

INSTRUCTION MANUAL
for
MODEL 5900A
FUNCTION GENERATOR

Manual No. 2490-675

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SECTION I GENERAL INFORMATION

INTRODUCTION

This instruction manual describes the circuit theory, operation, maintenance, calibration and suggested uses of the Hickok Teaching Systems Model 5900 Function Generator. An identifying view of the generator is found on the title page.

DESCRIPTION

The Model 5900 produces sinusoid, square or triangle wave outputs over a very wide range of frequencies. The output is referenced to 0V with plus and minus peaks. By use of the DC offset control, the output wave may be superimposed on a positive or negative level from 0V to the full amplitude of the wave.

The 5900 is a Voltage Controlled Generator and can be frequency modulated with an external voltage of only $\pm 3V_{AC}$ via the VCG input jack. The VCG input also facilitates analog to digital conversion.

A sync output jack supplies a +5V square wave simultaneously with all other functions. This may be used to sync oscilloscopes or to drive TTL logic devices since the output is referenced to ground.

The output stability, low sine wave distortion, fast square wave rise/fall times and very linear triangle wave, make the Model 5900 ideal for many general laboratory applications.

The generator is enclosed in a metal case and is provided with metal carrying handles which also serve to protect the panel and controls. The chassis is accessible by removing the two back rails and then lifting off the top and bottom covers. All controls and the dial are accurately calibrated.

The generator is equipped with a three-conductor power cable which when plugged into an appropriate receptacle grounds it. If it is necessary to operate the generator from a two contact outlet, use a three-pronged to two-pronged adapter and connect the green pigtail lead of the adapter to ground. A one-half ampere line fuse is mounted inside the unit (1/2A for 220V operation).

To operate the generator with the chassis above ground, use an isolation transformer (1:1) between the generator and the power line.

CAUTION

The Model 5900 uses direct coupling to all input/output jacks in order to provide the exceptional low frequencies, the adjustable d-c offset voltages and the very fast rise/fall times. Because of this d-c coupling, the operator is cautioned **NOT TO CONNECT THE INPUT/OUTPUT JACKS TO A VOLTAGE GREATER THAN +10V OR -5V.**

To place the input/output jacks on higher voltages, simply use a coupling capacitor of the appropriate size between the generator and the desired point of connection.

TECHNICAL DATA REFERENCE

Waveforms: Sinusoid, square and triangle
 Frequency Range: 0.03 Hz to 3 MHz

Dial Accuracy: $\pm 3\%$ of dial reading
 Maximum Output Amplitude: 20V p-p into open circuit
 10V p-p into 50 ohm load

Attenuation: 20 dB between HI and LO BNC connectors plus 40 dB continuously variable control (total of -60 dB)

DC Offset: 0V to $\pm 10V$ open circuit and 0 to $\pm 5V$ into 50 ohm load, continuously adjustable and independent of amplitude control. Push type control allows DC offset to be switched ON or OFF without disturbing the amplitude setting of the offset voltage.

Output Impedance: 50 ohms for sine, square and triangle.
 Sinewave Amplitude Flatness: 0.03 Hz to 1 MHz, 0.2 dB
 1 MHz to 2 MHz, 0.6 dB
 2 MHz to 3 MHz, 1.5 dB

Square Wave Amplitude Flatness: 0.03 Hz to 3 MHz, ± 0.3 dB
 Triangle Wave Amplitude Flatness: 0.03 Hz to 3 MHz, 0.3 dB
 Sinewave Total Harmonic Distortion: $< 2\%$ to 1 MHz

Triangular Waveform: $> 95\%$ Linearity to 1 MHz.
 Square Wave Transition Time: Rise time and fall time ≤ 50 ns

Sync Output: Square wave, simultaneously available with sine, square or triangle waveform, independent of amplitude control. Amplitude: $+5$ V referenced to ground (TTL compatible). Rise and fall time: ≤ 50 ns

VCG Input: Impedance: ≤ 100 ohms
 ± 3 V for $\geq 1000:1$ change in frequency on all ranges except $\times 0.1$ which is $\leq 300:1$
 Input impedance: 50 k ohms

AM Selector Switch Off: Same as basic 5900

AM Selector Switch, Internal:
 Output Level: $\leq 12V$ p-p into open circuit at 1MHz carrier
 Amplitude Flatness: ± 1 db for carrier frequencies between 850 KHz and 1640 KHz (commercial AM Band) and ± 2 db for carrier frequencies between 300KHz and 3MHz

Modulation Frequency: Sinusoidal, 1000Hz nominal 1% distortion
 Modulation Level: 90% minimum
 AM Selector Switch External:
 Input Level: 12V p-p nominal input for 100% modulation. Input is diode clamped for protection.
 Frequency Range: Frequencies down to 50Hz can be applied with only a 3db attenuation.

Power Requirements: 105 - 125 VAC @ 50 - 60 Hz, ≤ 15 VA, with taps for operation on 210 - 250 VAC @ 50 - 60 Hz.
 Dimensions: 8 1/2" (216 mm) wide x 7" (178 mm) high x 9" (229 mm) deep.
 Weight: Net: 9 lbs 6 oz (4,25 kg)
 Shipping: 10 lbs 12 oz (4,88 kg)

SECTION II
 THEORY OF OPERATION

GENERAL
 During the following circuit descriptions, reference to the block diagrams and schematics will aid in the basic understanding of the operation of the circuits in the Model 5900.

BASIC PRINCIPLE
 The Model 5900, like most other function generators, is built around a basic triangle-wave oscillator circuit. The triangular voltage waveform is derived from a capacitor which is alternately charged and discharged by constant-current generators. A level-detector circuit switches between the charge and discharge cycles when the triangle amplitude reaches predetermined limits. The frequency of the wave is proportional to the magnitude of the charging current and inversely proportional to the capacitor value. The square wave output is obtained from the level detector, while the sine wave is formed by rounding the peaks of the triangle in a suitable shaping circuit. Figure 1 is a block diagram of the complete generator. The various sections are described in more detail in the remainder of this section.

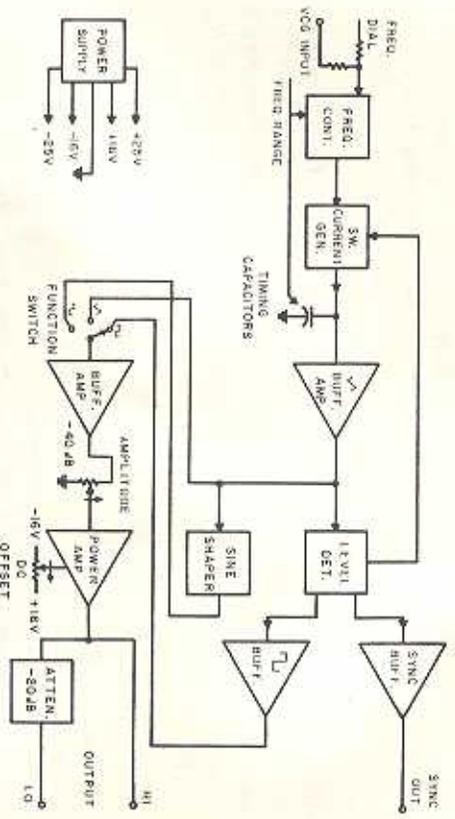


Fig. 1 Block diagram of 5900

FREQUENCY CONTROL

IC1 operates as an inverting amplifier, forcing the negative voltage at the emitter of Q1 to be proportional to the (positive) input voltage from the frequency dial plus the (positive or negative) VCG input, scaled by their respective connecting resistors. The output current to IC3 is therefore proportional to the frequency dial setting plus the VCG input. The resistor values are chosen so that the final output frequency (f) of the instrument can be expressed by the relation: $f = (f_D + VCG) / R$ where f_D is the dial reading (0.3 to 3), VCG is the voltage applied to the VCG input (-3 to $+3$ volts) and R is the range switch setting (0.1 to 10^6).

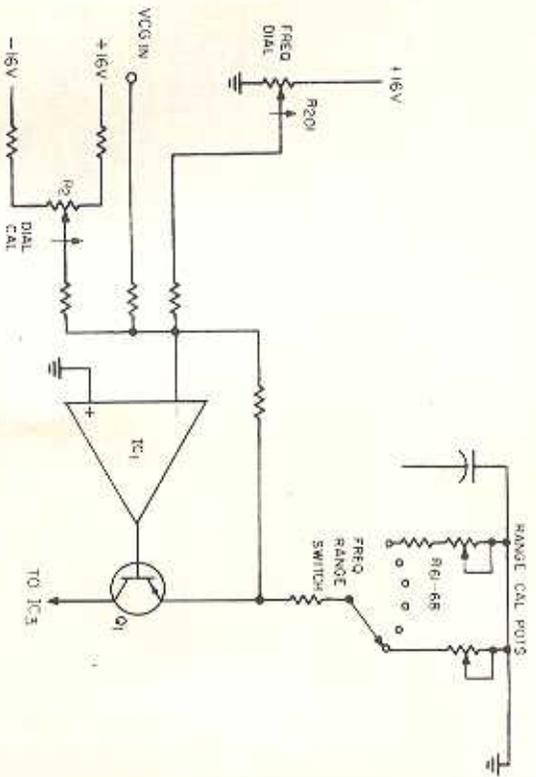


Fig. 2 Simplified schematic of Frequency Control circuit.

R2 is required to compensate for offset voltage in IC1 and small variations in the orientation of the frequency dial on the shaft of R201. R61 to 68 permit exact calibration of the eight frequency ranges, to compensate for tolerance variations in the timing capacitors and other frequency-determining components.

CURRENT GENERATORS

IC3 consists of an array of five essentially identical NPN transistors fabricated on a single silicon chip. They are utilized here in what is sometimes called a "current mirror" configuration. Because of their nearly identical characteristics and the manner in which they are interconnected, the collector currents in all five transistors are forced to be approximately equal. Thus the input current from Q1 in the frequency control circuit is "reflected" by transistor B up to the IC2-Q3 section, and three times the control current is "reflected" by transistors C,D and E to the emitters of Q6 and Q7.

IC2 and Q3 together form another "current mirror", but the resistors are chosen so that the collector current of Q3 is 1.5 times the input current (from transistor B of IC3). Thus there is a constant current of 1.5 times the control current charging the timing capacitor. Q6 and Q7 serve as a switch, controlled by the level detector, to alternately connect and disconnect IC3 C,D and E from the timing capacitor. This switched discharge

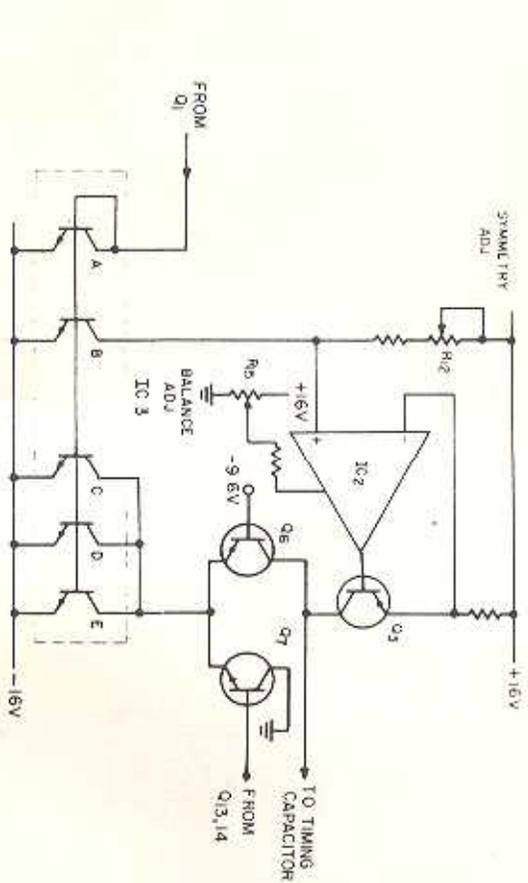


Fig. 3 Simplified schematic of switched current generator circuit.

current is three times the control current, so the net result is either a charging or discharging current of 1.5 times the control current. The rising and falling slopes of the triangular wave are therefore equal. Exact symmetry of the waveform is obtained by adjustment of R12 and R15; the former controls the 1.5x current ratio and the latter is the offset balance adjustment for IC2.

LEVEL DETECTOR

The basic triangle voltage wave is generated at the timing capacitor (selected by the range switch). To avoid loading, this waveform is isolated from the subsequent circuitry by source-follower/emitter-follower combination Q4 and Q5. The triangle is then applied to the base of Q10, the input of the level detector, where it is compared with the voltage on Q1 base. The cycle proceeds as follows. Suppose the triangle is rising, while Q11, Q12 and Q13 are all conducting. The voltage at the base of Q11 will be approximately equal to +V_{ref} (obtained from Q15; see complete schematic for details). The voltage divider at Q13/Q14 emitter applies a sufficient voltage to the base of Q7 (fig. 3) to divert the negative charging current to ground, permitting the timing capacitor to charge and the triangle to continue rising. When the triangle voltage reaches +V_{ref} Q10 starts to conduct and a regenerative switching action occurs, with Q11, Q12 and Q13 turning off, Q10 and Q14 turning on. The negative charging current now switches to the timing capacitor, the triangle starts down, and the voltage at Q11 base stabilizes at approximately -V_{ref}. The same sequence occurs in reverse when the triangle reaches -V_{ref}.

The regenerative switching action of the level detector is very fast, and the resulting waveform at Q13/Q14 emitter is a square wave with the same frequency and symmetry as the triangle, and a very fast (<<30ns) rise time.

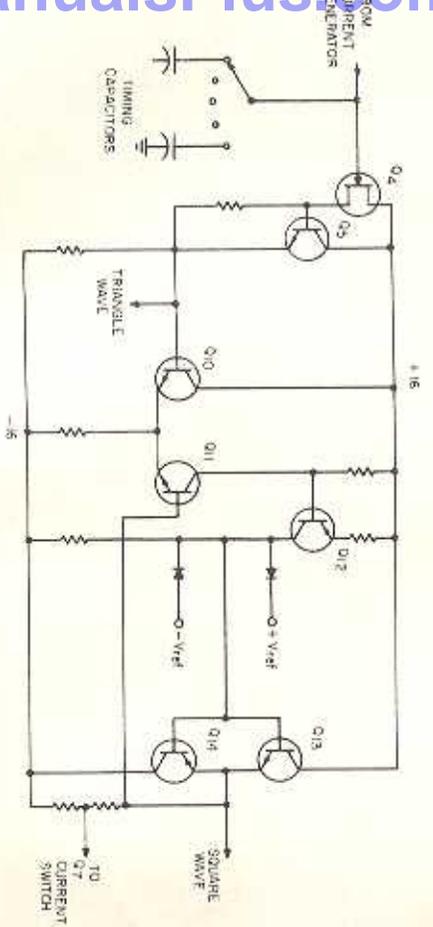


Fig. 4 Simplified schematic of level detector, square-wave, buffer-triangle buffer circuit.

