OPERATING INSTRUCTIONS

TYPE 1396-A

TONE-BURST GENERATOR

GENERAL RADIO COMPANY

B

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TYPE 1396-A

TONE-BURST GENERATOR

Form 1396-0100-B
April, 1965

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS, USA

TABLE OF CONTENTS

SPECIFICATIONS

SIGNAL INPUT (signal to be gated)
Frequency Range: dc to 500 kc/s.
Maximum Voltage Level: ±7 V (5 V, rms).
Input Impedance: Approximately 10 kΩ.
TIMING SIGNAL (signal that controls gate timing)
Frequency Range: dc to 500 kc/s.
Maximum Voltage Level: ±10 V.
Minimum Voltage Level: 1 V, p-to-p.
Input Impedance: Approximately 7 kΩ.
Triggering: Slope selectable, trigger level adjustable from −7 to +7 V.

GATE TIMING: Gate-open and -closed intervals can be independently set to 2, 4, 8, 16, 32, 64, or 128 cycles (periods) of timing signal. By means of a MINUS ONE switch, intervals can be set to 1, 3, 7, 15, 31, 63, or 127 cycles. The gate-closed intervals can also be timed in increments of one period of timing signal from 1 ms to 10 s. Fixed timing errors are less than 0.5 μs.

GATED SIGNAL OUTPUT
Gate-Open Output: Maximum signal level is ±7 V. Total distortion is less than −60 dB (compared to maximum level) at 1 kc/s and 10 kc/s.
Gate-Closed Output: Less than 140 mV, p-to-p, (−40 dB) with maximum signal input.
Pedestal Output (dc potential difference between open- and closed-gate output): Can be nulled from front panel. Less than 50-mV change with line voltage.
Switching Transients: Less than 140 mV, p-to-p, (−40 dB compared to maximum signal input), with 120-pF load.
Output Impedance: 600 Ω.
Gating Voltage Output (signal for triggering oscilloscope): Rectangular waveform of approximately +12 V at 10-kΩ source when the gate is closed and approximately −12 V at 20 kΩ when the gate is open.

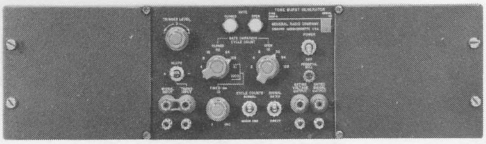
GENERAL
Ambient Operating Temperature: 0 to 50°C (32° to 122°F).
Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 15 W, approximately.
Accessories Supplied: TYPE CAP-22 Power Cord.
Accessories Required: External source for any desired frequency range between 0 and 500 kc/s.
Accessories Available: Relay-rack adaptor set (panel height 5¼ in).

MECHANICAL DATA Convertible-Bench Cabinet

Width		*Height*		*Depth*		*Net Wt*		*Ship Wt*	
in	*mm*	*in*	*mm*	*in*	*mm*	*lb*	*kg*	*lb*	*kg*
8	205	5⅞	150	7½	195	6½	3	9	4.1

See also *General Radio Experimenter*, May 1964.

Figure 1-1. The Type 1396-A Tone-Burst Generator. (Photograph below shows the instrument assembled with a Type 480-P308 Adaptor Plate Set for relay-rack mounting.)



SECTION 1

INTRODUCTION

The Type 1396-A Tone-Burst Generator (Figure 1-1) operates as a coherent gate upon a periodic input signal to produce, alternately, periods of no output (closed gate), and periods of an output waveform which is a replica of the input waveform (open gate), i.e., "tone bursts."

Figure 1-2 is an elementary block diagram of the instrument. The input signal is applied to the main gate and to the input circuits. The input circuits form one output trigger pulse per input cycle and the binary scaler opens and closes the main gate when the number of trigger pulses reaches a preset amount. Thus, the gate intervals are binary multiples of one period of timing input signal, and the gating and gated signal are coherent. That is, the gated output signal (tone burst) always starts and ends at the same points in the signal cycle.

In most applications it is desirable to apply the same signal to the TIMING INPUT terminals and to the SIGNAL INPUT terminals as described above. However, for flexibility, separate timing and input signals may be applied to the Type 1396-A (refer to paragraph 3.7 for an example of this application).

A feature which is not indicated in Figure 1-2 allows the gate to be held closed for long periods of time (up to 10 seconds). This timed mode is useful when the desired closed-gate interval exceeds 128 cycles, the maximum number of periods the scaler can count.

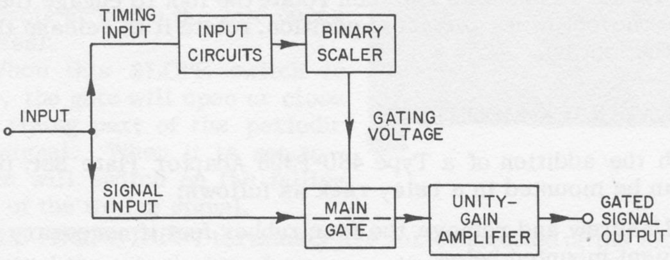


Figure 1-2. Elementary block diagram of the Type 1396-A Tone-Burst Generator.

SECTION 2

OPERATING PROCEDURE

2.1 INSTRUMENT LOCATION.

The instrument should be located so that the vent holes on the sides, top, and bottom are unrestricted. Ambient air temperature should be over 0 C (32 F) and less than 50 C (122 F).

2.2 MOUNTING.

2.2.1 BENCH MOUNTING.

To set the instrument in a tilted position, simply pull each front foot down as far as possible and then rotate the foot to engage the detent. To restore the foot to its retracted position, rotate it to release the catch and push the foot up.

2.2.2 RELAY-RACK MOUNTING.

With the addition of a Type 480-P308 Adaptor Plate Set, the Type 1396-A can be mounted in a relay rack as follows:

a. Unscrew and remove the four rubber feet if necessary to clear an instrument mounted below.

b. Remove the two screws in the upper left-hand and lower left-hand corners of the panel. These screws fasten the panel to the aluminum end frames.

c. Place the left-hand panel extension in front of the instrument panel so that the corner holes in the extension line up with those on the instrument and replace the two screws.

d. Attach the second adaptor plate on the right-hand side of the instrument in the same manner.

e. The unit can now be mounted in a standard 19-inch relay rack with No. 12-24 screws.

2.3 CONNECTION TO POWER SUPPLY.

Connect the Type 1396-A to a source of power as indicated by the legend at the power-input socket at the rear of the instrument, using the three-wire power cord provided. The third wire grounds the instrument frame and uninsulated binding posts. While normally supplied for 115-volt operation, the power transformer can be reconnected for 220- or 230-volt service (see schematic diagram, Figure 5-4). When changing connections be sure and replace line fuses with those for the new input voltage (refer to the Parts Lists). Measures should be taken so that the legend indicates the new voltage. New nameplates may be ordered from General Radio (Type 5590-0500 for 115 volts, Type 5590-1688 for 220 volts, and Type 5590-1664 for 230 volts).

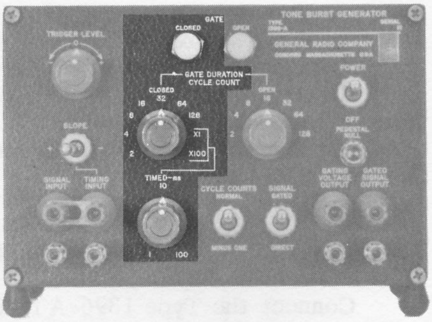
2.4 CONTROLS AND CONNECTORS.

The controls and connectors described below are on the Type 1396-A. The bottom terminal of each binding-post pair is connected to the instrument chassis and, via the power cord, to ground. All signals are dc coupled. The power jack is on the rear of the instrument.

TRIGGER LEVEL control sets the voltage level at which the gate will open and close (+7 to -7 volts). With the SLOPE control, the TRIGGER LEVEL control determines the relative phase of signal and gate (i.e., determines the point in the timing-signal cycle at which the gate opens and closes).

When this SLOPE switch is set to +, the gate will open or close on the rising part of the periodic timing signal. When it is set to − the gate will switch on the falling portion of the timing signal.

The TIMING INPUT terminals are for connection of the signal which is to control the gate timing. In most applications, this is also the SIGNAL INPUT signal, hence a strap is provided to put the two binding-post pairs in parallel.



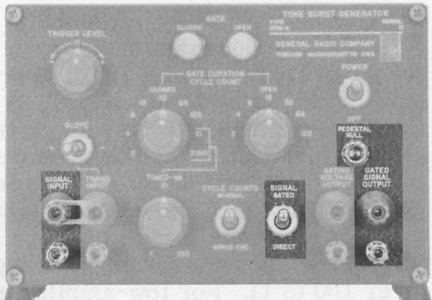
The GATE CLOSED lamp lights when the gate is closed.

The nine - position CLOSED switch sets the time during which the gate will be closed, i.e., no output. The first seven (unbracketed) positions set the time in whole numbers of cycles (periods) of timing input by counting the number of cycles of the timing-input signal.

The TIMED potentiometer allows the closed interval of the gate to be set by a "timer" circuit rather than by a cycle count. The timer circuit may be set from 1 ms to 10 sec, depending on its position and the multiplier position of the CLOSED switch. the phase of the gate is still determined by the TRIGGER LEVEL and slope controls and not by the TIMED control. Therefore, as the TIMED control is advanced, the closed-gate interval increases in jumps of one period.

The GATE OPEN lamp lights when the gate is open. When the gate is switching rapidly, both the OPEN and CLOSED lamps appear to be on simultaneously. If neither lamp is on, power is not applied to the instrument. For small signals, the gate-condition lamps are useful in adjusting the trigger level to coincide with the signal level. The lamps are operated by a power-line-frequency voltage which may yield slow beats in intensity at certain low gating frequencies.

The seven-position OPEN switch sets the open-gate interval in exactly the same way that the first seven positions of the CLOSED switch set the closed-gate interval.

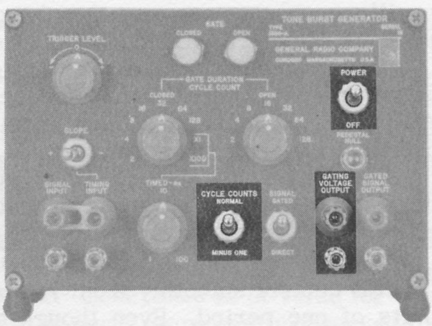


The SIGNAL INPUT terminals are for connection of the signal which is to be gated.

When the SIGNAL switch is in the GATED position, the instrument performs in the normal fashion as described above. When this switch is set to DIRECT, the gate is held open which may be useful for the initial setup of a tone-burst measuring system.

The PEDESTAL NULL screwdriver control allows any dc difference in output voltage between the open and closed intervals to be nulled out. This pedestal voltage is generated internally and is insignificant in amplitude for all but the lowest signal levels. This control should not be used to null out a dc component of the input signal.

The GATED SIGNAL OUTPUT terminals present the gated signal via a unity-gain amplifier with a 600-ohm output impedance.



The POWER switch disconnects both sides of the line from the transformer when it is in the OFF position.

When the CYCLE COUNTS switch is set to NORMAL, the OPEN and CLOSED switches operate as described above, with the number of counts indicated by the switch engraving. When the CYCLE COUNTS switch is set to MINUS ONE, the functions of the OPEN and CLOSED switches are unchanged but the numbers indicated by the engraving on both switches are reduced by one count. Thus, the open- or closed-gate interval can be set to 1, 3, 7, 15, 31, 63, or 127 cycles in addition to the normal 2, 4, 8, 16, 32, 64, or 128 cycles of timing signal.

The GATING VOLTAGE OUTPUT terminals present a pulse-type signal of approximately +12 volts when the gate is closed and approximately -12 volts when the gate is open.

2.5 TONE-BURST GENERATION – FAMILIARIZATION PROCEDURE.

Let us consider, for example, an application that requires tone-bursts of 16 cycles of a 10-kc sine-wave signal, spaced apart by 32 periods of the same 10-kc signal. A General Radio Type 1210-C Unit R-C Oscillator provides a convenient signal source for the Type 1396-A, and its output terminals can be directly connected to the SIGNAL INPUT terminals of the Type 1396-A. Connect the link between the SIGNAL INPUT and TIMING INPUT terminals. Adjust the amplitude of the input signal for approximately 7 volts peak, or just below the distortion level, since this gives the greatest ratio of signal to unwanted switching transients (over 100 to 1). For low-amplitude tone bursts of best quality, gate the signal at the 7-volt peak level and then attenuate to the desired level.

Set the controls as shown in the photograph, Figure 1-1, to produce the desired output at the GATING VOLTAGE OUTPUT terminals. To observe the effect of the TRIGGER LEVEL control, first reduce the level of the input signal to a few volts peak. The TRIGGER LEVEL control can shift the trigger point over the range of +7 to -7 volts. The instrument will trigger properly when the trigger level is adjusted within the voltage range of the input signal. When the instrument is triggering properly, the gate-condition lamps light alternately. (If the triggering is rapid, both lamps appear to be on simultaneously.) By observing the waveform on an oscilloscope, you can see the change in phase of the gated signal as the settings of the TRIGGER LEVEL and SLOPE controls are varied.

It is frequently difficult to trigger an oscilloscope on a tone-burst signal, particularly when the input frequency is changed. A GATING VOLTAGE OUTPUT pulse has been provided to assist in triggering. Set the oscilloscope triggering for dc mode, negative slope, and 0 level. Apply the GATING VOLTAGE OUTPUT pulse to the trigger input terminals of the oscilloscope. The trace will start as the gate opens. To start the trace as the gate closes, switch the oscilloscope to positive slope.

By setting the CLOSED switch to the X1 position and advancing the TIMED control smoothly from 1, you can change the closed-gate time in units of one period. Even though the closed-gate interval is now controlled by a timer circuit, a feature of the instrument's program keeps the phase of the gate with respect to the signal constant, i.e., coherent.

To hold the gate open, set the SIGNAL switch to the DIRECT position, which interrupts the normal operation of the instrument and does not permit the gate to close. When the gate is thus disabled, the gating signal that may be synchronizing an oscilloscope is interrupted. The synchronizing mode of the oscilloscope must be changed in order to view the continuous wave now supplied by the Tone-Burst Generator. Placing the SIGNAL switch in the DIRECT position does not open the gate, but it keeps the gate from closing after normal operation has opened it.

The gate may be operated without a timing-signal input. Set the TRIGGER LEVEL control off zero and cycle the SLOPE switch from + to - and back. Each cycle of the SLOPE switch produces the equivalent of one cycle of timing signal.

SECTION 3

APPLICATIONS

3.1 GENERAL.

The Tone-Burst Generator is a unique instrument which provides an instrumentation bridge in the gap between continuous-wave testing and step-function, or pulse, testing. The Type 1396-A Tone-Burst Generator finds diverse applications, from sonar-transducer calibration to the generation of controlled periodic line transients. A few of the applications are described in the following paragraphs. The examples generally assume that the Tone-Burst Generator operates on a sine wave; however, it can operate on any periodic waveform.

One of the useful features of the instrument is that the output signal is coherent, that is, the gate opens and closes at the same point in the signal voltage cycle for each tone burst. Coherence is of value for two reasons: first, the coherent tone burst is much more easily observed or analyzed by oscillographic or sampling methods; second, the frequency content of a tone burst depends upon the phase of the gate compared to the signal, as explained in paragraph 3.2. If the signals are not coherent, the phase, and hence the frequency content, is drifting, and test results are less reproducible or less clear than with a coherent tone burst.

Another useful feature is the control of the number of cycles in the tone burst which allows the production of tone bursts with consistent and controllable frequency content.

3.2 FREQUENCY CONTENT OF TONE BURSTS.
(Fourier-Series Expansion)

Applications frequently demand some knowledge of the frequency components of a tone burst of a sinusoidal signal. In general, the output voltages can be written as a Fourier series having only sine or cosine terms as follows:

$$e(t) = \sum_{n=1}^{\infty} a_n \begin{Bmatrix} \sin \\ \cos \end{Bmatrix} \left[\frac{2\pi n t}{(N+M)\,T} \right]$$

where:

$e(t)$ = the tone-burst voltage.
a_n = the amplitude of the nth component.
n = harmonic number (1, 2, 3, 4, etc.).
N = number of cycles of signal in the burst (OPEN count in the Tone-Burst Generator).
M = number of cycles (periods) of signal between bursts (CLOSED count in the Tone-Burst Generator).
T = the period of the signal being gated.

The sine series is used if the signal is gated on and off at zero crossings, and the cosine series is used if gating occurs at the peak point of the sinusoidal input voltage. The equation indicates that a tone burst is equivalent to a signal of amplitude a_1 at the repetition rate of the tone burst, plus a signal of amplitude a_2 at twice the repetition rate (the second harmonic), plus a signal of amplitude a_3 at three times the repetition frequency (the third harmonic), and so on, indefinitely. The amplitude of each component in the above series can be obtained from the following equation:

$$a_n = E \frac{N}{N+M} \left[\frac{\sin x}{x} \mp \frac{\sin y}{y} \right]$$

where:

$$x = 2N \left(\frac{n}{N+M} - 1 \right) \frac{\pi}{2}$$

$$y = 2N \left(\frac{n}{N+M} + 1 \right) \frac{\pi}{2}$$

E = the amplitude of the signal being gated.

To find the values of a_n, simply apply the values of N and M indicated by the controls on the Tone-Burst Generator and then evaluate the expression for values of n. Some care must be exercised when x or y equals zero since the two fractions assume indeterminate forms. The proper value of the fraction under these conditions is 1.

As an example of this analysis, consider a tone-burst signal that has one cycle on and one cycle off, or M = N = 1. For this case, the amplitude equation becomes:

$$a_n = E \left[\frac{\sin (n-2)\frac{\pi}{2}}{(n-2)\frac{\pi}{2}} \mp \frac{\sin (n+2)\frac{\pi}{2}}{(n+2)\frac{\pi}{2}} \right]$$

The two fractions in the bracketed expression are subtracted if the TRIGGER LEVEL control is adjusted so that the gate opens and closes at zero crossings of the input signal, and the terms are added if the control is adjusted for gating at the peak voltage point of the waveform. Table 3-1 gives the results of the amplitude equation for values of n equal to 1, 2, 3, 4, and 5 for both zero-crossing and peak-point gating.

