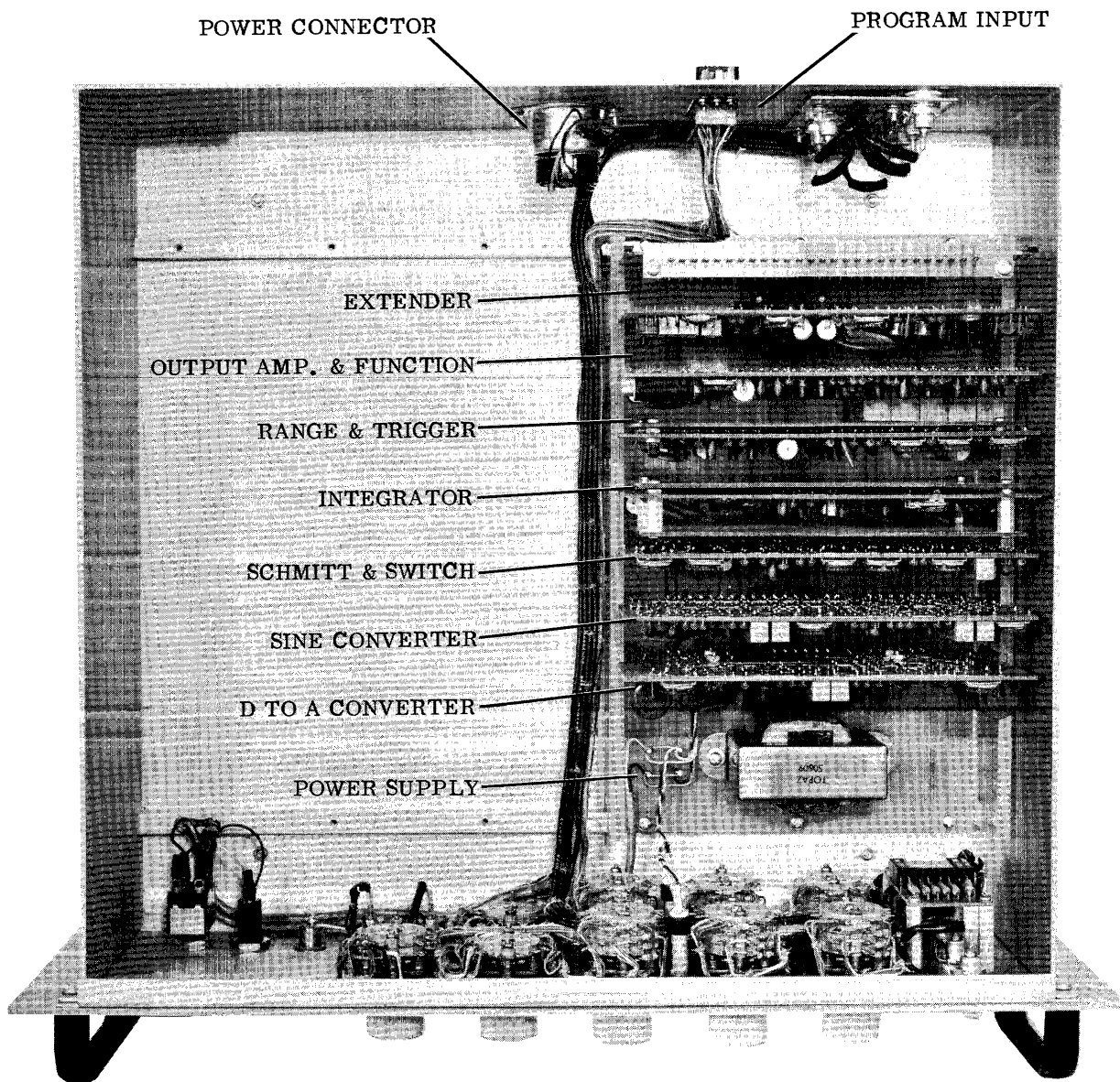


Figure 7-2. Mother Board Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
	017-109-00	EXTENDER	1	Wavetek
	017-102-00	D to A CONVERTER	1	Wavetek
	017-105-00	INTEGRATOR	1	Wavetek
	017-107-00	OUTPUT AMPLIFIER	1	Wavetek
	017-101-00	POWER SUPPLY	1	Wavetek
	017-106-00	RANGE AND TRIGGER	1	Wavetek
	017-104-00	SCHMITT AND SWITCH	1	Wavetek
	017-103-00	SINE CONVERTER	1	Wavetek
	5201.0213	PINS, Connector	150	Elco

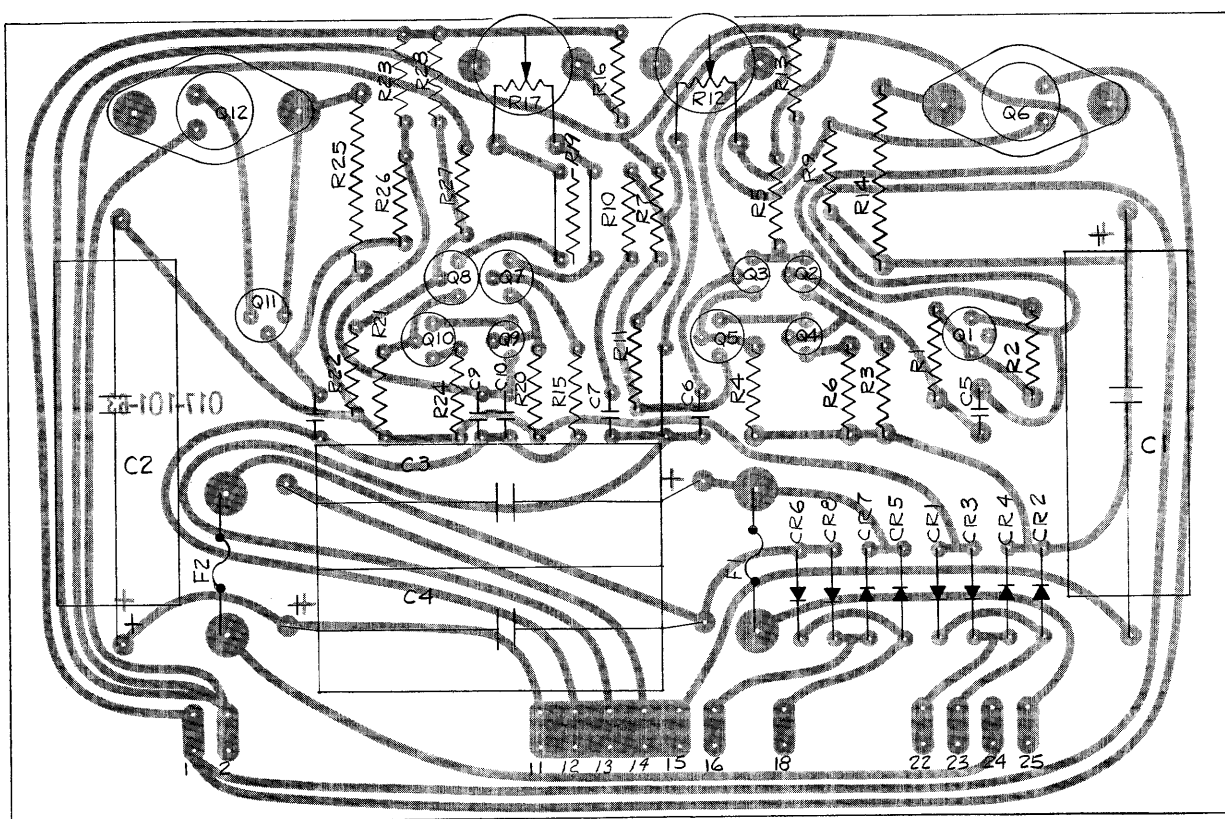


Figure 7-3. Power Supply Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C6	CCD-102	CAPACITOR, 0.001 μ f	1	Arco
C5, C7, C8, C9, C10	HY320	CAPACITOR, 0.1 μ f, 12 volts	5	Sprague
C3, C4	34-750-BP	CAPACITOR, 1000 μ f, at 25DC	2	Nashville
C1, C2	34-750-BP	CAPACITOR, 2000 μ f, at 15DC	2	Nashville
CR1 thru CR8	PS5666	DIODE	8	TRW
R10		RESISTOR, Carbon, 1/2w, 10% 10 Ω	1	Stackpole
R6, R11, R24, R26		RESISTOR, Carbon, 1/2w, 10% 100 Ω	4	Stackpole
R5, R7, R23		RESISTOR, Carbon, 1/2w, 10% 2200 Ω	3	Stackpole
R3, R21		RESISTOR, Carbon, 1/2w, 10% 2700 Ω	2	Stackpole
R4, R9, R16, R20		RESISTOR, Carbon, 1/2w, 10% 3900 Ω	4	Stackpole
R19		RESISTOR, Carbon, 1/2w, 10% 270 Ω	1	Stackpole
R22		RESISTOR, Carbon, 1/2w, 10% 820,000 Ω	1	Stackpole
R8, R25		RESISTOR, Carbon, 5w, 10% 10 Ω	2	IRC
R1	RN60D	RESISTOR, Metal Film, 1/4w, 1% 100 Ω	1	Electra
R15		RESISTOR, Metal Film, 1/4w, 1% 511 Ω	1	Electra
R27, R28		RESISTOR, Metal Film, 1/4w, 1% 1100 Ω	2	Electra
R2, R13		RESISTOR, Metal Film, 1/4w, 1% 2870 Ω	2	Electra
R12, R17	U201-250	RESISTOR, Variable, 250 Ω	2	CTS

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
Q2, Q3, Q4, Q9	2N3605	TRANSISTOR	4	G. E.
Q1, Q5, Q7, Q8, Q10, Q11	2N3638	TRANSISTOR	6	Fairchild
Q12	2N3740	TRANSISTOR	1	Motorola
Q6	40250	TRANSISTOR	1	RCA