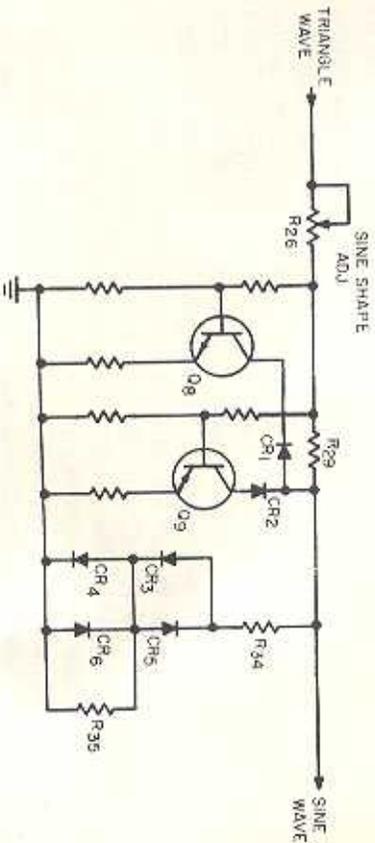


Fig 4A Sine-shaper circuitry.

SINE SHAPER

The triangle wave enters the sine shaper with a peak to peak amplitude of about ± 3.2 volts. The sine shaper circuit modifies this wave to an approximate sine wave of amplitude ± 1.3 volts. There are three amplitude regions of interest. When the triangle is smaller than 0.5 volts, it is transmitted without change. As the amplitude increases diode CR3 or CR5 begins to conduct and load the output (via R26, R29 and R34). When the sine wave amplitude reaches approximately ± 1.2 volts, CR4 or CR6 begins to conduct and provides additional loading. Finally, at about ± 1.5 volts, Q8 or Q9 turns on and greatly increases the loading. The transistors have sufficient gain to more than counteract the increasing input voltage and produce a negative crest at the top and bottom of the output waveform. Resistance R26 is used to adjust the output to the optimum wave shape.

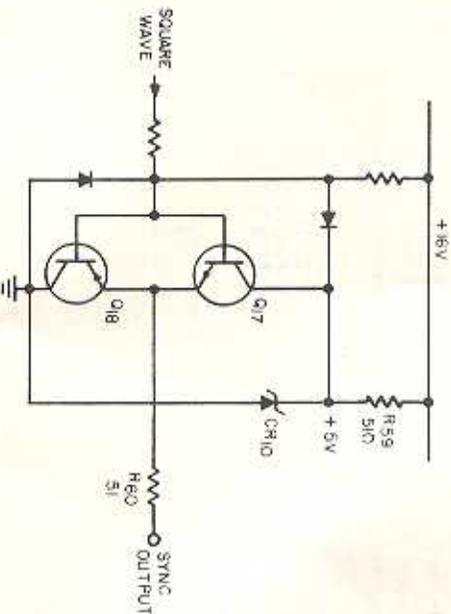


Fig. 5 Sync output circuit

SYNC OUTPUT

The sync output circuit produces a square wave with the same phase as the output square wave. The circuit consists basically of a complementary emitter follower, Q17/Q18. In order to make the sync output compatible with TTL logic, the output voltage is limited to ground and +5 volts, the latter obtained from zener diode CR10. A 51 ohm resistor is connected in series with the output connector to properly terminate the 50 ohm cable, eliminating reflections. The output impedance of the circuit is therefore approximately 50 ohms for 0 volts out, but at +5 volts the effective impedance is more nearly 100 ohms because of the finite impedance of the 5-volt supply. The allowable TTL loading is 5 standard gates for low output and over 500 gates for high output.

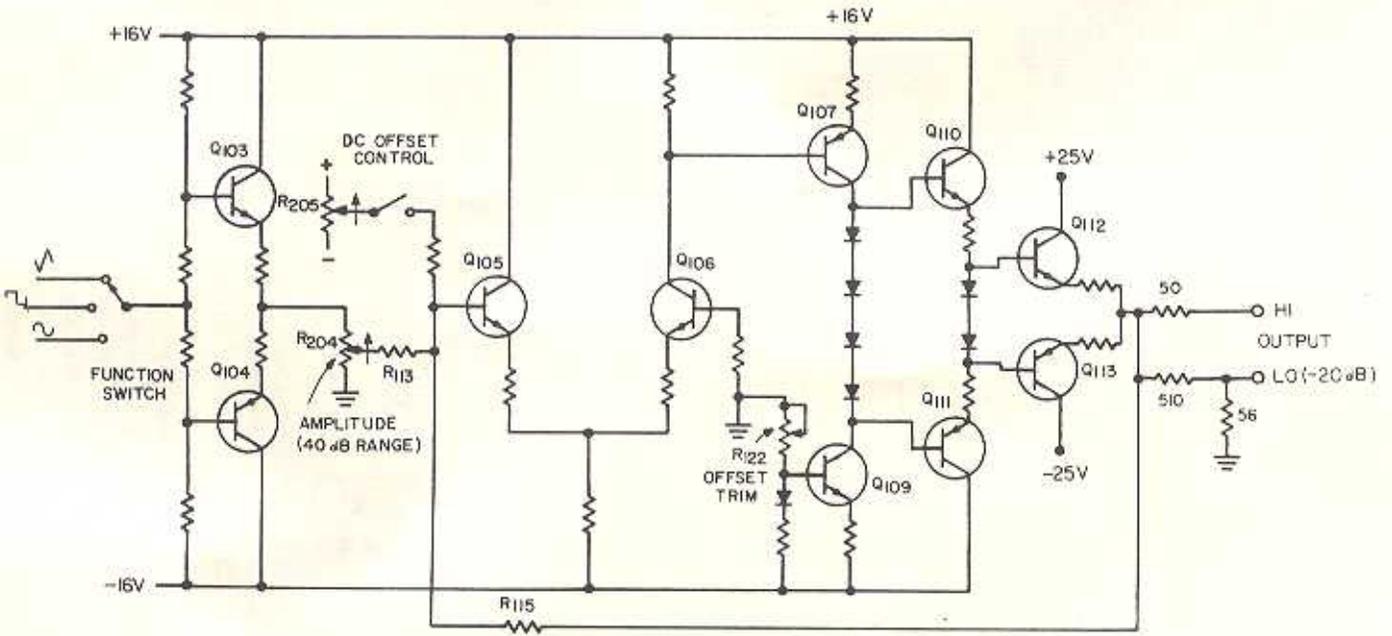


Fig. 6 Simplified schematic of output buffer and power amplifiers.

OUTPUT AMPLIFIER (Reference Fig. 6)

The waveform selected by the function switch passes through complementary emitter followers Q103/Q104 which prevent loading of the waveform generators by the amplitude control R204. The output of the amplitude control is applied to the output circuit, Q105 through Q113, which together constitute a wide-band, high slew-rate, feedback amplifier. The input differential stage, Q105/Q106, is followed by a PNP common emitter stage, Q107, which exhibits very high D.C. gain by virtue of its current-source collector load, Q109. Output from the circuit is taken from cascaded, compound emitter-followers, Q110 - Q113. Closed-loop gain of the amplifier is 8x, determined by the ratio of R115 to R113. The output slew-rate is in excess of 500 volts/microsecond, fully loaded. DC balance is obtained with trimmer R122, while DC offset control is provided by R205. Additional circuit elements are included to assure graceful overload performance and circuit stability (Q108, CR 106 and associated components - see complete schematic).

The Model 5900A function generator is provided with an amplitude modulation function for use at broadcast frequencies. An AM selector switch allows the user to choose between the internal, 1000Hz modulation signal, or an external modulation signal. The AM function can be disabled by turning the selector switch to the off position. In this mode the unit operates strictly as a function generator.

NOTE: Amplitude modulation is only useful on the 3kHz to 3MHz frequency ranges.

POWER SUPPLY

The power supply provides ± 25 volts, unregulated, from a standard full-wave rectifier circuit. The ± 16 volt regulated supply is controlled by IC4, a dual-voltage tracking regulator. Trimmer R106 is included to adjust the ± 16 volt supply; the negative output will then be -16 ± 0.3 volts. Regulation against line and load changes is better than ± 0.02 volts. Additional current capability is provided by booster transistors, Q101 and Q102. R103 and R104 sense the magnitude of the positive and negative load currents respectively, so IC4 can limit the output in case of overload.

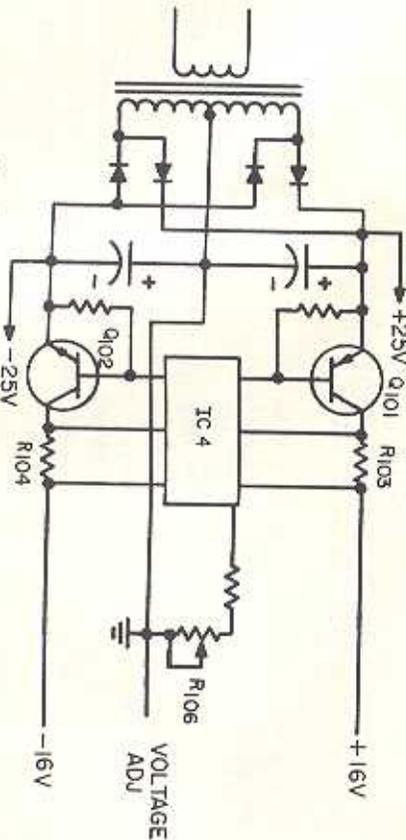
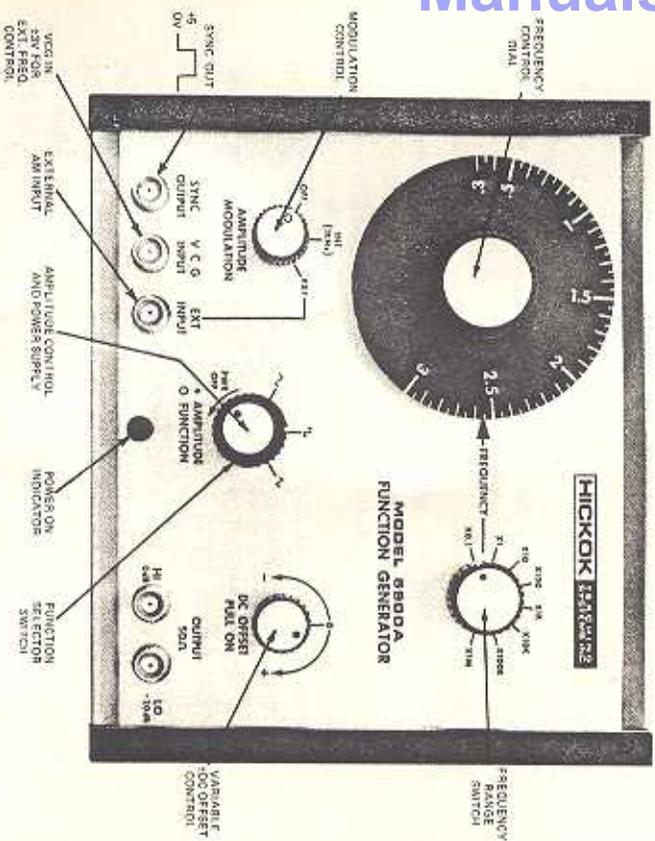


Fig. 7 Simplified schematic of Power Supply.



Front Panel Controls and Connections

SECTION III
OPERATING INSTRUCTIONS

GENERAL

Although the generator is "solid state" and does have instant "turn-on" capabilities, a fifteen minute warmup period should be allowed to assure optimum stability. The power switch is located on the Amplitude Control. The "OFF" position is full counterclockwise rotation.

FREQUENCY

The frequency of the output waveform is determined by the setting of the frequency dial multiplied by the setting of the range switch. For example, to obtain a 1000 Hz output, set the frequency dial to 1 and the range switch to x1k. If the output frequency is to be 30 Hz, set the frequency dial to 0.3 and the range switch to x100, or set the frequency dial to 3 and the range switch to x10.

FREQUENCY RANGE

The frequency dial is a linear potentiometer and the more nearly linear portion has been selected for the dial markings of 0.3 to 3. This means that the lowest frequency according to the dial is 0.3 x 0.1 or 0.03 Hz and the highest frequency is 3 x 1M or 3 MHz. However, by turning the frequency dial to the maximum counterclockwise position, a point beyond 3 MHz (approximately 3.2 MHz) is reached.

When the frequency dial is rotated to the maximum clockwise position, a point beyond the dial marking or OHZ is reached. It will be noted that the dial potentiometer is at OV and consequently the output is OHZ. Now when the dial is rotated slowly in a counterclockwise direction, until a waveform is being generated, it will be found that an extremely low frequency is obtained, approximately 0.0015 Hz. Therefore, it is possible to obtain frequencies between 0.0015 Hz and 0.03 Hz at a compromise in waveform symmetry.

FUNCTIONS

It is possible to select one of 3 waveforms at the HI and LO output jacks by turning the FUNCTION switch to sine, square or triangle symbol on the front panel.

The SINE WAVE is generally used when a fundamental frequency (low in harmonics) is desired such as testing the frequency response of amplifiers resonant circuits, transducers, etc.

The SQUARE WAVE is generally used when it is desired to test the response of an amplifier or electronic device to a step-change of voltage, such as rise and/or fall times and ringing. It is useful for a quick check of overall bandwidth and phase shift of coupling circuits. See Fig. 8 for typical waveforms that may be found at the output of devices when a square wave has been applied to their input.

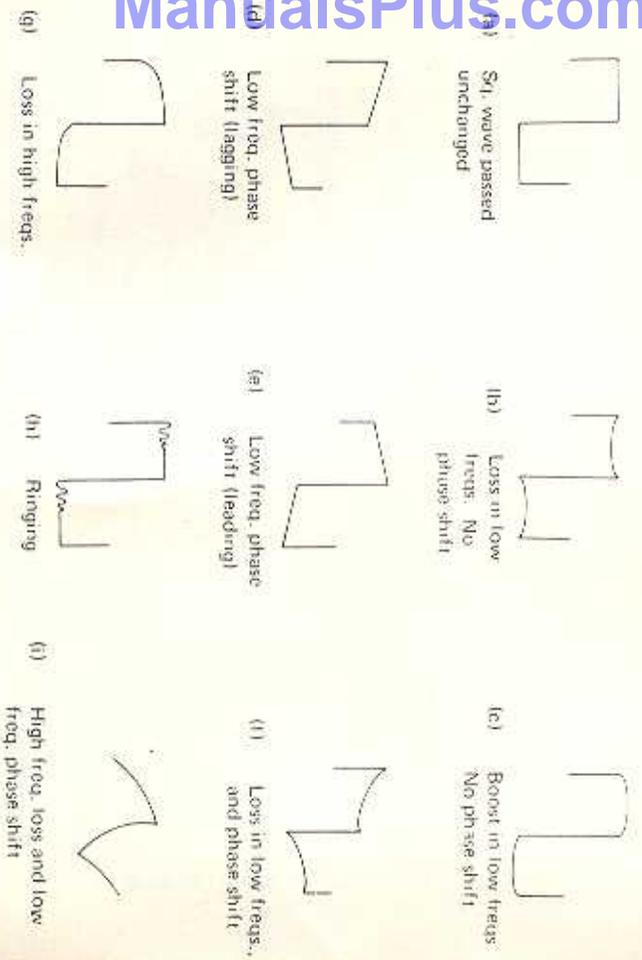


Fig. 8 Waveforms

The TRIANGLE WAVE is useful for testing the linearity of chart recorders, oscilloscopes, servo systems, amplifiers, and in general, wherever a linear change of voltage is required. It is easier to detect non-linearity and clipping in an amplifier with a triangle wave than with a sine or square wave. A SYNC PULSE is available at the SYNC OUT jack simultaneously with all other waveforms. This is a square wave that is in phase with the square wave available at the output jack. It is independent of the amplitude, function and DC offset controls. Its output swings from 0V to +5V and is therefore TTL compatible. This means that this output may be used as a clock source for TTL logic devices. Its rise and fall times are $\leq 50\text{ns}$; therefore, it is not only useful for synchronizing oscilloscopes but can be used anywhere a fast rise and fall time is required.