TABLE 3-1

n	a_n for zero-crossing gating	a_n for peak-point gating
1	0.424 E	0.212 E
2	0.500 E	0.500 E
3	0.255 E	0.382 E
4	0	0
5	0.061 E	0.152 E

Figure 3-1 is a plot of the first 31 harmonics of the above signal. In Figure 3-2, the first 31 harmonics of a second example are plotted. In this example the tone burst has eight cycles on and eight cycles off. Both curves were taken from an automatic plot of the frequency spectrum produced by a General Radio Type 1900-A Wave Analyzer and a Type 1521-A Graphic Level Recorder. In both examples, the tone burst had N = M so that values of a_n are zero for even values of n (except zero). Therefore, when a tone burst is "square", or has equal on and off times, none of the even harmonics (except the one at the input-signal frequency) are present.

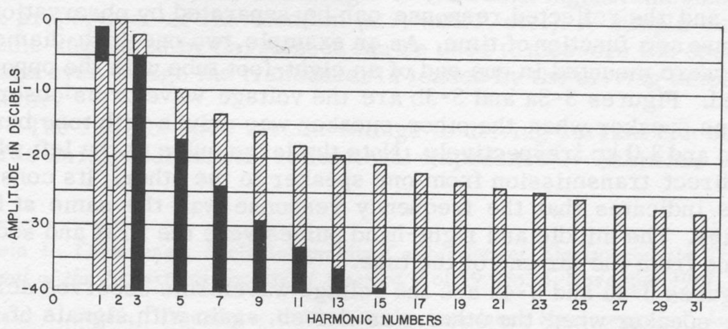
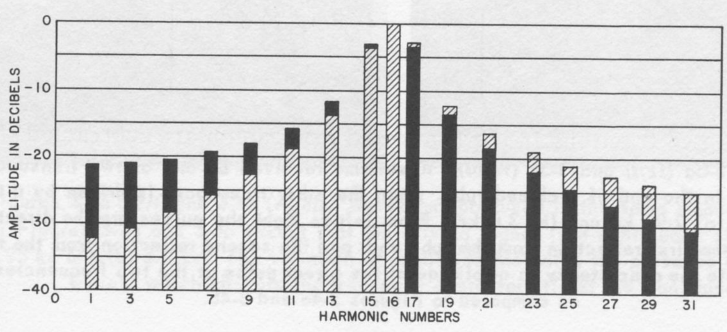


Figure 3-1. The first 31 harmonics of a tone-burst signal with one cycle on and one cycle off. The solid areas represent the components for zero-crossing gating, the lined areas are for peak-point gating.

Figure 3-2. The first 31 harmonics of a tone-burst signal with eight cycles on and eight cycles off. The solid areas represent the components for zero-crossing gating, the lined areas are for peak-point gating.



The spectra presented in Figures 3-1 and 3-2 indicate clearly the change in harmonic content as the phase of the gate is changed. The spectra change smoothly between the extreme values as the phase is changed from zero-crossing to peak-point gating. Such a change increases the amplitude of the high-frequency components and diminishes the amplitude of the low-frequency components.

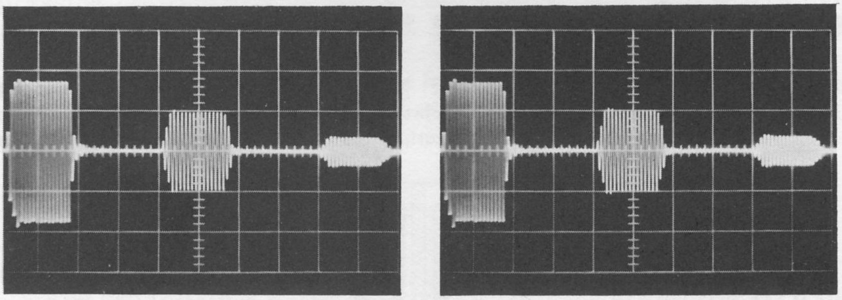
3.3 TESTING IN THE PRESENCE OF REFLECTIONS.

3.3.1 TRANSDUCER TESTING.

It is often necessary to test transducers in an environment that produces reflections, such as a reflection tank for testing sonar transducers or an echo chamber for testing speakers or microphones. With continuous-wave testing, the reflections can complicate measurements or introduce errors. Errors in frequency and phase curves are caused by the addition of reflected signals to increase or diminish the direct response. Such errors introduce familiar standing-wave patterns in the response curves.

With a tone-burst test signal energizing the transducer, the direct response and the reflected response can be separated by observation of the response as a function of time. As an example, two one-inch-diameter speakers were mounted in one end of an eight-foot tube with the opposite end closed. Figures 3-3a and 3-3b are the voltage waveforms observed across one speaker when the other speaker was driven with tone bursts of 2.95 kc and 3.0 kc, respectively. Note the large pulse at the left which was the direct transmission from one speaker to the other. Its constant amplitude indicates that the frequency response was the same at both frequencies. The middle and right-hand pulses were the first and second reflections from the far end of the tube.

Figures 3-4a and 3-4b are the voltage waveforms observed across the same speaker when the other was driven, again with signals of 2.95



Figures 3-3a (*left*) and 3-3b (*right*). Waveforms received by one of two transducers mounted in the end of a closed tube, when the other transducer is driven by a tone burst of (a) 2.95 kc and (b) 3.0 kc. From left to right the pulses are the direct response, the first reflection from the tube end, and the second reflection from the tube end. Note the consistency in amplitude of the direct pulse at the two frequencies as as compared to Figures 3-4a and 3-4b.

kc and 3.0 kc, but with the gate of the Tone-Burst Generator held open so that continuous waves resulted. Note that the reflection phenomena caused large differences (3:1) in the response of the system at the two frequencies. The larger signal occurs when the phases are such that the reflection adds to the direct signal. The smaller signal occurs when the reflection subtracts from the direct signal. It would be difficult to determine the transducer's response from the continuous-wave data.

3.3.2 SELF-RECIPROCITY TRANSDUCER CALIBRATION.

A transducer can be calibrated by measurement of its response to its own echo.[1] In this self-reciprocity calibration method, the transducer is driven as a speaker or transmitter by a brief tone burst. The transducer is located near a surface that produces total reflection of the sound waves. The echo is picked up by the transducer acting as a microphone or receiver. Both the desired calibration quantities, the speaker response and the microphone response, are proportional to the square root of the ratio of the open-circuit voltage produced by the echo to the driving current. The proportionality constant involves the distance between transducer and reflector, the wavelength of the sound signal, and some "handbook properties" of the medium (air, water, etc.). A simple calibration scheme suggested by Carstensen can be used to measure the open-circuit voltage even though the transducer is loaded by the driving amplifier and detector.[1]

The ratio of open-circuit voltage to driving current can be considered as an impedance, the "reflectional impedance".[2] Sabin has suggested

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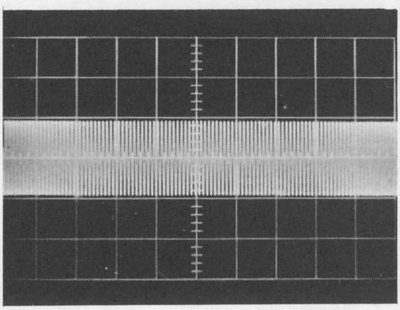
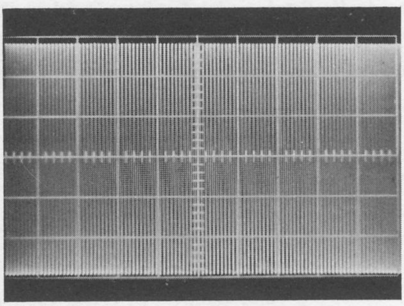
[1]Edwin L. Carstensen, "Self-Reciprocity Calibration of Electroacoustic Transducers," *Journal of the Acoustical Society of America*, Vol 19, No. 6, November 1947, pp 961-965.

[2]Gerald A. Sabin, "Transducer Calibration by Impedance Measurements," *Journal of the Acoustical Society of America*, Vol 28, No. 4, July 1956, pp 705-710.





Figures 3-4a (*left*) and 3-4b (*right*). Waveforms produced in the same manner as those in Figures 3-3a and 3-3b except that the driving signal is a continuous signal of (a) 2.95 kc and (b) 3.0 kc. The variation of amplitude indicates the presence of standing waves, which obscure the frequency characteristic of the transducer.

a simple, self-reciprocity calibration system in which the reflectional impedance is determined from two measurements of transducer impedance made on a conventional bridge.

It is thus possible to make absolute calibrations of a transducer with tone-burst excitation and standard electrical measurements, without an additional calibrated transducer (standard reciprocity tests). The self-reciprocity calibration may be done in a smaller chamber than the standard two-transducer calibration for the same chamber aberrations.

3.3.3 MEASUREMENT OF ROOM ACOUSTICS.

The reflection echoes produced in a concert hall are of great interest in evaluating the acoustical quality of the space. A typical test system consists of a sound source on the stage (a pistol shot or a speaker system driven by an electronic sound source), a microphone placed in the seating area, and analyzing equipment driven by the microphone. (See Figure 3-5). Comparisons of pistol-shot and continuous-wave excitation of a hall have shown significant differences in determining reverberation time, a cardinal acoustic property.[3] These differences indicate that the duration of the exciting signal is important, and a tone burst of controlled properties is very desirable.

An excellent discussion of the response of four halls (La Grande Salle, Montreal; Clowes Hall, Indianapolis; Symphony Hall, Boston; and Philharmonic Hall, New York City) to tone-burst tests is given by Schultz and Walters.[4]

3.4 TESTING OF RECTIFYING-TYPE CIRCUITS.

3.4.1 RECTIFIER CIRCUITS.

Many rectifying circuits lend themselves directly to tone-burst testing, (for example, the adjustment of automatic-gain-control circuits

[3] Theodore J. Schultz, "Problems in the Measurement of Reverberation Time," *Journal of the Audio Engineering Society*, October, 1963.

[4] Theodore J. Schultz and B. G. Watters, "Propagation of Sound Across Audience Seating," *Journal of the Acoustical Society of America*, Vol 36, No. 5, May, 1964.

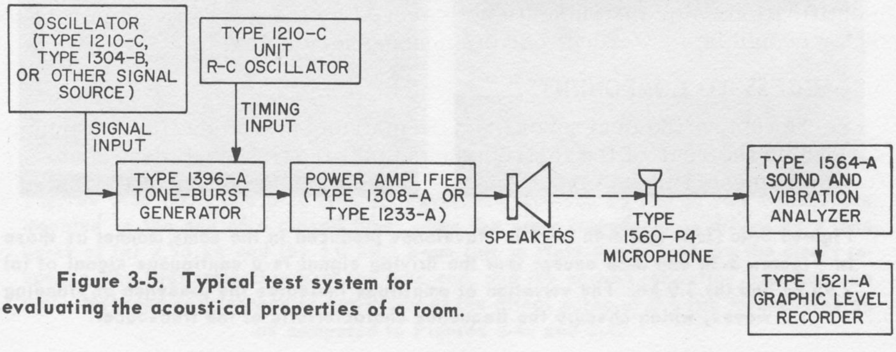


Figure 3-5. Typical test system for evaluating the acoustical properties of a room.

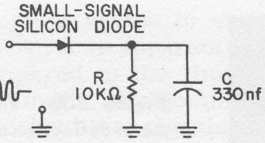


Figure 3-6a. Example of a simple rectifying circuit to be tested with a tone burst.

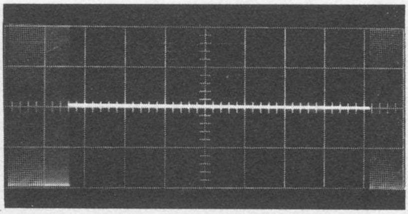


Figure 3-6b. Open-circuit voltage waveform of the Tone-Burst Generator output (32 cycles of 10-kc signal per burst). Scales are 2 volts per major division vertically, and 2 msec per major division horizontally.

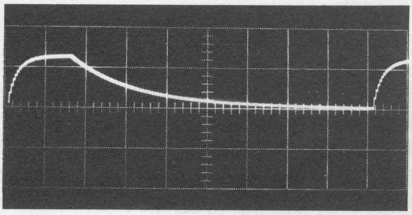


Figure 3-6c. Waveform of capacitor voltage when the voltage waveform of Figure 3-6b is applied to the circuit of Figure 3-6a. Scales are the same as in Figure 3-6b.

for proper response). The rectification efficiency and time constants of a circuit can be measured easily, for example, with the circuit shown in Figure 3-6a. Its associated waveforms are shown in Figures 3-6b and 3-6c.

3.4.2 AC METER BALLISTICS.

Tone-burst response tests for characteristics such as rise time, fall time, and overshoot, are frequently required for rectifying meters, particularly VU meters. Figure 3-7a shows a test system for measuring the meter deflection as a function of time.[5] The frequency at which the test is performed must be low enough so that the meter can reach full scale in 128 cycles. The tone bursts consist of 128 cycles of test frequency and their spacing is adjusted so that the meter returns to rest at

[5]This system is patterned after a similar system for dc meters, a description of which appeared in the January-February 1962 issue of the *General Radio Experimenter*.

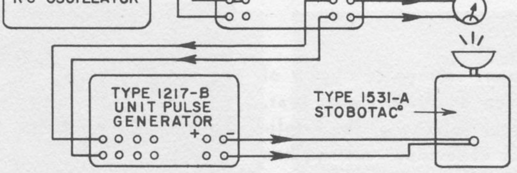


Figure 3-7a. Test system for measurement of ac meter deflection as a function of time.

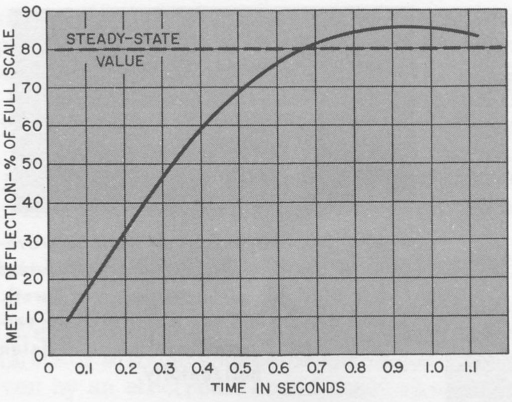


Figure 3-7b. Plot of ac meter deflection as a function of time when the meter is excited by a tone burst.

zero between each burst. The Type 1217-C Unit Pulse Generator acts as a delay circuit. Its negative output pulse starts as the Tone-Burst Generator's gate opens, and the pulse ends at a time determined by the settings of the PULSE DURATION controls. The end of this pulse initiates a microsecond flash of the Strobotac® electronic stroboscope. The PULSE DURATION controls set the time between the energizing of the meter and the flashing of the bright-light source. The ambient light should be controlled to permit accurate observation of deflection when the flash occurs, and to allow the scale to be seen between flashes.

Figure 3-7b is a plot of the deflection vs time of an ac meter when energized by a burst of 128 cycles of 40-cycle signal. The rise time from 10% to 90% of full scale is 0.5 second and the overshoot is 6%, which corresponds to a meter cutoff frequency of approximately 0.9 cycle.

3.5 TESTING WITH AMPLITUDE TRANSIENTS.

3.5.1 RECOVERY-FROM-OVERLOAD TESTS.

Recovery-from-overload tests are significant for many devices, including amplifiers. In audio amplifiers there may be an occasional overload on a peak input-signal excursion, but these overloads may be quite short and not noticeable if the recovery from overload is fast. In Figure 3-8a, the lower trace is the input voltage to an amplifier, and the upper trace is the output voltage. Note that overload occurred, but the amplifier returned to normal output as soon as the signal returned to its normal level. Figure 3-8b shows the waveforms of the same amplifier with larger input-voltage swings. The overdrive is now so extreme that

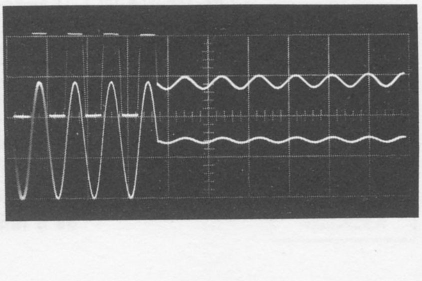


Figure 3-8a. Input voltage (4 cycles of 1-kc signal) to an amplifier under test, lower trace; output voltage of the amplifier, upper trace. The input voltage has four times the amplitude of the distortion level.

the bias point begins to shift at the output. On a different time scale, Figure 3-8c, it is apparent that the recovery from overload takes a long time compared to the time during which overload was present. Such distortion might be objectionable whereas pure overload might not.

Overload test signals from the Type 1396-A can be generated by the same method that a tone burst is generated (refer to paragraph 2.5). A variable resistor may be connected between the signal input and output as was done in the example above. The resistor allows some signal into the output when the gate is closed (e.g., the signal between bursts in Figure 3-8) so that signal distortion, in addition to base-line distortion, may be judged after overload.

3.5.2 MUSIC-POWER TESTS.

Peak-power tests of amplifiers require tone-burst signals to avoid loading the amplifier power supplies which shifts the bias points and to avoid excessive power dissipation. Music-power (peak) output tests of power amplifiers for consumer use require that a brief tone burst be applied and its amplitude be increased until five-percent distortion is observed.[6] If the distortion level is sharply defined, observation of the amplifier output waveform will indicate distortion. When an accurate distortion measurement is desired, a dual-channel or differential-input oscilloscope may be used and the amplifier input subtracted from the output to give only the distortion products.

3.5.3 LOUDSPEAKER DISTORTION MEASUREMENTS.

Distortion measurements can be made with tone-burst excitation of speakers.[7,8] A gated microphone is used to respond to the signal produced

[6] *EIA Standard RS-234-A*, November 1963, "Power Output Ratings of Packaged Audio Equipment for Home Use," Electronics Industries Association, 11 West 42nd Street, New York 36, New York ($0.25).

[7] M. C. Kidd, "Tone-Burst Generator Checks A-F Transients," *Electronics*, Vol 25, No. 7, July 1952.

[8] M. J. Whittemore, "Transistorized Tone Burst System for Transient Response Testing of Loudspeakers," *Journal of the Audio Engineering Society*, Vol 10, No. 3, July 1962.

