INTRUCTION MANUAL
FOR
MODEL 7054-1
SPIKE GENERATOR

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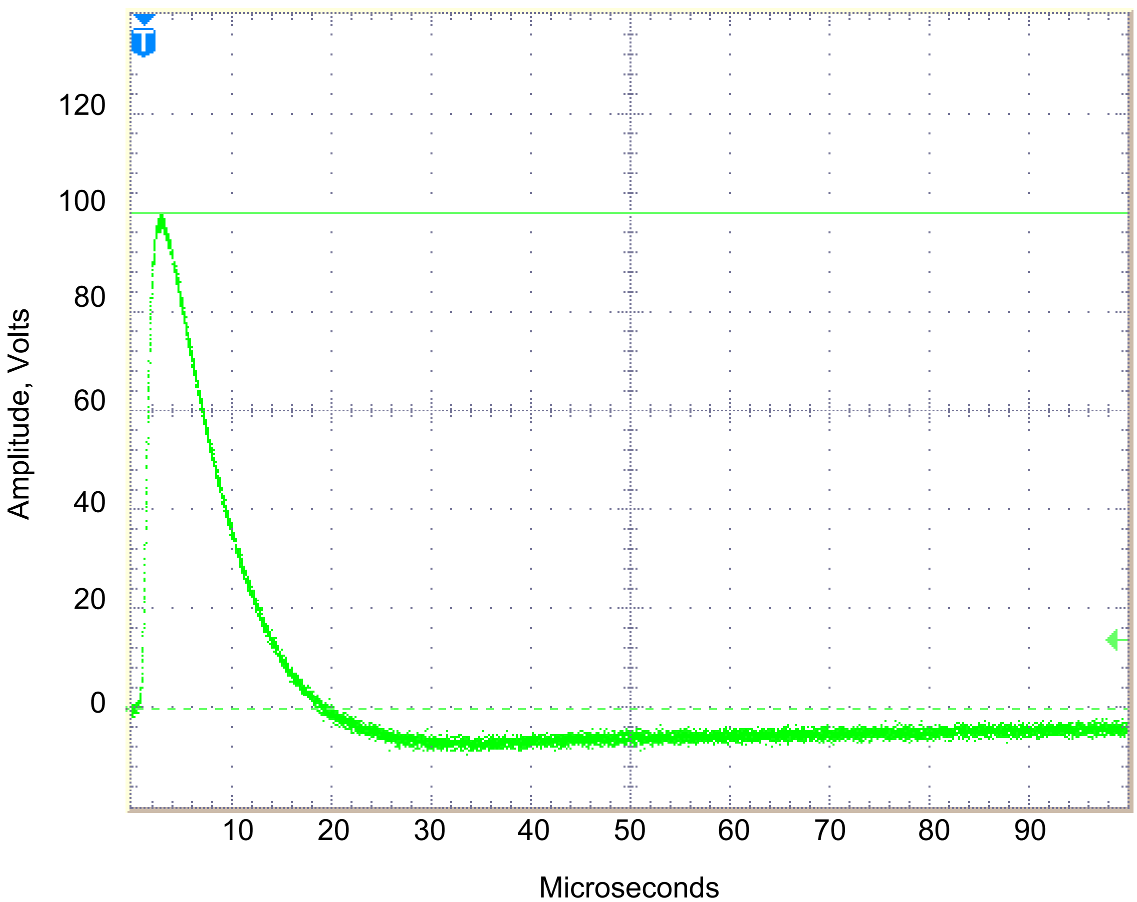
1.0 Application

The model 7054-1 Spike Generator was specifically designed for screen room use in making conducted transient susceptibility tests as required by MIL-STD-826A, MIL-STD-461A/462 and other RFI/EMI specifications.

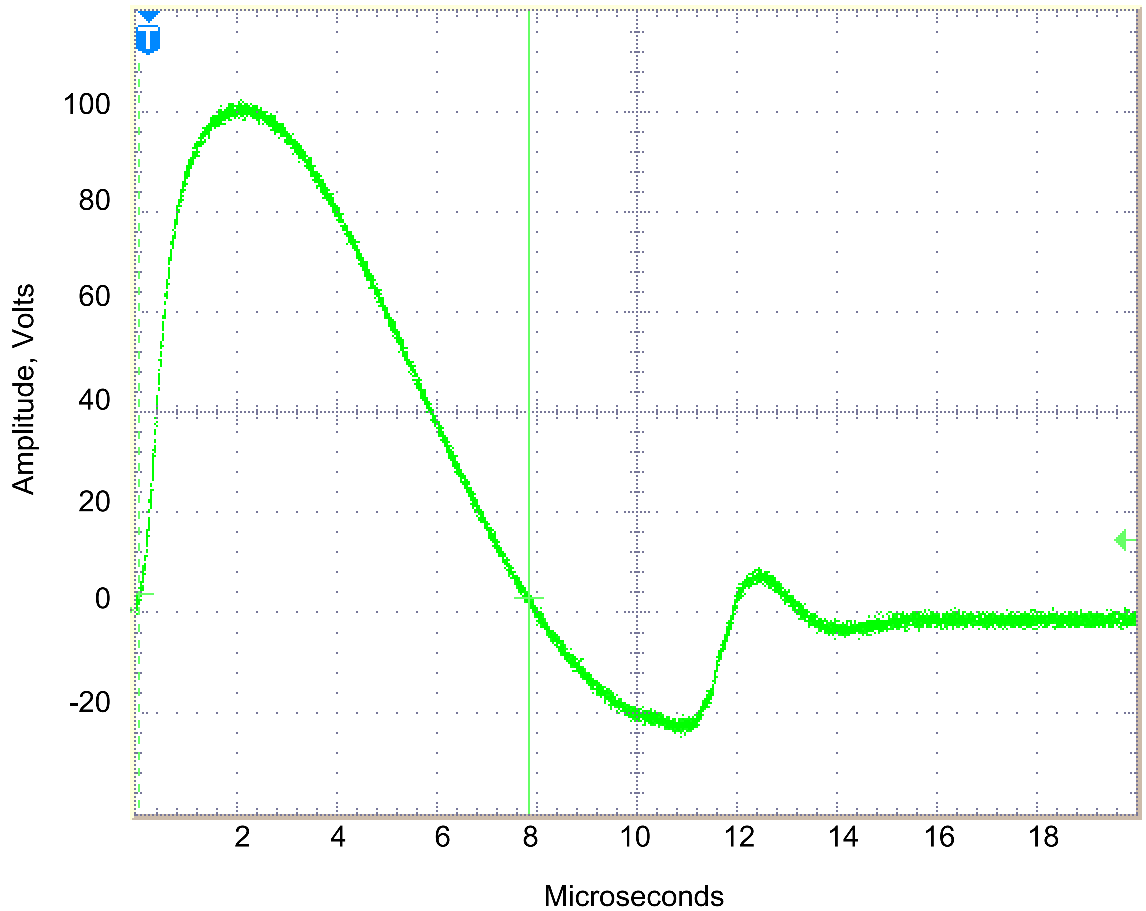
2.0 Description

The model 7054-1 Spike Generator provides a transient pulse (spike) with amplitude adjustable up to 600 V peak. Using parallel injection into a resistive load, the output transient closely follows an idealized curve with less than 1 µs rise time and falling to 10% of full voltage in approximately 10 µs. See Figure 1 and 2. The repetition rate is adjustable from 0.8 pulses per second (pps) to 10 pps.