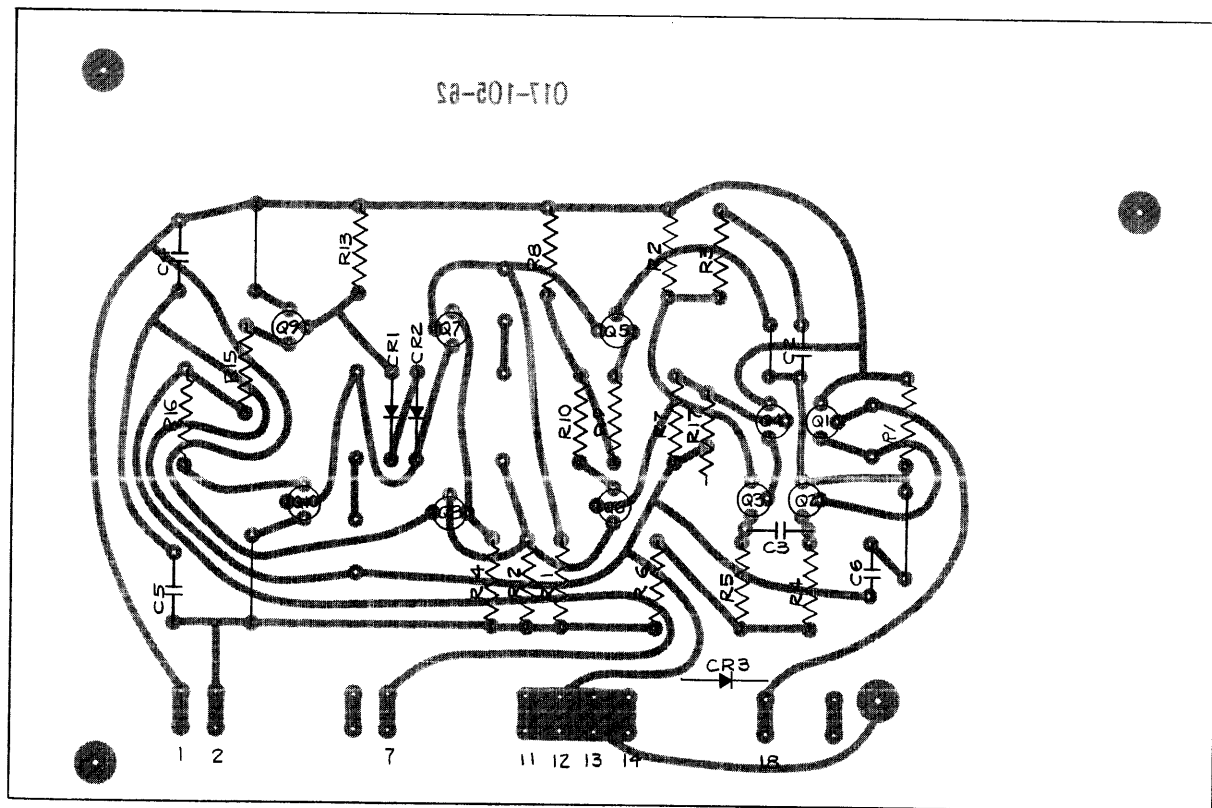


Figure 7-4. Integrator Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C4, C5	HY330	CAPACITOR, 0.47 μ v, 12 volts	2	Sprague
C3	DD-471	CAPACITOR, 470 pf, 1 Kv, 10%	1	CRL
C2	DD-331	CAPACITOR, 330 pf, 1 Kv, 10%	1	CRL
C1	DD-101	CAPACITOR, 100 pf, 1 Kv, 10%	1	CRL
C6	DD-220	CAPACITOR, 22 pf, 1 Kv, 10%	1	CRL
CR1, CR2, CR3	1N4009	DIODE	3	G. E.
R15, R16		RESISTOR, Carbon, 1/2w, 10% 15 Ω	2	Stackpole
R3, R14		RESISTOR, Carbon, 1/2w, 10% 100 Ω	2	Stackpole
R13		RESISTOR, Carbon, 1/2w, 10% 1000 Ω	1	Stackpole
R8		RESISTOR, Carbon, 1/2w, 5% 3000 Ω	1	Stackpole
R7		RESISTOR, Carbon, 1/2w, 5% 3300 Ω	1	Stackpole
R9, R10	RN60D	RESISTOR, Metal Film, 1/4w, 1% 100 Ω	2	Electra
R4, R5	RN60D	RESISTOR, Metal Film, 1/4w, 1% 1000 Ω	2	Electra
R11, R12	RN60D	RESISTOR, Metal Film, 1/4w, 1% 3830 Ω	2	Electra
R6	RN60D	RESISTOR, Metal Film, 1/4w, 1% 46400 Ω	1	Electra
R1, R2	RN60D	RESISTOR, Metal Film, 1/4w, 1% 110,000 Ω	2	Electra
Q5, Q6, Q10	2N3640	TRANSISTOR	3	Fairchild

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
Q7, Q8, Q9	2N3646	TRANSISTOR	3	Fairchild
Q1, Q2, Q3, Q4	2N3856	TRANSISTOR	4	G. E.

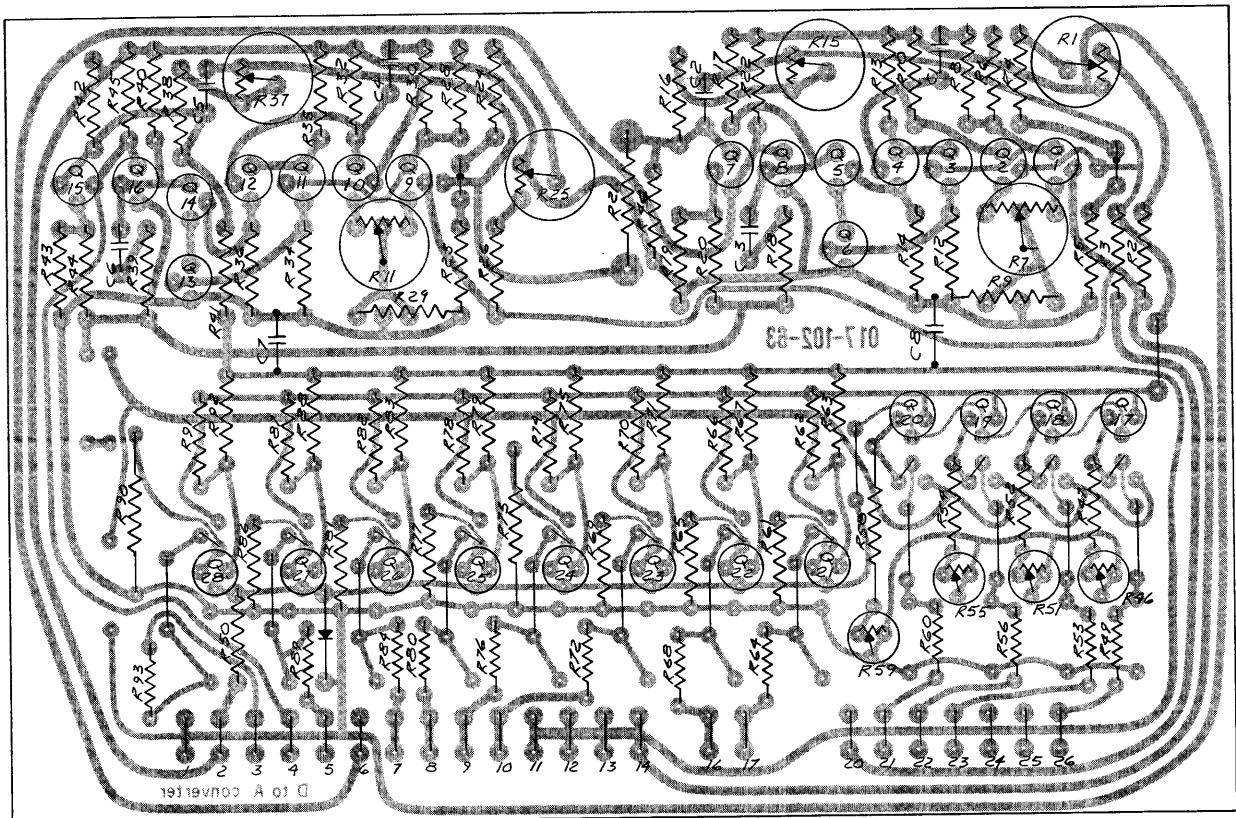


Figure 7-5. Reverse Logic D to A Converter Assembly

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C2, C5	DD-470	CAPACITOR, 47 pf, 1 Kv	2	CRL
C3, C6	DD-471	CAPACITOR, 470 pf, 1 Kv	2	CRL
C1, C4	CK-103	CAPACITOR, 0.01 μ f, 50 volts	2	CRL
CR1	1N751	DIODE	1	TRW
CR2	1N4009	DIODE	1	Motorola
R8, R30		RESISTOR, Carbon, 1/2w, 10% 33 Ω	2	Stackpole
R2, R26		RESISTOR, Carbon, 1/2w, 10% 100 Ω	2	Stackpole
R18, R39		RESISTOR, Carbon, 1/2w, 10% 220 Ω	2	Stackpole
R22, R45, R49, R90, R96, R102, R108		RESISTOR, Carbon, 1/2w, 10% 1000 Ω	7	Stackpole
R12, R34		RESISTOR, Carbon, 1/2w, 10% 1500 Ω	2	Stackpole
R13, R14, R35, R63		RESISTOR, Carbon, 1/2w, 10% 2200 Ω	4	Stackpole
R19, R43		RESISTOR, Carbon, 1/2w, 10% 2400 Ω	2	Stackpole
R14, R36		RESISTOR, Carbon, 1/2w, 10% 3300 Ω	2	Stackpole
R41		RESISTOR, Carbon, 1/2w, 10% 5600 Ω	1	Stackpole
R17, R40		RESISTOR, Carbon, 1/2w, 10% 6800 Ω	2	Stackpole
R20, R44		RESISTOR, Carbon, 1/2w, 10% 12,000 Ω	2	Stackpole
R4, R5, R23, R24		RESISTOR, Carbon, 1/2w, 10% 15,000 Ω	4	Stackpole

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R9, R29		RESISTOR, Carbon, 1/2w, 10% 27,000 Ω	2	Stackpole
R6, R10, R28, R32		RESISTOR, Carbon, 1/2w, 10% 47,000 Ω	4	Stackpole
R42, R89, R95, R101, R107, R111		RESISTOR, Carbon, 1/2w, 10% 100,000 Ω	6	Stackpole
R48, R53, R57, R61, R67, R73, R79, R85, R91, R97, R103, R109		RESISTOR, Carbon, 1/4w, 10% 1000 Ω	12	Stackpole
R50, R54, R58, R62, R68, R74, R80, R86, R92, R98, R104, R110		RESISTOR, Carbon, 1/4w, 10% 10,000 Ω	12	Stackpole
R66, R72, R78, R84		RESISTOR, Metal Film, 1/4w, 1% 1100 Ω	4	IRC
R38		RESISTOR, Metal Film, 1/4w, 1% 2870 Ω	1	IRC
R21		RESISTOR, Metal Film, 1/4w, 1% 3010 Ω	1	IRC
R16		RESISTOR, Metal Film, 1/4w, 1% 5760 Ω	1	IRC
R60, R82, R106		RESISTOR, Metal Film, 1/4w, 1% 9530 Ω	3	IRC
R3, R65, R71, R77, R83		RESISTOR, Metal Film, 1/4w, 1% 10,000 Ω	5	IRC
R56, R76, R100		RESISTOR, Metal Film, 1/4w, 1% 19,100 Ω	3	IRC
R52, R70, R94		RESISTOR, Metal Film, 1/4w, 1% 38,300 Ω	3	IRC
R47, R64, R88		RESISTOR, Metal Film, 1/4w, 1% 76,800 Ω	3	IRC
R37, R7, R11	FR-251M	RESISTOR, Variable, 250 Ω	3	Allen- Bradley