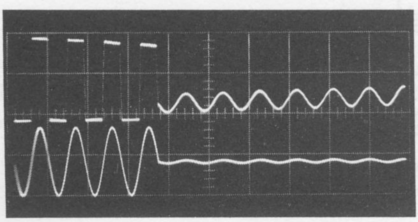


Figure 3-8b. Amplifier input voltage (lower trace) and output voltage (upper trace) for an input signal (4 cycles of 1 kc) with a voltage that is six times the distortion level. Note the shift in bias point indicated by the different output levels before and after overload.

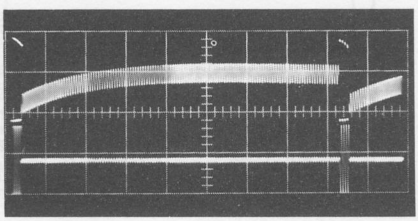


Figure 3-8c. The amplifier with the same input-voltage swings as in Figure 3-7b on a time scale increased ten times. Note that recovery from overload takes a long time compared to time during overload.

by the speaker after the tone burst has been cut off. This "hangover" is a measure of the distortion of the speaker. Such systems are suitable for sweep-measurement techniques and can be at least partially automated.

3.5.4 HIGH POWER TRANSIENTS.

The General Radio Type 1308-A Audio Oscillator and Power Amplifier can be combined with the Type 1396-A Tone-Burst Generator to produce tone bursts with power content as high as 200 watts. The Type 1308-A combines a 20-cps to 20-kc oscillator and a power amplifier capable of delivering 200 watts within the band of 50 cps to 1 kc. The Type 1396-A Tone-Burst Generator can be connected between the oscillator and the amplifier of the Type 1308-A. Remove shorting strap between J201 and J202. Connect the ≈ 1-volt signal from the OSC OUTPUT terminals (J201) at the rear of the Type 1308-A to the SIGNAL INPUT and TIMING INPUT terminals of the Type 1396-A through a coupling capacitor, and connect the GATING VOLTAGE OUTPUT terminals of the Type 1396-A to the AMP INPUT terminals (J202) of the Type 1308-A. This system produces tone bursts similar to those issuing from the Type 1396-A alone, but of much higher power level.

3.5.5 GENERATION OF LINE TRANSIENTS.

A system which produces controlled transients in the power-line signal is shown in Figure 3-9. The step-down transformer isolates the instruments from line voltage and drops the voltage to the proper range for operation of the instruments (0.5 volt rms). The boost transformer adds the gated and amplifier tone burst to the power-line supply to produce a controlled transient. Be sure that the polarity of the output connection is such that the amplifier voltage is added to the line voltage. With this system, up to 200 watts of power may be put into the incremental part of the transient. The boost transformer may be omitted if the total load current is less than 5 amperes rms.

3.5.6 FILTER TESTING.

The response of a passband filter to a suddenly applied signal in its passband is a commonly required measurement. Attempts to deduce the desired response from the results of a step-function test are tedious, particularly if the passband is narrow. Use of a continuous-signal test

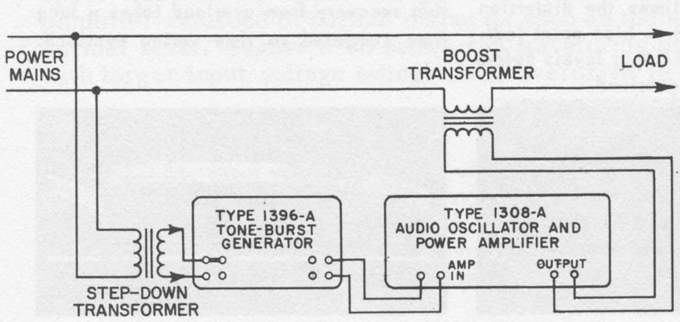


Figure 3-9. Tone-burst system for generating power-line transients.

is equally difficult, particularly if a minimum-phase network is not involved, in which case, phase, as well as amplitude, information is required. Testing with a Tone-Burst Generator produces the desired passband transient response directly.

3.6 OPERATING AT HIGH POWER LEVELS.

Tone-burst testing allows the average signal power to be kept arbitrarily low and, at the same time, the pulse, or burst, power level may be high. Such operation may be required if the device under test has nonlinearities (i.e., the test properties depend on power level) and the test equipment cannot operate continuously at the desired signal or power levels.

3.7 SYNTHESIS OF SIGNALS WITH VERY LOW DUTY RATIOS.

In some instances it is desirable to generate a tone burst consisting of a certain number of cycles of signal from one generator and to have the burst occur on the command of a second signal source. Suppose, for example, you wish to synthesize a signal similar to the one which modulates the standard time/frequency broadcasts on station WWV. You could use a burst of 7 cycles (WWV uses 5) of a 1-kc sinusoidal signal every second as determined by a narrow rectangular pulse with a 1-second prf. Figure 3-10 shows a connection of the Type 1396 that would produce the required signal. The CLOSED switch of the Type 1396-A should be set for 1 cycle and the OPEN switch for 7 cycles. The operation of this system is quite simple. Suppose the gate has just opened. The 1-kc signal will be gated into the output and through resistor R2 into the TIMING INPUT terminals. After seven cycles have occurred, the gate will close which will remove the 1-kc signal from the TIMING INPUT terminals. Since the instrument has removed its own source of 1-kc timing signal it will remain in a static condition until a timing input is received from the 1-second pulse source. R1 and C1 differentiate the narrow pulse so that the input circuits will respond to the pulse in the same way they respond to a cycle of sinusoidal signal. Upon receipt of the pulse the instrument records one cycle of timing signal, and opens its gate. The cycle then repeats. The value of R2 is selected to keep the feedthrough of 1-second pulses into the output signal at a negligible level.

In this application, the tone burst is controlled by two signal sources, and the question of periodicity of the tone burst might be examined in some detail. Consider first the case when there are exactly 1000 cycles

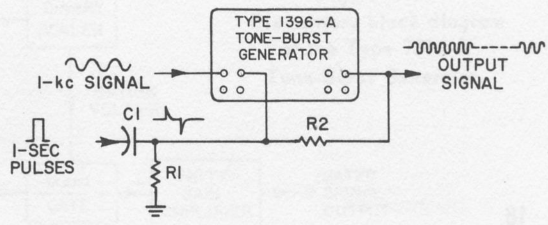


Figure 3-10. Connections of the Tone-Burst Generator that allow generation of a burst of 1-kc signal every second. Ground returns are not shown.

occurring in the 1-second interval. In practice, these signals must be derived from the same source or from sources electronically locked together. The tone burst starts at the end of the 1-second pulse and this start is always synchronous with some point in the signal cycle. Hence, the tone burst always starts and ends at the same point in the signal cycle. Because there is exact coherence between the two input signals, the output is coherent.

Now, consider the case when the 1-kc signal drifts slightly in frequency relative to the 1-second pulses. This condition usually occurs if two separate signal sources are used. Again, the tone burst starts at the end of the 1-second pulse. However, this start does not correspond with any particular point in the 1-kc signal cycle. Since the signal that closes the gate is the signal being gated, the gate will close at the same point in the signal cycle each time. With incoherent input signals, then, some portion of the first cycle is missing in each burst. Hence, incoherent tone bursts result.

3.8 TESTING OF LOW-SPEED DIGITAL EQUIPMENT.

The Type 1396-A Tone-Burst Generator can operate on any periodic waveform. If square or rectangular waveforms are applied to the instrument, it can generate pulse words at a bit rate determined by the gate settings of the Type 1396-A. Such words are useful in testing digital equipment. For testing binary devices the MINUS ONE setting of the CYCLE COUNTS switch is useful, since it permits testing with words containing an odd number of bits.

3.9 OPERATION WITH NONPERIODIC SIGNALS.

The Tone-Burst Generator will operate on signals that are not periodic, such as noise. The input circuits will produce a count when the TIMING INPUT signal passes through the triggering level with the proper slope. Between each count the signal must reverse slope long enough to produce a voltage change that will reset the input circuits.

SECTION 4

PRINCIPLES OF OPERATION

4.1 GENERAL.

The Tone-Burst Generator is basically a gating circuit with provisions for timing the opening and closing of the gate with signals derived from a timing signal. As shown in the simplified block diagram, Figure 4-1, the timing signal and the signal input to the gate are usually the same signal.

The main gate is a transmission gate of the shunt type, which accurately reproduces the input at the GATED SIGNAL OUTPUT terminals when the gate is open, and which permits no output when the gate is closed. The opening and closing of the main gate are controlled by the gating signal from the binary scaler. The scaler counts once per cycle of timing signal and can be controlled to set the gate-open and gate-closed intervals.

Figure 4-2 is a more detailed block diagram of the instrument. Amplifiers at the input and output of the main gate control impedances and provide higher output power. A balanced (differential or long-tailed-pair) amplifier shifts the dc level and polarity (LEVEL and SLOPE controls) of its output signal. The series Schmitt circuit produces a uniform

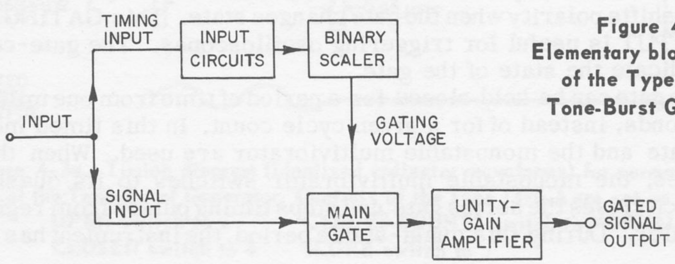


Figure 4-1. Elementary block diagram of the Type 1396-A Tone-Burst Generator.

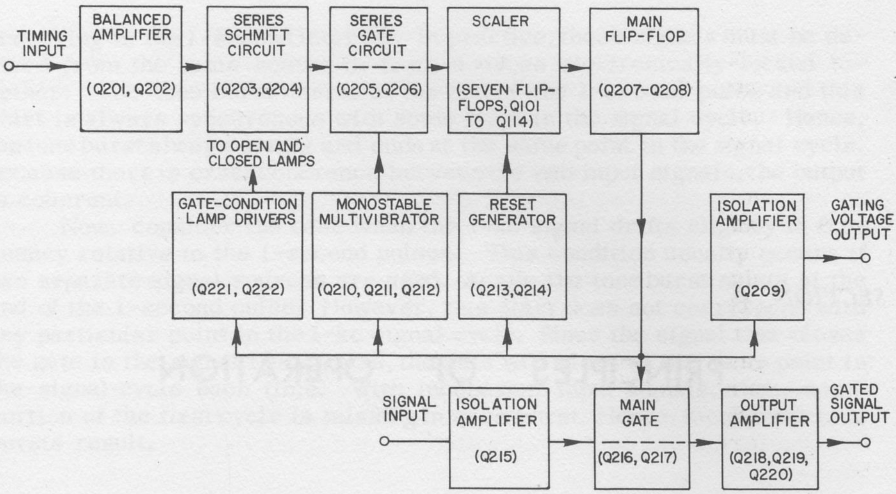


Figure 4-2. Detailed block diagram of the Type 1396-A Tone-Burst Generator.

pulse output from any periodic input waveform. The SLOPE and LEVEL controls determine the point on the input cycle at which the scaler is pulsed. Since the opening and closing of the main gate are coincident with pulsing of the scaler, the SLOPE and LEVEL controls adjust the point in the input-signal cycle when the gate opens or closes, i.e., the relative phase of signal and gate.

The series gate is locked open and can be disregarded in this discussion. The series gate is used only in timed operation.

The binary scaler drives the main flip-flop which is directly coupled to the main gate. Setting this flip-flop closes the main gate, and resetting the flip-flop opens the main gate. The set and reset signals are obtained from the collectors of the seven cascaded scaler flip-flops through the CLOSED and OPEN switches. The CLOSED switch sets the main flip-flop after the scaler has received 2, 4, 8, 16, 32, 64, or 128 counts (timing-signal cycles). The OPEN switch resets the main flip-flop in a similar fashion. The reset generator resets the scaler to zero after each action of the main flip-flop. With the CYCLE COUNTS switch in the MINUS ONE position, the scaler starts at one count instead of zero, which provides a cycle count of 1, 3, 7, 15, 31, 63, or 127. The SIGNAL switch can be set to DIRECT, which interrupts the set pulse and locks the main gate open.

The isolation amplifier driven by the main flip-flop provides a signal which shifts polarity when the gate changes state. This GATING VOLTAGE OUTPUT is useful for triggering oscilloscopes. The gate-condition lamps indicate the state of the gate.

The gate can be held closed for a period of time from one millisecond to 10 seconds, instead of for a given cycle count. In this timed mode, the series gate and the monostable multivibrator are used. When the main gate closes, the monostable multivibrator switches to its quasi-stable state which closes the series gate and stops timing pulses from registering in the scaler. During this quasi-stable period, the instrument has stopped with the main gate closed and the scaler at zero count (one count if the CYCLE COUNTS switch is in the MINUS ONE position). The monostable multivibrator stays in its quasi-stable state for a period set by the TIMED control and then reverts to its stable state which reopens the series gate. The next two input pulses (or one pulse for MINUS ONE operation) advance the scaler to 2 (1) and open the main gate. Therefore, the main gate opens from zero to two timing-signal periods after the multivibrator has switched back to its stable state. Since the main gate opens and closes when the input-circuit trigger pulses are developed and not when the monostable multivibrator returns to its stable state, the tone burst starts and stops at a phase determined by the TRIGGER LEVEL and SLOPE controls and not by the TIMED control. For this reason, the closed-gate interval will increase (jump) in units of one period of timing signal as the TIMED control is advanced. When the instrument is not operated in the timed mode, the monostable multivibrator is disconnected from the main flip-flop and it remains in its stable state, which holds the series gate open.

4.2 SEQUENCE OF OPERATION.

The timing diagrams of Figure 4-3 illustrate the sequence of operations in the Tone-Burst Generator. Figure 4-3a shows some idealized

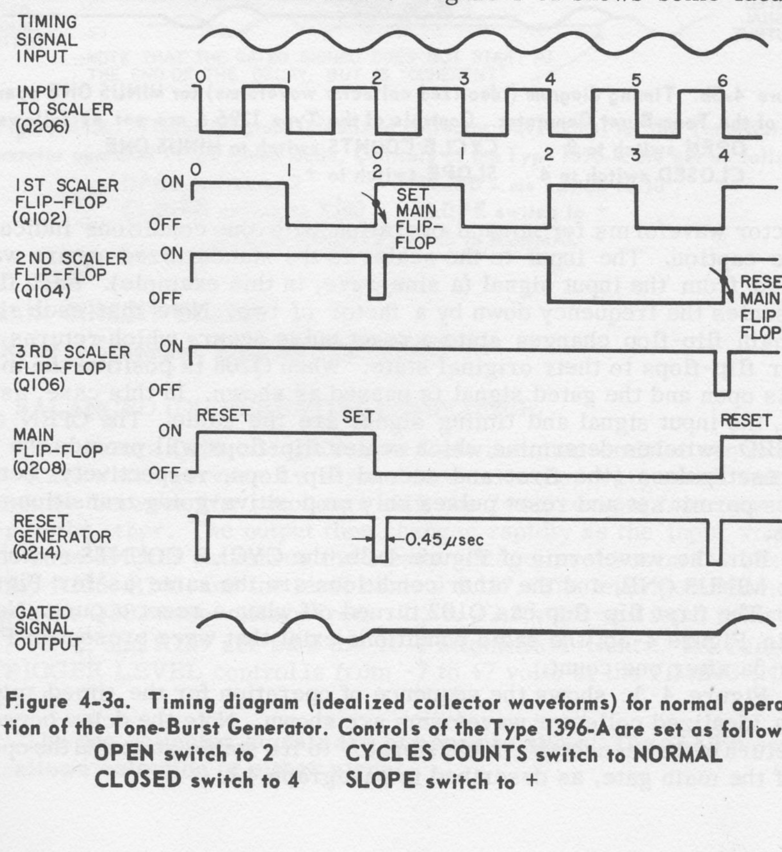


Figure 4-3a. Timing diagram (idealized collector waveforms) for normal operation of the Tone-Burst Generator. Controls of the Type 1396-A are set as follows:
OPEN switch to 2 CYCLES COUNTS switch to NORMAL
CLOSED switch to 4 SLOPE switch to +

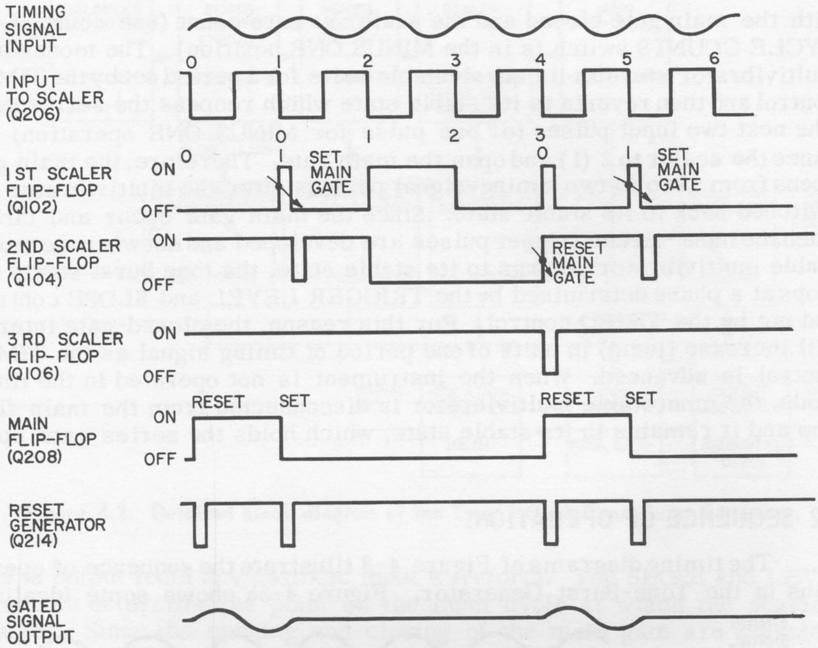


Figure 4-3b. Timing diagram (idealized collector waveforms) for MINUS ONE operation of the Tone-Burst Generator. Controls of the Type 1396-A are set as follows:

OPEN switch to 2 — CYCLE COUNTS switch to MINUS ONE
CLOSED switch to 4 — SLOPE switch to +

collector waveforms for normal operation with the conditions indicated in the caption. The input to the scaler is the standardized square wave derived from the input signal (a sine wave, in this example). Each flip-flop scales the frequency down by a factor of two. Note that each time the main flip-flop changes state a reset pulse occurs which returns the scaler flip-flops to their original state. When Q208 is positive the main gate is open and the gated signal is passed as shown. In this case, as is usual, the input signal and timing signal are the same. The OPEN and CLOSED switches determine which scaler flip-flops will provide the set and reset pulses (the first and second flip-flops, respectively, here). Diodes permit set and reset pulses only on positive-going transitions as shown.