Vertical: 20 V/div
Horizontal: 10 µs/div
Frequency: 10 pps
Amplitude: 100 V peak into 5 Ω load

Figure 1 – Pulse shape with 5 Ω load on either series or parallel output



Vertical: 20 V/div
Horizontal: 2 µs/div
Frequency: 10 pps
Amplitude: 100 V peak into 0.5 Ω load

Figure 2 – Pulse shape with 0.5 Ω load on either series or parallel output

A FUNCTION switch allows either recurring spikes at a selected rate or provides for single spikes by a panel-mounted push button. The FUNCTION switch also provides for synchronization with 60 Hz* or 400Hz lines.

When synchronizing with AC lines, the PULSE POSITION knob allows for phase adjustment of the spike to position it anywhere on the AC sine wave.

The PARALLEL output terminals provide for injection of the spike in parallel with the load. The SERIES output terminals provide connections for series injection. The output terminals are isolated from the chassis and the AC line.

3.0 Specifications

Spike Repetition Rate
Continuously adjustable from 0.8 pps to 10 pps

Spike Amplitude
Continuously adjustable from 5 V to 600 V peak

Spike Duration
Output falls to 10% of full voltage in approximately 10 μs with a 5 Ω load on the SERIES output terminals

Rise Time
Less than 1 μs into 5 Ω resistive load

Spike Shape
Ringing characteristic as per Figure 1 and Figure 2

Phase Adjustment
Adjustable from 0° to 360° on 60 Hz* or 400 Hz lines

Internal Impedance
Approximately 0.5 Ω

Power Line Current in Series Injection Mode
Handles 25 A RMS at power frequencies or DC

Power Requirement
115 V 60-400 Hz, 1.6 A**

Size
19” rack panel, 7” high x 12-3/4” deep, less projections

Weight
US: 36 lb.; Metric: 16.3 kg.

4.0 Operation

4.1 General

Parallel Injection is most often used for DC lines. Series injection is always used on AC lines. CAUTION! DO NOT CONNECT OUTPUT OF SPIKE GENERATOR IN PARALLEL WITH AC LINES. ALTHOUGH SERIES INJECTION CAN BE USED ON EITHER AC OR DC LINES, PARALLEL INJECTION MUST NOT BE USED ON AC LINES SINCE SEVERE DAMAGE TO THE SPIKE GENERATOR WILL RESULT.

4.2 Interconnections for Parallel Injection

As shown in Figure 3, connect the oscilloscope to the terminals marked PARALLEL. Also connect these terminals to the DC input power leads of the equipment under test. Take precautions to prevent grounding the load through the case of the oscilloscope. Use a Solar type 7032-1 Isolation Transformer or equivalent at the power input to the oscilloscope. All output terminals on the Spike Generator are isolated from the case of the unit.

When parallel injecting the spike into a DC line, it is desirable to use an inductor in series with the power source so that the spike is applied to the test sample without the R.F. shunting effect of the power source impedance. The secondary of Solar Type 6220-1A Audio Isolation Transformer is well suited for this application and is capable of carrying 50 A of test sample current.

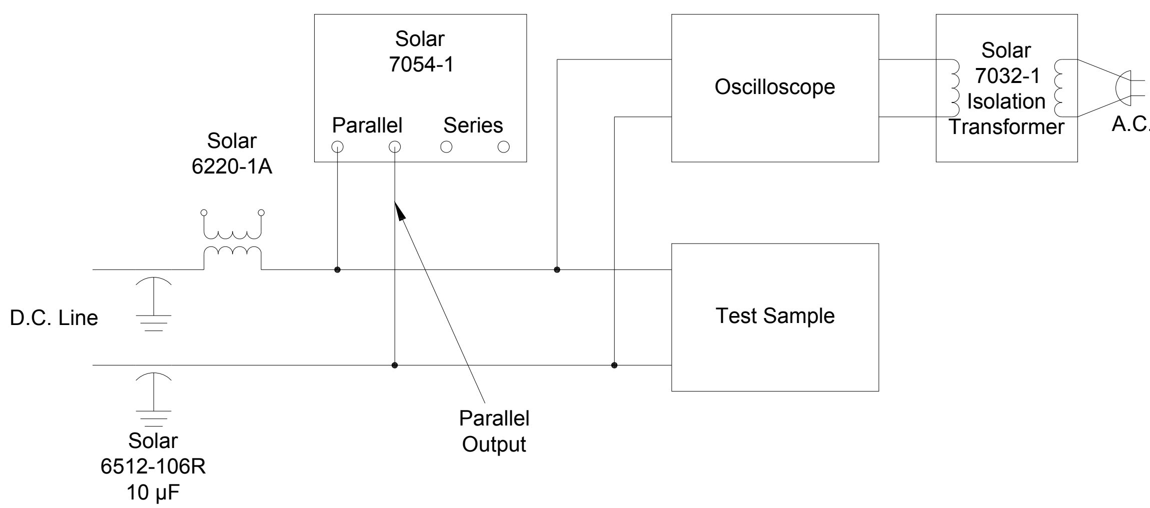


FIGURE 3 - PARALLEL INJECTION ON D.C. LINE

4.3 Interconnections for Series Injection

For series injection, connect the output terminals marked SERIES in series between the power source and the test sample as shown in Figure 4. It is recommended that the injection be in series with the ungrounded side of the power line.