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R1, R25	FR-252M	RESISTOR, Variable, 2500 Ω	2	Allen- Bradley
R15	62P-R500	RESISTOR, Variable, 500 Ω	1	Beckman
R55	62P-R1K	RESISTOR, Variable, 1000 Ω	1	Beckman
R51	62P-R2K	RESISTOR, Variable, 2000 Ω	1	Beckman
R59	FR-501M	RESISTOR, Variable, 500 Ω	1	Allen- Bradley
R46	62P-R5K	RESISTOR, Variable, 5000 Ω	1	Beckman
Q6, Q13, Q14, Q15, Q18, Q20, Q22, Q24, Q26, Q28, Q30, Q32, Q34, Q36, Q38, Q40, Q42	2N3646	TRANSISTOR	17	Fairchild
Q2, Q3, Q10, Q17	2N3903	TRANSISTOR	4	Motorola
Q1, Q11, Q12, Q19, Q21, Q23, Q25, Q27, Q29, Q31, Q33, Q35, Q37, Q39, Q41	2N3905	TRANSISTOR	15	Motorola
Q4, Q7, Q8, Q9, Q16	2N3640	TRANSISTOR	5	Fairchild

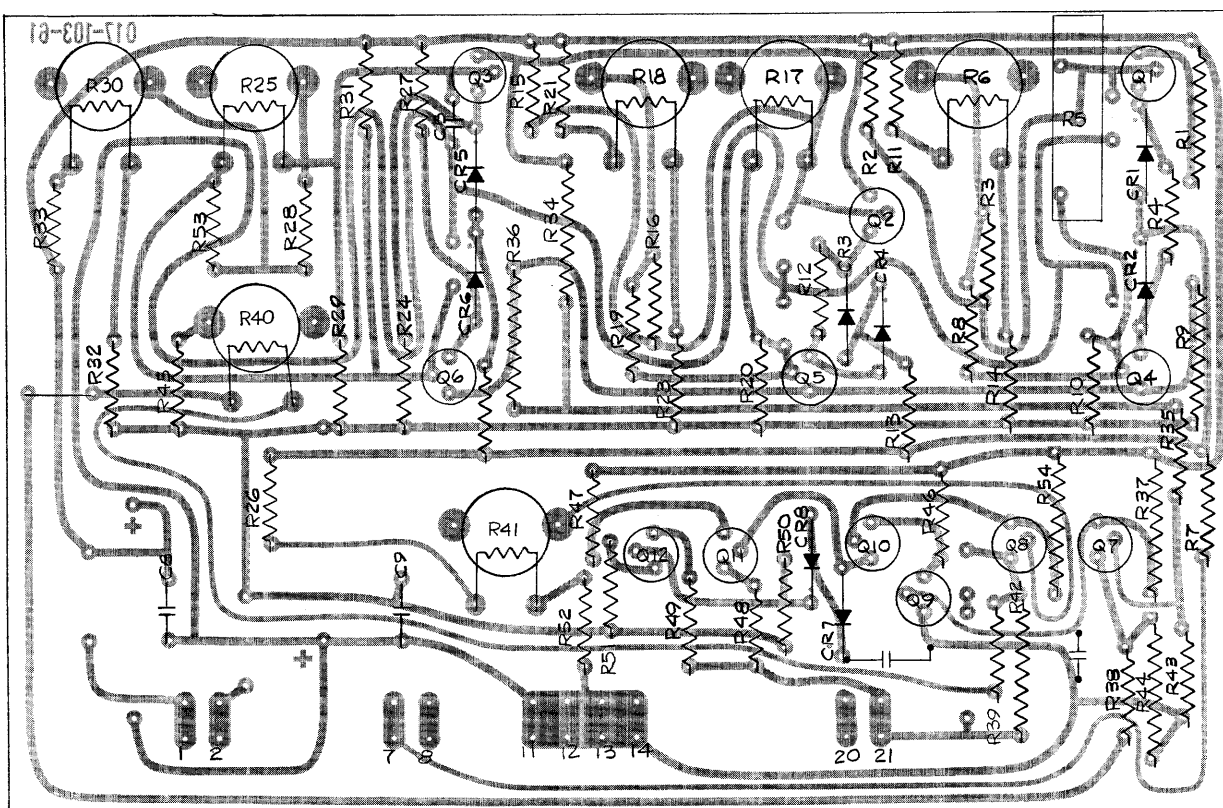
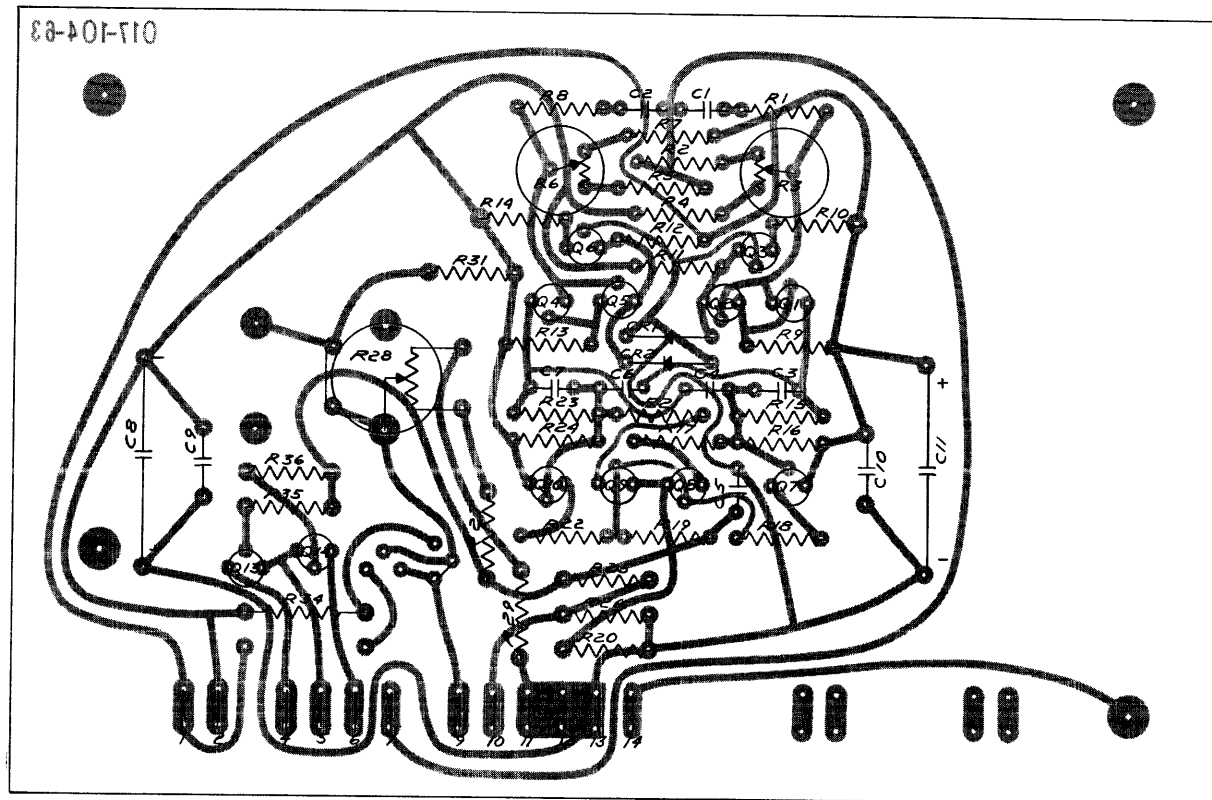


Figure 7-6. Sine Converter Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C8, C9	HY320	CAPACITOR, 0.1 μ f	2	Sprague
C12	DD-220	CAPACITOR, 22 pf	1	CRL
C13	DD-680	CAPACITOR, 68 pf	1	CRL
CR1 thru CR8	1N4009	DIODES	8	G. E.
R48, R49		RESISTOR, Carbon, 1/2w, 10% 15 Ω	2	Stackpole
R47, R51		RESISTOR, Carbon, 1/2w, 10% 47 Ω	2	Stackpole
R43, R46		RESISTOR, Carbon, 1/2w, 10% 180 Ω	2	Stackpole
R12, R28, R53		RESISTOR, Carbon, 1/2w, 10% 570 Ω	3	Stackpole
R38, R39		RESISTOR, Carbon, 1/2w, 10% 910 Ω	2	Stackpole
R4, R7, R13, R35		RESISTOR, Carbon, 1/2w, 10% 1000 Ω	4	Stackpole
R22		RESISTOR, Carbon, 1/2w, 10% 1500 Ω	1	Stackpole
R16, R19		RESISTOR, Carbon, 1/2w, 10% 1800 Ω	2	Stackpole
R11, R14, R21, R23		RESISTOR, Carbon, 1/2w, 10% 2200 Ω	4	Stackpole
R50		RESISTOR, Carbon, 1/2w, 10% 2700 Ω	1	Stackpole
R52		RESISTOR, Carbon, 1/2w, 10% 2400 Ω	1	Stackpole
R3, R8, R32, R33		RESISTOR, Carbon, 1/2w, 10% 3300 Ω	4	Stackpole
R2, R10, R15, R20, R24, R27, R29, R31		RESISTOR, Carbon, 1/2w, 10% 4700 Ω	8	Stackpole

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R26		RESISTOR, Carbon, 1/2w, 10% 5600 Ω	1	Stackpole
R45		RESISTOR, Selected Value	1	
R1, R9	CEC-TO	RESISTOR, Metal Film, 1/2w, 1% 316 Ω	2	IRC
R34, R36	CEC-TO	RESISTOR, Metal Film, 1/2w, 1% 1000 Ω	2	IRC
R37, R42, R44, R54	CEC-TO	RESISTOR, Metal Film, 1/2w, 1% 10,000 Ω	4	IRC
R40	U201-250	RESISTOR, Variable, 250 Ω	1	CTS
R6, R18, R30	U201-500	RESISTOR, Variable, 500 Ω	3	CTS
R41	U201-1K	RESISTOR, Variable, 1000 Ω	1	CTS
R17, R25	U201-5K	RESISTOR, Variable, 5000 Ω	2	CTS
R5	75PR5K	RESISTOR, Variable, 5000 Ω	1	Beckman
Q7, Q8	2N3646	TRANSISTOR, Matched Pair	2	Fairchild
Q9, Q10	2N3640	TRANSISTOR, Matched Pair	2	Fairchild
Q4, Q5, Q6, Q12	2N3640	TRANSISTOR	4	Fairchild
Q1, Q2, Q3, Q11	2N3646	TRANSISTOR	4	Fairchild



CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C8, C11	TL-1135	CAPACITOR, 100 μ fd, 12 volts	2	Sprague
C9, C10	HY-330	CAPACITOR, 0.47 μ fd, 12 volts	2	Sprague
C1, C2	DD-221	CAPACITOR, 220 pf, 1 K, 10%	2	CRL
C4, C6	DD-470	CAPACITOR, 47 pf	2	CRL
C3, C7	DD-220	CAPACITOR, 22 pf	2	CRL
C5	DD-100	CAPACITOR, 10 pf	1	CRL
CR1, CR2	1N4009	DIODE	2	G. E.
R18, R22		RESISTOR, Carbon, 1/2w, 10% 10 Ω	2	Stackpole
R17, R21		RESISTOR, Carbon, 1/2w, 10% 47 Ω	2	Stackpole
R19		RESISTOR, Carbon, 1/2w, 5% 62 Ω	1	Stackpole
R10, R14		RESISTOR, Carbon, 1/2w, 10% 470 Ω	2	Stackpole
R16, R24		RESISTOR, Carbon, 1/2w, 10% 560 Ω	2	Stackpole
R1, R8		RESISTOR, Carbon, 1/2w, 10% 750 Ω	2	Stackpole
R20		RESISTOR, Carbon, 1/2w, 10% 820 Ω	1	Stackpole
R15, R23		RESISTOR, Carbon, 1/2w, 10% 1000 Ω	2	Stackpole
R35, R36		RESISTOR, Carbon, 1/2w, 10% 2200 Ω	2	Stackpole
R9, R13		RESISTOR, Carbon, 1/2w, 10% 3300 Ω	2	Stackpole
R11, R12		RESISTOR, Carbon, 1/2w, 10% 4700 Ω	2	Stackpole

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R34		RESISTOR, Carbon, 1/2w, 10% 100,000 Ω	1	Stackpole
R26	RN60D	RESISTOR, Metal Film, 1/4w, 1% 54.9 Ω	1	Electra
R25	RN60D	RESISTOR, Metal Film, 1/4w, 1% 499 Ω	1	Electra
R27	RN60D	RESISTOR, Metal Film, 1/4w, 1% 511 Ω	1	Electra
R2, R5	RN60D	RESISTOR, Metal Film, 1/4w, 1% 825 Ω	2	Electra
R4, R7	RN60D	RESISTOR, Metal Film, 1/4w, 1% 2000 Ω	2	Electra
R29	RN60D	RESISTOR, Metal Film, 1/4w, 1% 1620 Ω	1	Electra
R31		RESISTOR, Selected Value	1	
Q1, Q5, Q6, Q7, Q9, Q14	2N3640	TRANSISTOR	6	Fairchild
Q2, Q3, Q4, Q8, Q10	2N3646	TRANSISTOR	5	Fairchild
Q13	2N3903	TRANSISTOR	1	Motorola
R3, R6	FR251M	RESISTOR, Variable, 250 Ω	2	Allen- Bradley
R28	U201-250	RESISTOR, Variable, 250 Ω	1	CTS

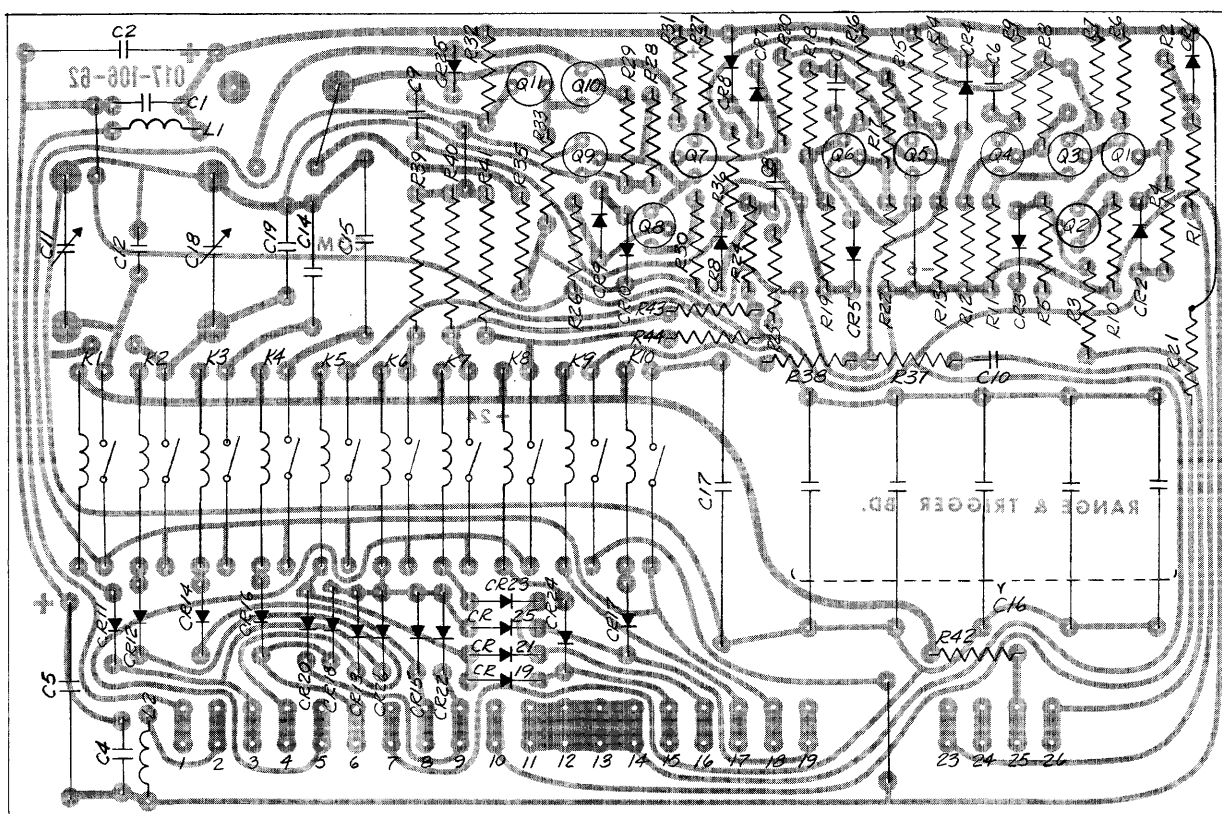


Figure 7-8. Range and Trigger Assembly.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
C14	WMF1S1	CAPACITOR, 0.01 μ f, 1%	1	CDE
C15	1PJ-104F	CAPACITOR, 0.1 μ f, 1%	1	Arco
C17	210B1C105F	CAPACITOR, 1 μ f, 1%	1	Electro- Cube
C16	ZX3022	CAPACITOR, 10 μ f, (2 μ f x 5)	1(5)	Elpac
C7	DD-300	CAPACITOR, 30 pf disc	1	CRL
C12, C13	DM15-680J	CAPACITOR, 68 pf, Silvermica	2	Arco
C6	DD-331	CAPACITOR, 330 pf disc	1	CRL
C19	DD-911	CAPACITOR, 910 pf, Silvermica	1	Arco
C1, C4	HY330	CAPACITOR, 0.47 disc	2	Sprague
C2, C5	TL1135	CAPACITOR, 100 μ f, 12 volts	2	Sprague
C11, C18	825 AZ	CAPACITOR, Variable, 4-5-25 pf	2	CRL
C8	DD-300	CAPACITOR, 30 pf	1	CRL
C10, C9	DD-470	CAPACITOR, 47 pf	2	CRL
L1, L2	9210-70	CHOKES, 75 μ h,	2	Miller
CR1 thru CR10, CR27	1N4009	DIODE	11	G. E.
CR11 thru CR26	PS5666	DIODE	16	TRW
R29		RESISTOR, Carbon, 1/2w, 10% 47 Ω	1	Allen- Bradley
R27		RESISTOR, Carbon, 1/2w, 10% 150 Ω	1	Allen- Bradley
R42		RESISTOR, Carbon, 1/2w, 10% 220 Ω	1	Allen- Bradley

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R30		RESISTOR, Carbon, 1/2w, 10% 270 Ω	1	Allen- Bradley
R7, R15		RESISTOR, Carbon, 1/2w, 10% 820 Ω	2	Allen- Bradley
R1, R16, R31, R32, R33		RESISTOR, Carbon, 1/2w, 10% 1000 Ω	5	Allen- Bradley
R9, R11		RESISTOR, Carbon, 1/2w, 10% 1500 Ω	2	Allen- Bradley
R20, R28, R38		RESISTOR, Carbon, 1/2w, 10% 1800 Ω	3	Allen- Bradley
R3, R5, R10		RESISTOR, Carbon, 1/2w, 10% 2200 Ω	3	Allen- Bradley
R43, R44		RESISTOR, Carbon, 1/2w, 10% 3300 Ω	2	Allen- Bradley
R4, R26, R37		RESISTOR, Carbon, 1/2w, 10% 4700 Ω	3	Allen- Bradley
R8		RESISTOR, Carbon, 1/2w, 10% 5600 Ω	1	Allen- Bradley
R6, R17, R18, R35		RESISTOR, Carbon, 1/2w, 10% 10,000 Ω	4	Allen- Bradley
R14, R36		RESISTOR, Carbon, 1/2w, 10% 15,000 Ω	2	Allen- Bradley
R19, R24		RESISTOR, Carbon, 1/2w, 10% 22,000 Ω	2	Allen- Bradley
R12, R23, R25		RESISTOR, Carbon, 1/2w, 10% 33,000 Ω	3	Allen- Bradley
R21		RESISTOR, Carbon, 1/2w, 10% 1 Meg.	1	Allen- Bradley
R13		RESISTOR, Carbon, 1/2w, 10% 220,000 Ω	1	Allen- Bradley
R2		RESISTOR, Carbon, 1/2w, 10% 2700 Ω	1	Allen- Bradley
R39	CEC-TO	RESISTOR, Metal Film, 1/4w, 1% 3010 Ω	1	IRC

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY.	MFR.
R40	CEC-TO	RESISTOR, Metal Film, 1/4w, 1% 30,100 Ω	1	IRC
R41	CEC-TO	RESISTOR, Metal Film, 1/4w, 1% 301,000 Ω	1	IRC
Q9	2N3563	TRANSISTOR	1	Fairchild
Q1, Q3, Q4, Q5, Q6, Q8, Q10, Q11	2N3605	TRANSISTOR	8	G. E.
Q2, Q7	2N3640	TRANSISTOR	2	Fairchild
K1 thru K10	101-2	RELAY	10	Electrol