For the waveforms of Figure 4-3b, the CYCLE COUNTS switch is set to MINUS ONE, and the other conditions are the same as for Figure 4-3a. The first flip-flop has Q102 turned off when a reset occurs. Note, that in Figure 4-3b, the same conditions exist that were present in Figure 4-3a after one count.

Figure 4-3c shows the sequence of operation for the timed mode. Again, idealized collector waveforms are shown. Note the delay between the return of the monostable multivibrator to its stable state and the opening of the main gate, as described in paragraph 4.1.

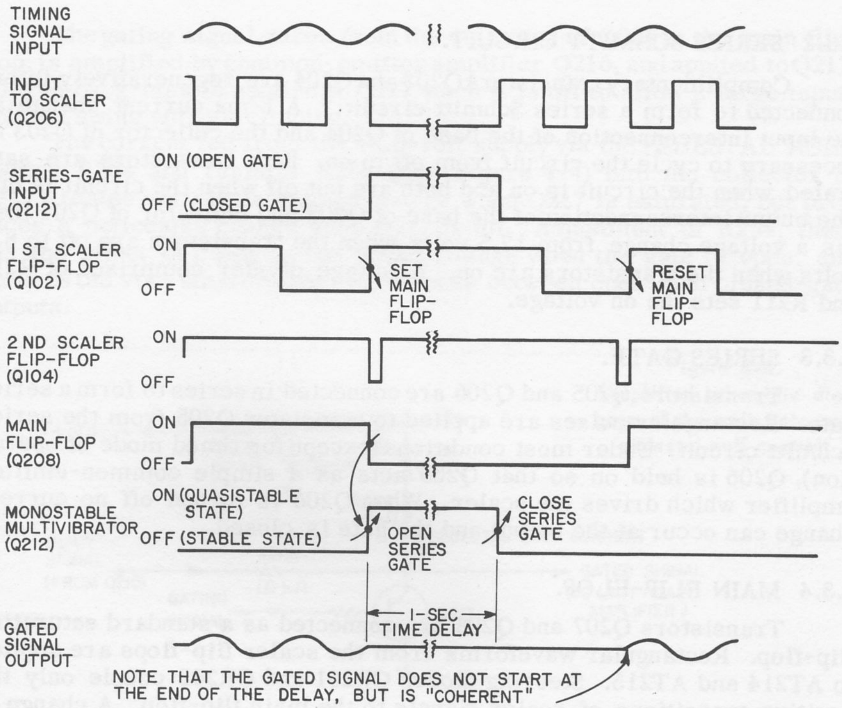


Figure 4-3c. Timing diagram (idealized collector waveforms) for the Tone-Burst Generator operated in the timed mode. Controls of the Type 1396-A are set as follows:

OPEN switch to 2 | **TIMED - ms switch to 10**
CLOSED switch to X100 | **SLOPE switch to +**
CYCLE COUNTS switch to NORMAL

4.3 MAIN CIRCUIT BOARD.
(Refer to Schematic Diagram, Figure 5-8.)

4.3.1 BALANCED (DIFFERENTIAL) AMPLIFIER.

Transistors Q201 and Q202 have their common-emitter connection fed by R205 which serves as a 2-ma current source. Very small voltage differences between the two bases shift the 2-ma current from one collector to the other. The output then changes rapidly as the input voltage on the base of Q201 traverses the steady voltage level set on the base of Q202 by R206, R208, and the level control R207. The level potentiometer changes the Q202 base voltage from -2.2 to +2.2 volts and input resistors R201, R202, and R269 act as a 3.2-to-1 attenuator. Hence, the range of the TRIGGER LEVEL control is from -7 to +7 volts at the TIMING INPUT terminals.

The two collector signals are of opposite slope. The SLOPE switch S101 allows selection of either signal.

4.3.2 SERIES SCHMITT CIRCUIT.

Complimentary transistors Q203 and Q204 are regeneratively interconnected to form a series Schmitt circuit.[9] A 1-ma current change at the input interconnection of the base of Q204 and the collector of Q203 is necessary to cycle the circuit from off to on. Both transistors are saturated when the circuit is on and both are cut off when the circuit is off. The output interconnection of the base of Q203 and collector of Q204 then has a voltage change from 12.5 volts when the transistors are off to 8.5 volts when the transistors are on. A voltage divider comprised of R210 and R211 sets the on voltage.

4.3.3 SERIES GATE.

Transistors Q205 and Q206 are connected in series to form a series gate. Rectangular pulses are applied to transistor Q205 from the series Schmitt circuit. Under most conditions (except for timed mode of operation), Q206 is held on so that Q205 acts as a simple common-emitter amplifier which drives the scaler. When Q206 is turned off no current change can occur at the output and the gate is closed.

4.3.4 MAIN FLIP-FLOP.

Transistors Q207 and Q208 are connected as a standard saturating flip-flop. Rectangular waveforms from the scaler flip-flops are applied to AT214 and AT215. Steering diodes CR201 and CR202 couple only the positive transitions of scaler signals to the main flip-flop. A change in state of the main flip-flop occurs only when a positive-going transition is applied to the on (saturated) transistor.

The SIGNAL switch S105 can be set to DIRECT to remove the signal at the base of Q208 which stops the flip-flop with Q208 conducting and holds the main gate open. Normally S105 is in the closed (gated) position. The 20-volt collector-voltage swing is symmetrical about ground.

4.3.5 MAIN GATE AND ISOLATION AMPLIFIER.

The main gate is isolated from the SIGNAL INPUT terminals by the emitter-follower circuit with transistor Q215. Diodes CR205 and CR206 prevent overdriving the input of Q215. Q215 feeds the main gate which consists mainly of the 1-kΩ resistor R248 and transistor Q217 in series to ground as shown in Figure 4-4. R248 and Q217 serve as a voltage divider with the output taken across Q217. When this transistor is heavily saturated, it has a collector-to-emitter resistance of 10 ohms or less, so very little of the input signal appears across the transistor and the gate is closed. When Q217 is turned off, almost all the signal appears across it and the gate is open. Thus, gating action is accomplished by turning Q217 on and off. Since the transistor is in parallel with the output signal, this circuit is called a shunt gate.

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[9] James K. Skilling, "New Complementary Transistors Make Series Schmitt Circuits Practical," *Electronics*, August 31, 1962. Reprints are available from General Radio Company, free upon request.

The gating signal, taken from the collector of Q208 in the main flip-flop, is amplified by common-emitter amplifier Q216, and applied to Q217. A large back-bias is applied to Q217 when it is off to allow a large input-voltage swing without clipping.

The current fed from the +8.0-volt supply via the PEDESTAL NULL control R254 and resistor R268 (see Figure 4-4) into the collector of Q217 creates very little voltage change when Q217 is saturated, but produces a noticeable change when Q217 is off. Adjustment of R254, then, has the effect of changing the output voltage when the gate is open, and reduces the very small voltage differences between open- and closed-gate outputs.

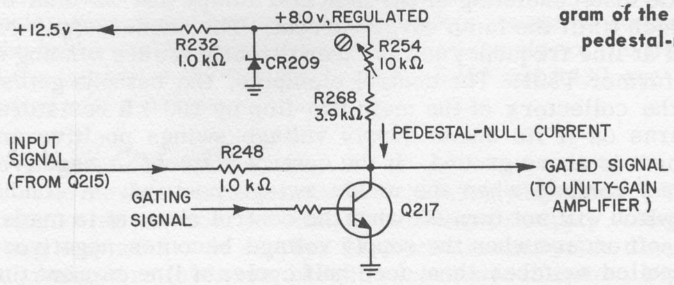

Figure 4-4. Simplified schematic diagram of the main gate and pedestal-null control.

4.3.6 DC-COUPLED OUTPUT AMPLIFIER.

Transistors Q218 and Q219 are connected in the same manner as the balanced amplifier Q201 and Q202 (refer to paragraph 4.3.1). In addition, Q220 is connected to provide negative feedback. If the voltage level at the base of Q218 is changed, Q220 drives the base of Q219 in the same direction. Q220, then makes the base of Q219 track the input base, Q218. The signal voltage at the collector of Q220 is slightly greater than the base voltage at Q218 because of the voltage-divider action of R258 and R257. This gain makes up for losses in other parts of the circuit, so that the total gain from the SIGNAL INPUT terminals to the GATED SIGNAL OUTPUT terminals equals 1 when the gate is open. The output resistor R260 limits short-circuit current and stabilizes the output resistance near 600 ohms.

Capacitors C220 and C219 control the high-frequency roll-off of the amplifier. Capacitor C218 partially neutralizes switching transients produced at the base of Q218. When the gate is opening or closing and no signal input is present, some very small switching transients (less than 50 mv peak-to-peak) may be observed at the GATED SIGNAL OUTPUT terminals. C218 and C219 are adjusted to minimize these switching transients. Care should be taken in the adjustment of C219 to ensure that the amplifier does not become conditionally unstable with large-amplitude signals.

4.3.7 GATING-VOLTAGE-OUTPUT ISOLATION AMPLIFIER.

Q209 operates as a common-emitter amplifier. It is driven by the collector of Q208 in the main flip-flop. Q209 is cut off when the main gate is open, and saturated when the gate is closed. R227 limits the output current. The output-voltage swing is nearly symmetrical about ground.

Standard compensation techniques may be used, if desired, to correct the "squareness" of the GATING VOLTAGE OUTPUT signal for capacitance loads. For example, a 16-kΩ resistor across the GATING VOLTAGE OUTPUT terminals compensates for a 12-pf probe capacity.

4.3.8 GATE-CONDITION LAMP DRIVERS.

The gate-condition lamp drivers are silicon-controlled switches, or low-current silicon-controlled rectifiers.[10] These four-layer devices have an anode load consisting of the indicator lamps and 22-ohm series resistors which limit the lamp surge current. The anode supply voltage is sinusoidal at line frequency and is taken directly from a winding on the power transformer T501. The control elements, the cathode gates, are coupled to the collectors of the main flip-flop by 100-kΩ resistors. An off switch turns on if its anode supply voltage swings positive and its control element is above ground. If the control element is negative, the switch will not conduct when the anode swings positive. A conducting controlled switch will not turn off when the control element is made negative. Turn-off occurs when the supply voltage becomes negative. The silicon-controlled switches, then, feed half cycles of line current through the indicator lamps when their control elements are positive.

4.3.9 RESET GENERATOR.

The series connection of Q213 and Q214 in the reset generator forms a circuit similar to the series gate. In steady state, both transistors are biased on to saturation by base resistors returned to 6.9 volts. The output voltage at the collector of Q214 is nearly 12.5 volts. Each series transistor is coupled by a capacitor to a collector of the main flip-flop. The coupling capacitors are "tapped down" on the flip-flop load resistors so that a swing of about 3 volts results. Negative transitions of the flip-flop collector have no effect on the output of the reset generator since they tend to turn on the already saturated transistors. A positive transition at a flip-flop collector is coupled through to the base of a reset transistor and turns it off. As a result, the base voltage rises above the emitter voltage by a few volts and starts an exponential decay toward the collector-supply voltage. When the coupling capacitor has discharged enough to drop the base voltage to less than the emitter voltage, the transistor turns on and the base voltage is clamped. For about 0.5 microsecond, then, the transistor is turned off and the output voltage drops producing a negative reset pulse. Since the main flip-flop has one negative-going collector each time it changes state, a reset pulse is generated each time the main gate opens or closes.

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[10] *General Electric Transistor Manual*, Sixth Edition, Chapter 13.

4.3.10 MONOSTABLE MULTIVIBRATOR.

Transistors Q211 and Q212 form a saturating flip-flop circuit. Transistor Q210 is a unijunction transistor connected as a relaxation oscillator.[11] The flip-flop is in its stable state when transistor Q211 is on. Timing resistors R233 (TIMED control) and R234 couple the collector of Q211 and one of the timing capacitors C211 or C212. In the stable state, the timing-capacitor voltage is low and the emitter of the unijunction transistor is well below its firing point.

An input pulse to the flip-flop at anchor terminal AT224 changes the state of the flip-flop and the timing capacitor begins a positive exponential charge. When the timing-capacitor voltage reaches the firing voltage of the unijunction transistor (near zero volts), the timing capacitor discharges rapidly through inductor L201 producing a positive pulse. The positive pulse is coupled through C223 to the base of Q211 and turns that transistor on changing the flip-flop back to its stable state. The duration of the quasi-stable state is determined by the size of the timing capacitor and the setting of the TIMED control. R229 and R230 are used for calibration of the ranges.

4.4 SCALER CIRCUITS.

The scaler contains seven saturating flip-flops. The collector-voltage swing is about 5 volts. The collector supply voltage is 5.6 volts floating atop a 6.9-volt supply. The normal reset pulse turns on the right-hand transistors (even numbered in schematic diagram, Figure 5-6), and turns off the left-hand transistors. When the CYCLE COUNTS switch is set to MINUS ONE, the first flip-flop is reset with the left-hand transistor on. Note that the steering diodes of the first flip-flop, CR102 and CR103, are poled oppositely from the diodes in the other flip-flops, CR104, CR105, etc. The first flip-flop changes state on negative input transitions and the other six flip-flops change state on positive transitions. These effects are shown in the timing diagrams of Figure 4-3. The signal at the collector of the right-hand transistor of each flip-flop is fed to the OPEN and CLOSED switches.

4.5 SWITCHES.

The OPEN and CLOSED GATE DURATION switches are standard rotary switches. The OPEN switch, S103, selects the scaler flip-flop which will reset the main flip-flop. The CLOSED switch, S102, selects the scaler flip-flop which will set the main flip-flop. The last two positions of the CLOSED switch put the instrument in the timed mode for the closed-gate interval. These last two positions of S102 are shown on the schematic diagrams for the scaler board (Figure 5-6) and the main circuit board (Figure 5-8) and they perform the following functions when the CLOSED switch is set to either of the TIMED positions:

a. The first scaler flip-flop is connected to the main flip-flop, so that there is minimum delay between the end of the monostable-multivibrator pulse and the opening of the main gate.

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11 *General Electric Transistor Manual*, Sixth Edition, Chapter 13.

b. The input of the monostable multivibrator is connected to the output of the main flip-flop, which starts the multivibrator circuit when the gate closes.

c. The X1 position of the CLOSED switch selects the 0.22-μf timing capacitor C212 and the calibrating resistor R229 for a closed-gate interval of 1 ms to 100 ms. The X100 position selects the 22-μf timing capacitor C211 and calibrating resistor R230 for a closed-gate interval of 100 ms to 10 sec.

4.6 POWER-SUPPLY CIRCUITS.

There are three basic power-supply requirements for the Type 1396-A Tone-Burst Generator, which correspond to the secondary winding numbers on the schematic diagram, Figure 5-4.

Secondary winding 1 provides a sinusoidal voltage for the gate-condition indicator lamps.

Secondary winding 2 feeds a bridge rectifier and filter and supplies 5.6 volts for the scaler-circuit board.

Secondary winding 3 supplies the main-circuit board with a center-tapped voltage of 25 volts via a bridge rectifier and filter. The center tap is grounded so that the supply voltages are +12.5 and -12.5 volts. For proper operation these supplies must remain symmetrical about ground in spite of small variations in ground-supply current. Transistors Q501 and Q502 equalize the ground current. R501 and R502 act as a divider and Q501 acts as an emitter-follower to establish the divider voltage at the ground terminal. Transistor Q502 aids the action of Q501. The output drift due to temperature changes is compensated by CR511. Note that the positive side of the 5.6-volt supply is connected to the +12.5-volt line.

The forward-biased silicon diode CR509, which is a voltage-dropping device, provides hold-off bias for the flip-flops in the instrument.

SECTION 5

SERVICE AND MAINTENANCE

5.1 WARRANTY.

We warrant that each new instrument sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, district office, or authorized repair agency personnel will be repaired, or, at our option, replaced without charge.

5.2 SERVICE.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

5.3 ACCESS TO COMPONENTS.

To remove the dust cover from the instrument, remove the two thumb screws on the rear of the instrument and pull the U-shaped dust cover off the instrument. Hinged circuit boards at the top and bottom of the instrument provide easy access to the components. These boards are hinged to the panel. Place the instrument face down. At the rear of each circuit board, remove the two screws that hold the board to the frame of the instrument. Swing the boards away from the panel (as you would the covers of a book, see Figure 5-2).

5.4 MAINTENANCE.

No routine maintenance of this instrument is necessary.

5.5 TROUBLE-SHOOTING.

If the instrument has been properly set up as delineated in Section 2, and unsatisfactory performance is suspected, the following Test Table can be used to determine the existence of and to identify failures. To localize a fault, perform, in sequence, the tests indicated by a ★. To isolate the fault, once it is localized, perform the remaining tests for that section of the instrument. Refer to the pertinent paragraphs of Section 4, Principles of Operation, in conjunction with the Test Table, Table 5-1.

All voltages are measured with nominal line voltage (115, 220, or 230 volts) applied to the instrument, and with the POWER switch on. Since supply voltages, and hence most internal signal voltages, are proportional to line voltage, variations of ±10% in the values listed below may be expected. The metal instrument frame is at ground potential. The abbreviation AT indicates an anchor terminal on an etched-circuit board.

Measurements are made with a standard 20 kΩ/volt multimeter or vacuum-tube instrument unless noted. To observe waveforms, use of a probe with 10-MΩ resistance and 12-pf (or less) capacitance is recommended. Be careful to avoid short-circuits to ground on measurements between two points which are not at ground potential.