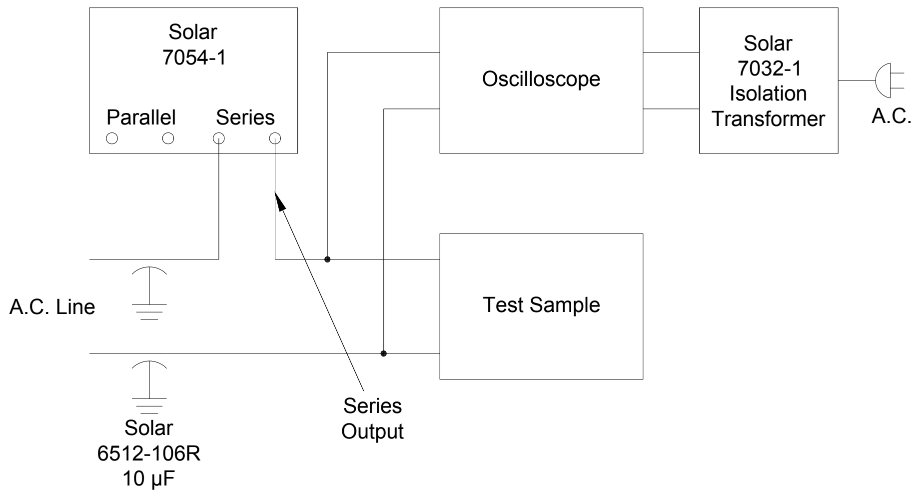


FIGURE 4 - SERIERS INJECTION ON A.C. LINE

The series connection is capable of handling 25 A RMS or DC This connection inserts approximately 75 µH in series with the test sample. The power frequency voltage drop across this reactance is 4.75 V at 25 A, 400 Hz.

The oscilloscope should be connected across the SERIES output terminals to indicate the shape and magnitude of the spike being injected into the circuit. See Figure 5. However, the spike as it appears on the AC waveform into the test sample is best seen by connecting the oscilloscope across the power input leads to the test sample, as shown in Figure 4. Precautions must be taken to avoid grounding the hot side of the power line through the case of the oscilloscope.

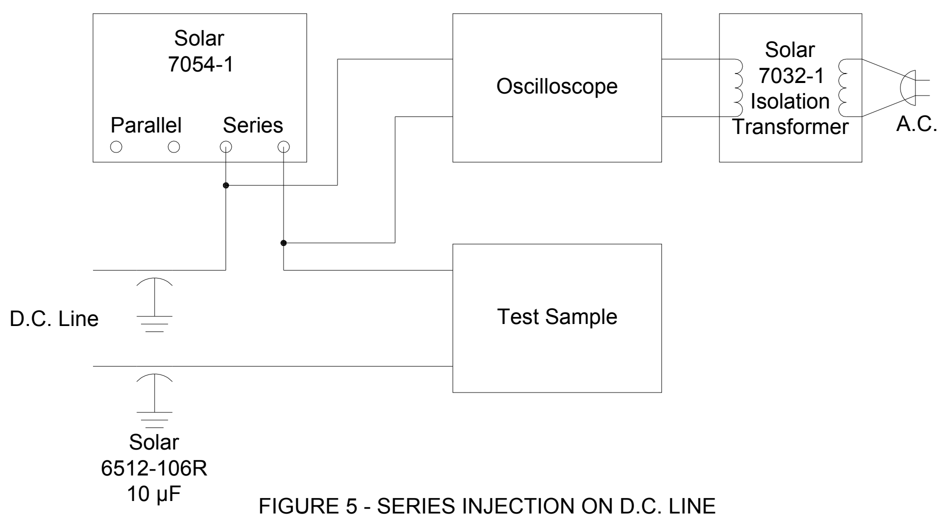


FIGURE 5 - SERIES INJECTION ON D.C. LINE
OSCILLOSCOPE MEASURING 7054-1 SPIKE ONLY

4.4 FUNCTION Switch

This control enables the operator to select from three functions. In the extreme left, SINGLE PULSE position, it provides for pushbutton operation of single transients. The FREQUENCY P.P.S. position selects the variable repetition rate function. The last two FUNCTION switch positions select pulse positioning on 60Hz and 400Hz AC power signals respectively.

4.5 Pulse Positioning

With the equipment connected for series injection on AC lines, as shown in Figure 4, place the FUNCTION switch in 60 Hz* or 400 Hz SYNC position as required. The power cord of the Spike Generator must be connected to the same power source as the test sample.

However, when operating on a 400 Hz power line for the pulse position test, it is necessary to connect the blower fan to the standard 60 Hz* line. See figure 6. This is accomplished by removing the parallel blade connector, P1, from its socket (adjacent to the fuses on the rear panel) and connecting it to a primary power source of 115 V 60 Hz*.

Connect the oscilloscope across the power input to the test sample. Avoid grounding the hot side of the line through the case of the oscilloscope. A power line isolation transformer such as Solar type 7032-1 is suggested at the power input to the scope, as shown in figures 4 and 6.

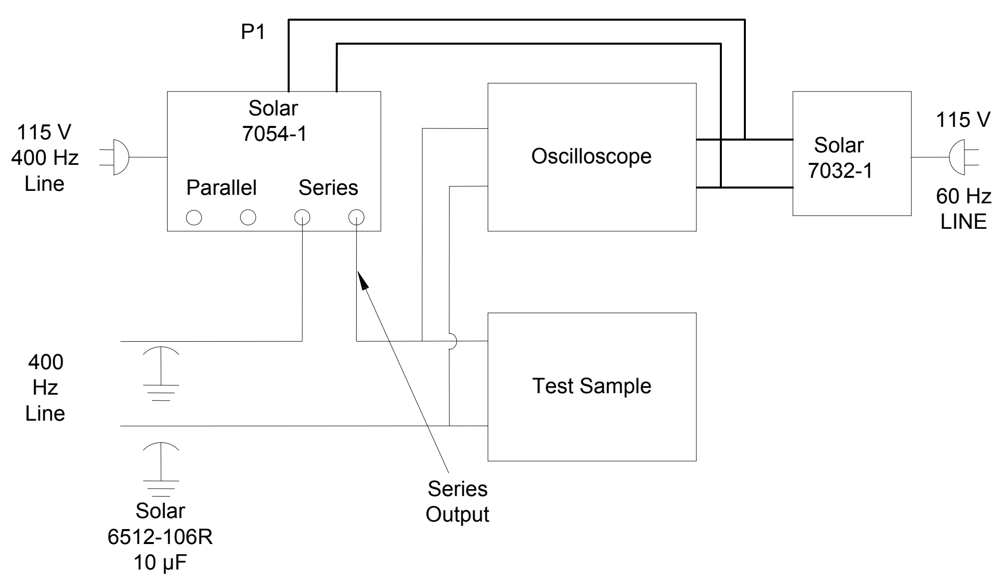


FIGURE 6 - SETUP FOR PULSE POSITION TEST ON 400 Hz LINE

The PULSE POSITION control in conjunction with the polarity reversing switch will enable phase shift of the injected spike through 360° as observed on the oscilloscope. The phase reversing switch at the bottom of the panel will allow adjustment of the spike position to the positive half cycle or the negative half cycle of the power line sine wave. Due to the phase difference existing, the knob position corresponding to the voltage zero crossover will differ from one test sample to another.