A PULSE OUTPUT which is often required is easily obtained with the 5900. Refer to the "Applications Section" for the procedure.

CONNECTING NETWORKS

The HI and LO output jacks represent a 50 ohm source. For those cases when it is desired to couple a square wave into a load other than 50 ohms, it is necessary to match the generator's output to the load to prevent distortion of the square wave, especially for fast rise and fall times. Even a co-ax cable will ring slightly if not terminated properly.

Matching pads are quite easily constructed. Figure 9 shows three L-pads that will match the 5900 to the most commonly encountered impedances. Impedance Z1 represents the 5900 output and Z2 represents the load that

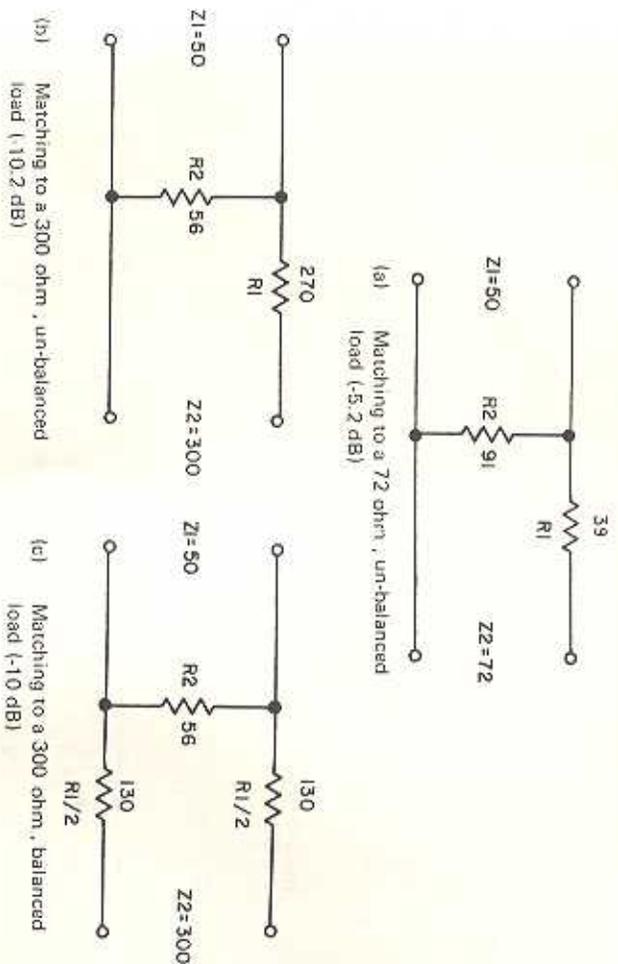


Fig. 9 Three of the most commonly used L-type matching pads showing their insertion loss

is to be connected to the 5900. If a co-ax cable is to be connected to the 5900, connect the L-pad to the free end (load end) of the cable, not to the 5900 end. The L-pads shown represent minimum loss, however, there is a loss as indicated in dB.

The resistors selected in Fig. 9 are stock values of the $\pm 10\%$ 1/4W size that are nearest to the calculated values. Note that they must be non-inductive resistors (carbon, not wire-wound).

To match the 5900 to impedances other than those shown in Fig. 9, the following is suggested: If Z2 is a balanced load, just put half the resistance of R2 in one leg and half in the other leg as shown in Fig. 9(c). Also note that Z1 represents the smaller impedance and Z2 the larger impedance.

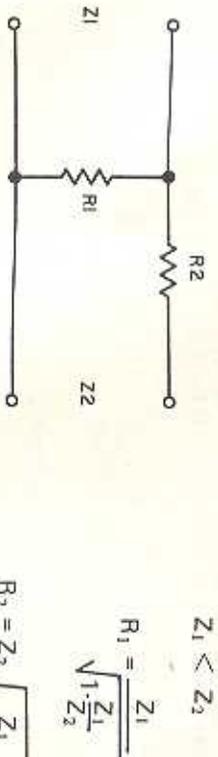


Fig. 10 Calculating a minimum-loss L-Pad for matching the 5900 to a load that is not 50 ohm

$$Z_1 < Z_2$$

$$R_1 = \frac{Z_1}{\sqrt{1 - \frac{Z_1}{Z_2}}}$$

$$R_2 = Z_2 \sqrt{1 - \frac{Z_1}{Z_2}}$$

ATTENUATION NETWORK

The attenuation of the output signal from the 5900 is 60 dB which is adequate for most applications. However, there may be applications where a greater attenuation is required, such as connecting to the input of a very high-gain pre-amplifier. In this case, use an attenuator pad between the 5900 and the load. Figure 11 shows a T-pad attenuator for unbalanced (a) balanced (b) configurations. Note that Z represents the 5900's output impedance and the load's impedance, in both cases, 50 ohms.

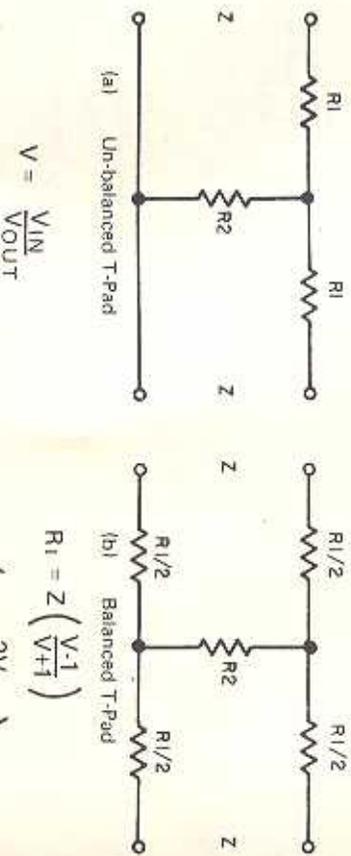


Fig. 11 Calculating R1 and R2 for T-Pad attenuators

The preceding formulas give a close approximation of the required values. The variable attenuator allows a 40 dB change, thus compensating for inaccuracies.

As an example, suppose you want to attenuate the output of the 5900 by 80 dB. An additional 20 dB pad is required (80 dB - 60 dB).

Find V for 20 dB: $dB = 20 \log V$ Note: $V = \left(\frac{V_{in}}{V_{out}}\right)$

Substitute 20 for dB: $20 = 20 \log V$
Divide by 20: $1.0 = \log V$
Take anti-log: $10 = V$

$\therefore V = \left(\frac{V_{in}}{V_{out}}\right) = 10$

Substitute 10 for V and calculate for R1 and R2 in the following formulas:

$$R1 = Z \left(\frac{V-1}{V+1} \right) \quad R2 = Z \left[\frac{2V}{(V+1)(V-1)} \right]$$

$$= 50 \left(\frac{10-1}{10+1} \right) \quad = 50 \left[\frac{2(10)}{(10+1)(10-1)} \right]$$

$$= 50 (0.8182) \quad = 50 (0.202)$$

$$= 40.91 \text{ ohms} \quad = 10.1 \text{ ohm}$$

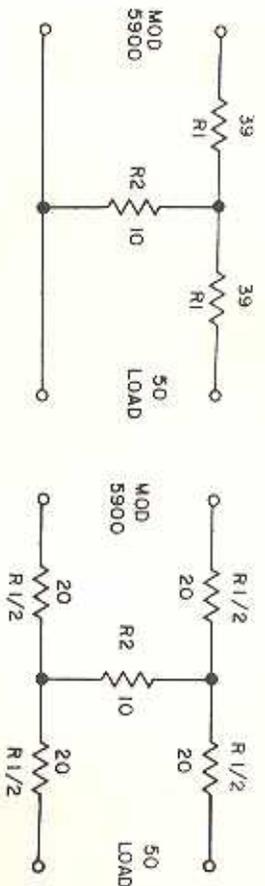


Fig. 12 20dB T-Pad attenuator for balanced and un-balanced 50 ohm loads

DIFFERENTIATING NETWORK

There are times when a sharp "spike" is desired instead of a square wave. This is accomplished by connecting a differentiating network at the output terminals (Fig. 13).

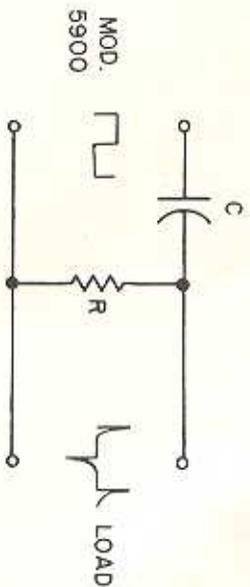


Fig. 13 RC Differentiating network

The sizes of the resistor and capacitor depend on the desired operating frequency and the width of the required pulse. As a rule-of-thumb the pulse width should be about 1/10th the width of one-half cycle of the square wave, at the frequency required. The sizes of the resistor and capacitor are generally found by experimenting, but a close approximation can be found in the following manner:

$W_p = \frac{1}{20F}$ where: W_p is the pulse width in seconds and F is the frequency of the square wave in Hz.

Example: A spike is desired at a repetition of 1 KHz.

$W_p = \frac{1}{20F} = \frac{1}{(20)(1000)} = 50 \text{ us}$

Since the time constant of an RC network is $T = RC$ (where T is in seconds, R is in ohms and C is in Farads) $C = \frac{T}{R}$. Arbitrarily select a resistance of 10 k ohms and solve for a capacitor for an RC time constant of 50 us.

$$C = \frac{T}{R} = \frac{50 \times 10^{-6}}{10,000} = 0.005 \mu F$$

SECTION IV VCG APPLICATIONS FOR FAMILIARIZATION

To display an FM modulated signal on an oscilloscope:
Before connecting equipment as shown, adjust the two generators as follows, using a scope for monitoring:

- Set FUNCTION switch for a triangle-wave output at a frequency of 0.1 Hz.
 - Adjust amplitude for 3V p-p.
 - Pull out the DC offset control and adjust in a clockwise direction so that the amplitude of the triangle wave varies from 0V to +3V.
- Connect the two generators and the scope as shown in Fig. 14. Adjust 5900 (# 1) as follows:
- FUNCTION control for a sine or triangle wave.
 - Amplitude control to mid-rotation.
 - DC offset control pushed in.
- Adjust scope as follows:
- Vertical amplifier for 1V/div, d-c coupled.
 - Horizontal time base for 2 ms/div, internal trigger. If desired, external trigger can be obtained from Sync output of 5900 (#1).

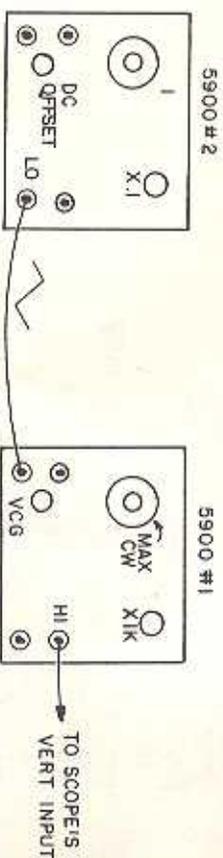


Fig. 14 To display FM modulation

After the waveform is displayed, familiarize yourself by varying the FUNCTION and FREQUENCY controls of the two generators. For example, if the output of 5900 (# 2) is a square wave at 100 Hz, the scope will display bursts of sine waves (pulse modulation). It may be necessary to rotate 5900 (# 1) frequency dial for a stable waveform. Now, rotating the DC offset control clockwise will produce bursts of high frequency pulses alternately with bursts of low frequency pulses.

It can be seen that if the VCG of one 5900 generator is connected to the output of a one-shot whose amplitude swings between 0 and +3V dc, it is possible to create single bursts of signals for any number of cycles/burst if the one-shot's pulse width is variable.

To display the frequency response of a Bandpass circuit such as a 455 KHz I-F transformer by automatically varying the frequency from below resonance to above resonance set up equipment as shown in Fig. 15.

- Procedure:
1. Connect the sine wave output (HI) of the 5900 (#1) to the primary of I-F transformer; 5900 (#2) is not connected yet.
 2. Connect the oscilloscope's vertical input to the secondary of the I-F transformer.
 3. Adjust the 5900's output for a sine wave of approximately 10V p-p (amplitude control at mid-point).
 4. Adjust scope's vertical amplitude for 5V/div.
 5. Adjust scope's time base for 2 us/div and its trigger on internal (auto mode). For a more desirable trigger, connect the 5900's sync output to scope's external trigger input.
 6. Adjust the 5900's frequency dial and range switch for the resonant frequency (F_r) of the I-F transformer. Simply observe the scope for the maximum output as the frequency dial is turned. Do not touch the frequency dial after this setting.
 7. Adjust the scope's vertical gain and/or the 5900 amplitude control for full screen deflection.
 8. Adjust the scope's time base for about 8 cycles of the sine wave.
 9. Now connect the triangle LO output of the 5900 (#2) generator to the VCG input of 5900 (#1).
 10. Adjust 5900 (#2) as follows:
 - FREQUENCY range switch at x0.1
 - FREQUENCY dial at 1
 - DC offset pushed in
 - AMPLITUDE vernier at OV output (CCW)

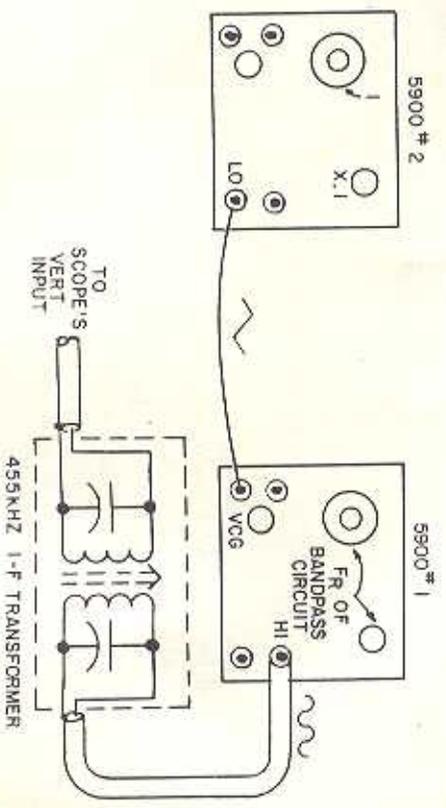


Fig. 15 To display response of Bandpass circuit

11. While observing the oscilloscope, adjust the AMPLITUDE control of the 5900 (#2) clockwise until the amplitude begins to vary.
12. Continue adjusting the AMPLITUDE control until about two cycles appear on the scope when the frequency is below resonance and about 14 cycles appear when the frequency is above resonance. The second 5900's output will be approximately 0.6V p-p or about 30% rotation from counterclockwise. This is not critical and is left up to the operator. If the triangle out is too low, the sweeping action will not cover the entire bandwidth of the I-F transformer. If it is too large, the sweeping action will cover such a wide frequency span that the resonant point will represent a very small portion and cause viewing to be critical. See Fig. 16 for the waveforms of a typical I-F transformer. To help in understanding, three points on the response curve are shown.