TABLE 5-1 TEST TABLE

POWER SUPPLY

POWER SUPPLY - The power-supply board is on the rear panel of the instrument. Measurements are made with no connections to the front panel (no signal source, no load, etc.).

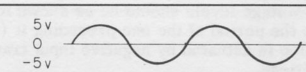
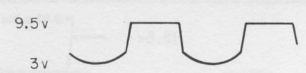
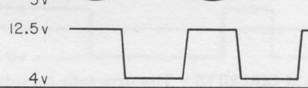
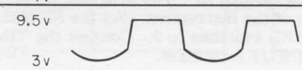
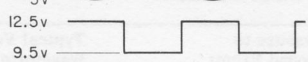
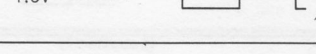
Test	Measurement Between:	Nominal Voltage	If Test Fails:
★ Line Voltage	Contact points in center of fuse-holder caps.	115, 220, or 230 v ac	Check fuses. See specifications for power and line-voltage requirements.
± 12.5-Volt Supply			
Input to Rectifiers	AT501 and AT502	40 v rms ac	The power transformer is conservatively designed and is protected by fuses. Any voltage variations are usually due to line and/or load changes.
Input to Filters	AT504(+) and AT505	47 v dc + less than 2, peak-to-peak (1.2 peak-to-peak, typical)	Check rectifiers CR501 through CR504 and capacitor C501.
★ Output	AT511 and ground	+13 v dc	Check filter capacitors C501 and C502. Check neutral current-equalizer circuit (below). Low dc may indicate excessive (>100 ma) loading from other circuits.
	AT512 and ground	-13 v dc	
Output Ripple	AT511 and ground AT512 and ground	Less than 20 mv peak-to-peak (5 mv, typical)	
Bias	AT511(+) and AT509	0.75 v dc	Check diode CR509

POWER SUPPLY (Cont)

Test	Measurement Between:	Nominal Voltage	If Test Fails:
5.6-Volt Supply			
Input to Rectifiers	AT503 and AT510	20 v rms ac	Voltage variations are usually due to line and/or load changes.
Input to Filters	AT507(+) and AT506	23 v dc + less than 1 peak-to-peak (0.35 typical)	Check Rectifiers CR505 through CR508 and filter capacitor C503.
★ Output	AT511(+) and AT506	5.6 v dc	Check C503. Low dc may indicate excessive (over 100 ma) loading from other circuits.
Output Ripple		less than 30 mv peak-to-peak (15 mv, typical)	
Neutral Current-Equalizer Circuit			
Q501, Q502	Emitter Q502(+) and ground	6.9 v	Check for proper load by measuring current flowing into AT508. It should be (typically) 12 ma for open gate and -1 ma for closed gate. Check Q501, Q502, and CR511.
	Base Q502 and ground	6.3 v	
	Base Q501 and ground	within ±0.4 of ground	

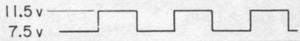
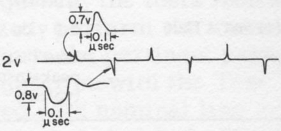
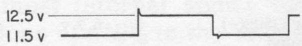
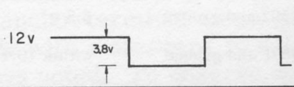
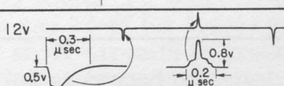
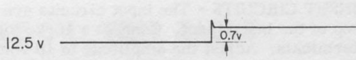
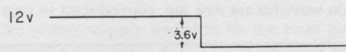
INPUT

INPUT CIRCUITS - The input circuits are on the main circuit board at the top of the instrument. Connect a 10-kc signal source to the TIMING INPUT terminals. Adjust the amplitude to 10 volts, peak-to-peak. Set the SLOPE switch to + and the TRIGGER LEVEL control to 0. Small aberrations appear-on waveforms are not reproduced in this table.

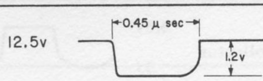
Test	Measure to Ground From:	Typical Voltage Waveform	If Test Fails:
★ Input Signal	AT203		Check connections.
Balanced Amplifier			
	Q201 Collector		Check Q201, Q202 and associated components. (If the SLOPE control is set to −, the Q201 level of 9.5 becomes 12, and the Q202 level of 12 becomes 9.5.)
	Q202 Collector		
Series Schmitt Circuit			
Input	AT209		Check the SLOPE switch S101 and its wiring.
★ Output	Q204 Collector		Check Q203 and Q204.
Series Gate			
Gating Voltage	Q211 Collector	-10 dc	If the gating voltage is positive the gate will open and no output will appear. Check the monostable circuit. (Be sure that the CLOSED switch is not set to either X1 or X100.)
★ Output	AT213		

SCALER

SCALER CIRCUITS - The scaler circuits are on the board at the bottom of the instrument. Set the CLOSED and OPEN switches to 4 and the SIGNAL switch to NORMAL. Waveforms shown start at positive transitions of gating output voltage.

Test	Measure to Ground From:	Typical Voltage Waveform	If Test Fails:
Board Input	AT108		Check wiring.
1st Flip-Flop			
Input	Junction C101, CR101, CR102, and CR103.		Check C101, CR101, CR102, and CR103.
Base	Q102 Base		Q101 has the same waveforms, but of opposite phase. Check Q101, Q102, and associated components.
★Output	Q102 Collector (AT101)		
2nd Flip-Flop			
Input	Junction CR104, CR105, and R143		Check CR104 and CR105.
Base	Q104 Base		Check Q103, Q104, and associated components.
★Output	Q104 Collector (AT102)		

★To check all seven scaler flip-flops, note the output voltage at AT101 through AT107 with the OPEN and CLOSED switches set to 128. Voltage levels should be as shown for the second flip-flop and each output square wave should have twice the period of the one preceding it (refer to the timing diagrams in Figure 4-3). Note that the first flip-flop is actuated by negative input transitions, but the following flip-flops are actuated by positive transitions.

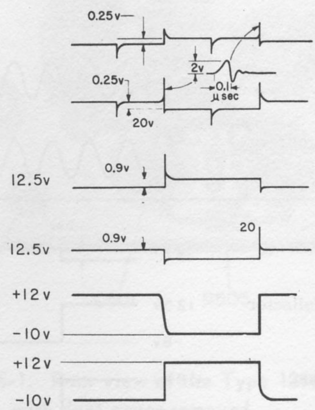
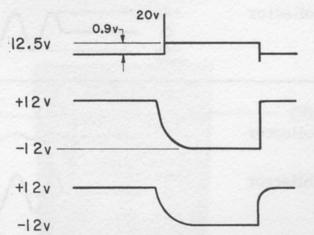
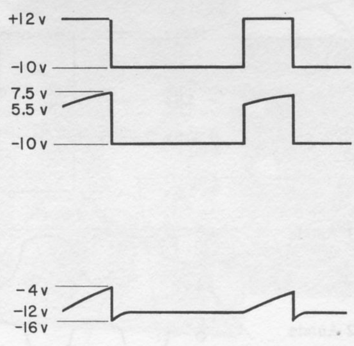
Reset Pulse	AT111		Check Q213, Q214, and associated components.

PROGRAM

PROGRAM CIRCUITS - The program circuits are on the main circuit board at the top of the instrument. Set the SIGNAL switch to GATED and the OPEN and CLOSED switches to 2. Connect the TIMING INPUT terminals to the SIGNAL INPUT terminals.

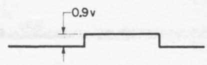
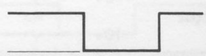
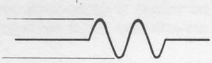
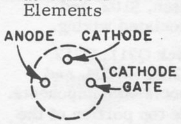
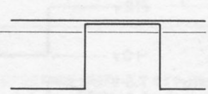
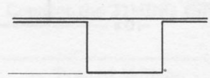
Test	Measure to Ground From:	Typical Voltage Waveform	If Test Fails:
Main Flip-Flop			
Driving Signal	AT214		Check switch S102. (Same waveform as output of flip-flop 1)
	AT215		Check switch S103, and S105. (Same waveform as output of flip-flop 1)
(Cont)			

PROGRAM CIRCUITS (Cont)

Test	Measure to Ground From:	Typical Voltage Waveform	If Test Fails
Main Flip-Flop (Cont)			
Input Signal	CR201 Anode		Check CR201, CR202, Q207, Q208, and associated components. An overload, such as would result from a failure of a circuit driven by the main flip-flop, can cause a failure of the main flip-flop. (Attachment of oscilloscope probe in base circuit may cause the main flip-flop to fail; in which case check over-all performance by collector waveform observations.)
	CR202 Anode		
Bases	Q207 Base		
	Q208 Base		
Outputs	Q207 Collector		
★	Q208 Collector		
Gating-Voltage Isolation Amplifier			
Base	Q209 Base		Check Q209 and associated components. Rise time when feeding 1-MΩ, 12-pf probe is 4 µsec, and fall time is 7 µsec.
Collector	Q209 Collector		
Output	AT216		
Monostable Multivibrator			
Set CLOSED switch to X1, the TIMED control to 1, and the OPEN switch to 64.			
Driving Signal	AT224		Check the CLOSED switch, S102, and associated wiring.
Flip-Flop Collector (Multivibrator Output)	Q211 Collector		Check Q211, Q212, CR203, CR204, and associated components. (The top portion of the waveform will become flat and increase in amplitude to 10 volts as the TIMED control is advanced to 100. Return the control to 1.)
Unijunction Timing	Q210 Emitter (AT220)		Check Q210, S102, and setting of R229 and R230. (The potentiometers calibrate the open-gate time interval when the TIMED control is at 10.)

(Continued)

PROGRAM CIRCUITS (Cont)

Test	Measure to Ground From:	Typical Voltage Waveform	If Test Fails:
Signal-Input Isolation Amplifier (Q215) Set OPEN and CLOSED switches to 2.			
Input	AT227	+5 v, 0, −5 v 	Check interconnection of input and timing signals, and wiring.
Output	Q215 Emitter	+ 4.4 v, − 5.6 v 	
Main Gate			
Gating-Voltage Amplifier Base	Q216 Base	12.5 v 	Check Q216, Q217, and associated components.
Gating-Voltage Amplifier Output	Q216 Collector	12.5 v, −6 v 	
Main-Gate Transistor Base	Q217 Base	+ 0.9 v, −6 v 	
Main-Gate Transistor Collector	Q217 Collector	+4 v, 0, −4 v 	
Output Amplifier			
Q218	Q218 Collector	12 v 	Check Q218, Q219, Q220, CR207, and associated components. Small spurious oscillations present at certain parts of the waveforms may be due to conditional oscillation of the amplifier. Check adjustment of C219.
Q220	Q220 Collector	+6 v, 0, −6 v 	
Q220	Q220 Emitter	12 v 	
Q219	Q219 Base	+4 v, 0, −4 v 	
Gate-Condition Lamp Drivers			
at Control Elements  BOTTOM VIEW OF ETCHED BOARD AT Q221 & Q222.	Cathode gate of Q221	+0.8 v, 0, − 3.5 v 	Check Q221, Q222, and pilot lamps. For access to the pilot lamps, unscrew the white "lens" over the lamp.
	Cathode gate of Q222	+ 0.8 v, − 3.5 v 	
at Anode Switch to + Line Sync on Oscilloscope	Q221 Anode	1.6 v, 0, −24 v 	The half-wave signal is normal. A full-wave signal indicates failure of Q221 or Q222 to fire. No signal probably indicates an open lamp.
	Q222 Anode	1.6 v, 0, −24 v 	

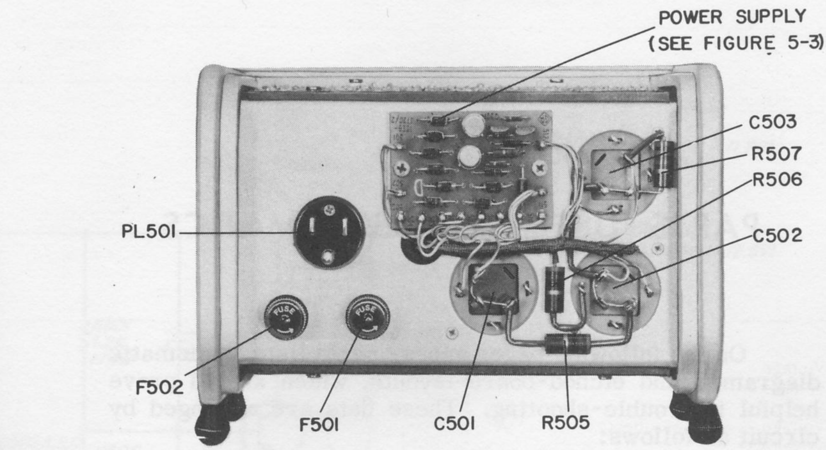


Figure 5-1. Rear view of the Type 1396-A with dust cover removed.

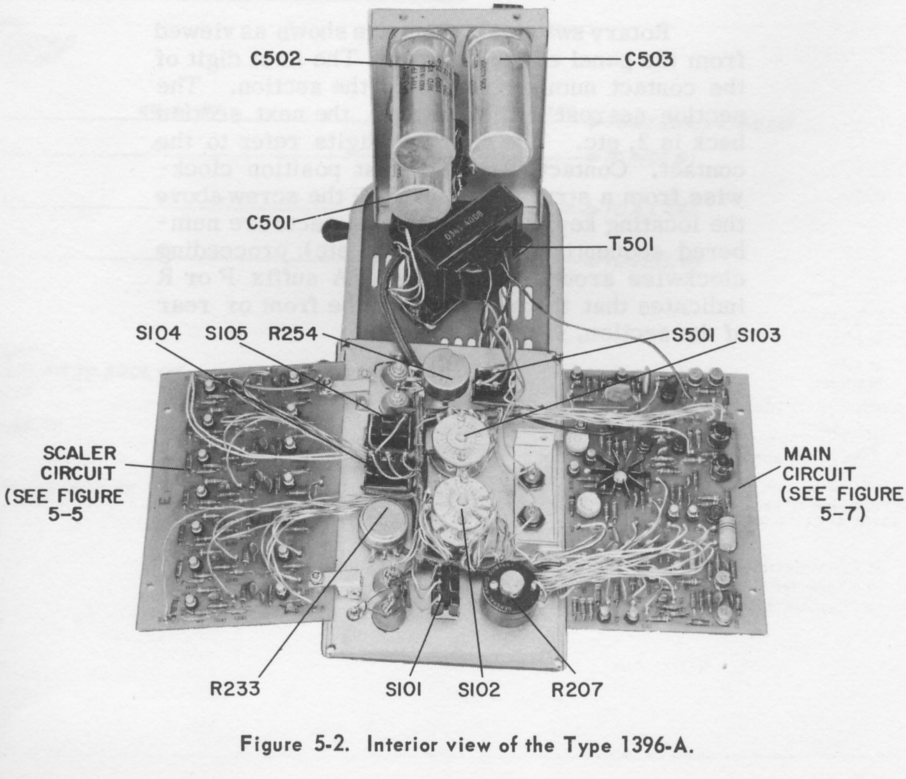


Figure 5-2. Interior view of the Type 1396-A.

PARTS LISTS AND SCHEMATICS

On the following pages appear parts lists, schematic diagrams, and etched-board layouts, which should prove helpful in trouble-shooting. These data are arranged by circuit as follows:

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

PARTS LIST

RESISTORS

REF NO.		PART NO.
R501	Composition, 1.2 kΩ ±5% 1/4 w	6099-2125
R502	Composition, 1.2 kΩ ±5% 1/4 w	6099-2125
R503	Composition, 6.2 kΩ ±5% 1/4 w	6099-2625
R504	Composition, 560 Ω ±5% 1/2 w	6100-1565
R505	Composition, 82 Ω ±5% 2 w	6120-0825
R506	Composition, 82 Ω ±5% 2 w	6120-0825
R507	Composition, 180 Ω ±5% 2 w	6120-1185

CAPACITORS

C501A,B,C	Electrolytic, 900 µf 100 v	4450-4000
C502A,B,C	Electrolytic, 3000 µf 25 v	4450-0700
C503A,B,C	Electrolytic, 1500-1500 µf 25 v	4450-0700
C504	Ceramic, 0.01 µf	4401-3100
C505	Ceramic, 0.01 µf	4401-3100

MISCELLANEOUS

CR501 through CR509	DIODE, Type 1N3253	6081-1001
CR510	DIODE, Type 1N753A	6083-1006
CR511	DIODE, Type 1N645	6082-1016
F501	FUSE, 115 v, 0.15 a	5330-0500
	FUSE, 230 v, 0.1 a	5330-0400
F502	FUSE, 115 v, 0.15 a	5330-0500
	FUSE, 230 v, 0.1 a	5330-0400
PL501	PLUG, Power	4240-0600
Q501	TRANSISTOR, Type 2N1304	8210-1304
Q502	TRANSISTOR, Type 2N1131	8210-1025
S501	SWITCH, Toggle, POWER	7910-1500
T501	TRANSFORMER	0345-4008