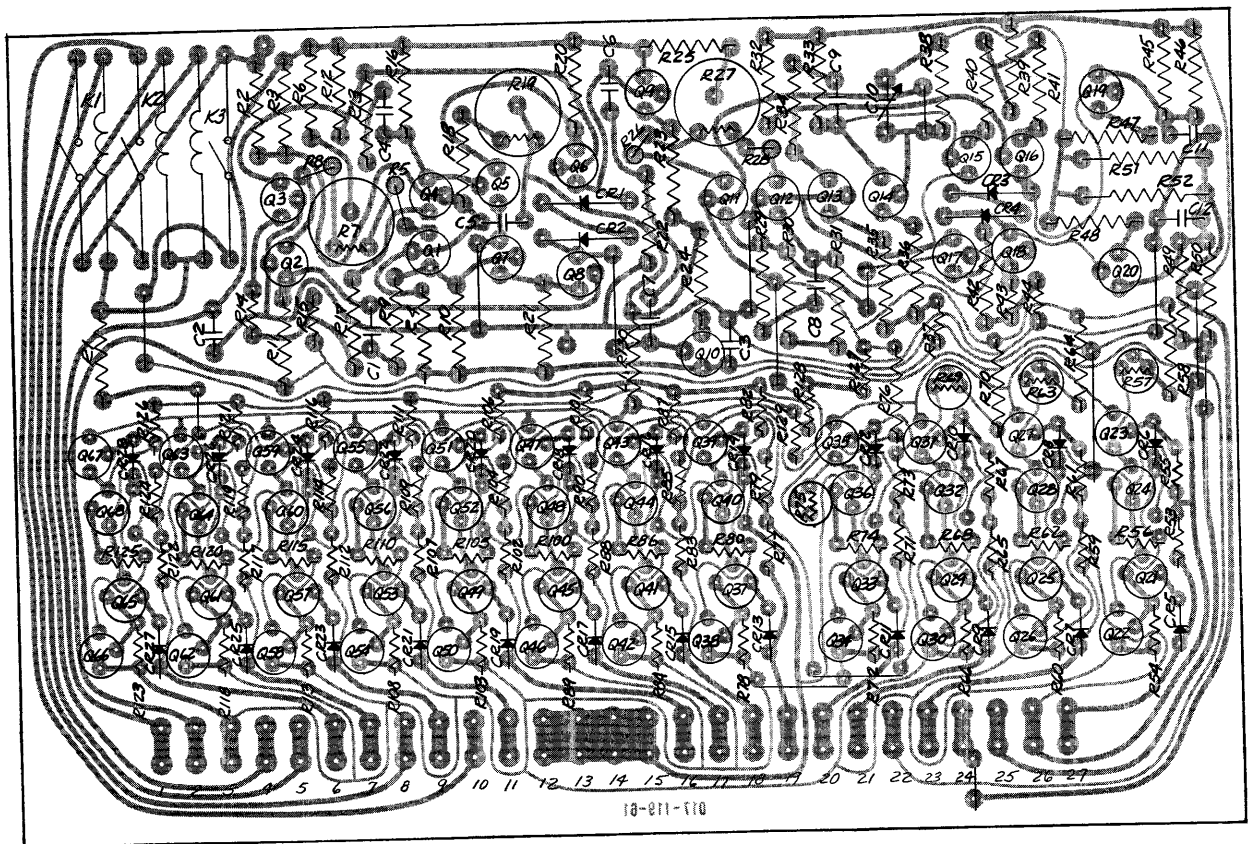


Figure 7-9. Output Amplifier and Function Assembly

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY	MFR
R23, R24, R47, R48	RC20GF150K	RESISTOR, Carbon, 1/2w, 10% 15 Ω	4	Stackpole
R22, R40, R41, R42, R43, R45, R46, R49, R50	RC20GF470K	RESISTOR, Carbon, 1/2w, 10% 47 Ω	9	Stackpole
R5, R8, R26, R28	RC20GF750K	RESISTOR, Carbon, 1/2w, 10% 75 Ω	4	Stackpole
R14, R17, R35, R36	RC20GF121K	RESISTOR, Carbon, 1/2w, 10% 120 Ω	4	Stackpole
R20, R21	RC20GF151K	RESISTOR, Carbon, 1/2w, 10% 150 Ω	2	Stackpole
R1	RC20GF681K	RESISTOR, Carbon, 1/2w, 10% 680 Ω	1	Stackpole
R9, R13, R29, R34, R39, R44	RC20GF102K	RESISTOR, Carbon, 1/2w, 1 % 1000 Ω	6	Stackpole
R6, R10, R11, R12, R15, R16	RC20GF272K	RESISTOR, Carbon, 1/2w, 10% 2700 Ω	6	Stackpole
R25, R37, R56, R62, R68, R74, R80, R86, R100, R105, R111, R115, R120, R125	RC20GF562K	RESISTOR, Carbon, 1/2w, 10% 5600 Ω	14	Stackpole
R54, R60, R66, R72, R78, R84, R85, R103, R108, R113, R118, R123	RC20GF103K	RESISTOR, Carbon, 1/2w, 10% 10,000 Ω	12	Stackpole
R30, R31, R32, R33, R53, R55, R59, R61, R65, R67, R71, R73, R77, R79, R83, R85, R88, R90, R102, R104, R107, R109, R112, R114, R117, R119, R122, R124	RC20GF223K	RESISTOR, Carbon, 1/2w, 10% 22,000 Ω	28	Stackpole

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY	MFR
R51, R52	RN65D	RESISTOR, Metal Film, 1/2w, 1% 100 Ω	2	Corning
R76, R106, R126	RN60D	RESISTOR, Metal Film, 1/4w, 1% 976 Ω	3	Corning
R2, R18	RN60D	RESISTOR, Metal Film, 1/4w, 1% 1000 Ω	2	Corning
R70, R101, R121	RN60D	RESISTOR, Metal Film, 1/4w, 1% 1960 Ω	3	Corning
R38	RN60D	RESISTOR, Metal Film, 1/4w, 1% 3010 Ω	1	Corning
R64, R87, R116	RN60D	RESISTOR, Metal Film, 1/4w, 1% 3920 Ω	3	Corning
R58, R82, R111	RN60D	RESISTOR, Metal Film, 1/4w, 1% 7870 Ω	3	Corning
R27, R75	62PR50	RESISTOR, Variable, 50 Ω	2	Beckman
R69	62PR100	RESISTOR, Variable, 100 Ω	1	Beckman
R63	62PR200 Ω	RESISTOR, Variable, 200 Ω	1	Beckman
R57	62PR500	RESISTOR, Variable, 500 Ω	1	Beckman
R7	FR101M	RESISTOR, Variable, 100 Ω	1	Allen- Bradley
R19	FR251M	RESISTOR, Variable, 250 Ω	1	Allen- Bradley
C8, C9	DD050	CAPACITOR, 5 pf	2	CRL
C1, C4, C6, C7	DD220	CAPACITOR, 22 pf	4	CRL
C5	DD100	CAPACITOR, 10 pf	1	CRL
C11, C12	CK103	CAPACITOR, 0.01 μ f	2	CRL
C2, C3	UK10-104	CAPACITOR, 0.1 μ f, 10 volts	2	CRL

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY	MFR
C10	538-011- COPO-92R	CAPACITOR, Variable, 5.5 - 18 pf	1	Erie
CR1 thru CR28	FD6666	DIODE	28	Fairchild
Q23, Q27, Q31, Q35, Q39, Q43, Q47, Q51, Q55, Q59, Q63, Q67	2N2714	TRANSISTOR	12	G. E.
Q19	2N2959	TRANSISTOR	1	Motorola
Q20	2N3134	TRANSISTOR	1	Motorola
Q1, Q2, Q5, Q6, Q10, Q21, Q24, Q25, Q28, Q29, Q32, Q33, Q36, Q37, Q40, Q41, Q44, Q45, Q48, Q49, Q52, Q53, Q56, Q57, Q60, Q61, Q64, Q65, Q68	2N3640	TRANSISTOR	29	Fairchild
Q22, Q26, Q30, Q34, Q38, Q42, Q46, Q50, Q54, Q58, Q62, Q66	2N3646	TRANSISTOR	12	Fairchild
Q3, Q4, Q7, Q8, Q9	2N3563	TRANSISTOR	5	Fairchild
Q13, Q14, Q17, Q18	2N3903	TRANSISTOR	4	Motorola
Q11, Q12, Q15, Q16	2N3905	TRANSISTOR	4	Motorola
K1, K2, K3	101-2	RELAY	3	Electro
	NF-207	HEAT SINK	2	Wakefield
	017-119-61	BOARD, Printed Circuit	1	Wavetek