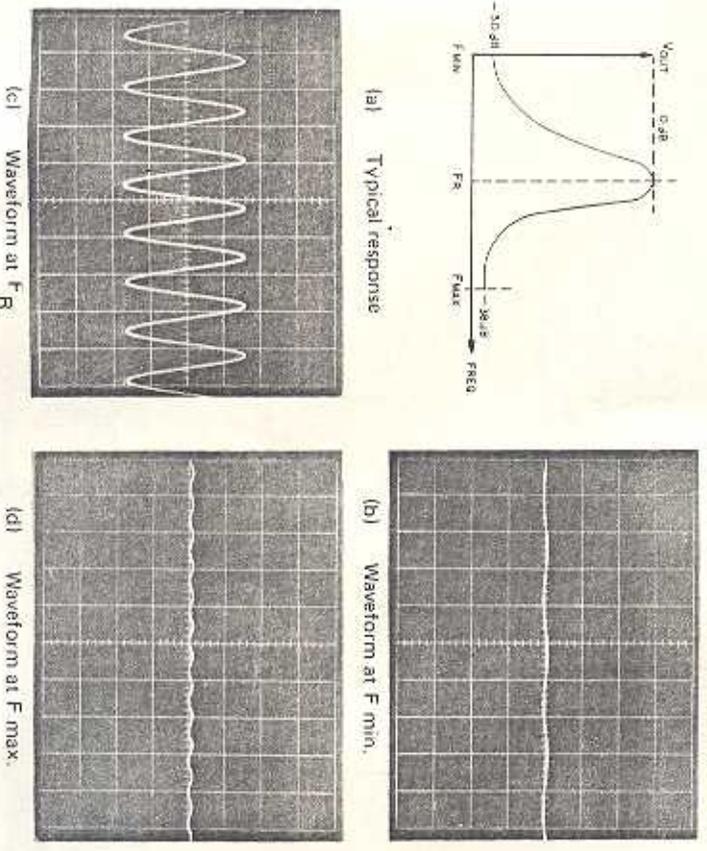
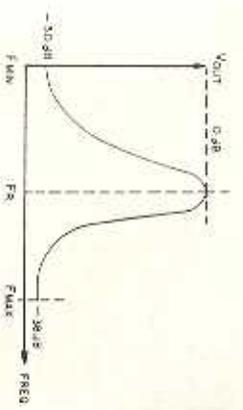


Fig. 16 Response of Bandpass circuit

Figure 16 A shows an approximation of the response of a typical I-F transformer. Figure 16 B shows the scope waveform when the frequency of 5900 (#1) is at its lowest point. Note that 2 cycles are displayed. Figure 16 C shows the scope waveform when the 5900 is at the resonant frequency (F_r) of the I-F transformer (note that 8 cycles are displayed). Figure 16 D shows the scope waveform when the frequency of 5900 is at its highest point.

In the above set up, direct cables are used. If it is desired, a low capacitance probe may be used between the I-F transformer and the scope's vertical input. This will reduce the loading. Remember, however, a low-capacitance probe divides the voltage by 10; therefore, adjust the scope's vertical input to a sensitivity 10x that of a direct probe for an equivalent vertical display. To enhance the display of a bandpass amplifier, use a dual trace scope (e.g. the HTS 5003). Connect the output of the I-F transformer to channel A and the HI output of the 5900 (#1) to channel B. Set the scope to alternate sweep. The channel B display will show that the generator signal fed to the I-F transformer is of constant amplitude, while channel A shows the response of the I-F transformer to vary as the frequency passes through resonance.

To demonstrate another characteristic of the I-F transformer, change the output of 5900 (#1) from a sine wave to a square wave and observe on channel A of the dual-trace scope that the output of the tuned circuit (secondary of I-F) is still a sine wave.

To expand on this, change the output of the 5900 (#1) to a triangular wave and notice that the output is still a sine wave.

Using any of the above displays, increase the rate of sweep of 5900 (#2) to produce various patterns. A high sweep rate effectively shows an overall response similar to Figure 16 A.

To display the frequency response of a low-pass RC filter proceed as follows:

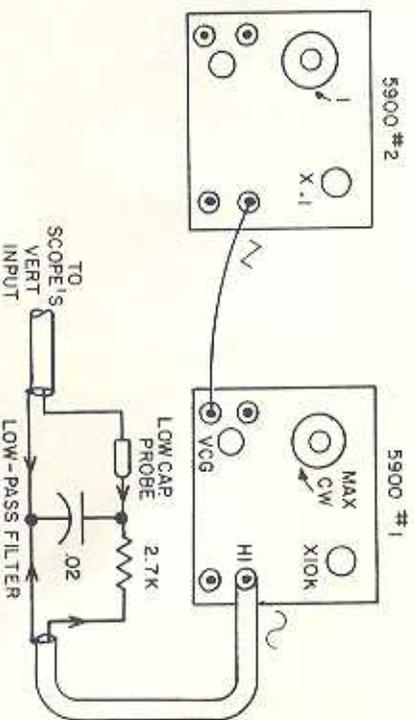


Fig. 17 To display response of Low-Pass filter

Procedure:

1. Before connecting equipment as shown, adjust the two generators as follows, using a scope for monitoring:

- Gen. # 1: - FUNCTION switch on sine wave.
- FREQUENCY dial on 1
- FREQUENCY range switch on x10k
- AMPLITUDE control for 10V p-p at HI output.

DC offset control pushed in. Now, turn the FREQUENCY dial to maximum clockwise setting for the remainder of experiment.

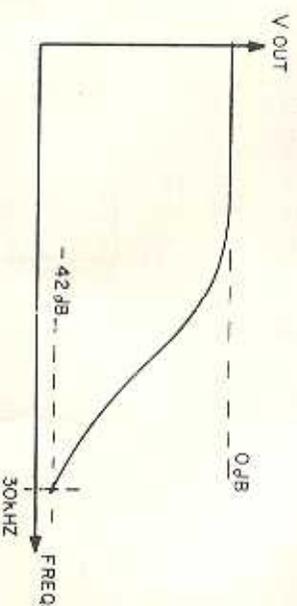
Gen. # 2: - FREQUENCY dial on 1

- DC offset pushed in
- FUNCTION switch on triangle
- Turn AMPLITUDE control clockwise until a 3V p-p triangle wave is obtained at HI output.
- Pull out the DC offset knob.
- Turn DC offset knob clockwise until the 3V p-p triangle varies between 0 and +3V. (Scope's vert. input must be on dc-coupling to make this adjustment).
- Set frequency range switch on x0.1 for the remainder of the experiment.

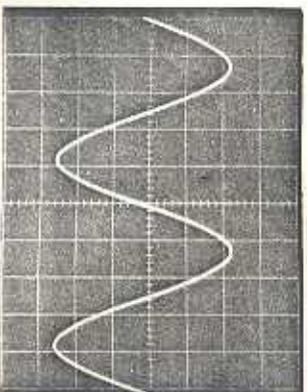
2. Connect equipment as shown in Fig. 17, being careful not to disturb the settings of the two generators.

3. Adjust the scope as follows:

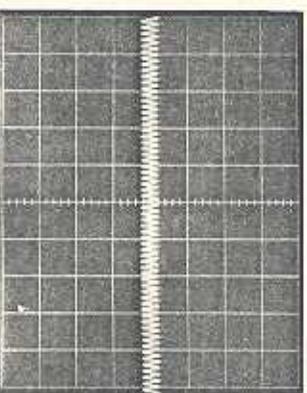
- Vertical input to 0.2V/div
- Horizontal time base to 0.2 ms/div
- Trigger on Internal and Auto Mode. External trigger may be connected to Sync output of 5900 (#2) if desired.



(a) Typical response of Low-Pass filter



(b) Response at ≈ 1KHz



(c) Response at ≈ 30 KHz

Fig. 18 Response of Low-Pass filter

- Now observe the waveform on the scope and note that when the second generator is at its lowest frequency, the full 10V p-p passes through the low-pass filter. However, as the frequency starts rising, the voltage across the output of the filter drops off until at 30 KHz it is 0.9V (-42 dB).
- See Fig. 18 for waveforms viewed on the scope at two points during sweep. These are compared to a typical response curve of a low-pass filter.

To display the frequency response of a high-pass filter, the equipment required is the same as for the low-pass filter in previous example.

Procedure:

- Set up the equipment as shown in Fig. 19.
- Make adjustments identical to that of the low-pass filter.
- See Fig. 20 for typical response and wave forms taken at two points during sweep of the second generator.

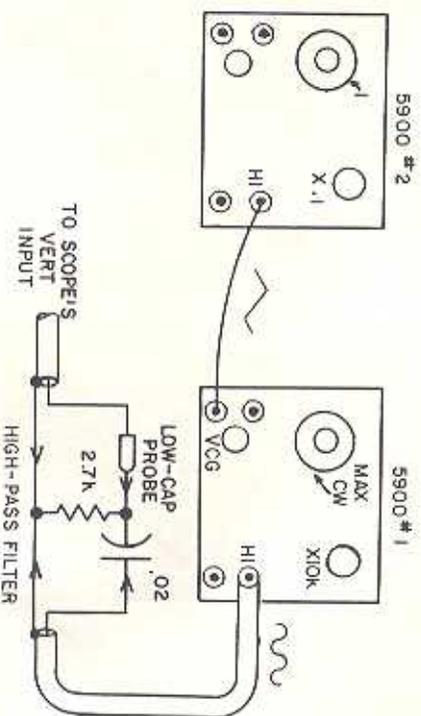


Fig. 19 To display response of High-Pass filter

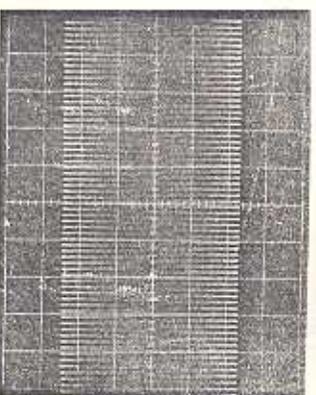
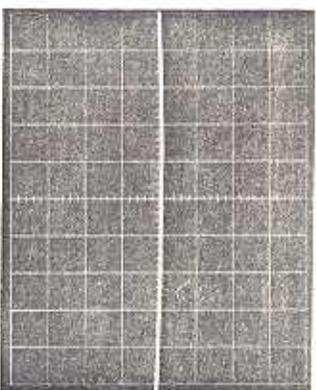
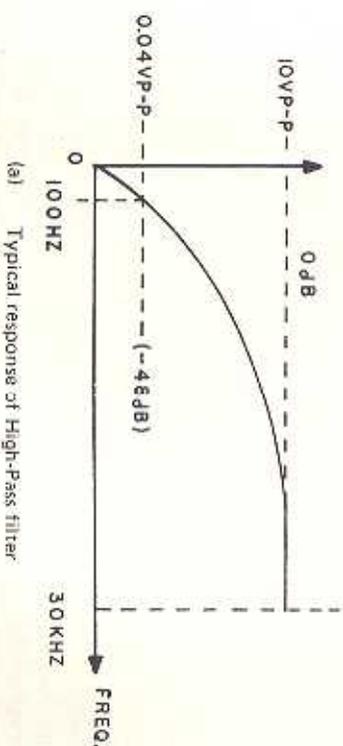


Fig. 20 Response of High-Pass filter

Mechanical Analog-To-Digital (A/D) Conversion displayed.

Procedure:

- Connect equipment as shown in Fig. 21A.
- Adjust scope as follows:
 - Vertical Amplitude at 2V/div.
 - Horizontal time base at 0.2 ms/div.
 - Trigger on internal (external trigger from Sync output of 5900 may be used also).
- Adjust 5900 generator as follows:
 - Frequency dial to maximum clockwise setting.
 - Frequency range switch to x10k.
 - Function to sine, square or triangle wave.
 - Amplitude to 10V p-p (mid rotation).
 - DC offset switch pushed in.
- Adjust 1k pot for 0V as indicated on voltmeter. The scope should confirm this in that no output signal is displayed.
- Adjust pot for 1.00V and measure frequency output of the generator with either a scope or a frequency counter like the Hickok 3301. Record frequency
- Adjust pot for 2.00V. Measure and record the frequency.
- Adjust pot for 3.00V. Measure and record the frequency.

8. When the values recorded in Steps 5, 6, and 7 are recorded on graph paper, they will reveal a reasonably linear response, such as typical response of Fig. 21B.

It is easy to visualize applications for converting an analog voltage to a frequency. For example, if a rack and pinion were connected to the shaft of the pot, linear motion could be read out as Hz/inch.

9. Adjust the 1k pot for the lowest voltage that produces an output signal from the generator. It will be necessary to reduce the scope's horizontal time base to approximately 50 ms/div to view this. The generator's output will be non linear at this extremely low voltage (approx. 25 mV). However the frequency may be as low as 1.6 Hz which when compared to 30 KHz at 3V is a ratio of 30,000:1.6 or 18,750:1. A low frequency is more easily obtained if the 1k pot is a 10-turn type.

10. To enhance the experiment, use the Hickok 5900 dual trace scope and connected channel B of the scope in place of the voltmeter. Use the dc coupled mode and adjust the vertical input of channel B to 0.5V/div. Set the 1k pot for 0V and center the trace of channel B on bottom line of the screen. Now it will be possible to compare the dc voltage and the frequency output simultaneously. Incidentally, it is now evident how the 5900 can be controlled from a remote location using the set up in Fig. 21A.