When synchronizing on a 60 Hz* line, the spike appears on every 8^{th} sine wave of the power frequency. On a 400 Hz line, the spike appears on every 64^{th} sine wave. The spike position, however, is the same on each sine wave on which the spike appears. This periodic injection of the spike is due to the 7.5** pps rate on 60 Hz* lines and a rate of 6.2 pps on 400 Hz lines. (In this equipment, the repetition rate must be kept below 10 pps to allow time for the charging of the capacitors which provide the energy for the spike.)

CAUTION: WHEN OPERATING ON A 400 HZ POWER LINE, DO NOT LEAVE THE FUNCTION SWITCH IN THE 60 HZ POSITION FOR PROLONGED PERIODS SINCE IT MAY CAUSE OVERHEATING OF THE POWER SUPPLY.

Upon completion of the 400 Hz pulse positioning test, reinsert the parallel blade connector into the mating socket. This connector should remain in this position for all other uses of the Spike Generator.

4.6 Repetition Rate

The calibration of the knob in pps is reasonably accurate (approximately ±10%) at all panel markings. For applications where the exact rate is important, it may be measured on the time base scale of the associated oscilloscope. The rate is independent of load conditions.

4.7 Spike Amplitude

The amplitude of the spike is adjustable from approximately 5 V to 600 V peak by means of the AMPLITUDE knob. The calibration of this scale is most accurate at 100 V with a resistive load greater than 5 Ω and with a repetition rate of 10 pps. For adjustment of amplitude into unknown loads, the knob must be adjusted while watching the spike amplitude on an oscilloscope with calibrated vertical amplitude.

4.8 Amplitude with Low Impedance Loads

Since the internal impedance of the Spike Generator is of the order of 0.25-1.0 Ω, the amplitude into a matched load will be one half that of the open circuit amplitude. This characteristic enables the operator to estimate the load impedance when it is approaching the internal impedance of the generator.

4.9 Pulse Shape

When unloaded or connected to a purely resistive load, the spike shape is approximately that of Figure 1. For low impedance or reactive loads, the shape is modified in terms of load. Figure 2 indicates the spike shape when connected to a 0.5 Ω resistive load.

5.0 Maintenance and Calibration

Periodically make the following tests to verify the performance of the Spike Generator. Make any adjustments required to bring the performance within the specified limits.

5.1 Equipment Required

The following equipment is required for the tests and adjustments described below:

1. Variac, 105-135 V, 60 to 400 Hz,* capable of handling 2 A
2. AC voltmeter, range suitable for measuring line voltage at 60 ** and 400 Hz
3. Calibrated oscilloscope
4. DC voltmeter
5. Single phase 400 Hz power source, capable of supplying 2 A
6. 5 Ω resistor, ±10%, ≥ 20 W
7. 6 V, 400 Hz transformer

5.2 Preliminary Procedure

Be sure the line cord of the Spike Generator is disconnected from the primary source. Remove screws in top cover and in bottom cover.

Connect the variac to a 115 V 60 Hz* power source. Plug the Spike Generator into output of variac. Connect the voltmeter across the variac output and maintain 115 V*** input to Spike Generator throughout the test.

5.3 Voltage Check

DC voltage across the 500 μF capacitor C6, should be 4 V ±10% for older 7054-1's or 7 V ±10% for more recent 7054-1's. Voltage across the 500 μF capacitor C12 should be 18 V DC ±10%. See Figure 7. If necessary, adjust the sliders on R8 shown in Figure 8 to obtain these voltages.

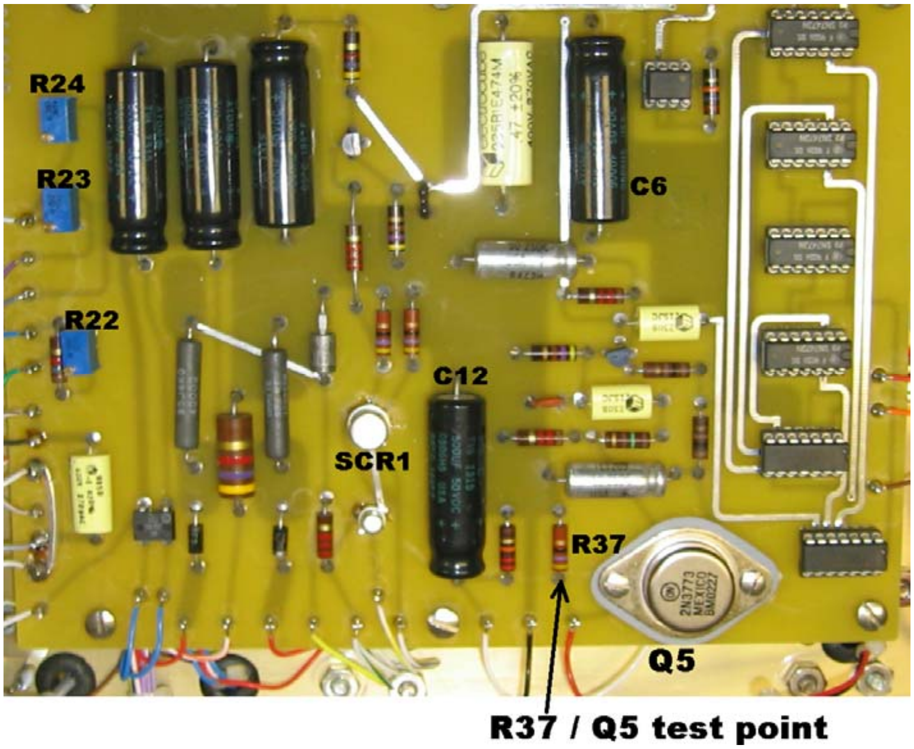


FIGURE 7- PRINTED CIRCUIT BOARD REFERENCE DESIGNATORS

The DC voltage out of rectifier CR1 should be at least 350 V for rightmost rotation of the knob. See Figure 8 for CR1 measurement point.