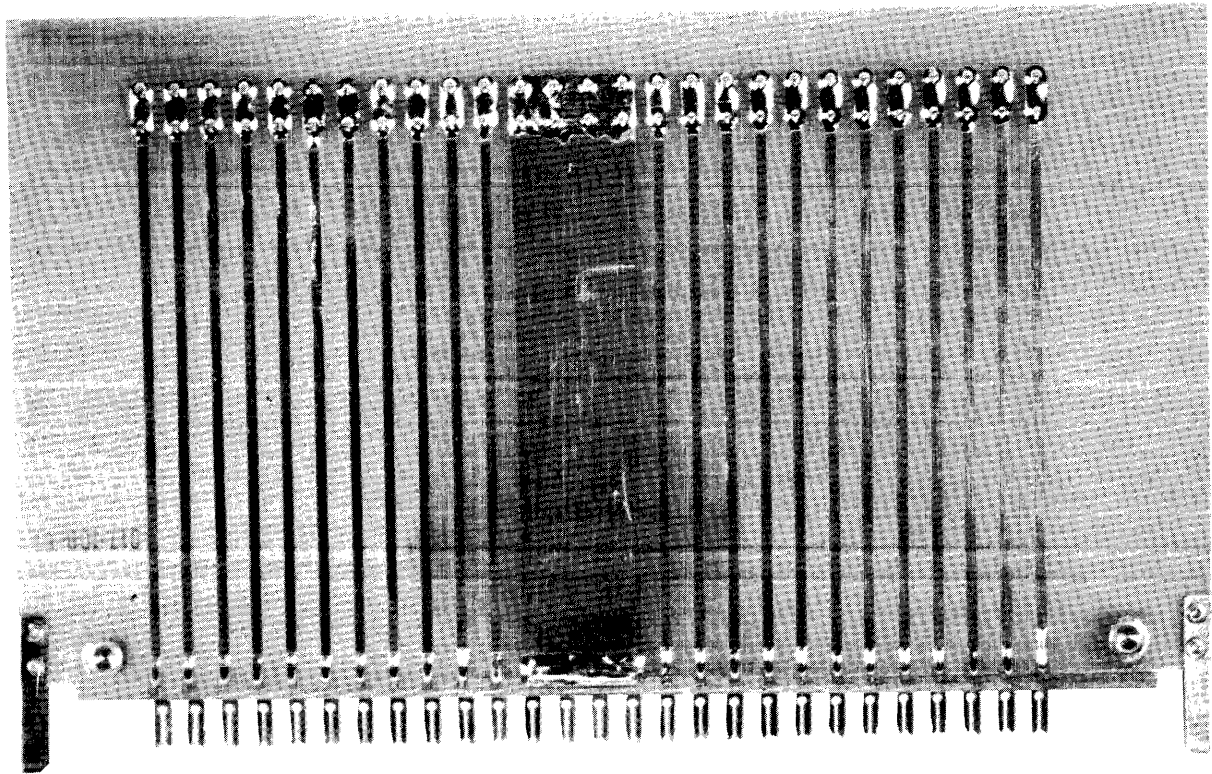
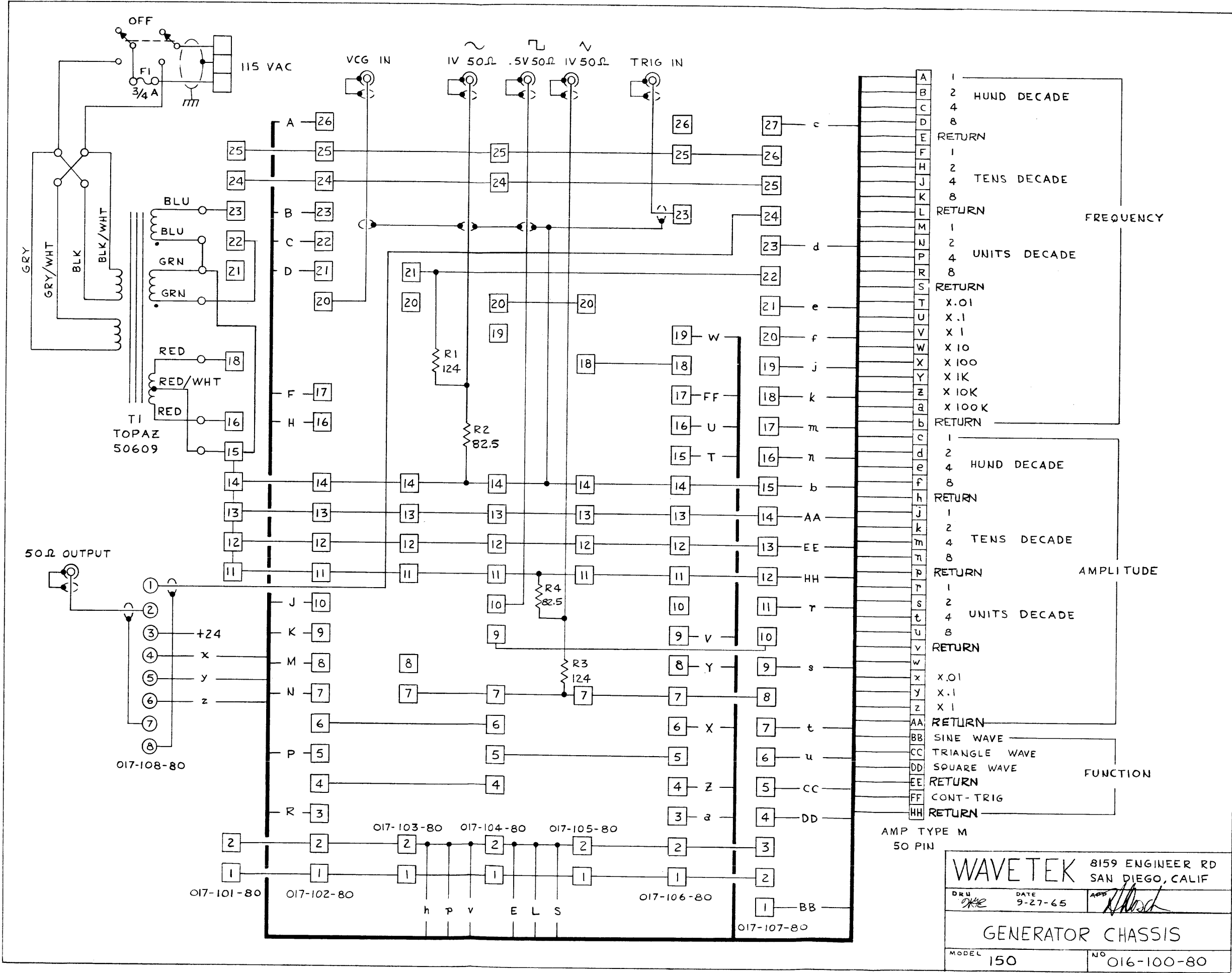


Figure 7-10. Extender Board.

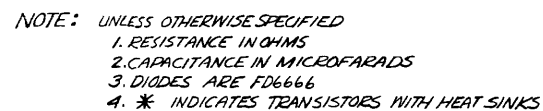
SECTION VIII
SCHEMATIC DIAGRAMS



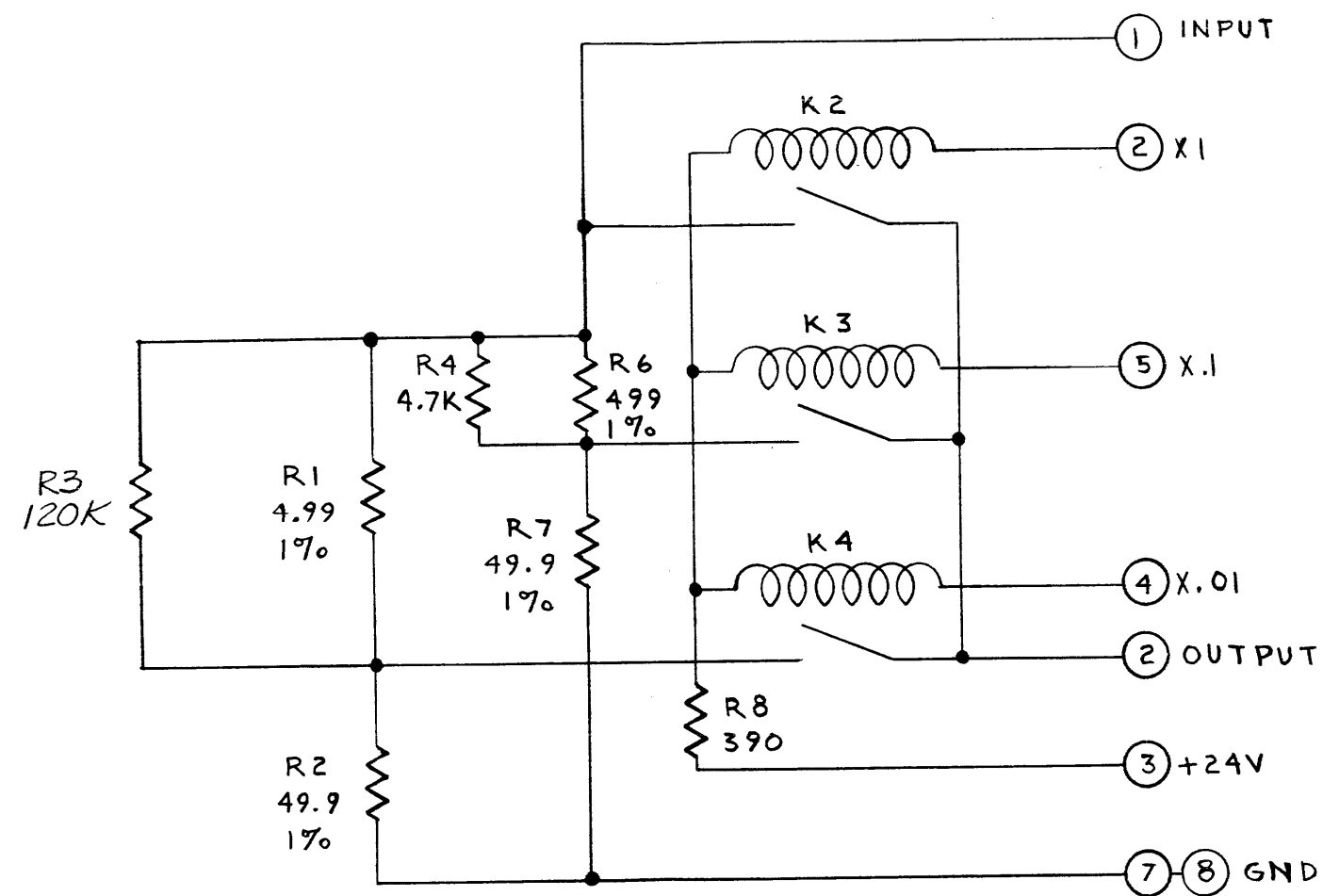
UNLESS OTHERWISE SPECIFIED:

1. RESISTANCE IN OHMS.
2. CAPACITANCE IN MICROFARADS.
3. ALL DIODES ARE IN4009,
4. Q1, Q4 + Q2, Q3 ARE MATCHED PAIRS.

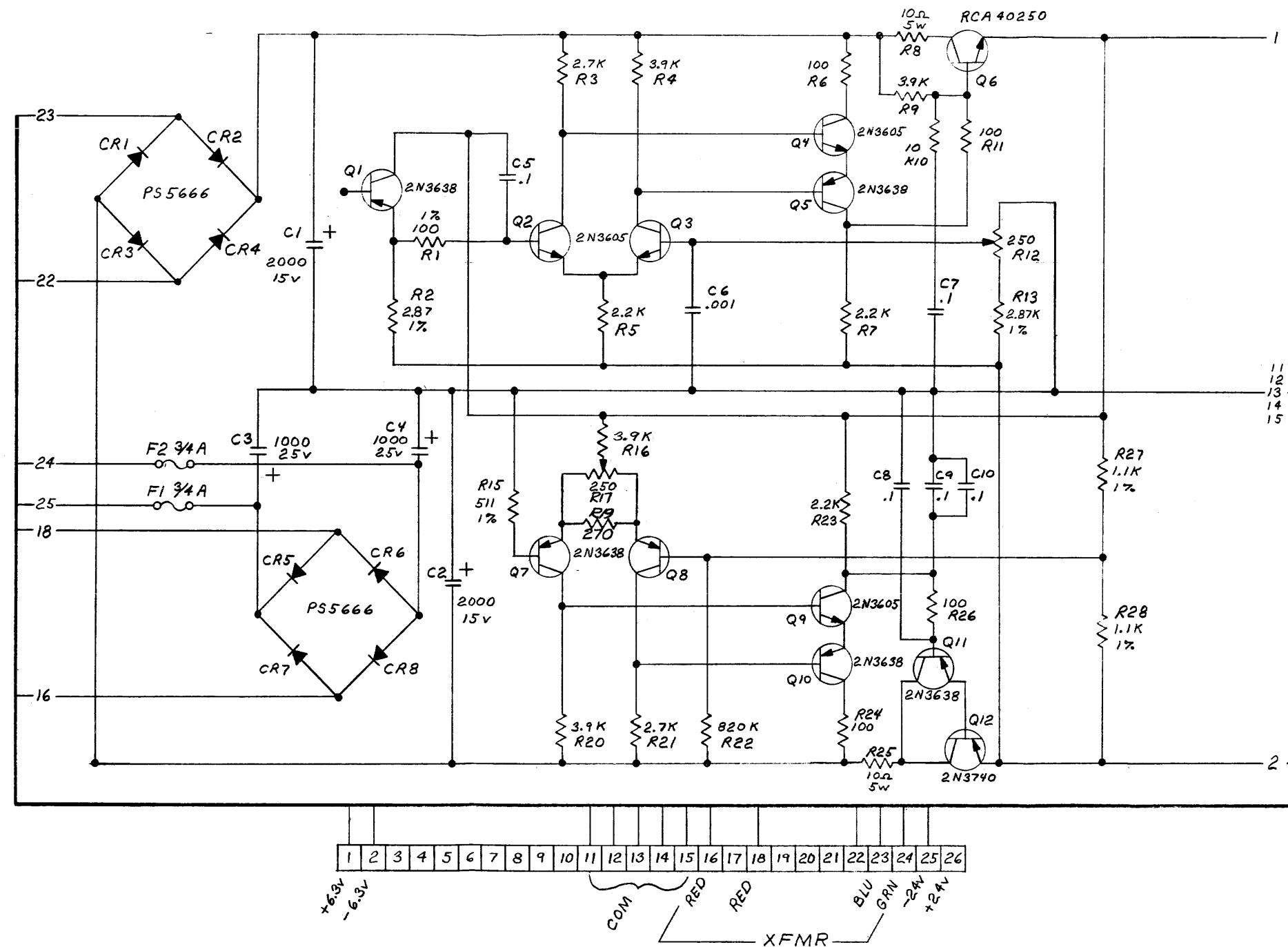
WAVETEK		SAN DIEGO, CALIF	
DRN DRX.	DATE 12-28-65	APP	<i>[Signature]</i>
INTEGRATOR			
MODEL: 150+155		NO. 017-105-81	