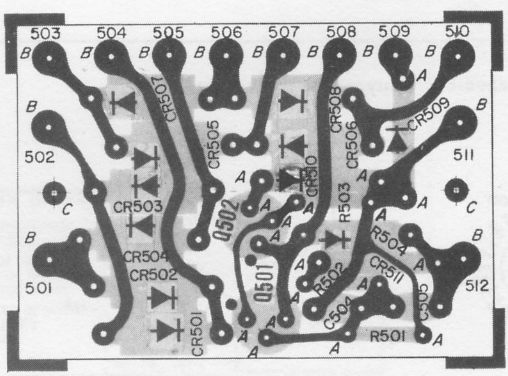
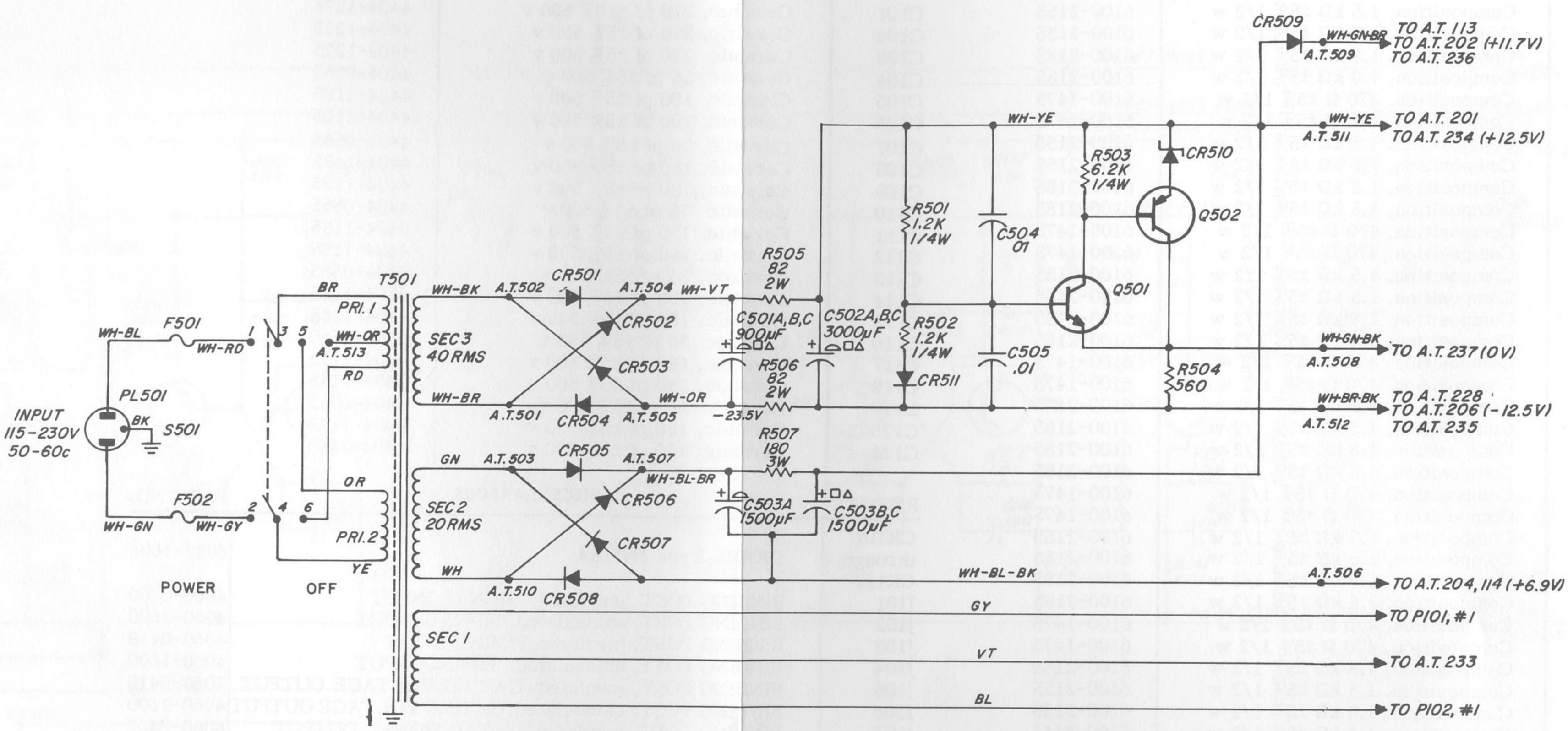


Figure 5-3. Etched-board layout for power-supply circuits.



NOTE UNLESS SPECIFIED	
1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.	5. RESISTANCE IN OHMS K = 1000 OHMS M = 1 MEGOHM
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.	6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.	7. ◯ KNOB CONTROL
	8. ⦸ SCREWDRIVER CONTROL
	9. AT = ANCHOR TERMINAL
4. RESISTORS 1/2 WATT.	10. TP = TEST POINT

ANCHOR TERMINALS USED: A.T. 501–513

AT513 is on a stand-off insulator next to T501.

NOTE:

FOR 115V OPERATION CONNECT S501, #3 TO S501, #5 & S501, #4 TO S501, #6
F501 & F502 = 0.15 AMPS

FOR 230V OPERATION CONNECT S501, #5 TO S501, #6
F501 & F502 = 0.1 AMPS

FOR 220V OPERATION REPLACE WIRE AT S501, #6 WITH WH-OR
F501 & F502 = 0.1 AMPS

Figure 5-4.
Schematic diagram of the power-supply circuits.

PARTS LIST

RESISTORS

REF NO.		PART NO.
R101	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R102	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R103	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R104	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R105	Composition, 470 Ω ±5% 1/2 w	6100-1475
R106	Composition, 470 Ω ±5% 1/2 w	6100-1475
R107	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R108	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R109	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R110	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R111	Composition, 470 Ω ±5% 1/2 w	6100-1475
R112	Composition, 470 Ω ±5% 1/2 w	6100-1475
R113	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R114	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R115	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R116	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R117	Composition, 470 Ω ±5% 1/2 w	6100-1475
R118	Composition, 470 Ω ±5% 1/2 w	6100-1475
R119	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R120	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R121	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R122	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R123	Composition, 470 Ω ±5% 1/2 w	6100-1475
R124	Composition, 470 Ω ±5% 1/2 w	6100-1475
R125	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R126	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R127	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R128	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R129	Composition, 470 Ω ±5% 1/2 w	6100-1475
R130	Composition, 470 Ω ±5% 1/2 w	6100-1475
R131	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R132	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R133	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R134	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R135	Composition, 470 Ω ±5% 1/2 w	6100-1475
R136	Composition, 470 Ω ±5% 1/2 w	6100-1475
R137	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R138	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R139	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R140	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R141	Composition, 470 Ω ±5% 1/2 w	6100-1475
R142	Composition, 470 Ω ±5% 1/2 w	6100-1475
R143 through R148	Composition, 1 kΩ ±5% 1/2 w	6100-2105

PARTS LIST (Cont)

CAPACITORS

REF NO.		PART NO.
C101	Ceramic, 270 pf ±10% 500 v	4404-1278
C102	Ceramic, 220 pf ±5% 500 v	4404-1225
C103	Ceramic, 220 pf ±5% 500 v	4404-1225
C104	Ceramic, 56 pf ±5% 500 v	4404-0565
C105	Ceramic, 100 pf ±5% 500 v	4404-1105
C106	Ceramic, 100 pf ±5% 500 v	4404-1105
C107	Ceramic, 56 pf ±5% 500 v	4404-0565
C108	Ceramic, 180 pf ±5% 500 v	4404-1185
C109	Ceramic, 180 pf ±5% 500 v	4404-1185
C110	Ceramic, 56 pf ±5% 500 v	4404-0565
C111	Ceramic, 180 pf ±5% 500 v	4404-1185
C112	Ceramic, 180 pf ±5% 500 v	4404-1185
C113	Ceramic, 56 pf ±5% 500 v	4404-0565
C114	Ceramic, 180 pf ±5% 500 v	4404-1185
C115	Ceramic, 180 pf ±5% 500 v	4404-1185
C116	Ceramic, 56 pf ±5% 500 v	4404-0565
C117	Ceramic, 180 pf ±5% 500 v	4404-1185
C118	Ceramic, 180 pf ±5% 500 v	4404-1185
C119	Ceramic, 56 pf ±5% 500 v	4404-0565
C120	Ceramic, 180 pf ±5% 500 v	4404-1185
C121	Ceramic, 180 pf ±5% 500 v	4404-1185

MISCELLANEOUS

REF NO.		PART NO.
CR101 through CR122	DIODE, Type 1N118A	6082-1006
J101	BINDING POST, insulated, SIGNAL INPUT	4060-0400
J102	BINDING POST, uninsulated, SIGNAL INPUT	4060-1600
J103	BINDING POST, insulated, TIMING INPUT	4060-0410
J104	BINDING POST, uninsulated, TIMING INPUT	4060-1600
J105	BINDING POST, insulated, GATING VOLTAGE OUTPUT	4060-0410
J106	BINDING POST, uninsulated, GATING VOLTAGE OUTPUT	4060-1600
J107	BINDING POST, insulated, GATED SIGNAL OUTPUT	4060-0400
J108	BINDING POST, uninsulated, GATED SIGNAL OUTPUT	4060-1600
P101	PILOT LIGHT, 2LAP-9, CLOSED	5600-0309
P102	PILOT LIGHT, 2LAP-9, OPEN	5600-0309
Q101 through Q114	TRANSISTOR, Type 2N711A	8210-7111
S101	SWITCH, Toggle, SLOPE	7910-0800
S102	SWITCH, Rotary Wafer, GATE DURATION, CLOSED	7890-3520
S103	SWITCH, Rotary Wafer, GATE DURATION, OPEN	7890-3520
S104	SWITCH, Toggle, CYCLE COUNTS	7910-0800
S105	SWITCH, Toggle, SIGNAL	7910-1000

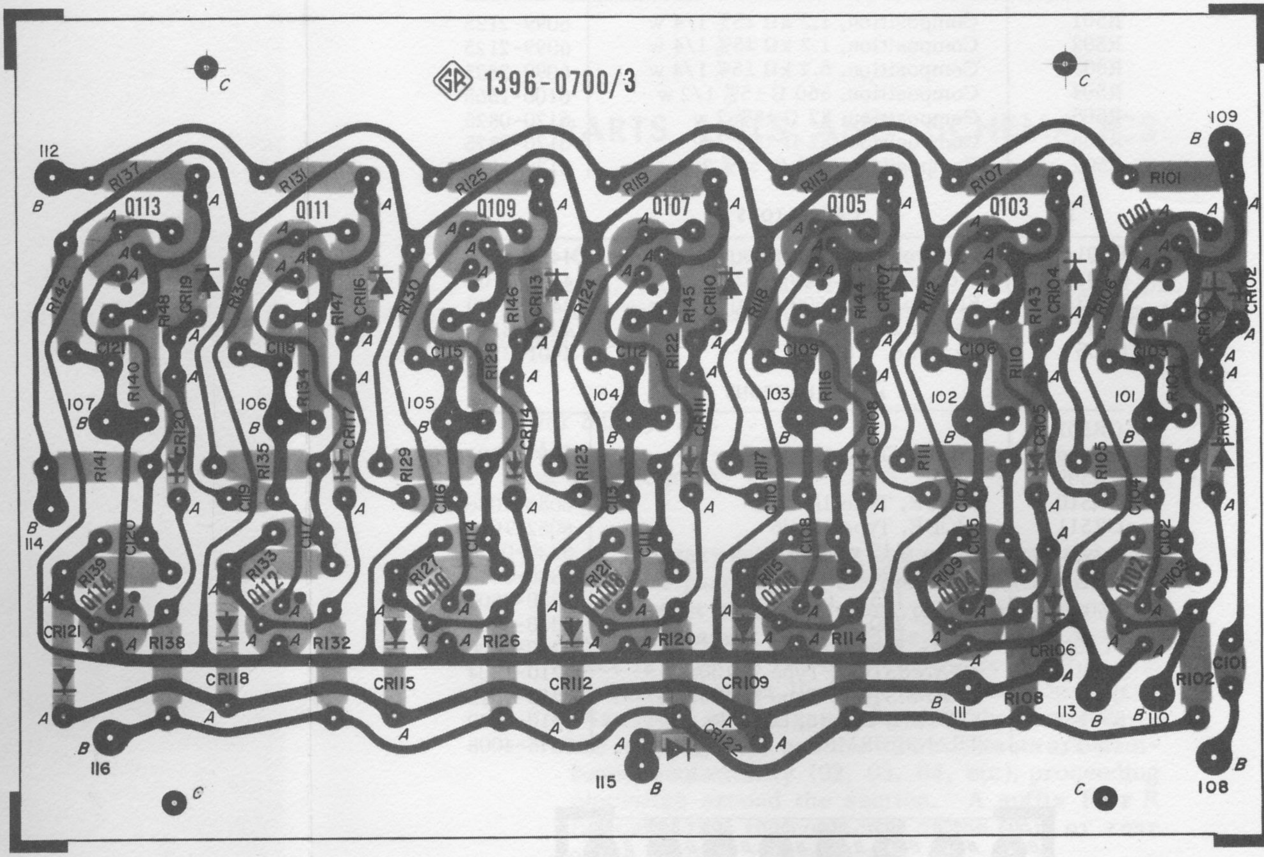
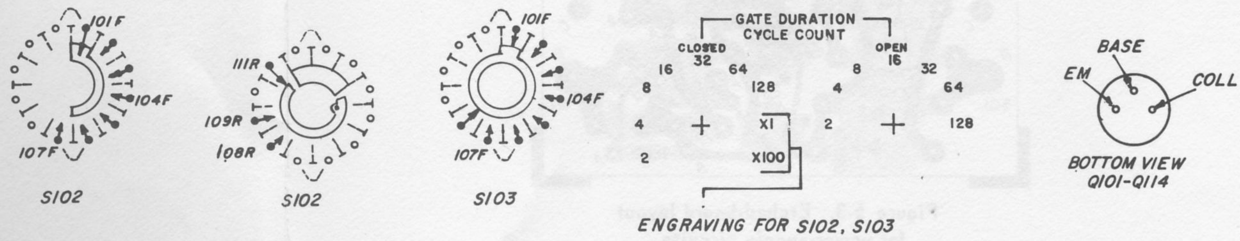
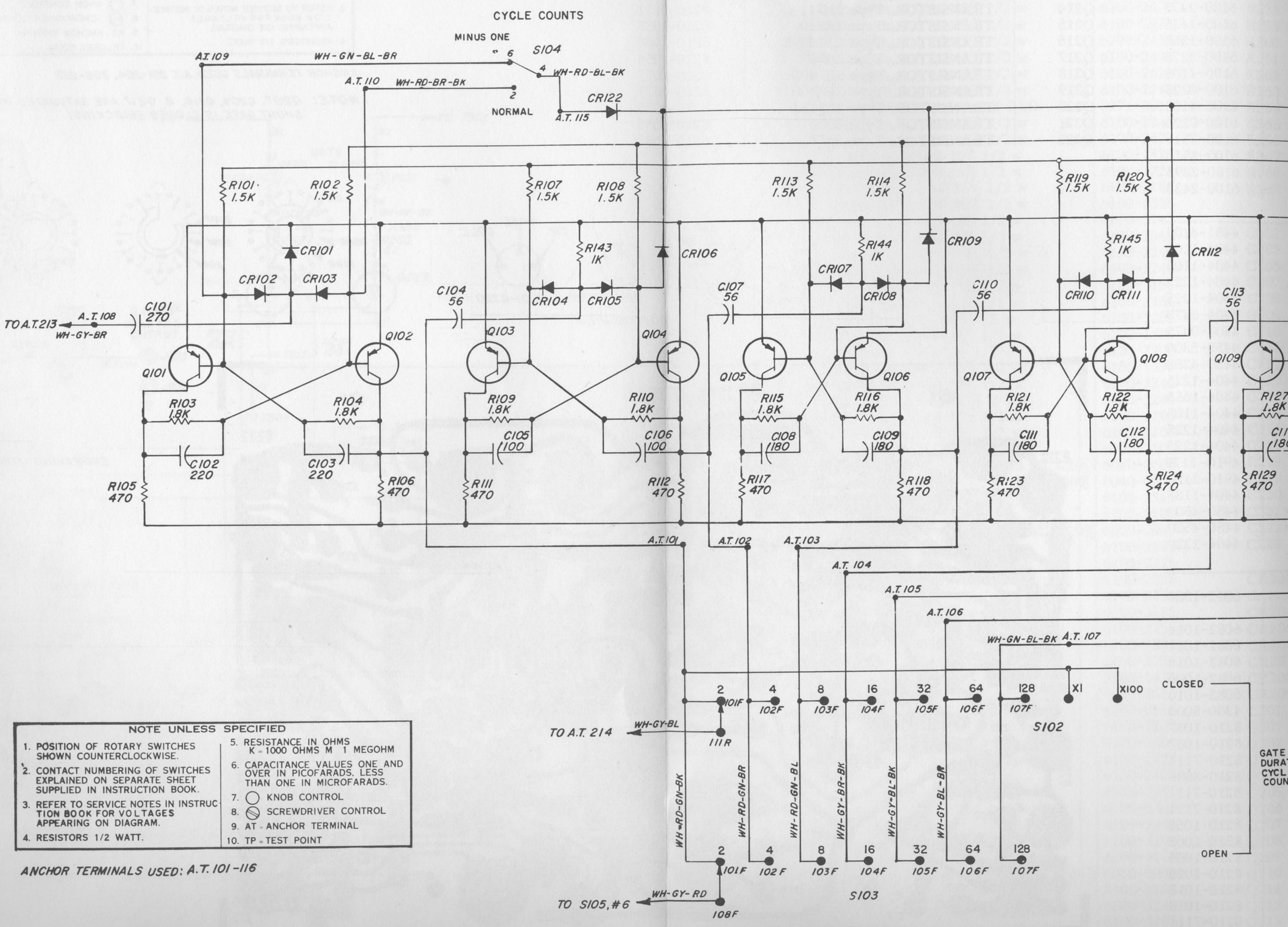


Figure 5-5. Etched-board layout for the scaler.