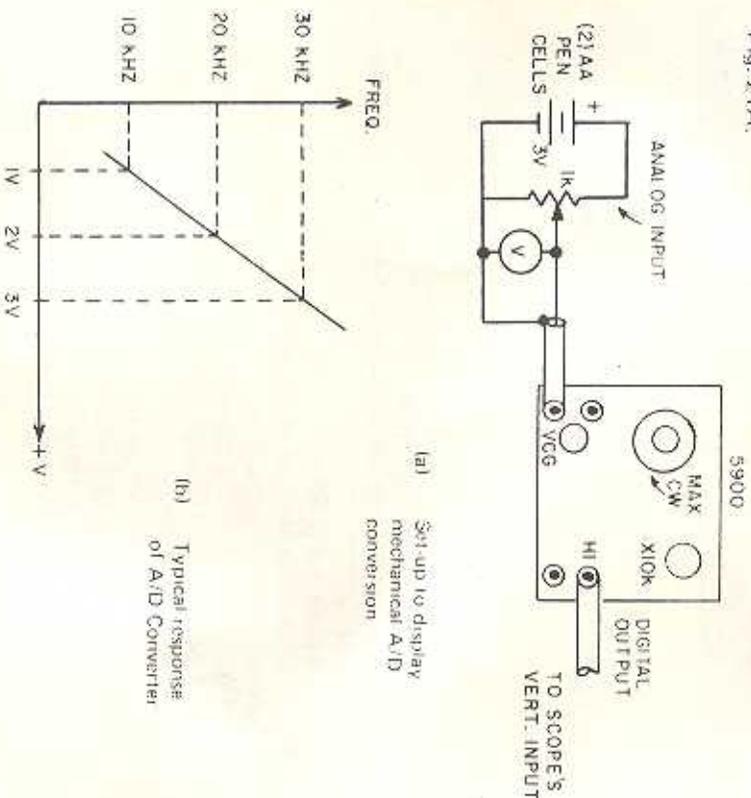


Fig. 21 Mechanical A/D conversions

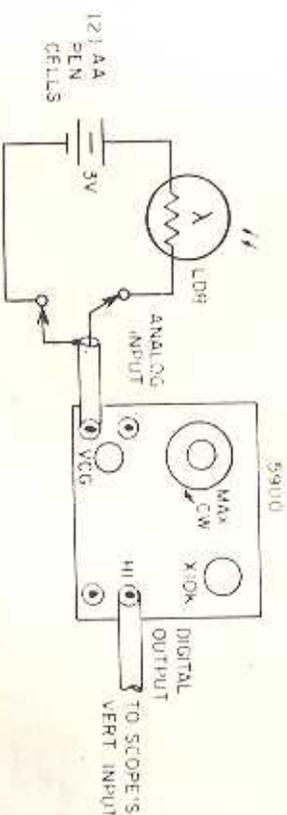


Fig. 22 To display optical A/D conversion

Optical analog to digital (A/D) conversion

Procedure:

1. Connect equipment as shown in Fig. 22.

2. Adjust scope as follows:

Vertical amplifier at 2V/div

Horizontal time base at 0.2 ms/div

Trigger on internal (or external connected to Sync output)

3. Adjust 5900 generator as follows:

FREQUENCY dial to max, clockwise setting

FREQUENCY range switch to x10k

FUNCTION switch on sine, square or triangle (triangle is better for first experience).

AMPLITUDE control set at 10V p.p (mid rotation)
DC offset switch pushed in

4. The ambient room light will now cause a triangle wave to appear on the scope (assuming the function switch is on triangle). Blocking the light will cause 0 Hz output. Facing the LDR directly towards the light will increase the frequency. It is obvious that the frequency of the generator is proportional to light.

Room light, however, is not the best for demonstration purposes. It fluctuates at the rate of 120 Hz causing multiple images to appear on the scope. Actually, the LDR is tracking the 120 Hz fluctuation as it frequency-modulates the 5900. For a better demonstration, use a light source powered from a dc voltage (e.g. a flashlight). If the room light is blocked out allowing only the steady light to fall on the LDR, the signal from the generator will be extremely crisp and stable. Now, the generator will respond to the slightest change in light. It can be seen that with a light meter a calibration could be made for Hz/foot-candles, etc. For an interesting experiment, hold the LDR near the pilot lamp of the 5900 generator or the scope and monitor the light intensity.

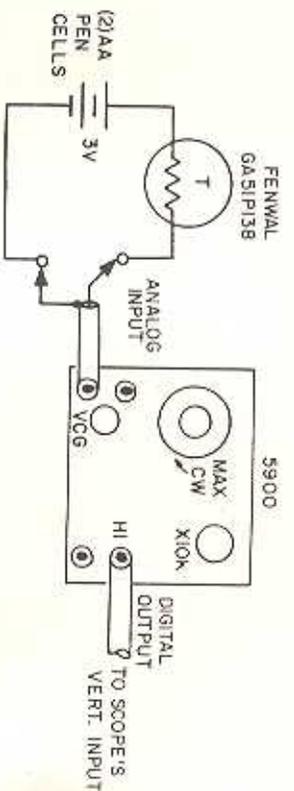


Fig. 23 To display temperature A/D conversion

Temperature analog-to-digital (A/D) conversion.

Procedure:

1. Connect the equipment as shown in Fig. 23.
2. Adjust scope as follows:
 - Vertical amplifier at 2V/div
 - Horizontal time base at 0.2 ms/div
 - Trigger on internal (or external trigger connected to sync output of 5900).
3. Adjust 5900 generator as follows:
 - Frequency dial to maximum clockwise setting
 - frequency range switch to x10k
 - Function switch to sine, square or triangle
 - Amplitude 10V p-p (mid rotation)
 - DC offset switch pushed in
4. The ambient room temperature will cause a waveform to appear on the scope. The frequency is proportional to the temperature. To obtain a reasonably large step function, plunge the tip of the thermistor in a cup of cold water and take a frequency reading using the scope or a digital counter. Then hold the probe between the thumb and index finger for a higher temperature. Take a frequency reading. The difference in frequency may be as much as 7000 Hz. It can be seen that if the two extremes of temperature were measured with an accurate thermometer, and the thermistor were calibrated accordingly, it would be possible to read temperature as a digital number such that $T = Hz/^\circ F$. Of course it would be necessary to make a calibration curve.

To phase-lock the HTS 5900 generator with another 5900 or other signal source, use a single transistor connected in the circuit shown in Fig. 24. Note that no external power is required since the sync output of the 5900 drives the unit.

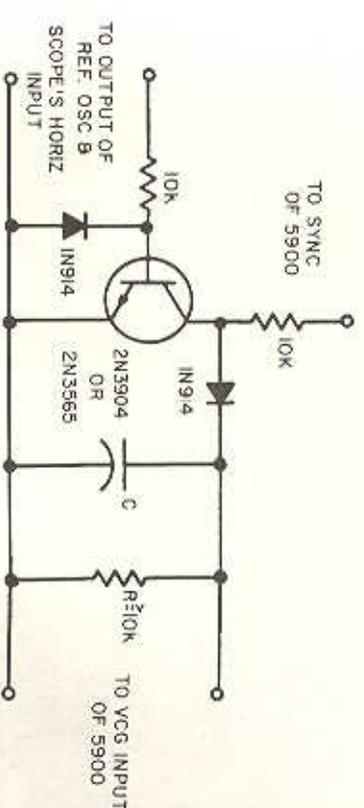


Fig. 24 Schematic of circuit used to phase-lock the 5900

R and C are selected according to the desired phase-lock frequency (F). The formula for selecting R and C is:

$R \approx 10x \text{ to } 100x (1/F)$. For example, to phase-lock the 5900 at 1000 Hz, use an R of 20k ohms and a C of 1 uf.

See Fig. 25 for equipment set up to phase-lock two signals for viewing stable lissajous patterns and adjust equipment as follows:

1. Set the two generators and the scope to produce equal deflection on the vertical and horizontal trace. (Scope's internal time base is switched off and the input is connected to the horizontal external input).
2. Set the two generators to approximately the same frequency, then adjust one of the generators carefully and slowly until a single trace is locked in. With care the two signals can be locked in at a phase angle of 90° as shown in Fig. 26.

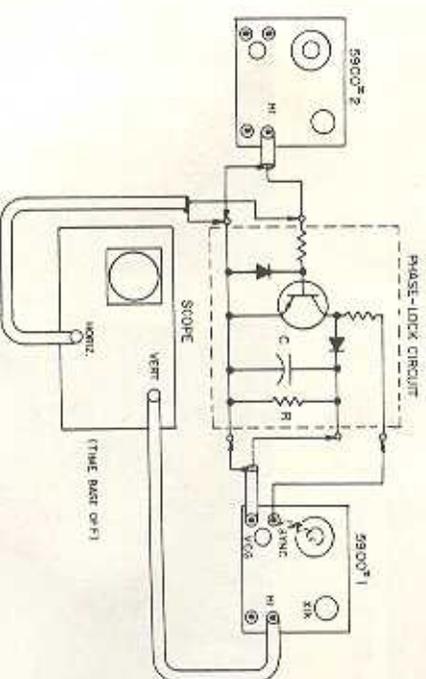


Fig. 25 Equipment set up for phase-locking two generators.

See Fig. 27 for two sine waves in which the frequency of V:H is 3:4

See Fig. 28 for two triangle waves in which the frequency of V:H is 1:1 at approximately a 26.5°. A 90° would produce a square.

See Fig. 29 for two triangles in which the frequency of V:H is 3:2.

The phase-lock capability is useful for observing two waveforms on a dual-trace scope such as the HTS 5003. The equipment connection is identical to Fig. 25 with one exception, instead of connecting the put-out of the reference oscillator to the horizontal input of the scope, connect it to the channel B vertical input of the scope and adjust the scope for alternate or chopped sweep.

See Fig. 30 for two sine waves whose frequency ratio is 1:2.

See Fig. 31 for the same two waveforms, but with the scope in the A-B mode.

See Fig. 32 for a frequency ratio of 1:3 and Fig. 33 for A-B of the same.

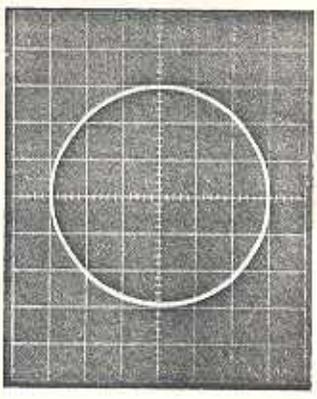


Fig. 26 Sine waves with freq. ratio of V:H = 1:1 ≈ 90°

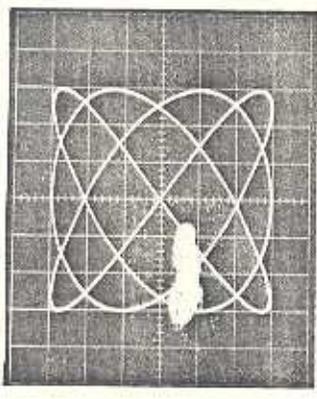


Fig. 27 Two sine waves with V:H = 3:4

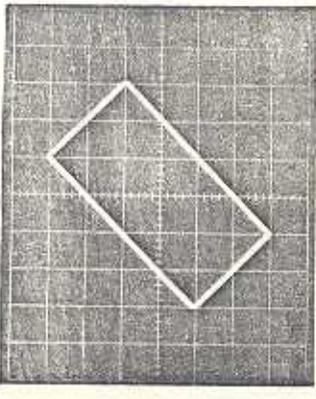


Fig. 28 Two triangles waves with V:H = 1:1 ≈ 26.5°

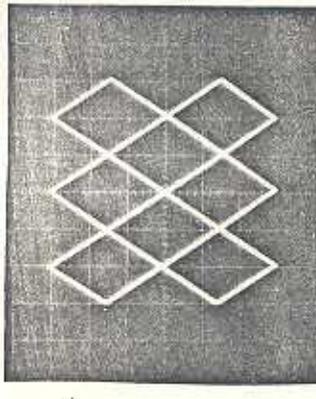


Fig. 29 Two triangle waves with V:H = 3:2

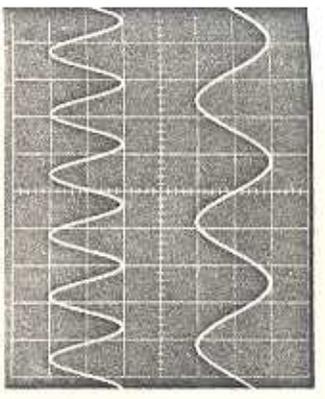


Fig. 30 Two sine waves with freq. ratio of 1:2 viewed on dual channel in alternate mode

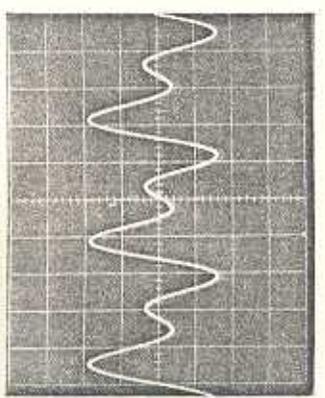


Fig. 31 Two sine waves with freq. ratio of 1:2 viewed on dual channel in A-B mode

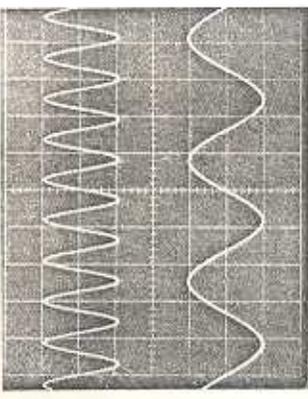


Fig. 32 Two sine waves with freq. ratio of 1:3 viewed on dual channel in alternate mode

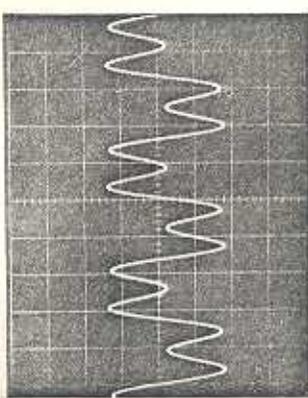


Fig. 33 Two sine waves with freq. ratio of 1:3 viewed on dual channel in A-B mode

To obtain a pulse output, vary the duty cycle of the sync output.

Procedure:

1. Set-up equipment as shown in Fig. 34.

2. Adjust 5900 as follows:

- Frequency dial at 1
 - Frequency range switch at x10k
 - Function switch to triangle
 - Amplitude on maximum clockwise setting
 - DC offset switch pulled out, and in center of its rotation range.
3. Adjust scope as follows:
- Vertical amplifier on 2V/div, dc-coupling
 - Horizontal sweep rate on 0.1 ms/div
 - Internal trigger, (+) slope

4. Now, while observing waveform on scope, note that approximately 10 pulses are displayed, but as the d-c offset control is rotated counterclockwise, the frequency is reduced, and the duty cycle decreases.

5. Continue adjusting the d-c offset counterclockwise until the positive pulse (TTL high), +5V, is 0.1 ms (100 us) in duration.

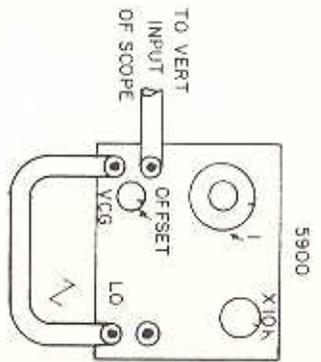


Fig. 34 To obtain a pulse output from 5900

- Now set the scope's sweep rate to 0.5 ms/div and notice that the TTL low level, OV duration is approximately 2.85 ms (2850 us), a duty cycle of: $(0.1 \text{ ms}/2.85 \text{ ms} + 0.1 \text{ ms}) \times 100$ or 3.39%. (Fig. 35)
- If the Function switch is changed from a triangle to a sine wave, the duty cycle will have a greater decrease.