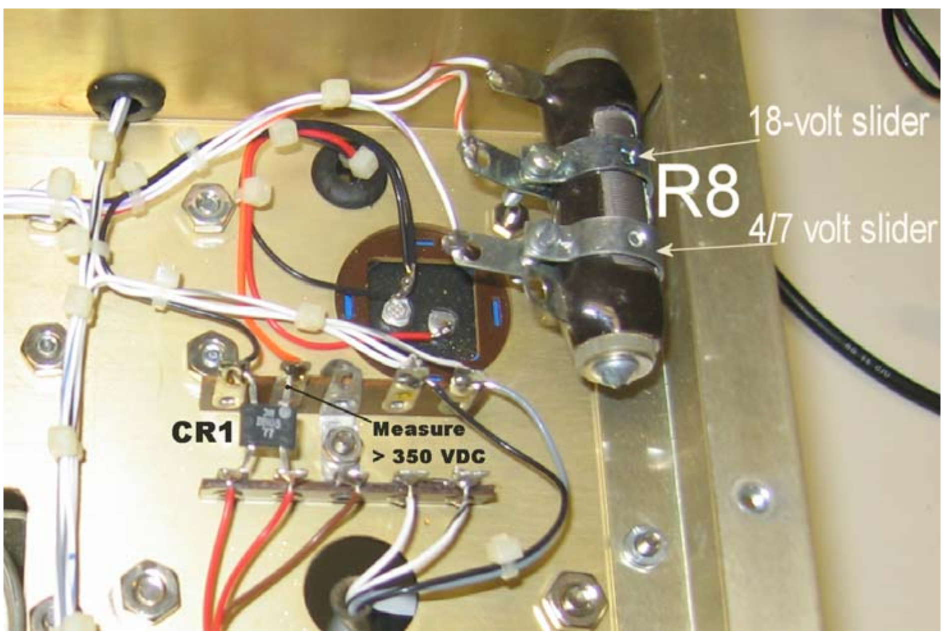
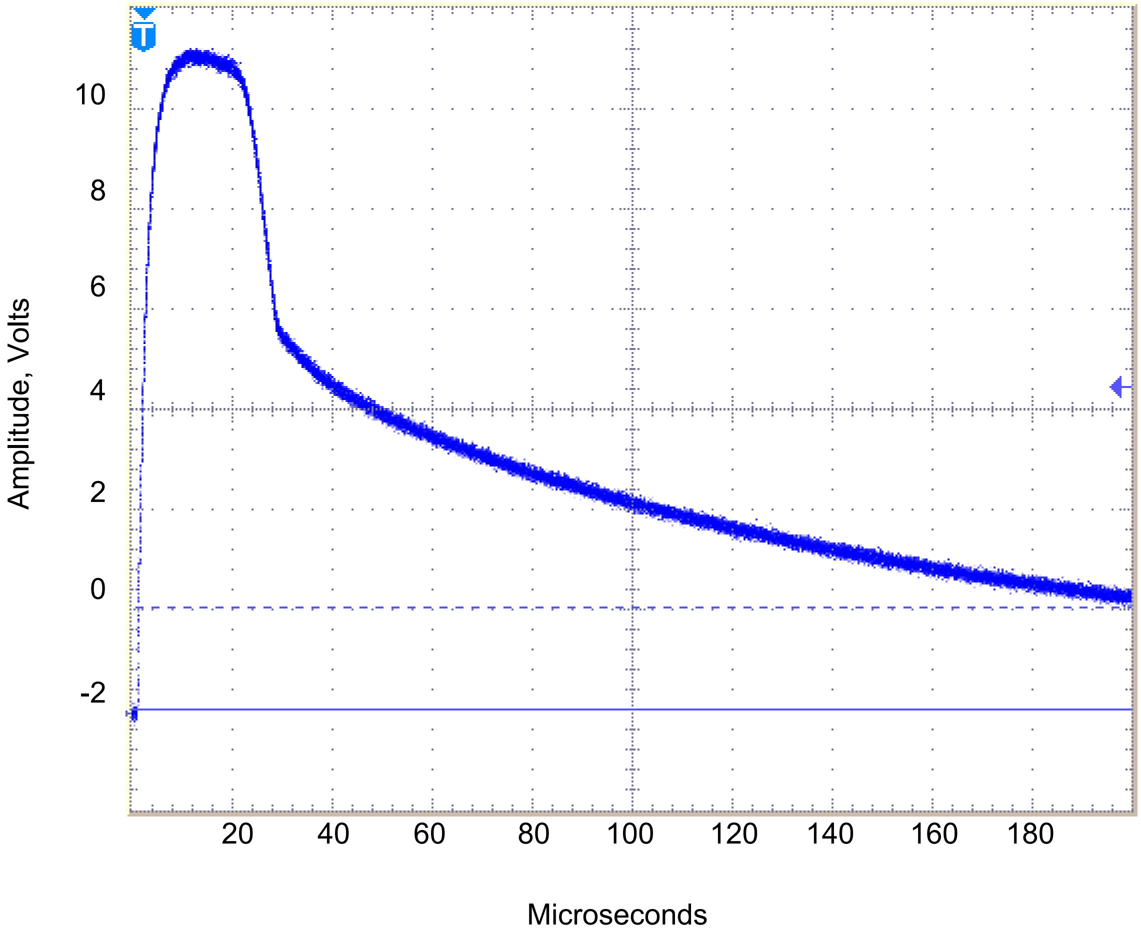