NOTE UNLESS SPECIFIED

1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.
4. RESISTORS 1/2 WATT.
5. RESISTANCE IN OHMS K = 1000 OHMS M 1 MEGOHM
6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS.
7. ◯ KNOB CONTROL
8. ⊘ SCREWDRIVER CONTROL
9. AT = ANCHOR TERMINAL
10. TP = TEST POINT

ANCHOR TERMINALS USED: A.T. 101-116

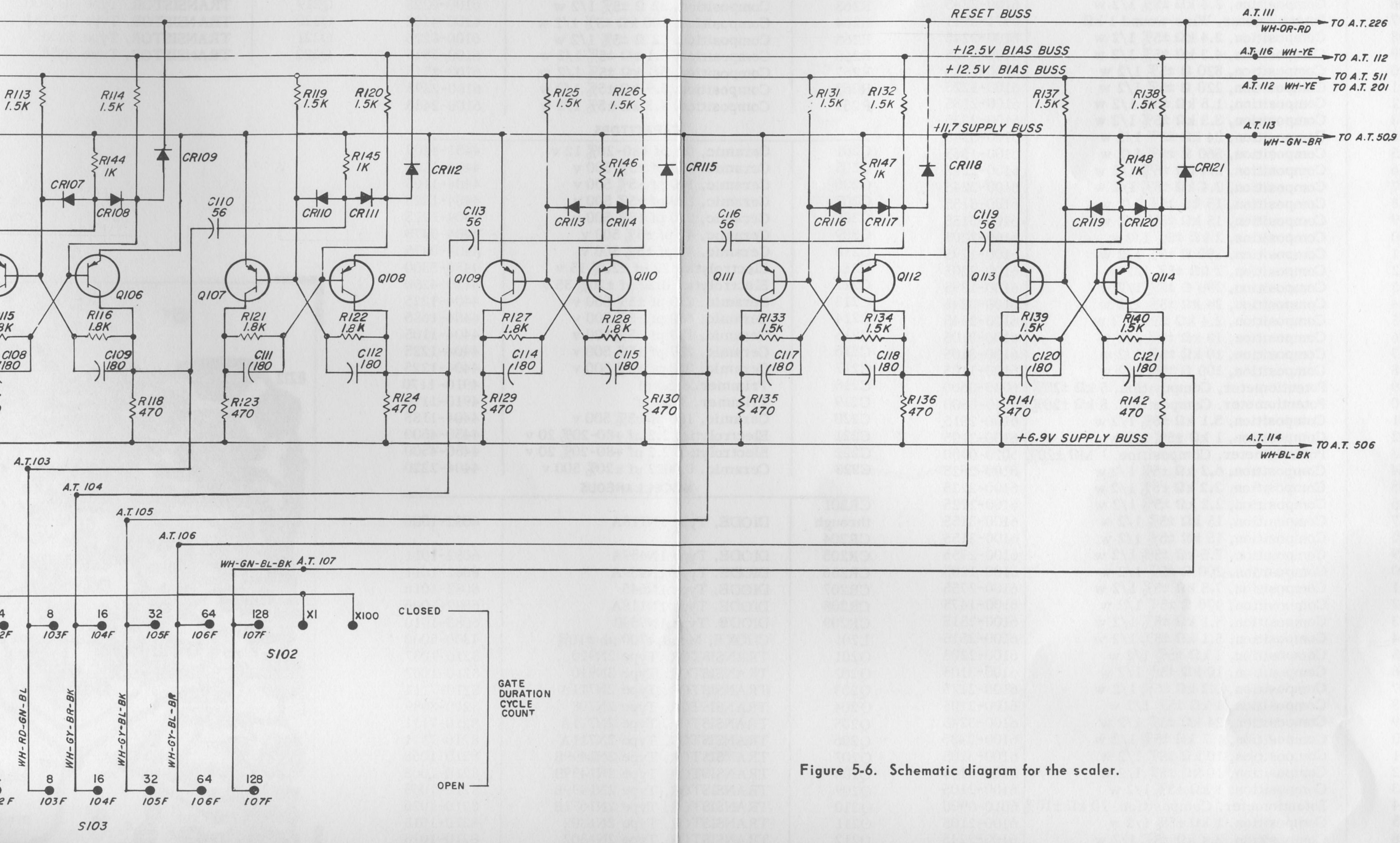


Figure 5-6. Schematic diagram for the scaler.

PARTS LIST

RESISTORS

REF NO.		PART NO.
R201	Composition, 4.7 kΩ ±5% 1/2 w	6100-2475
R202	Composition, 4.3 kΩ ±5% 1/2 w	6100-2435
R203	Composition, 4.3 kΩ ±5% 1/2 w	6100-2435
R204	Composition, 4.3 kΩ ±5% 1/2 w	6100-2435
R205	Composition, 6.2 kΩ ±5% 1/2 w	6100-2625
R206	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R207	Potentiometer, Wire-wound 1 kΩ	0971-3911
R208	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R209	Composition, 4.3 kΩ ±5% 1/2 w	6100-2435
R210	Composition, 820 Ω ±5% 1/2 w	6100-1825
R211	Composition, 220 Ω ±5% 1/2 w	6100-1225
R212	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R213	Composition, 3.3 kΩ ±5% 1/2 w	6100-2335
R214	Composition, 24 kΩ ±5% 1/2 w	6100-3245
R215	Composition, 560 Ω ±5% 1/2 w	6100-1565
R216	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R217	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R218	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R219	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R220	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R221	Composition, 390 Ω ±5% 1/2 w	6100-1395
R222	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R223	Composition, 390 Ω ±5% 1/2 w	6100-1395
R224	Composition, 24 kΩ ±5% 1/2 w	6100-3245
R225	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R226	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R227	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R228	Composition, 100 Ω ±5% 1/2 w	6100-1105
R229	Potentiometer, Composition, 5 kΩ ±20%	6040-0600
R230	Potentiometer, Composition, 5 kΩ ±20%	6040-0600
R231	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R232	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R233	Potentiometer, Composition, 1 MΩ ±20%	6020-0900
R234	Composition, 6.2 kΩ ±5% 1/2 w	6100-2625
R235	Composition, 2.2 kΩ ±5% 1/2 w	6100-2225
R236	Composition, 2.2 kΩ ±5% 1/2 w	6100-2225
R237	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R238	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R239	Composition, 7.5 kΩ ±5% 1/2 w	6100-2755
R240	Composition, 200 Ω ±5% 1/2 w	6100-1205
R241	Composition, 7.5 kΩ ±5% 1/2 w	6100-2755
R242	Composition, 470 Ω ±5% 1/2 w	6100-1475
R243	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R244	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R245	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R246	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R247	Composition, 1.2 kΩ ±5% 1/2 w	6100-2125
R248	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R249	Composition, 24 kΩ ±5% 1/2 w	6100-3245
R250	Composition, 4.7 kΩ ±5% 1/2 w	6100-2435
R251	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R252	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R253	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R254	Potentiometer, Composition, 10 kΩ ±10%	6010-0900
R255	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R256	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R257	Composition, 10 kΩ ±5% 1/2 w	6100-3105

PARTS LIST (Cont)

RESISTORS (Cont)

REF NO.		PART NO.
R258	Composition, 4.7 kΩ ±5% 1/2 w	6100-2475
R259	Composition, 430 Ω ±5% 1/2 w	6100-1435
R260	Composition, 560 Ω ±5% 1/2 w	6100-1565
R261	Composition, 27 kΩ ±5% 1/2 w	6100-3275
R262	Composition, 100 kΩ ±5% 1/2 w	6100-4105
R263	Composition, 22 Ω ±5% 1/2 w	6100-0225
R264	Composition, 100 kΩ ±5% 1/2 w	6100-4105
R265	Composition, 22 Ω ±5% 1/2 w	6100-0225
R266	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R267	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R268	Composition, 3.9 kΩ ±5% 1/2 w	6100-2395
R269	Composition, 4.3 kΩ ±5% 1/2 w	6100-2435

CAPACITORS

C201	Ceramic, 0.1 μf +80-20% 12 v	4431-4109
C205	Ceramic, 100 pf ±5% 500 v	4404-1105
C206	Ceramic, 100 pf ±5% 500 v	4404-1105
C207	Ceramic, 220 pf ±5% 500 v	4404-1225
C208	Ceramic, 220 pf ±5% 500 v	4404-1225
C209	Ceramic, 47 pf ±5% 500 v	4404-0475
C210	Ceramic, 47 pf ±5% 500 v	4404-0475
C211	Electrolytic, 22 μf ±20% 15 v	4450-5300
C212	Electrolytic, 0.22 μf ±20% 35 v	4450-4280
C213	Ceramic, 220 pf ±5% 500 v	4404-1225
C214	Ceramic, 680 pf ±5% 500 v	4404-1685
C215	Ceramic, 100 pf ±5% 500 v	4404-1105
C216	Ceramic, 220 pf ±5% 500 v	4404-1225
C217	Ceramic, 220 pf ±5% 500 v	4404-1225
C218	Trimmer, 8-50 pf	4910-1170
C219	Trimmer, 8-50 pf	4910-1170
C220	Ceramic, 180 pf ±5% 500 v	4404-1185
C221	Electrolytic, 2.2 μf +80-20% 20 v	4450-4500
C222	Electrolytic, 2.2 μf +80-20% 20 v	4450-4500
C223	Ceramic, 0.0022 μf ±20% 500 v	4404-2220

MISCELLANEOUS

CR201 through CR204	DIODE, Type 1N118A	6082-1006
CR205	DIODE, Type 1N459A	6082-1011
CR206	DIODE, Type 1N459A	6082-1011
CR207	DIODE, Type 1N645	6082-1016
CR208	DIODE, Type 1N118A	6082-1006
CR209	DIODE, Type 1N959B	6083-1010
L201	CHOKE, Metal, 4700 μh ±10%	4300-5000
Q201	TRANSISTOR, Type 2N910	8210-1037
Q202	TRANSISTOR, Type 2N910	8210-1037
Q203	TRANSISTOR, Type 2N711A	8210-7111
Q204	TRANSISTOR, Type 2N708	8210-3089
Q205	TRANSISTOR, Type 2N711A	8210-7111
Q206	TRANSISTOR, Type 2N711A	8210-7111
Q207	TRANSISTOR, Type 2N1499B	8210-1068
Q208	TRANSISTOR, Type 2N1499B	8210-1068
Q209	TRANSISTOR, Type 2N1499B	8210-1068
Q210	TRANSISTOR, Type 2N1671B	8210-1026
Q211	TRANSISTOR, Type 2N1302	8210-1018
Q212	TRANSISTOR, Type 2N1302	8210-1018
Q213	TRANSISTOR, Type 2N711A	8210-7111

PARTS LIST (Cont)

MISCELLANEOUS (Cont)

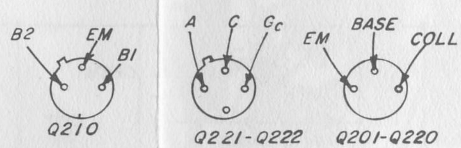
REF NO.		PART NO.
Q214	TRANSISTOR, Type 2N711A	8210-7111
Q215	TRANSISTOR, Type 2N910	8210-1037
Q216	TRANSISTOR, Type 2N1499B	8210-1068
Q217	TRANSISTOR, Type 2N709	8210-1054
Q218	TRANSISTOR, Type SE-4002	8210-1077
Q219	TRANSISTOR, Type SE-4002	8210-1077
Q220	TRANSISTOR, Type 2N1131	8210-1025
Q221	TRANSISTOR, Type 3N58	8210-1053
Q222	TRANSISTOR, Type 3N58	8210-1053

NOTE UNLESS SPECIFIED

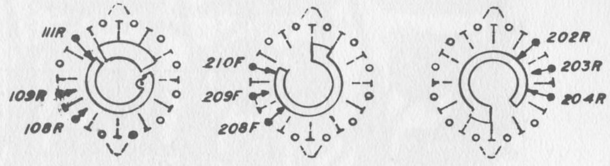
1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.
4. RESISTORS 1/2 WATT.
5. RESISTANCE IN OHMS K = 1000 OHMS M = 1 MEGOHM
6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS.
7. ◯ KNOB CONTROL
8. ⊘ SCREWDRIVER CONTROL
9. AT = ANCHOR TERMINAL
10. TP = TEST POINT

ANCHOR TERMINALS USED: A.T. 201-204, 206-237

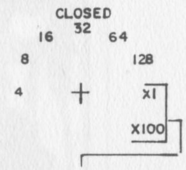
NOTE: Q207, Q209, Q216, & Q217 ARE SATURATED WHEN SHUNT GATE IS CLOSED (BLOCKING)



BOTTOM VIEW



S102



ENGRAVING FOR S102

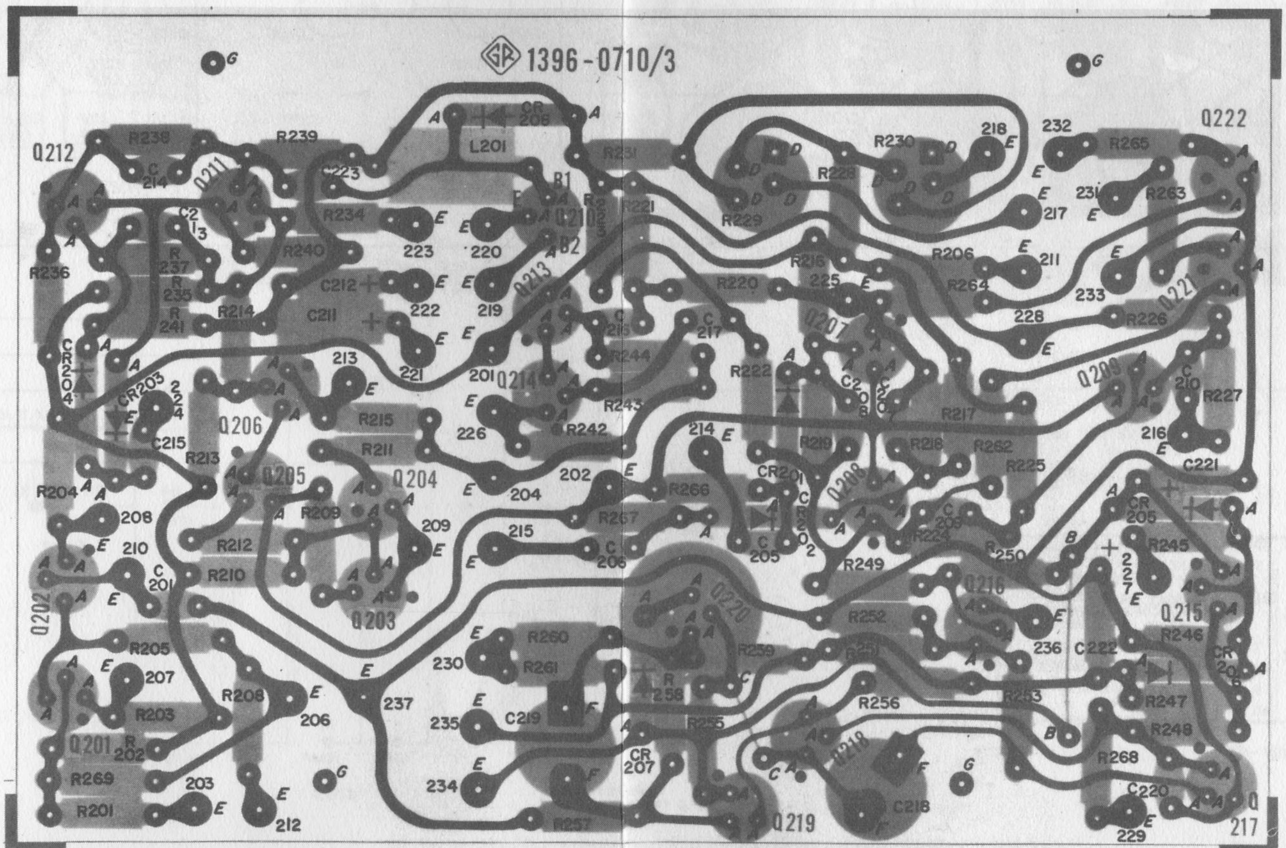
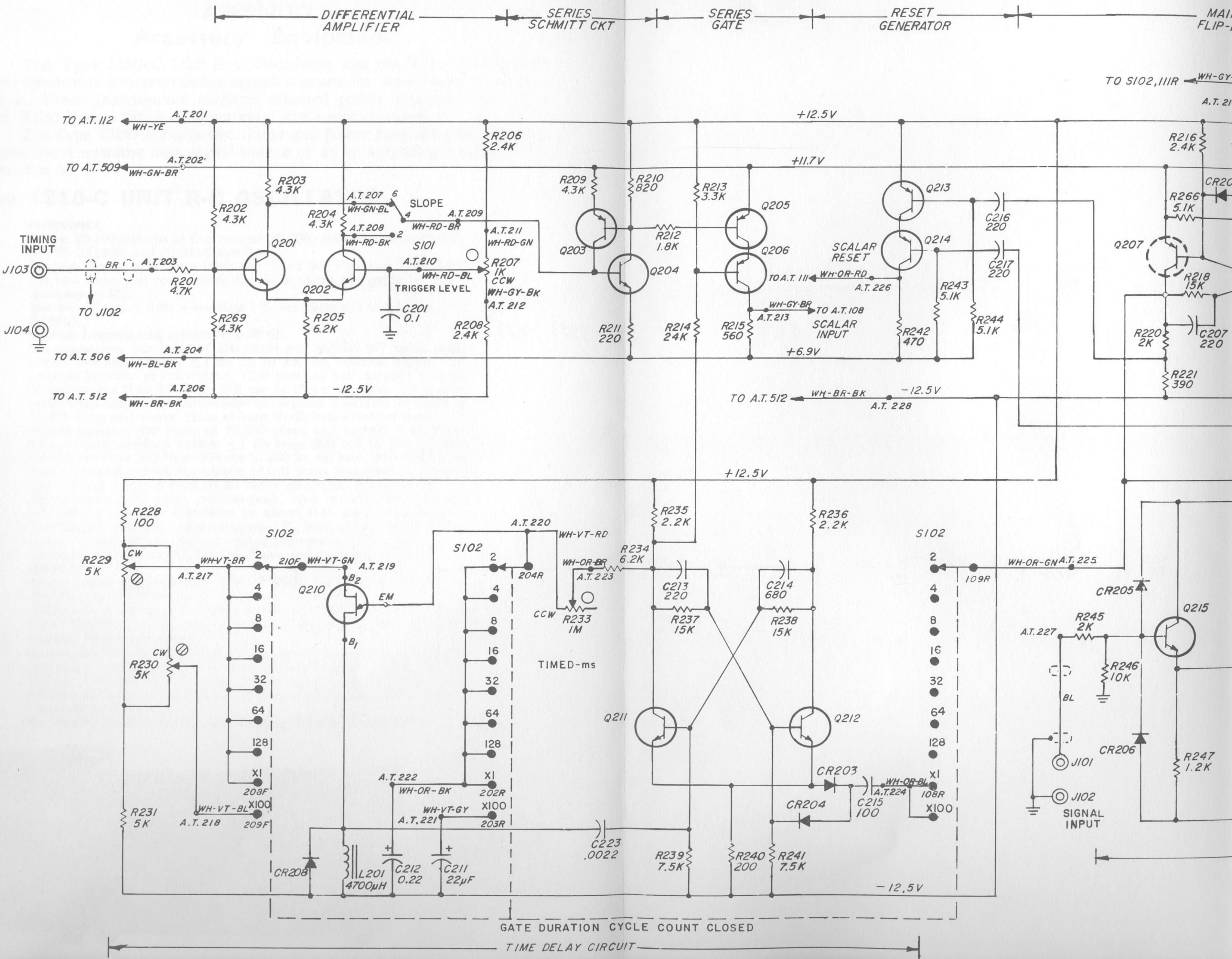


Figure 5-7. Etched-board layout for main-circuit board (input and program).