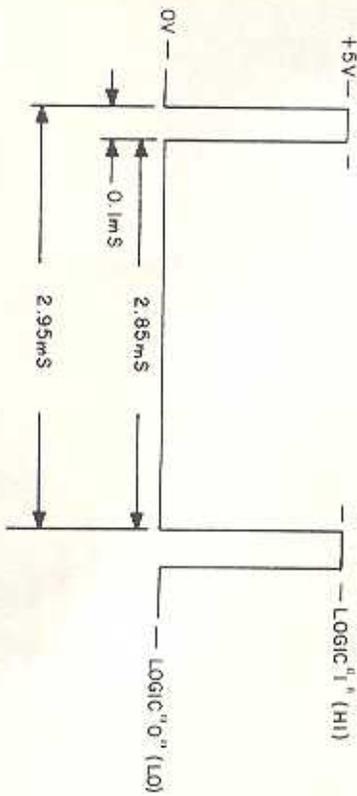


Fig. 35 Typical pulse output of 5900

To generate complex FM patterns, using 3 or more 5900 generators, set up Equipment as shown in Fig. 36.

Procedure:

- Adjust 5900 (# 1) to a desirable audio signal such as 2 kHz initially.
- Adjust the frequency and function (sine, square, triangle) of the three generators for various combinations of sounds and wave patterns. There will seem to be an infinite number of possibilities, ranging from sirens to bird calls.

- Alternate methods of connecting the speaker for louder sounds are to insert A-F amplifier between speaker and 5900 (# 1), or tune 5900 (# 1) to approximately 1000 KHz and loosely couple the output to an AM radio whose frequency dial is tuned to 1000 KHz (or some frequency not used locally). This is the least desirable method since it reduces the number of combinations obtainable with (3) 5900 generators. If an even greater number of possibilities are desired, connect a fourth 5900 output to the VCG input of 5900 (# 3).

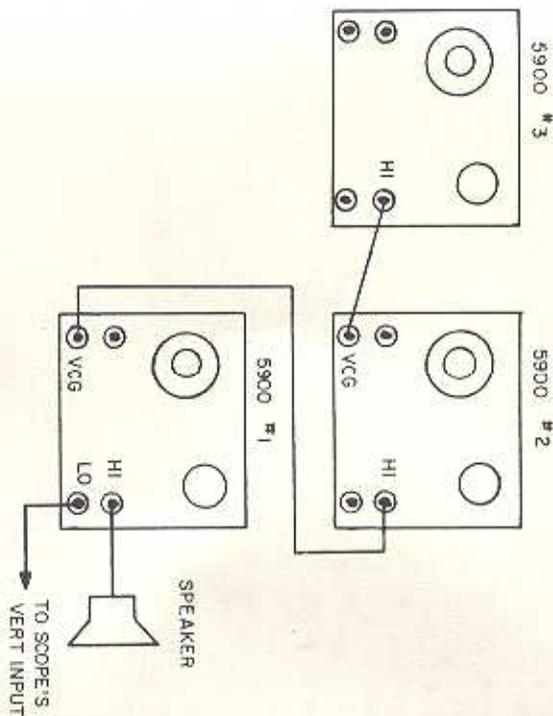


Fig. 36 To generate complex FM patterns

An alternate to Step 3 is to couple a high Z microphone into the VCG input of 5900 (#1) instead of the other generators; or connect an LDR as shown in earlier experiments, to listen to light changes. If only two 5900's are used, it is possible to demonstrate vibrato, frequency-shift keying (FSK), and so forth. If the three generators are connected independantly to three separate speakers (not interconnected as in Fig. 36) it is possible to demonstrate unison, octave, fifth harmonic, harmony, dissonance, beats, diffraction, and so forth.

SECTION V
CALIBRATION

CALIBRATION

If the need should arise for calibration, the following procedure should be followed.

GENERAL

Check all equipment used in these calibration procedures against suitable laboratory standards before beginning.

All calibration procedures are done at 115 VAC (230 VAC if so wired at power transformer).

RECOMMENDED EQUIPMENT

- Hickok Model 5003 oscilloscope or equivalent.
- Hickok DMS 3200 with DP 150A Plug-in or equivalent.
- Hickok DMS 3200 with DP 160 Plug-in or equivalent.
- 50 ohm coax patch cable 24" long, BNC connectors both ends, (3 required).
- Tektronix 011-0049-01 Termination (50 ohm).
- Digital voltmeter, Hickok Model 3300 (±16V) or equivalent.

CALIBRATION PROCEDURE

Power Supply Adjustment:

1. Connect the unit to 115 VAC, 50-60 Hz (or 230 VAC, 50-60 Hz if power transformer is so wired).
2. Connect the digital voltmeter between the positive voltage test point and chassis ground. Adjust R106 (see Fig. 38) until the voltage is 16.0 ±0.1 volts.
3. Vary the primary voltage from 100 VAC to 130 VAC (or 200 - 260 VAC) and check that the voltage reading does not vary by more than ±0.02 volts.
4. Restore the primary voltage to 115 VAC (230 VAC). Connect the voltmeter between the negative voltage test point and ground. Check that the reading is within the range -16.0 ±0.4V.
5. No adjustment is provided for (3) or (4) above. If the unit fails either test, do not attempt to calibrate; seek and correct the problem before proceeding.

Symmetry Adjustment:

1. Connect the high output to the oscilloscope, using the 50-ohm termination.
2. Set the frequency control dial at 3, the range switch at x1k, the DC offset switch off (pushed in), the function selector to triangle, and the amplitude at about 1/2 scale. Adjust the scope controls to display one complete cycle of the waveform.
3. Adjust R12 so that the waveform is exactly symmetrical (i.e. the rising portion is the same duration as the falling portion), Fig. 37.

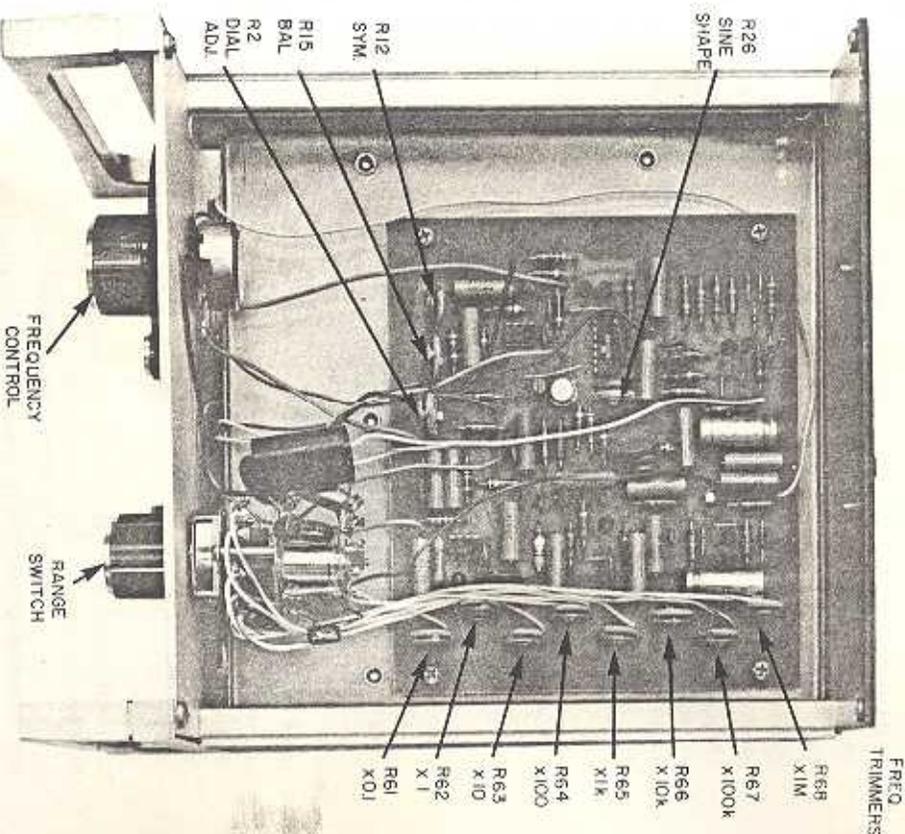


Fig. 37 Top view of chassis

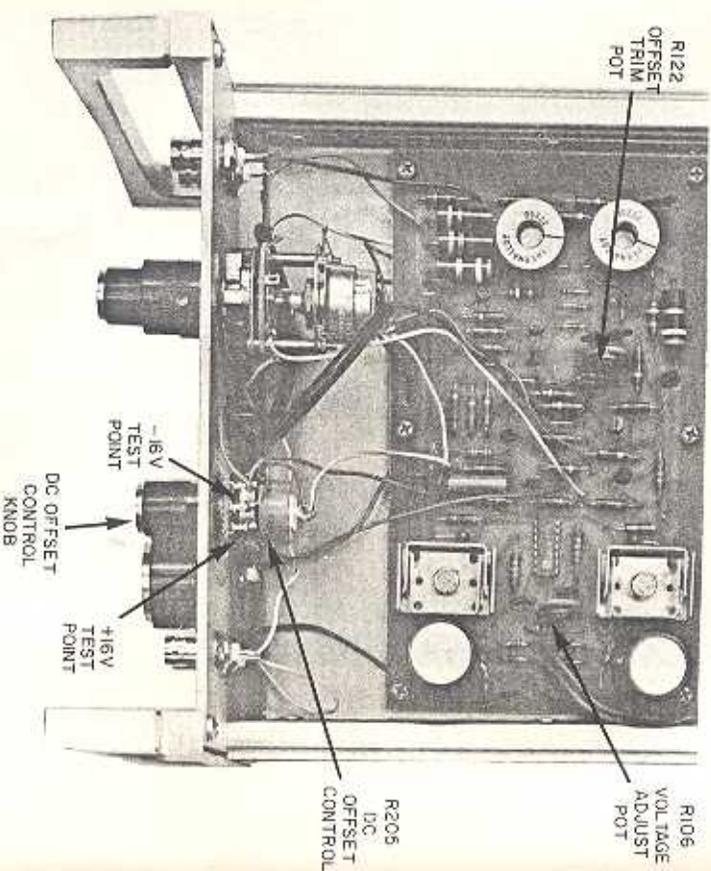


Fig. 38 Bottom view of chassis

- Change the range switch to $\times 100k$ and rotate the frequency control dial clockwise until the frequency is as low as possible. Adjust R15 until the waveform is exactly symmetrical.

Dial Tracking:

- Rotate the frequency control fully clockwise. Check that dial marking 1.90 ± 0.05 is centered at the bottom (180° opposite the frequency index mark).

- Connect the sync output from the unit to the frequency counter. Set the dial to exactly 3.00 and the range switch to $\times 1k$. Adjust R65 to give a frequency reading of exactly 3000 Hz.
- Set the dial to 0.30. Adjust R2 to give a frequency reading of exactly 300 Hz.
- Repeat Steps (2) and (3) until both readings are correct. Then rotate the dial fully CW. The output should cease (frequency goes to zero); if not, loosen the set-screws and rotate the dial clockwise 0.05 units on the shaft and go back to Step (2).

- Check intermediate points on the dial. All frequency counter readings should fall within ± 50 Hz of the corresponding dial setting. Departures from exact equality are a result of non-linearity of the frequency control potentiometer, which cannot be corrected by electrical adjustments. If the deviations are all in the same direction, the end-point readings can be adjusted slightly in the opposite direction to obtain the best overall agreement. If the dial cannot be made to track within the specification, the control potentiometer must be replaced.

Frequency Calibration:

- Set the dial at or near 1.00 so that the frequency counter reading is exactly 1000 ± 1 Hz. (Dial should be within 1.00 ± 0.05).
- Change the range switch to $\times 10k$. Adjust R66 for a frequency reading of $10,000 \pm 10$ Hz.
- Change range switch to $\times 100k$. Adjust R67 for $100,0 \pm 0.1$ KHz.
- Change range switch to $\times 1M$. Adjust R68 for 1000 ± 1 KHz.
- Change range switch to $\times 100$. Adjust R64 for 100.0 ± 0.1 Hz.
- Change range switch to $\times 10$. Since direct frequency measurement is too slow on this range and lower ranges, change to a period measurement. Adjust R63 such that the output period is 100.0 ± 0.1 millisecc.
- Change range switch to $\times 1$. Adjust R62 for period of 1000 ± 1 millisecc.
- Change range switch to $\times 0.1$. Adjust R61 for period of $10,00 \pm 0.01$ sec.

Sine Wave Adjustment:

- Set the range switch to $\times 1k$, frequency dial to 1.00, function switch to sine, amplitude to approx. $\frac{1}{2}$ of full scale, and observe the sine wave on the oscilloscope.
- Adjust R26 for most satisfactory sine wave shape. This adjustment can be made as follows:
 - by sight, study a perfect sine wave (e.g. from a Wien-bridge oscillator) for comparison,
 - (preferred method) by forming a Lissajous figure. Operate the scope in the X-Y mode. Drive the X-axis with the output of a Wien-bridge oscillator set at 1 KHz. Phase-lock the test unit to this oscillator (see fig. 39) and adjust the frequency control of one of the oscillators slightly until the scope pattern approaches a straight line. Adjust R26 for the best straight line. To obtain a good line, it may also be necessary to adjust R12 very slightly, if the waveform symmetry is not perfect.

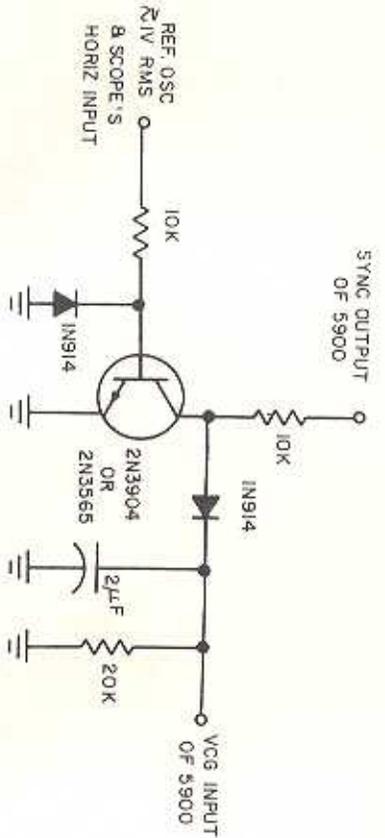


Fig. 39 Phase-lock circuit

by measuring waveform distortion with a distortion analyzer as directed and adjust R26 (and R12 if necessary) for minimum distortion.