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
SINE WAVE COMMAND	+6.3V	-6.3V	SOURCE WAVE COMMAND	TRIANGLE WAVE COMMAND	UNITS DEC 8	UNITS DEC 4	TRIANGLE WAVE INPUT	SQUARE WAVE INPUT	SQUARE WAVE INPUT	UNITS DEC 1	COM	TENS DEC 8	TENS DEC 4	TENS DEC 2	TENS DEC 1	HUNDREDS DEC 8	HUNDREDS DEC 4	SINE WAVE INPUT	HUNDREDS DEC 2	AMPLIFIER OUT	-24V	+24V	HUNDREDS DEC 1				



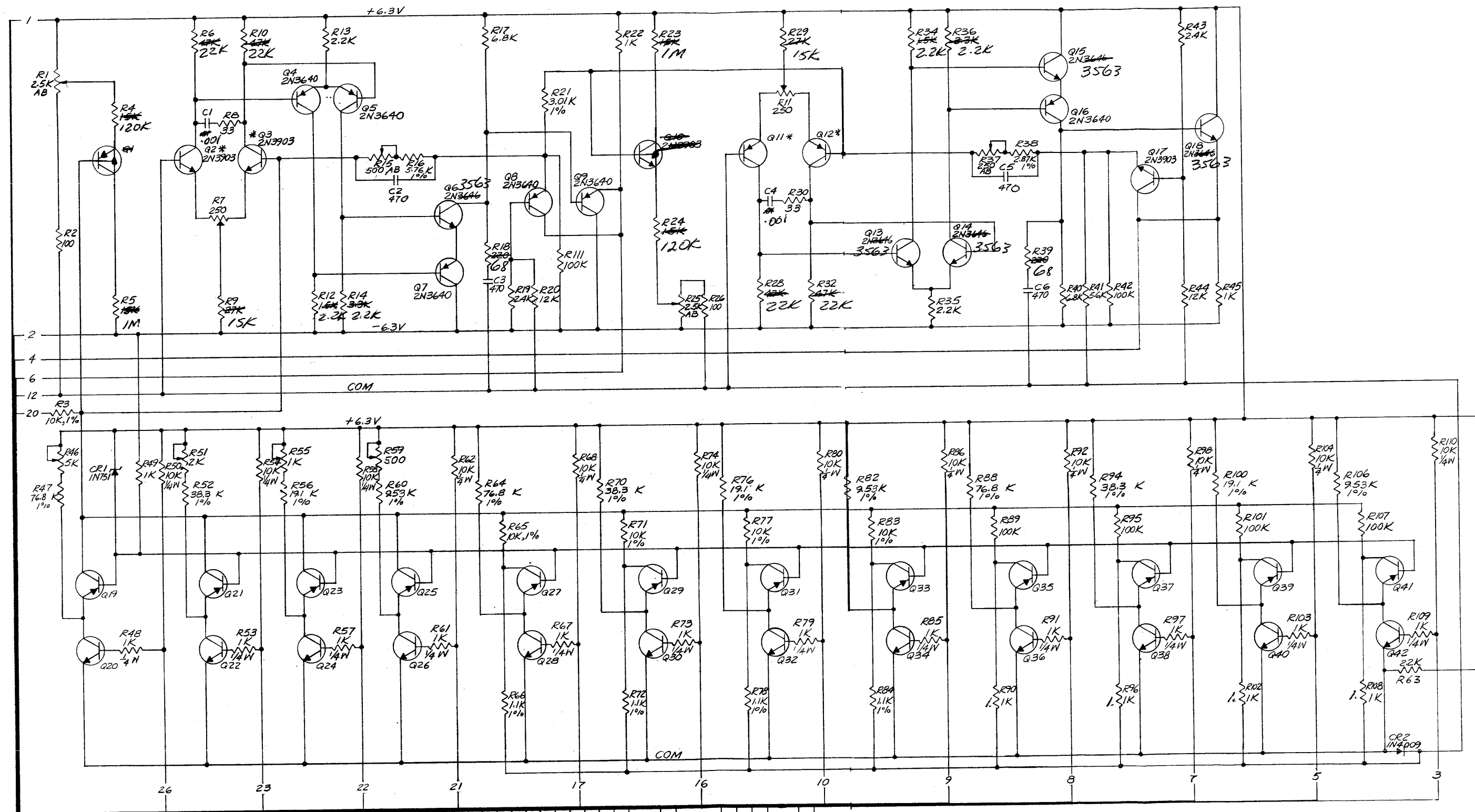
WAVETEK		8159 ENGINEER RD SAN DIEGO, CALIF	
DRN PA Marsh	DATE 3-7-66	APP <i>[Signature]</i>	
OUTPUT ATTENUATOR			
MODEL 150-155		NO 017-108-81	



NOTES

- UNLESS OTHERWISE SPECIFIED:
1. RESISTANCE IN OHMS
 2. CAPACITANCE IN MICROFARADS
 3. ALL 2N3605 MAY BE REPLACED WITH 2N3646.