DIFFERENTIAL AMPLIFIER
SERIES SCHMITT CKT
SERIES GATE
RESET GENERATOR
MAIN FLIP-
TO S102,111R
WH-GY
TO A.T. 112
A.T. 201
WH-YE
TO A.T. 509
A.T. 202
WH-GN-BR
+12.5V
+11.7V
R206 2.4K
R203 4.3K
R202 4.3K
R204 4.3K
A.T. 207
WH-GN-BL
A.T. 208
WH-RD-BK
SLOPE
S101
A.T. 209
WH-RD-BR
A.T. 211
WH-RD-GN
A.T. 210
WH-RD-BL
R207 1K
CCW
TRIGGER LEVEL
WH-GY-BK
A.T. 212
TIMING INPUT
J103
BR
A.T. 203
R201 4.7K
TO J102
Q201
Q202
C201 0.1
J104
R269 4.3K
R205 6.2K
R208 2.4K
TO A.T. 506
A.T. 204
WH-BL-BK
TO A.T. 512
A.T. 206
WH-BR-BK
-12.5V
R209 4.3K
R210 820
R213 3.3K
R212 1.8K
Q203
Q204
Q205
Q206
R211 220
R214 24K
R215 560
TO A.T. 111
WH-OR-RD
A.T. 226
WH-GY-BR
TO A.T. 108
A.T. 213
SCALAR INPUT
+6.9V
Q213
Q214
SCALAR RESET
C216 220
C217 220
R243 5.1K
R244 5.1K
R242 470
TO A.T. 512
WH-BR-BK
A.T. 228
-12.5V
R216 2.4K
R266 5.1K
CR20
Q207
R218 15K
R220 2K
C207 220
R221 390
+12.5V
R228 100
S102
R229 5K
CW
WH-VT-BR
A.T. 217
2
210F
WH-VT-GN
A.T. 219
B2
Q210
EM
B1
4
8
16
32
64
128
X1
208F
X100
209F
R230 5K
R231 5K
WH-VT-BL
A.T. 218
A.T. 220
WH-VT-RD
S102
204R
WH-OR-BR
A.T. 223
R234 6.2K
CCW
R233 1M
TIMED-ms
A.T. 222
WH-OR-BK
202R
WH-VT-GY
A.T. 221
203R
CR208
L201 4700µH
C212 0.22
C211 22µF
C223 .0022
R235 2.2K
R236 2.2K
C213 220
C214 680
R237 15K
R238 15K
Q211
Q212
CR203
CR204
C215 100
WH-OR-BL
A.T. 224
108R
R239 7.5K
R240 200
R241 7.5K
-12.5V
S102
WH-OR-GN
A.T. 225
109R
CR205
Q215
A.T. 227
R245 2K
R246 10K
BL
J101
J102
SIGNAL INPUT
CR206
R247 1.2K
GATE DURATION CYCLE COUNT CLOSED
TIME DELAY CIRCUIT

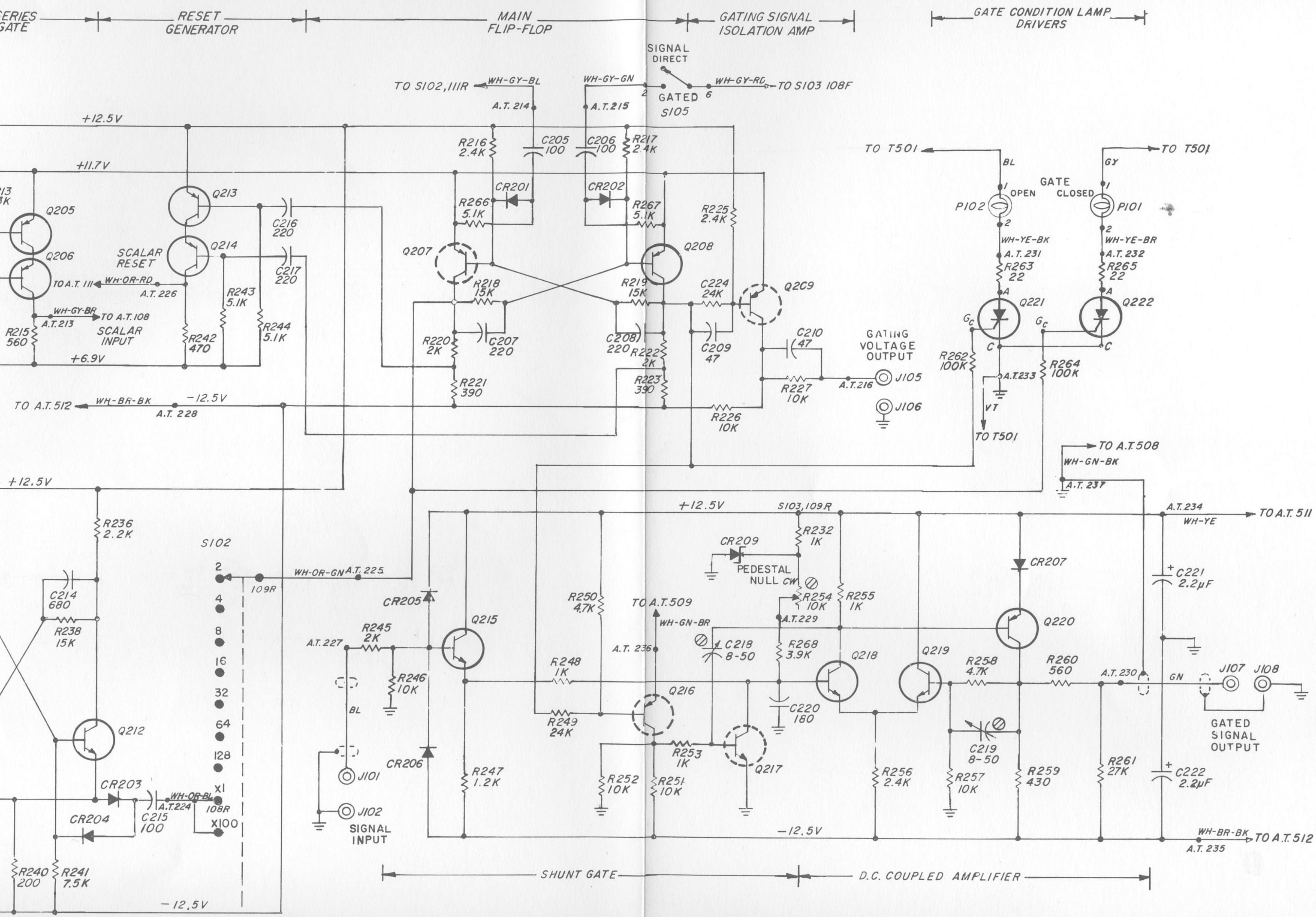


Figure 5-8. Schematic diagram for main circuits (input and program).

APPENDIX
Accessory Equipment

The Type 1210-C Unit R-C Oscillator and the Type 1217-B Unit Pulse Generator are convenient signal sources for tone-burst measurements. These instruments require external power supplies: the Type 1203-B and Type 1201-B, respectively, are recommended.

The Type 1308-A Audio Oscillator and Power Amplifier can be used in tone-burst systems as a signal source or as an amplifier, as described in Section 3.

Type 1210-C UNIT R-C OSCILLATOR

FREQUENCY

Range: 20-500,000 cps in five ranges: 20-200, 200-2000, 2000-20,000, 20,000-200,000, and 50,000-500,000 cps.

Controls: Range selection switch and TYPE 907 Precision Dial. Dial has two scales and covers each decade in about 4½ turns.

Accuracy: ±3%.

Stability: Warmup drift is less than 1%, complete in 1 to 2 hours.

OUTPUT

Control: Logarithmic, calibrated 0-50 db.

Low-Impedance: (for loads of 500 ohms and higher) 0-7 volts, open circuit, constant within ±1 db up to 200 kc; internal output impedance 50 ohms at full output, 1250 ohms at half output; no-load distortion less than 1% from 200 cps to 10 kc, less than 1.5% over entire frequency range. Attenuator calibration is reliable for loads of 12,000 ohms and above. Hum at least 60 db below output level.

High-Impedance: (for loads of 10,000 ohms and higher) 0-45 volts, open circuit, constant within ±1 db from 200 cps to 150 kc; distortion less than 5% from 200 cps to 200 kc, no load (reduced under load). Internal output impedance 14,000 ohms regardless of attenuator setting. Hum at least 50 db below maximum output level.

Square-Wave: 0-30 volts, peak-to-peak, open circuit; rise time approximately ⅓ μsec (decreases to about 0.15 μsec with load of 1000 ohms); overshoot approximately 1%; hum at least 60 db below output voltage level; internal output impedance 2500 ohms.

Terminals: Two TYPE 938 Binding Posts, one grounded to panel.

GENERAL

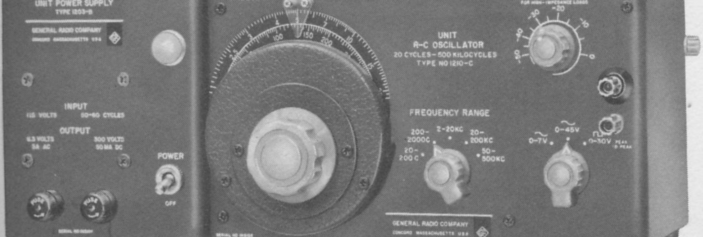
Power Supply Recommended: TYPE 1203-B Unit Power Supply for operation from 115 volts, 50 to 400 cps.

Accessories Available: For higher output (3 watts) use TYPE 1206-B Unit Amplifier: for graphic recording, TYPE 907-R144 Dial Drive.

Cabinet: Unit Instrument.

Dimensions: Width 10¾, height 5¾, depth 7 inches (275 by 150 by 180 mm), over-all. As shown here, including power supply, 15 by 5¾ by 7 inches (385 by 150 by 180 mm), over-all. Relay-rack adaptor set listed below mounts both instrument and power supply (panel 19 by 7 inches).

Net Weight: 5½ pounds (2.5 kg). **Shipping Weight:** 12 pounds (5.5 kg).



Type 1210-C Unit R-C Oscillator with Type 1203-B Unit Power Supply.

Type 1217-C UNIT PULSE GENERATOR

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 c/s to 1.2 Mc/s, with calibrated points in a 1-3 sequence from 10 c/s to 300 kc/s, and 1.2 Mc/s, all ±5%. Continuous coverage with an uncalibrated control.

Externally Controlled: Aperiodic, dc to 2.4 Mc/s with 1 V, rms, input (0.5 V at 1 Mc/s and lower); input impedance at 0.5 V, rms, approximately 100 kΩ shunted by 50 pF. Output pulse is started by negative-going input transition.

OUTPUT-PULSE CHARACTERISTICS

Duration: 100 ns to 1 s in 7 decade ranges, ±5% of reading or ±2% of full scale or ±35 ns, whichever is greater.

Rise and Fall Times: Less than 10 ns into 50 or 100 Ω; typically 60 ns + 2 ns/pF external load capacitance into 1 kΩ (40 V).

Voltage: Positive and negative 40-mA current pulses available simultaneously. Dc coupled, dc component negative with respect to ground. 40 V, peak, into 1-kΩ internal load impedance for both negative and positive pulses. Output control marked in approximate output impedance.

Overshoot: Overshoot and noise in pulse, less than 10% of amplitude with correct termination. **Ramp-off:** Less than 1%.

Synchronizing Pulses:

Pre-pulse: Positive and negative 8-V pulses of 150-ns duration. If positive sync terminal is shorted, negative pulse can be increased to 50 V. Sync-pulse source impedance:

positive — approx 300 Ω; negative — approx 1 kΩ.

Delayed Sync Pulse: Consists of a negative-going transition of approximately 5 V and 100-ns duration coincident with the late edge of the main pulse. Duration control reads time between prepulse and delayed sync pulse. This negative transition is immediately followed by a positive transition of approximately 5 V and 150 ns to reset the input circuits of a following pulse generator.

Stability: Prf and pulse-duration jitter are dependent on power-supply ripple and regulation. With Type 1201 Power Supply external-drive terminals short-circuited, prf jitter and pulse-duration jitter are each 0.01%. With Type 1203 Power Supply, they are 0.05% and 0.03%, respectively. (Jitter figures may vary somewhat with range switch settings, magnetic fields, etc.)

GENERAL

Power Required: Type 1203 or Type 1201 Unit Power Supply is recommended.

Accessories Available: Type 1217-P2 Single-Pulse Trigger, rack-adaptor panel for both generator and power supply (19 by 7 in).

MECHANICAL DATA Unit-Instrument Cabinet

With power supply	*Width*		*Height*		*Depth*		*Net W*		*Ship W*	
	in	*mm*	*in*	*mm*	*in*	*mm*	*lb*	*kg*	*lb*	*kg*
	15	385	5¾	150	6½	165	9½	4.4	12	5.5

See also *General Radio Experimenter*, December 1964.

Unit pulse generator with power supply.

Single-pulse trigger

Type 1201-B UNIT REGULATED POWER SUPPLY

Input: 105 to 125 volts (210 to 250 volts for Type 1201-BQ18), 50 to 60 cps, 90 watts full load at 115 volts. Can also be operated from 110- to 125-volt, 400-cycle supply for applications where a 400-cycle, 6.3-volt output can be tolerated.

Output: 300 volts dc regulated to ±0.25%, 70 milliamperes maximum; 6.3 volts ac unregulated at 4 amperes maximum.

Ripple: Less than 1 millivolt, rms, (120 cps) at full load.

Connectors: Three-wire line cord permanently attached. Standard four-terminal receptacle mounted on cabinet side for convenient connection to Unit Instruments.

Accessories Supplied: Mating plug for equipment other than Unit Instruments.

Cabinet: Unit Instrument.

Dimensions: Width 5, height 5¾, depth 6¼ inches (130 by 150 by 160 mm), over-all, not including power cord.

Net Weight: 6 pounds (2.8 kg).

Shipping Weight: 11 pounds (5 kg).

Type 1203-B UNIT POWER SUPPLY

Input: 105 to 125 volts (210 to 250 volts for Type 1203-BQ18), 50 to 60 cps, 50 watts full load at 115 volts. Can also be operated from 110- to 125-volt, 400-cycle supply for applications where a 400-cycle, 6.3-volt output can be tolerated.

Output: At 115-volt input — 300 volts dc (±5%) at 50 milliamperes; 6.3 volts ac at 3 amperes. (With ac load at 1.5 amperes or less, maximum dc load is 65 milliamperes, about 285 volts dc.)

Regulation: At no load, dc output is 380 volts.

Ripple: Less than 80 millivolts, rms, (120 cps) at full load.

Connectors: Three-wire line cord permanently attached. Standard four-terminal receptacle on cabinet side for convenient connection to Unit Instruments.

Accessories Supplied: Mating plug for equipment other than Unit Instruments.

Cabinet: Unit Instrument.

Dimensions: Width 5, height 5¾, depth 6¼ inches (130 by 150 by 160 mm), over-all, not including power cord.

Net Weight: 5 pounds (2.3 kg).

Shipping Weight: 10 pounds (4.6 kg).

Type 1201-B

Type 1203-B

Type 1308-A AUDIO OSCILLATOR AND POWER AMPLIFIER

OUTPUT

Power: 200 voltamperes, 50 cps to 1 kc. See curves below.

Voltage and Current Ranges: 0 to 4, 12.5, 40, 125, 400 volts, rms.
0 to 5, 1.6, 0.5 amperes, rms.

Optimum Load Impedance: 8, 80, 800 ohms. Will operate satisfactorily with higher-impedance or nonlinear loads. Output transformer will pass dc equal to rated ac.

Regulation and Response Time: (See curves.) Less than 20% no load to full load — 20 cps to 1 kc. (Bandwidth greater than 10 kc provides essentially instantaneous regulation.)

Frequency: Internal oscillator covers 20–20,000 cps continuously.

Harmonic Distortion at Rated Output: (See curves.) 1% 100 cps – 10 kc
2% 50–100 cps

Hum: More than 50 db below maximum output.

GENERAL

Overload Protection: Electronic overload circuit trips at approximately 1½ full-scale current (manual reset); thermal protection on transistor heat sink (automatic reset).

Load Power Factor:
Any at full ratings — continuous operation to 30 C ambient.
Any at full ratings — intermittent operation to 50 C ambient.
0.7 to 1.0 at full ratings — continuous operation to 50 C ambient.

Meters: 0 to 5, 15, 50, 150, 500 volts.
0 to 0.05, 0.16, 0.5, 1.6, 5 amperes.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 70 to 500 watts, depending on load. For 50-cycle supply, maximum output must be reduced 20%

Amplifier:
Input Impedance — 10 kilohms.
Sensitivity — Approximately 2 volts needed for full output.

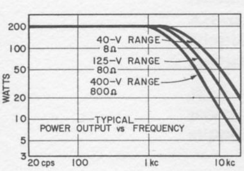
Terminals: Binding posts and 4-terminal connector at rear.

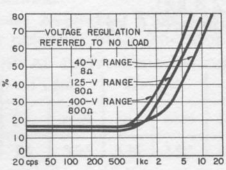
Cabinet: Rack-bench.

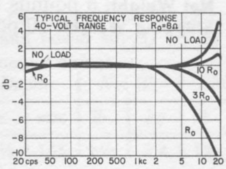
Dimensions: Bench model — width 19, height 7, depth 16¼ (485 by 180 by 414 mm), over-all; rack model — panel 19 by 7 inches (485 by 180 mm), depth behind panel 15 inches (385 mm).

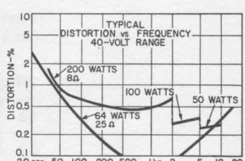
Net Weight: 91 pounds (42 kg).

Shipping Weight: 105 pounds (48 kg).









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