D.C. Offset Trim:

1. Turn the output amplitude control fully counterclockwise. Be certain the front panel DC Offset control is off (pushed in). Use the DC input connection to the oscilloscope.
2. Set the function generator output to zero volts by adjusting R122. Gradually increase the oscilloscope sensitivity to obtain the best offset trim adjustment. Note that this adjustment may show drift resulting from transient thermal effects; allow time for the adjustment to stabilize. This adjustment may be sensitive to instrument orientation; therefore, adjust for best balance with instrument right side up.

Amplitude Modulation Calibration:

1. Position variable resistors R312, R320 and R322 at their midpoints.
2. Monitor test point TP-1 using the 10:1 probe with the oscilloscope set for .5 volts/division.
3. Slowly adjust R320 until oscillation just occurs. The waveform observed at TP-1 should be 12V p-p. Note that any other setting of R320 will result in a decreased peak to peak amplitude accompanied by considerable distortion. Nominal frequency is 1000Hz.
4. Remove the probe from TP-1 and connect it to monitor the signal at TP-2.
5. Set the frequency range selector at X1M, function selector switch for sine wave output, AM selector switch for EXT., and turn the amplitude control (R204) to its maximum clockwise position.
6. Adjust the carrier amplitude pot R322 for a .9 volt p-p signal.
7. Set the AM selector switch to INT.
8. Set the modulation adjustment pot R312 for 90-100% modulation. Note that there is an interaction between R312 and R322 so that alternate adjustments may be necessary to insure an optimum waveform, i.e., maximum output swing with 100% modulation. When properly adjusted the output swing should be about 1.8V p-p without the emergence of clipping.
9. Set the AM selector switch EXT. and apply a 10V p-p $\pm 1V$ 1KHz ($\pm 30\%$) sine wave to the EXT. modulation output. Verify that the waveform is amplitude modulated from 50-100%.

**SECTION VI
MAINTENANCE**

GENERAL

The Model 5900 has been built under the high standards of Hickok workmanship and should provide reliable operation almost indefinitely. If the 5900 requires service, refer to the schematic diagram, Fig. 43 and to Fig. 40 and Fig 41 for component location on the two printed circuit boards.

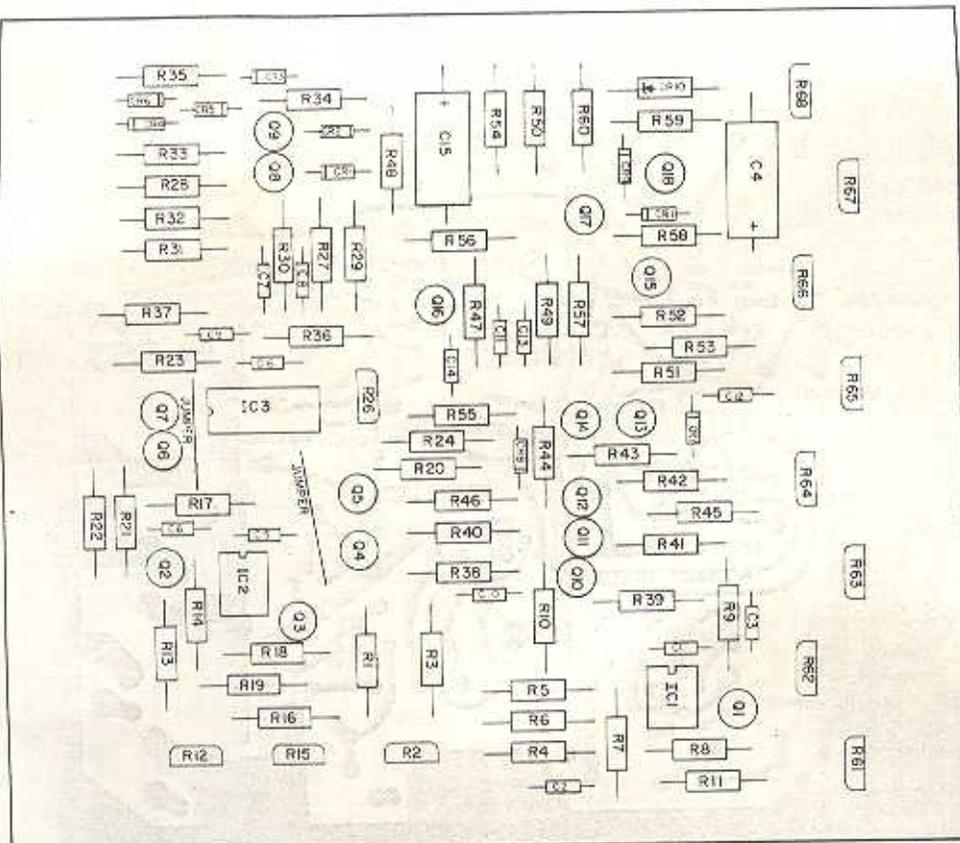


Fig. 40 Component layout of top printed circuit board

The schematic diagram shows typical values of key d-c voltages. To further aid in troubleshooting, there are 27 waveforms taken from the schematic labeled W1 to W27. These refer to 27. These typical scope waveforms are shown in Fig. 42. The waveforms are obtained when the 5900 and oscilloscope are preset according to the notes on the schematic. The waveforms in each case show the d-c and a-c components, therefore making it unnecessary to show the d-c voltages on the schematic where a waveform applies.

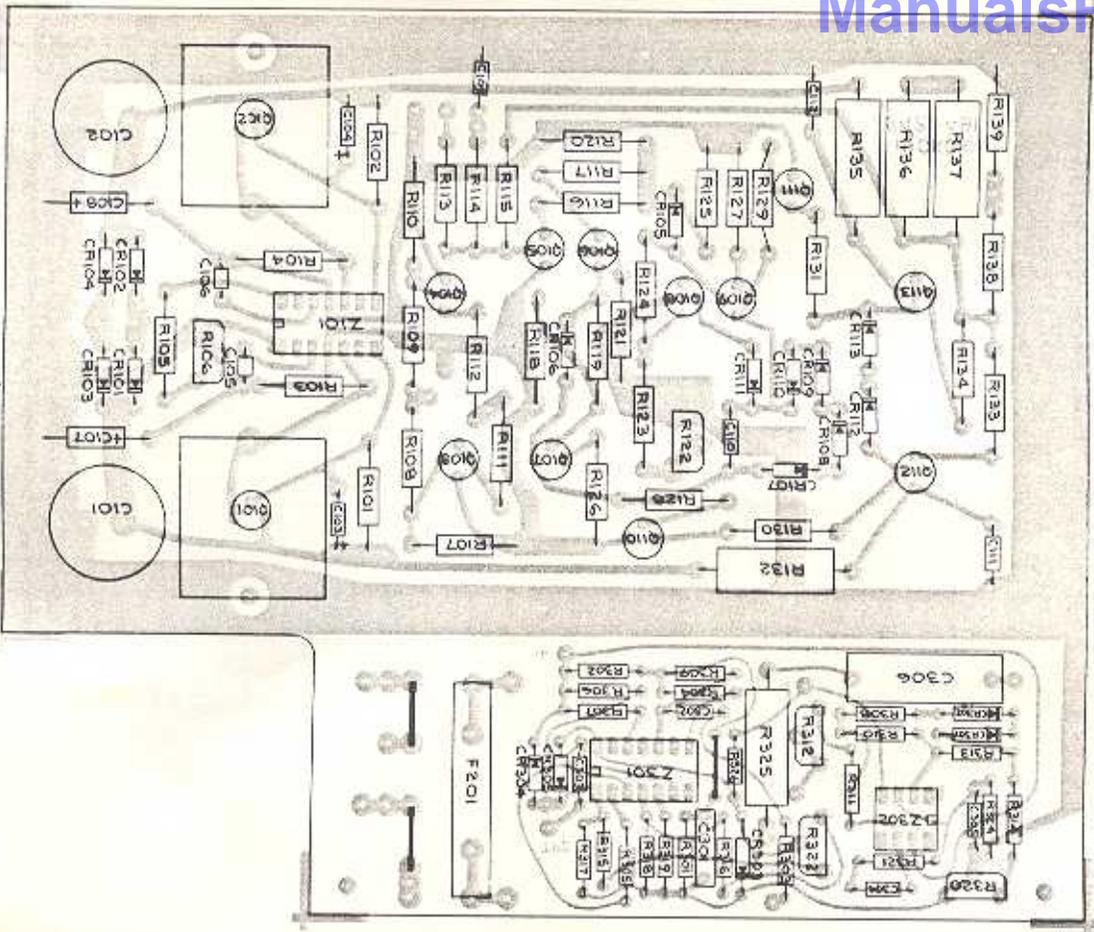


Fig. 41 Component layout of bottom printed circuit board

SECTION VII
PARTS LIST
MODEL 5900A

REF. DESIG.	PART NUMBER	DESCRIPTION
		Booklet, Instruction
C4, C15	2490-675	Capacitor, fixed, electrolytic, 100uF/25V
C101, C102	3085-483	Capacitor, fixed, electrolytic, 100uF/35V
C208	3096-518	Capacitor, fixed, dipped mica, 51pF/500V, 5%
C205	3090-95	Capacitor, fixed, dipped mylar, 0.068uF/100V, 5%
C7, C8, C11	3110-251	Capacitor, fixed, disc ceramic, 5.8pF/1000V, 10%
C9, C13	3110-330	Capacitor, fixed, disc ceramic, 15pF/1000V, 10%
C5, C10	3110-331	Capacitor, fixed, disc ceramic, 39pF/1000V, 10%
C1	3110-192	Capacitor, fixed, disc ceramic, 1000pF/1000V, 10%
C105, C106	3110-332	Capacitor, fixed, disc ceramic, 0.01uF/25V, 20%
C6, C111, C112	3110-160	Capacitor, fixed, disc ceramic, 0.05uF/50V, +80%-20%
C2, C3, C12, C14, C16, C109, C110	3110-333	Capacitor, fixed, disc ceramic, 0.1uF/25V, 20%
C201		
C204	3103-135	Capacitor, fixed, metallized polyester, 0.68uF/100V, 10%
C207	3103-136	Capacitor, fixed, polystyrene, 680pF/600V, 5%
C206	3103-137	Capacitor, fixed, polystyrene, 6800pF/600V, 5%
C103, C104	3085-485	Capacitor, fixed tantalum, epoxy dipped, 4.7uF/6.3V, +50%-20%
C202	3085-486	Capacitor, fixed, tantalum, epoxy sealed, 6.8uF/25V, 10%
C107, C108	3085-467	Capacitor, fixed, tantalum, epoxy dipped, 10uF/25V, +50%-20%

REF. DESIGN.	PART NUMBER	DESCRIPTION
C301	3103-149	Capacitor, fixed, metallized polyester, .1uF, 10%, 100V
C302, C303, C304, C305	3111-527	Capacitor, fixed, disc ceramic, .01 uF, 20%
C306	3090-106	Capacitor, fixed, metallized mylar, 1 uF, 10%, 250V
C203	3085-487	Capacitor, fixed, tantalum, epoxy sealed, 33uF/25V, 10%
CR1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 105, 106, 107, 108, 109, 110, 111, 112, 113, 304, 305	3870-175	Diode, signal, 1N914
CR10	3870-320	Diode, zener, 1N57298
CR101, 102, 103, 104	3870-329	Diode, rectifier, 1N4003 or equiv.
CR301, CR302	3870-302	Diode, zener, 1N5731B
CR303	3870-303	Diode, 1N5734B
F201	6900-100	Fuse, pig tail, 1/2 amp slo-blo for 115V unit
F201	6900-101	Fuse, pig tail, 1/4 amp, fast-blo for 230V unit
IC1, IC2	8415-38 9800-101	Heat Sink, used with Q112 and Q113 Integrated Circuit, operational amplifier, N.S., LM301AN (mini-dip)
IC3	9800-121	Integrated Circuit, transistor array, RCA CA3086 (DIP)
IC4	9800-122	Integrated Circuit, dual voltage regulator, SG SG4501N
Z301	9800-143 11505-234 11505-217 11505-216 11505-219 11505-236 12270-60 16020-62	Integrated Circuit, MC1496P Knob, Frequency dial Knob, Frequency Range Switch Knob, D.C. offset control Knob, Function/Power Switch Knob, Function/Power Switch Knob, Function/Power Switch Lamp, pilot, with resistor Pad, transistor (used with Q112 and Q113)

REF. DESIGN.	PART NUMBER	DESCRIPTION
J201, J202, J203, J204, J205	3475-303	Connector: Coaxial, UG-1094/u
R201	3475-303	Receptacle, bulkhead, BNC
R205/IS203	16925-832	Resistor, variable, 1k ohms, 10% 2-1/4W, freq. control, linear taper
R12, R63, R64, R65, R66, R67, R68	16925-639	Resistor, variable, 10k ohms, 30%, 1/2W, DC offset control, linear taper
R26	16925-762	Resistor, variable, trimmer, 500 ohms, 20%, 1/4W
R2, R62, R122	16925-754	Resistor, variable, trimmer, 1000 ohms, 20%, 1/4W
R312	16925-768	Resistor, variable, trimmer, 2.5k ohms, 20%, 1/4W
R15, R61, R322	16925-763	Resistor, variable, trimmer, 50k ohms, 20%, 1/4W
R106	16925-749	Resistor, variable, trimmer, 250k ohms, 20%, 1/4W
R320	16925-855	Resistor, variable, trimmer, 250k ohms, 20%, 1/4W
R103, R104	18526-111	Resistor, fixed, 2.7 ohms, 5%, 1/2W
R111, R112	18470-120	Resistor, fixed, 12 ohms, 5%, 1/4W
R133, R134	18470-390	Resistor, fixed, 39 ohms, 5%, 1/4W
R130, R131	18470-510	Resistor, fixed, 51 ohms, 5%, 1/4W
R60, R116, R117, R126, R127, R315, R316	18470-560	Resistor, fixed, 56 ohms, 5%, 1/4W
R139	18470-750	Resistor, fixed, 75 ohms, 5%, 1/4W
R101, R102	18470-101	Resistor, fixed, 100 ohms, 5%, 1/4W
R10, R119, R42, R125, R121, R128, R129	18470-181	Resistor, fixed, 180 ohms, 5%, 1/4W
R32, R33, R118, R124	18470-221	Resistor, fixed, 220 ohms, 5%, 1/4W
R314	18470-331	Resistor, fixed, 330 ohms, 5%, 1/4W
R41	18470-511	Resistor, fixed, 510 ohms, 5%, 1/4W
R59, R123, R138	18470-821	Resistor, fixed, 820 ohms, 5%, 1/4W
R29		