WAVETEK		SAN DIEGO, CALIF	
DRN	DATE	APP	
DRX.	12-28-65		
POWER SUPPLY			
MODEL:		NO.	
150, 155		017-101-81	

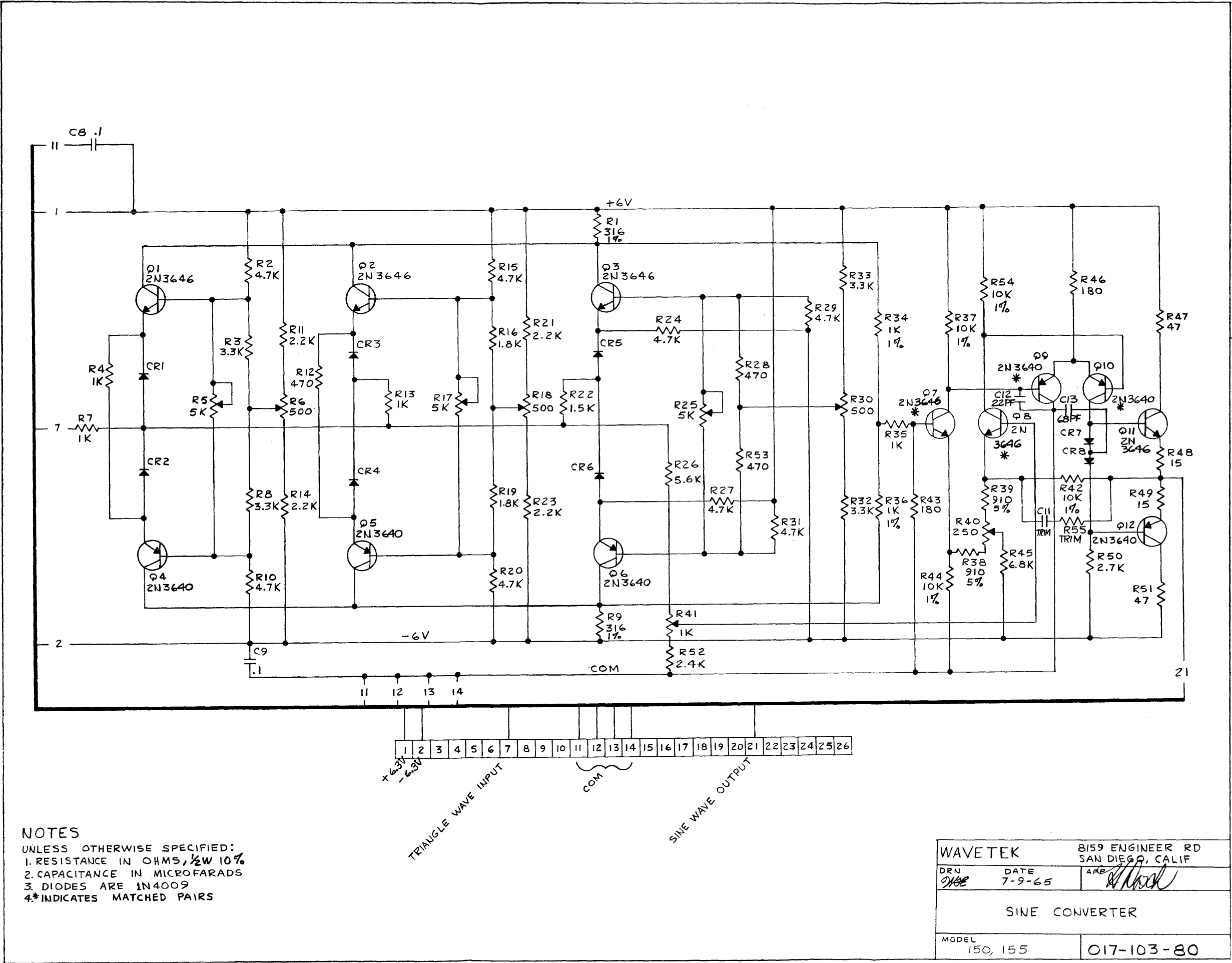


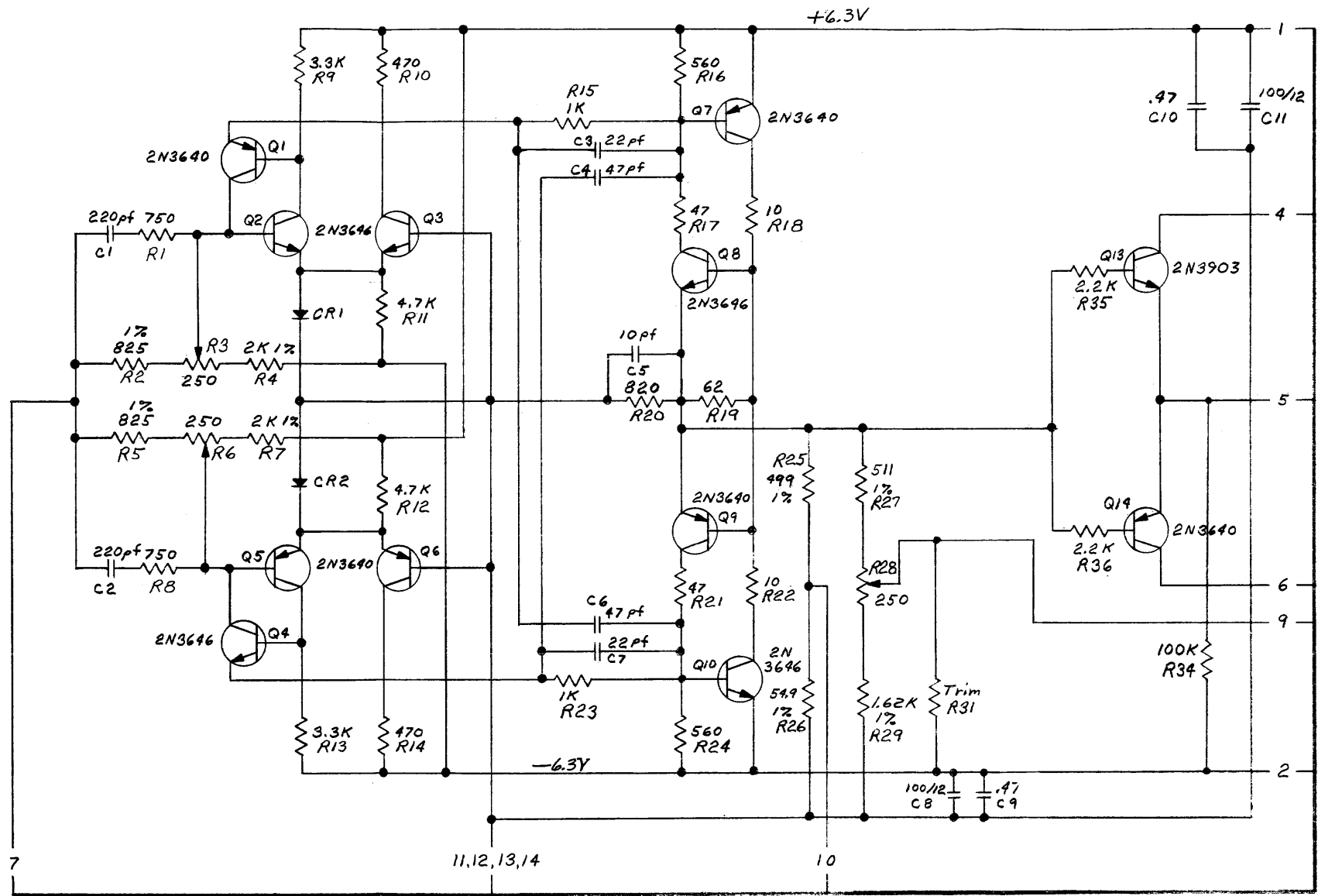
6. * INDICATES MATCHED PAIR V_{BE} .
 5. *T* INDICATES TRIM.
 4. NPN'S ARE 2N3646's.
 3. PNP'S ARE 2N3905's.
 2. CAPACITANCE IS IN MICROFARADS.
 1. RESISTANCE IS IN OHMS.

NOTE: UNLESS OTHERWISE SPECIFIED

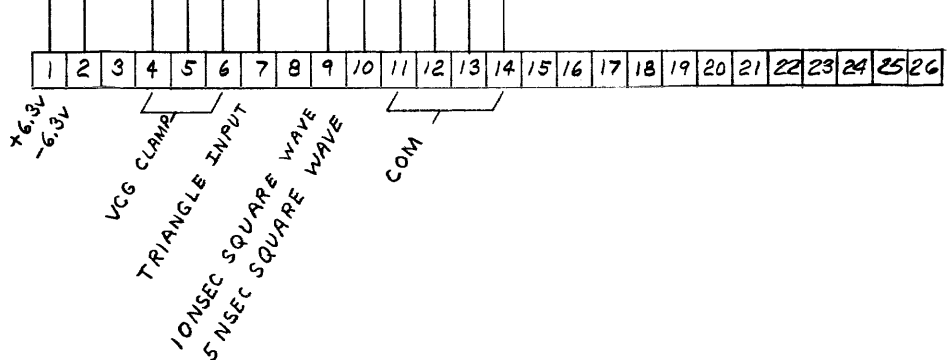
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
 +6.3V
 -6.3V
 VCG CLAMP
 VCG DEC 4
 VCG DEC 2
 VCG DEC 1
 TENS DEC 4
 TENS DEC 2
 TENS DEC 1
 INPUT
 HUNDREDS DEC 8
 HUNDREDS DEC 4
 HUNDREDS DEC 2
 +24V
 HUNDREDS DEC 1

WAVETEK		8159 ENGINEER RD SAN DIEGO, CALIF.	
DWN:	DATE:	APP'D:	
F. WHITELOCK	3-7-6		
D to A CONVERTER			
MODEL:	150,155	NO.:	017-102-84

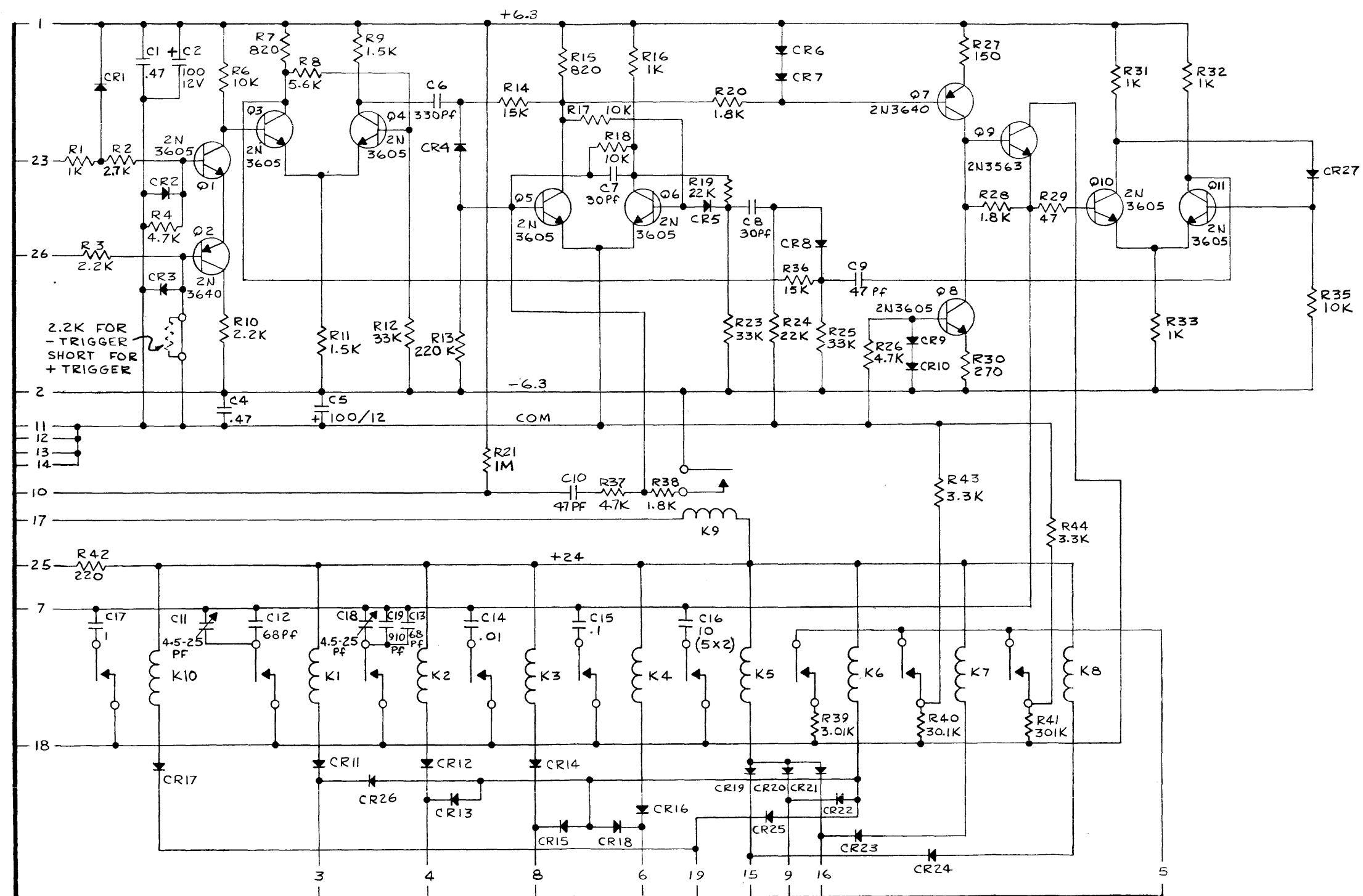




NOTES
UNLESS OTHERWISE SPECIFIED:
1. RESISTANCE IN OHMS.
2. CAPACITANCE IN MICROFARADS.
3. All DIODES ARE 1N4009.



WAVETEK		SAN DIEGO, CALIF	
DRN	DATE	APP	
DRX.	12-28-65		
SCHMITT + SWITCH			
MODEL:		NO.	
150, 155		017-104-82	



NOTES

- UNLESS OTHERWISE SPECIFIED:
1. RESISTANCE IN OHMS
 2. CAPACITANCE IN MICROFARADS
 - 3 DIODES CR1-10, 27 ARE IN 4009
 - 4 DIODES CR11-26 ARE P55666

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26										
+6.3V		-6.3V		X100K		X10K		INPUT		X100		OUT		X1K		X1		SINGLE CYCLE		COM		X0.1		TRIG.-CONT.		INTEG. SUM. JUNCT.		X10		+TRIG		+2A		-TRIG	

WAVETEK

8159 ENGINEER RD
SAN DIEGO, CALIF

DRN	DATE
242	7-15-65

APP

RANGE & TRIGGER BOARD

MODEL
150, 155

NO. 017-106-80