FIGURE 8- ADJUSTMENT SLIDERS AND MEASUREMENT POINT

5.4 Trigger Waveform

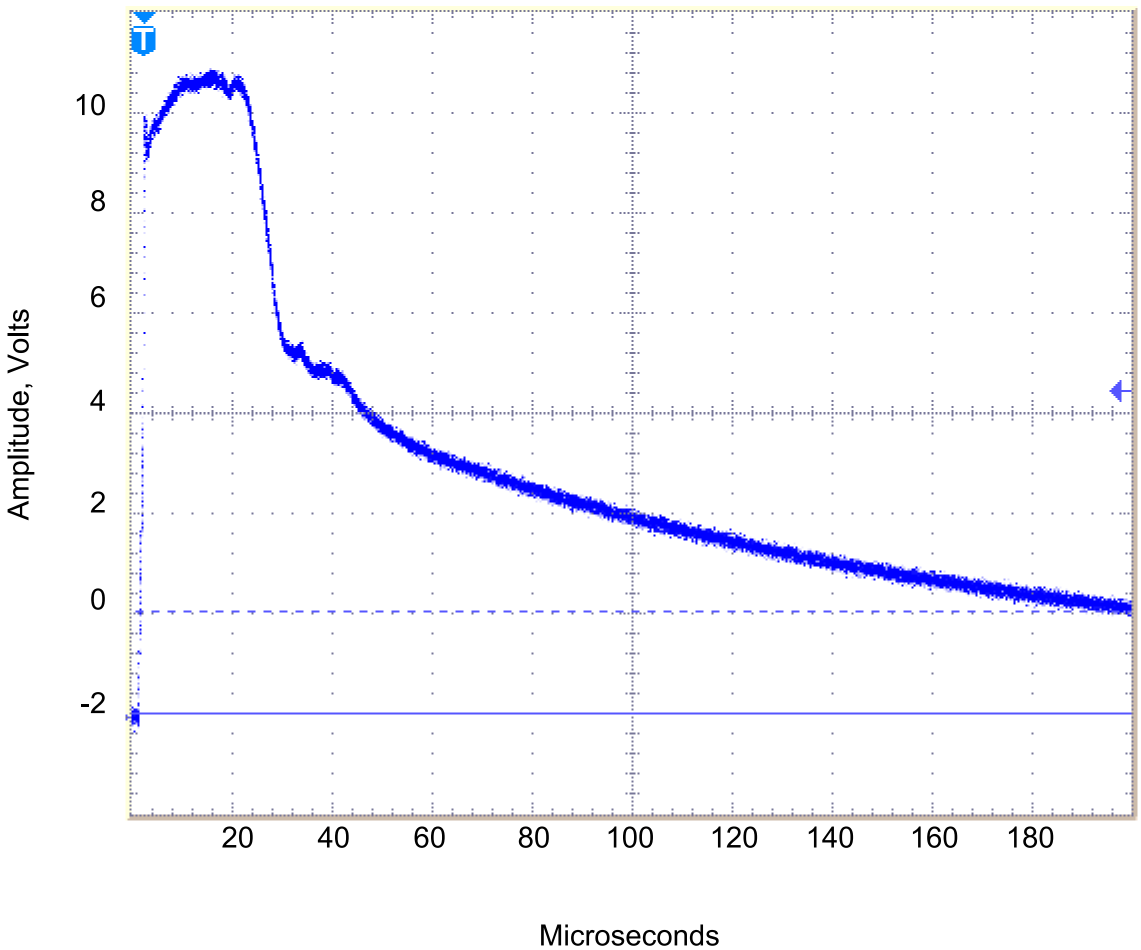
Connect the oscilloscope across R37 at the output of Q5 in Figure 7. The common lead of the oscilloscope may be left on the negative end of C6 or C12. With the FUNCTION switch at FREQUENCY P.P.S., the frequency at 10 pps, the AMPLITUDE knob at zero, the waveform should be similar to that of Figure 9.



Vertical: 2 V/div
Horizontal: 20 µs/div

FIGURE 9 – Waveform at output of Q5, Amplitude at zero

With the AMPLITUDE knob adjusted for maximum output, the waveform of Figure 9 will be modified due to kickback from the SCR firing and will resemble that of Figure 10.



Vertical: 2 V/div
Horizontal: 20 µs/div

FIGURE 10 – Waveform at output of Q5, Amplitude at maximum

5.5 Check and Adjustment of Maximum Amplitude

To check and, if required, adjust the maximum amplitude, proceed as follows:

Connect the 5 Ω resistor across the SERIES output terminals on the Spike Generator.

Connect oscilloscope input to SERIES output terminals on the Spike Generator.

Adjust oscilloscope controls to display 600 V peak at 10 pps.

Turn Spike Generator on.

Set FUNCTION switch to the FREQUENCY P.P.S. position.

Set FREQUENCY P.P.S. knob to 10.

Rotate AMPLITUDE control to the leftmost position.

Oscilloscope should display peak amplitude of at least 600 V.

On the oscilloscope, verify that the pulse reaches peak amplitude in less than 1 μs and decays to zero in 8-14 μs.

Adjust AMPLITUDE control until oscilloscope displays 100 V peak.

Verify that AMPLITUDE knob indicates 100. If it does not, loosen set screws and move knob on shaft to indicate 100 when oscilloscope displays peak amplitude of 100 V.

NOTE: All other tests and adjustments will be made at 100 V amplitude.

5.6 Check and Adjustment of Frequency Calibration

To check and adjust the frequency calibration, proceed as follows:

Place the 5 Ω 20 W or greater resistor on the SERIES output terminals and connect the oscilloscope across it.

Set FUNCTION switch to FREQUENCY P.P.S. and the rate to 10.

Set oscilloscope sweep for 20 ms/div and set vertical amplifier to 5V/div.

There should be a pulse on every 5th division on the oscilloscope grid and a total of 3 pulses.

If necessary, adjust 5K potentiometer, R22, in Figure 7, until a pulse appears at each major division on the oscilloscope, with a total of 10 pulses. With the oscilloscope sweep adjusted for 0.1 sec/div, this display corresponds to a frequency of 10 pps.

5.7 Check and Adjustment of Range of Pulse Position Control at 60 Hz

To check and adjust the range of the PULSE POSITION control at 60 Hz*, proceed as follows:

Set FUNCTION switch on Spike Generator to 60~SYNC.

Set oscilloscope sweep for 1 ms/div, automatic sweep triggered to the positive (+) half of the line cycle.

Rotate PULSE POSITION control on Spike Generator. One pulse should appear on oscilloscope. If more than one pulse appears, replace SCR1 in Figure Sissy

When the PULSE POSITION control is rotated over its full range, the pulse should move 8 ½ ** divisions on the oscilloscope grid. If necessary, adjust potentiometer R23, in Figure Sissy, until the PULSE POSITION control moves the pulse 8 ½** oscilloscope divisions over its full range.

5.8 Check and Adjustment of Range of Pulse Position Control at 400 Hz

To check and adjust the range of the PULSE POSITION control at 400 Hz, proceed as follows:

Connect a variac to 115 V*** 400Hz power source. Maintain 115 V *** output from the variac throughout the following tests.

Connect a 6 V, 400 Hz transformer to the external trigger input to the oscilloscope. The transformer must use the same power source as the Spike Generator.

Turn on the Spike Generator and set the FUNCTION switch to 400~SYNC, and the sync phase switch (marked + and -) to +.

Set the oscilloscope sweep for 0.2 ms/div, automatic sweep, external trigger. The oscilloscope should display a single pulse.

Rotate PULSE POSITION control clockwise and counterclockwise so pulse travels across the display.

The pulse should travel 6¼ divisions.

If necessary, adjust R24, in Figure Sissy, until the pulse travels 6¼ divisions.

5.9 Check of Single Pulse Function

To check generation of a single pulse, proceed as follows:

Set the FUNCTION switch to the leftmost position to SINGLE PULSE.

Press the pushbutton switch several times. Observe that each time the switch is depressed a pulse appears on the oscilloscope.