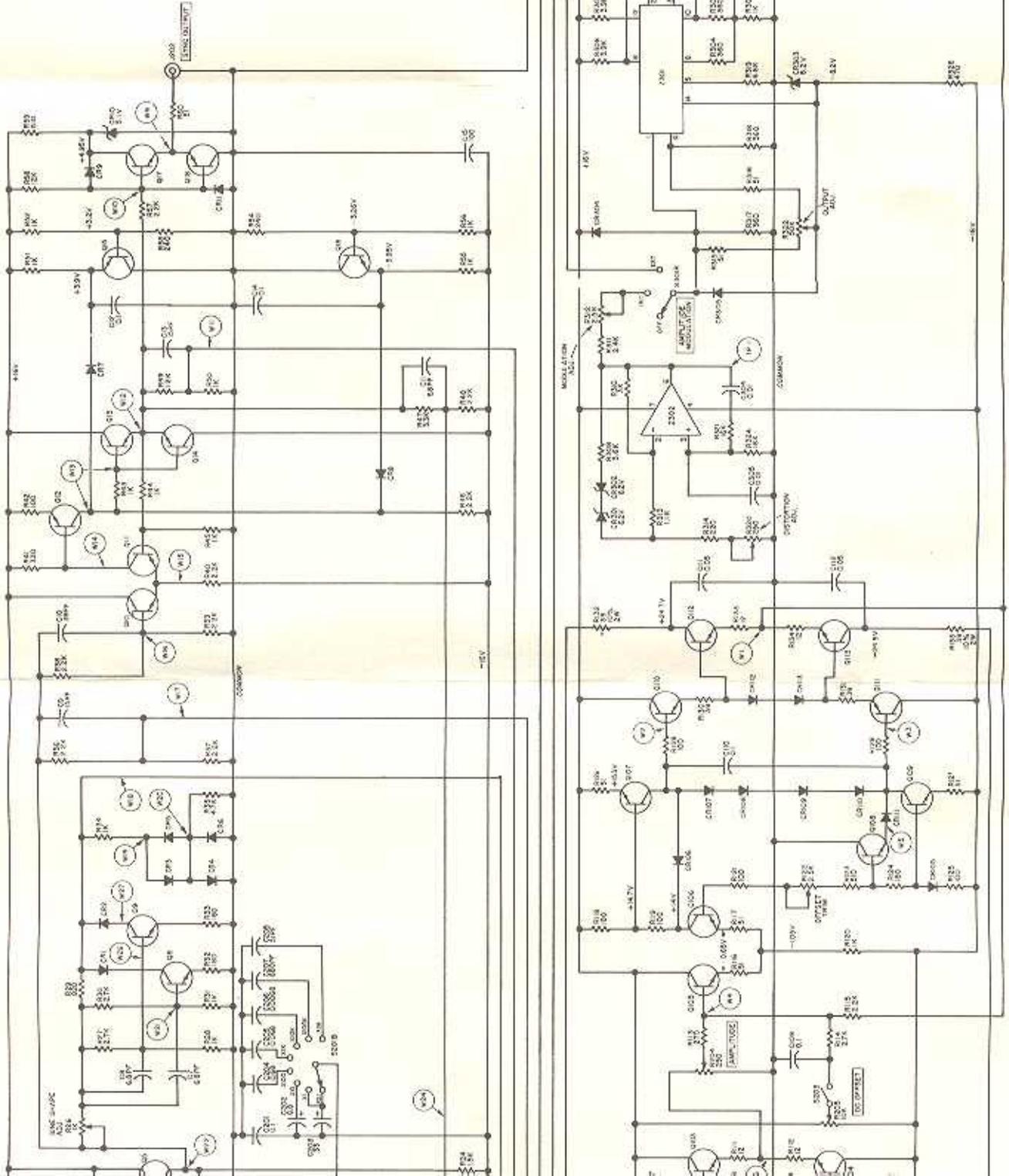
REF. DESIG.	PART NUMBER	DESCRIPTION
R9, R17, R18,	187	Resistor, fixed, 1k ohms, 5%, 1/4W
R20, R21, R28,		
R31, R34, R43,		
R44, R45, R50,		
R51, R52, R55,		
R56, R108, R109,		
R120, R202, R301		
R302, R305		
R313	18470-112	Resistor, fixed, 1.1k ohms, 5%, 1/4W
R24	18470-152	Resistor, fixed, 1.5k ohms, 5%, 1/4W
R23, R36, R37,	18470-222	Resistor, fixed 2.2k ohms, 5%, 1/4W
R38, R39, R40,		
R46, R48, R57,		
R115		
R27, R30, R114	18470-272	Resistor, fixed, 2.7k ohms, 5%, 1/4W
R22, R47	18470-332	Resistor, fixed, 3.3k ohms, 5%, 1/4W
R35	18470-472	Resistor, fixed, 4.7k ohms, 5%, 1/4W
R1, R3, R58	18470-123	Resistor, fixed, 12k ohms, 5%, 1/4W
R107, R110,	18470-223	Resistor, fixed, 22k ohms, 5%, 1/4W
R303		
R7, R105	18470-333	Resistor, fixed, 33k ohms, 5%, 1/4W
R5	18470-824	Resistor, fixed, 820k ohms, 10% 1/4W
R16	18415-472	Resistor, fixed, 4.7M ohms, 10% 1/2W
R14	18416-102	Resistor, fixed, 10M ohms, 10%, 1/2W
R132, R135	18430-392	Resistor, fixed, 39 ohms, 10% 2W
R136, R137	18431-101	Resistor, fixed, 100 ohms, 5% 2W
R53, R54	18470-241	Resistor, fixed, 240 ohms, 5%, 1/4W
R113	18470-271	Resistor, fixed, 270 ohms, 5%, 1/4W
R19, R49	18470-122	Resistor, fixed, 1.2k ohms, 5%, 1/4W
R11, R13	18470-162	Resistor, fixed, 1.6k ohms, 5%, 1/4W
R203	18470-363	Resistor, fixed, 36k ohms, 5%, 1/4W
R6	18470-683	Resistor, fixed, 68k ohms, 5%, 1/4W
R8	18470-913	Resistor, fixed, 91k ohms, 5%, 1/4W
R4	18470-334	Resistor, fixed, 330k ohms, 5%, 1/4W
R306, R307	18470-392	Resistor, fixed, 3.9k ohms, 5%, 1/4W
R321, R324	18470-163	Resistor, fixed, 16k ohms, 5%, 1/4W
R326	18470-471	Resistor, fixed, 470 ohms, 5%, 1/4W
R319	18470-682	Resistor, fixed, 6.8k ohms, 5%, 1/4W

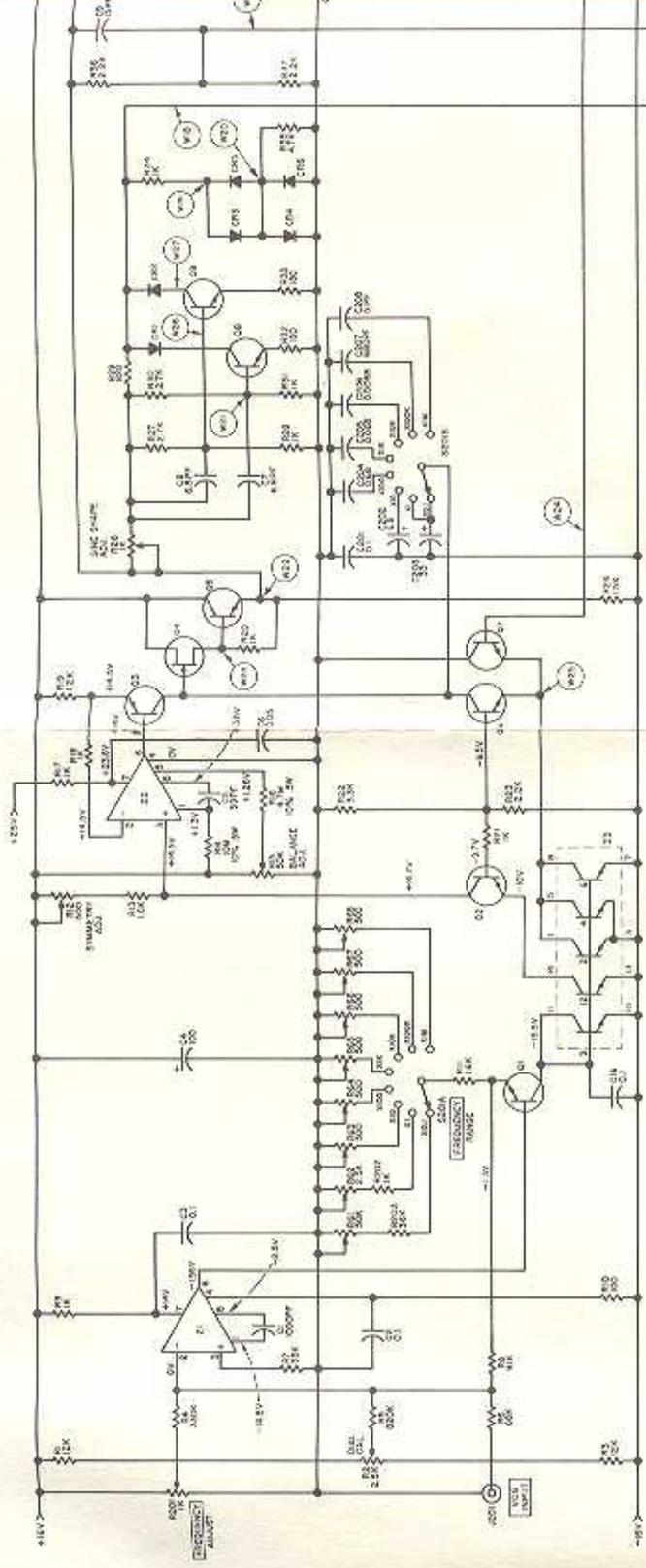
REF. DESIG.	PART NUMBER	DESCRIPTION
R304, R309,	18470-361	Resistor, fixed, 360 ohms, 5%, 1/4W
R317, R318,		
R311	18470-242	Resistor, fixed, 2.4k ohms, 5%, 1/4W
R310	18470-302	Resistor, fixed, 3k ohms, 5%, 1/4W
R308	18470-362	Resistor, fixed, 3.6k ohms, 5%, 1/4W
R325	18575-731	Resistor, fixed, wire wound, 3.5k ohms, 105, 5W
S301	19912-715	Switch rotary, amplitude modulation selector
S201	19912, 687	Switch, rotary, frequency range
R204, S202,	19912-688	Switch, rotary, power, function, amplitude with 250 ohm, 30%, 1/2W
S204		pot, with SPST switch
T201	20800-417	Transformer, power, 115/230VAC input, 36V CT, 0.5Amp Sec.
Q9, Q12, Q14,	20861-139	Transistor, 2N3906
Q15, Q18, Q104,		
Q107, Q111	20861-141	Transistor, 2N3904
Q6, Q7, Q8,		
Q10, Q11, Q13,		
Q16, Q103, Q105,		
Q106, Q108,		
Q109, Q110		
Q1, Q3	20861-275	Transistor, 2N4249
Q2	20861-347	Transistor, T2484
Q4	20861-348	Transistor, FET, 2N5246
Q5, Q112	20861-349	Transistor, 2N2219A
Q17	20861-350	Transistor, 2N4275
Q101	20861-352	Transistor, 40410
Q102	20861-353	Transistor, 40389
Q113	20861-351	Transistor, 2N2905A
	4150-125	Dial, Frequency indicator

SCHEMATIC WIRING DIAGRAM
MODEL 5900A FUNCTION GEN.

SYMBOLS	
LIST USED	NOT USED
8000	8000
8001	8001
8002	8002
8003	8003
8004	8004
8005	8005
8006	8006
8007	8007
8008	8008
8009	8009
8010	8010
8011	8011
8012	8012
8013	8013
8014	8014
8015	8015
8016	8016
8017	8017
8018	8018
8019	8019
8020	8020
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8050	8050

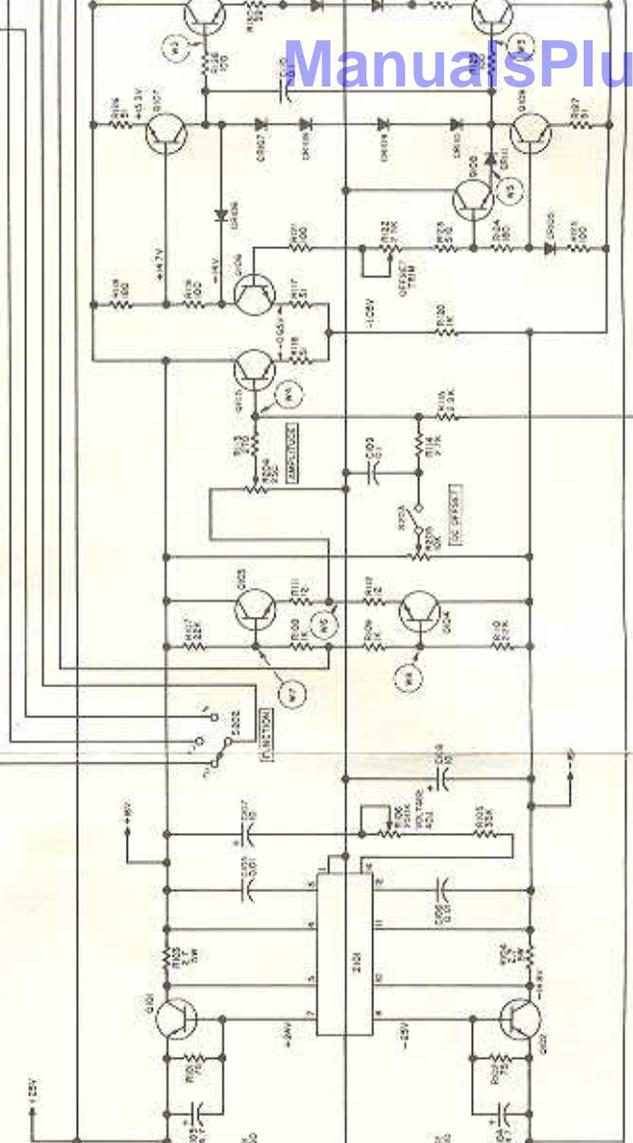
NOTE: UNLESS OTHERWISE SPECIFIED ALL RESISTOR VALUES ARE IN OHMS, UNLESS NOTED, IN K.
UNLESS OTHERWISE SPECIFIED ALL CAPACITOR VALUES ARE IN MICROFARADS (U.F.).





NOTE: TRANSISTORS ARE IDENTIFIED BY THE FOLLOWING CONDITIONS:
 (A) TRANSISTOR TYPE
 (B) MANUFACTURER'S PART NUMBER
 (C) PACKAGE TYPE
 (D) PIN CONNECTIONS
 (E) TOLERANCE BANDS
 (F) TO SPECIFICATION 500000
 (G) SCHEMATIC SYMBOL 100-100

NOTE: THE CENTERLINE ON THE WAVEFORM IS ON THE 0V LINE.
 (A) THE DC AND AC COMPONENT ARE REPRESENTED.
 (B) ALL VOLTAGE AND WAVEFORMS ARE NOMINAL.



SHOWN WAVEFORM FOR INVERTER OPERATION
 FOR 100% DUTY OPERATION DISCONNECT
 #1, #2 & #3



W5 2V/div



W10 2V/div



W15 2V/div



W20 0.5V/div



W25 5V/div