When this test is completed, return the Spike Generator to operation from a 60 Hz* primary source.

5.10 Compare Trigger Waveforms

See Figure 11. Prepare the oscilloscope to measure around 300 volts. Connect a scope probe ground lead to the 7054-1 chassis. Turn the 7054-1 on. Set the AMPLITUDE knob to maximum. Set the FUNCTION knob to FREQUENCY P.P.S.. Set the repetition rate knob to 10 pps. Being careful not to touch any component leads with your hand, probe the top terminal of each of the eight indicated 2K Ω 50 W resistors to verify that the waveforms are about the same on each resistor.

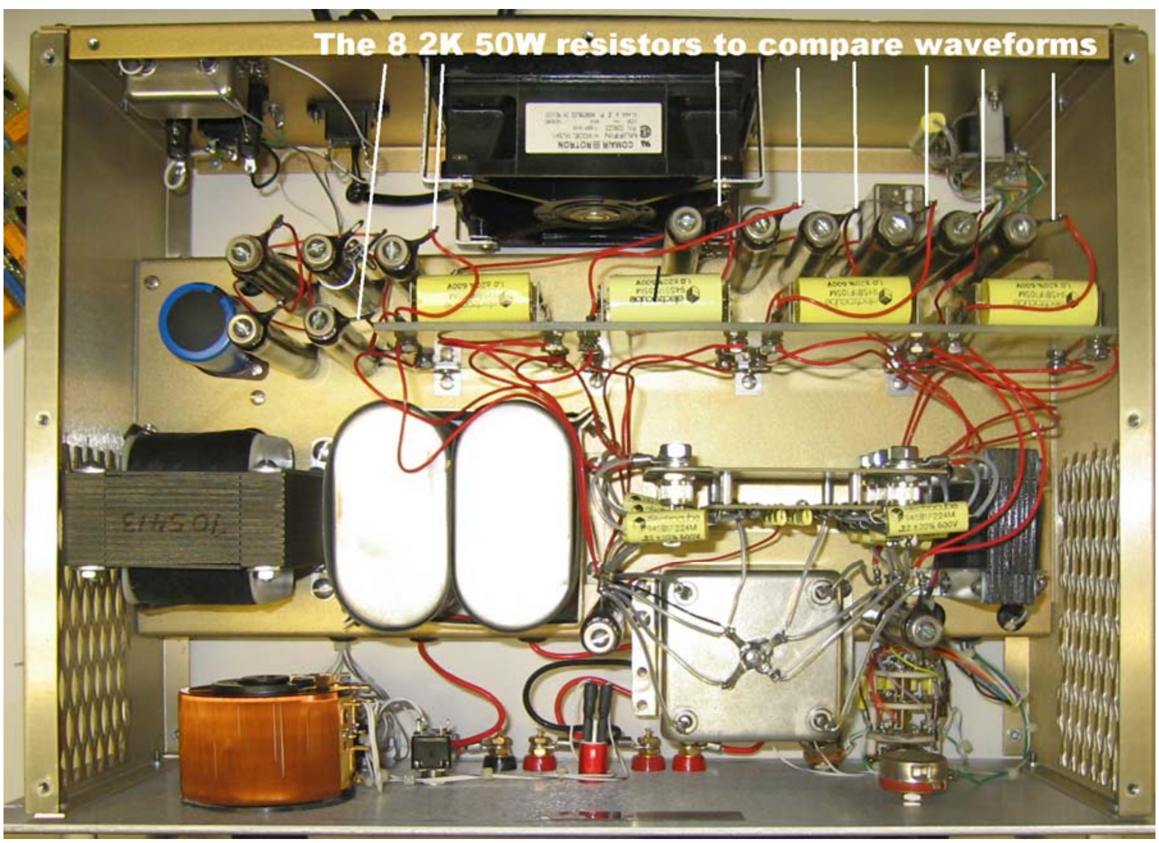


FIGURE 11- 2K Ω 50 W RESISTORS

6.0 Parts List

Reference Designator	Description
B1	Filter Muffin Fan, Rotron
C1	Capacitor, 0.1 µF 400 V GMV, Mylar Foil, 250B
C2	Capacitor, 500 µF 50 V DC, Electrolytic
C3	Capacitor, 80 µF 450 V DC, Sprague TVL-1735
C4	Capacitor, 500 µF 50 V DC, Electrolytic
C5	Capacitor, 270 pF, DM, Mica
C6	Capacitor, 500 µF 50 V DC, Electrolytic
C7	Capacitor, .33 µF 200 V 5%, Metalized Mylar, 210B
C8	Capacitor, 500 µF 50 V DC, Electrolytic
C9	Capacitor, .22 µF 200 V 5%, Metalized Mylar, 210B
C10	Capacitor, .15 µF 200 V 5%, Metalized Mylar, 210B
C11	Capacitor, .033 µF 200 V 5%, Metalized Mylar, 210B
C12	Capacitor, 500 µF 50 V DC, Electrolytic
C13	Capacitor, 1 µF 200 V 10%, Metalized Mylar, 210B
C14	Capacitor, 50 µF 25 V, Sprague TE-1209
C15	Capacitor, 1 µF 200 V 10%, Metalized Mylar, 210B
C16	Capacitor, .01 µF 150 V, Disc
C17	Capacitor, 50 µF 25 V, Sprague TE-1209
C18	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C19	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C20	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C21	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C22	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C23	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C24	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C25	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C26	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C27	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C28	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C29	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C30	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C31	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C32	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C33	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C34	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C35	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C36	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C37	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200

C38	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C39	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C40	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C41	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C42	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C43	Capacitor, .33 µF 100 V GMV, Metalized Mylar, 210B
C44	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C45	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C46	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C47	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C48	Capacitor, 2 µF 600 V, Cornell-Dubilier DYR-6200
C49	Capacitor, .22 µF 400 V, GMV, Mylar Foil, 250B
C50	Capacitor, 10 µF 1000 V, Cornell-Dubilier, T10100
C51	Capacitor, 10 µF 1000 V, Cornell-Dubilier, T10100
CR1	Diode Quad, Motorola MDA-920-7
CR2	Not Used
CR3	Diode, 1 A 200 V, Diodes DI-72
CR4	Diode, 1 A 200 V, Diodes DI-72
CR5	Diode Bridge, 1 A 100 V, Motorola MDA-920-3
DS1	Pilot Light, Eldema EG01-RCB-NE2E 100K
F1	Fuse, 115 V: 2 A
F2	Fuse, 115 V: 2 A
FL1	Line Filter, Solar
IC1	Integrated Circuit, Motorola MC-890P
IC2	Integrated Circuit, Motorola MC-890P
IC3	Integrated Circuit, Motorola MC-890P
IC4	Integrated Circuit, Motorola MC-890P
IC5	Integrated Circuit, Motorola MC-892P
J1	Jack, 2 wire AC
J2	Jack, Banana Type
J3	Jack, Banana Type

L1	Toroid, Solar 705408
L2	Toroid, Solar 705408
L3	Toroid, Solar 705408
L4	Toroid, Solar 705408
L5	Toroid, Solar 705408
L6	Toroid, Solar 705408
L7	Toroid, Solar 705408
L8	Toroid, Solar 705408
P1	Plug, 2 Wire AC
P2	Plug, 3 Wire AC
Q1	Transistor, Motorola 2N3904
Q2	Transistor, Motorola 2N3904
Q3	Unijunction Transistor, Motorola 2N2647
Q4	Transistor, Motorola 2N3905
Q5	Transistor, Motorola 2N3773
R1	Resistor, Part of DS1 (Add 150K 1/2 W for 230 V)
R2	Resistor, 100 Ω 50 W WW, Ohmite
R3	Resistor, 2K Ω 50 W WW, Ohmite
R4	Resistor, Dividohm, 1 K Ω 50 W WW, Ohmite
R5	Resistor, 4 K Ω 4 W WW, Ohmite
R6	Resistor, 4.7 K Ω 1 W 10%, Ohmite
R7	Resistor, 1.2 K Ω 5 W WW, Ohmite
R8	Resistor, 150 Ω 25 W WW, Ohmite, Dividohm
R9	Resistor, 2.2 K Ω 1/2 W 10%
R10	Resistor, 1.2 K Ω 1/2 W 10%
R11	Resistor, 12 K Ω 1/2 W 10%
R12	Resistor, 8.2 K Ω 1/2 W 10%
R13	Resistor, 27 K Ω 1/2 W 10%
R14	Resistor, 10 K Ω 1/2 W 10%
R15	Resistor, 220 Ω 1/2 W 10%
R16	Resistor, 3.3 K Ω 1/2 W 10%
R17	Resistor, 1.2 K Ω 1/2 W 10%
R18	Resistor, 1.2 K Ω 1/2 W 10%
R19	Resistor, 1.2 K Ω 1/2 W 10%
R20	Resistor, Variable 50 K Pot
R21	Resistor, Variable 50 K Pot
R22	Resistor, Variable 5 K Trimpot, Bourns 3067P
R23	Resistor, Variable 5 K Trimpot, Bourns 3067P
R24	Resistor, Variable 20 K Trimpot, Bourns 3067P

R25	Resistor, 2.2 K Ω 1/2 W 10%
R26	Resistor, 47 Ω 1/2 W 10%
R27	Resistor, 47 Ω 1/2 W 10%
R28	Resistor, 1 K 1/2 W 10%
R29	Resistor, 10 K Ω 1/2 W 10%
R30	Resistor, 22 K Ω 1/2 W 10%
R31	Resistor, 1.2 K Ω 1/2 W 10%
R32	Resistor, 100 K Ω 1/2 W 10%
R33	Resistor, 470 K Ω 1/2 W 10%
R34	Resistor, 150 K Ω 1/2 W 10%
R35	Resistor, 100 K Ω 1/2 W 10%
R36	Resistor, 1.2 K Ω 1/2 W 10%
R37	Resistor, 47 Ω 1/2 W 10%
R38	Resistor, 2K Ω 50 W WW, Ohmite
R39	Resistor, 2K Ω 50 W WW, Ohmite
R40	Resistor, 51 Ω 1/2 W 5%
R41	Resistor, 51 Ω 1/2 W 5%
R42	Resistor, 51 Ω 1/2 W 5%
R43	Resistor, 2 Ω 3 W WW, Ohmite
R44	Resistor, 51 Ω 1/2 W 5%
R45	Resistor, 2 Ω 3 W WW, Ohmite
R46	Resistor, 1 Ω 25 W WW, Ohmite
R47	Resistor, 2K Ω 50 W WW, Ohmite
R48	Resistor, 2K Ω 50 W WW, Ohmite
R49	Resistor, 51 Ω 1/2 W 5%
R50	Resistor, 51 Ω 1/2 W 5%
R51	Resistor, 51 Ω 1/2 W 5%
R52	Resistor, 2 Ω 3 W WW, Ohmite
R53	Resistor, 51 Ω 1/2 W 5%
R54	Resistor, 2 Ω 3 W WW, Ohmite
R55	Resistor, 1 Ω 25 W WW, Ohmite
R56	Resistor, 2K Ω 50 W WW, Ohmite
R57	Resistor, 2K Ω 50 W WW, Ohmite
R58	Resistor, 51 Ω 1/2 W 5%
R59	Resistor, 51 Ω 1/2 W 5%
R60	Resistor, 51 Ω 1/2 W 5%
R61	Resistor, 2 Ω 3 W WW, Ohmite
R62	Resistor, 51 Ω 1/2 W 5%
R63	Resistor, 2 Ω 3 W WW, Ohmite
R64	Resistor, 1 Ω 25 W WW, Ohmite
R65	Resistor, 2K Ω 50 W WW, Ohmite
R66	Resistor, 2K Ω 50 W WW, Ohmite
R67	Resistor, 51 Ω 1/2 W 5%

R68	Resistor, 51 Ω 1/2 W 5%
R69	Resistor, 51 Ω 1/2 W 5%
R70	Resistor, 2 Ω 3 W WW, Ohmite
R71	Resistor, 51 Ω 1/2 W 5%
R72	Resistor, 2 Ω 3 W WW, Ohmite
R73	Resistor, 1 Ω 25 W WW, Ohmite
R74	Resistor, 1 K Ω 50 W WW, Ohmite (230 V only)
S1	Switch, SPST Toggle, Smith 584
S2	Switch, DPDT Toggle, Smith 588
S3	Switch, SPDT Push Button, Switchcraft 103
S4	Switch, Rotary, Centralab PA2023
SCR1	Silicon Controlled Rectifier, Motorola 2N2322
SCR2	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR3	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR4	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR5	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR6	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR7	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR8	Silicon Controlled Rectifier, Motorola MCR-3935-8
SCR9	Silicon Controlled Rectifier, Motorola MCR-3935-8
T1	Variable Transformer, 115 V: Ohmite VTO2; 230 V: Superior 12
T2	Power Transformer, Calemco 6301
T3	Power Transformer, Calemco 6302
T4	Power Transformer, Solar 705407
VR1	Zener Diode, Motorola IN3027B