PRELIMINARY
OPERATING AND SERVICING MANUAL

MODEL 215A

PULSE GENERATOR

Serials Prefixed: 249-

01508-2

Printed: Dec. 1962

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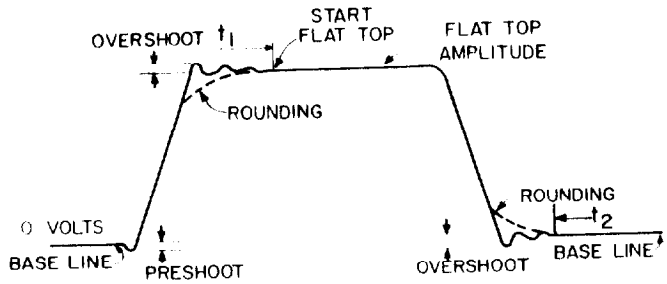
Table 1-1. Specifications

OUTPUT PULSE:

Output Source Impedance	50 Ω; 3% maximum reflection when driven by 1 nsec rise time pulse from external 50 ohm system



*Rise Time	less than 1.0 nsec, 10-90%
*Fall Time	less than 1.0 nsec, 10-90%
*Peak Voltage	greater than 10 volts into 50 ohms; greater than 20 volts open circuit
*Polarity	(+) or (-)
*Leading edge only:	
Perturbations on flat top	less than 2% of pulse amplitude
Time to achieve flat top (t_1)	less than 6 nsec
*Overshoot and ringing	less than 5% peak, less than 10% peak-to-peak of pulse amplitude
*Corner rounding	Occurs no sooner than 95% of pulse amplitude
*Trailing edge only:	
Overshoot	less than 5%
Rounding	less than 5%
Time to settle within 2% of baseline (t_2)	Varies with width setting, 10 to 25 ns from 10% of falling edge.
*Baseline shift	less than 0.1% under all conditions
*Preshoot	less than 1%
Attenuator	0-12 db in 1 db steps, absolute accuracy within ±0.1 db
*Pulse length between 50% points	Continuously adjustable, 0 to 100 nsec. Dial accuracy within ±5% ±3 nsec. Width jitter < 50 ps.
External DC bias	Up to 100 ma (5v) may be safely applied to the output. At 0 db Attenuator Setting, up to 10 ma (0.5v) may be applied without significant change in pulse shape (5% droop), increasing to 40 ma at 12 db setting. In many cases when dc bias is applied, adjusting front panel pulse shape controls will restore original pulse shape.

REPETITION RATE, TRIGGER AND TIMING

Repetition Rate Sources:

Internal Repetition Rate	less than 100 pps to greater than 10^6 pps internal, in 4 ranges. Period jitter less than 3×10^{-3} of period.
Manual	Push button single pulse
External Triggering:	AC coupled external trigger input accepts sine waves 10 cps to 1 Mc, pulses 0 to 1 Mc; triggers on either positive or negative slope.
Trigger level	External trigger level continuously variable, from approximately +8 to -8 volts.
Sensitivity	Requires minimum of 1.0 volt peak-to-peak. External pulses must be at least 30 nsec wide. Maximum input 50v, 1/2 watt average power.
Input Impedance	Input impedance ≈ 50 ohms or High Z available by front panel switch. High Z is approximately 100K ohms for (-) slope setting, or approximately 5.0K ohms for (+) slope setting.
Countdown	The 215A will also count down and synchronize with any frequency up to 100 Mc of 2v rms amplitude. Pulse rep frequency always less than 1.3 Mc. Jitter less than 10% of period of external trigger signal.
External Trigger Delay	Delay time between 2 nsec rise time, 2 volt step applied to ext. trigger input, and leading edge of output pulse is fixed at ≈ 300 nsec. Jitter less than 50 psec.
External gating	In the "gated" mode, a +1 volt gate pulse will allow pulses to reach the outputs. Maximum input voltage 50v peak, 20v rms.
Trigger output pulse	
Width	50 nsec ±20% into 50 Ω
Amplitude	Greater than 1 volt peak into 50 ohms
Rise time	less than 5 nsec
Polarity	(+) or (-)
Trigger advance	Timing of trig. out pulse is continuously adjustable from 10 nsec delay to 140 nsec advance with respect to leading edge of output pulse. Dial accuracy within ±10% ±5% nsec. Jitter less than 50 picoseconds.

GENERAL

Power consumption	115 or 230 V ±10%, 50 to 60 cps, 60 watts.
Dimensions	5-1/4" high, 16-3/4" wide, 18-3/8" deep. Hardware furnished for conversion to rack mount.
Accessories	Furnished: hp 10120A, 50 ± 0.5 , BNC Coaxial Cable, 3 ft. Available: hp 10240A Coaxial Blocking Capacitor,

*These specifications are measured with hp Model 185A/B Oscilloscope, 187B Plug-In, 187B-76 Tee Connector with hp 908A 50 ohm Termination, and Weinschel 30 db pad type 50-30, and apply for all rep rates, all amplitudes, and both polarities.

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. SCOPE OF MANUAL.

1-3. This manual provides preliminary operating and maintenance information for the ℌ Model 215A Pulse Generator. The specifications for this instrument are given in table 1-1. A more complete manual will be available at a later date. To obtain this manual, fill out and return the attached card.

1-4. DIFFERENCES BETWEEN INSTRUMENTS.

1-5. The Hewlett-Packard Company uses a two-section, eight-digit serial number to identify instruments (e.g. 000-00000). The serial number is located on a plate attached to the rear panel of the instrument. The first three digits are a serial prefix number, also appearing on the title page of this manual, and the last five digits refer to a specific instrument. If the first three digits of the instrument serial number are not the same as those on the title page, change sheets included with the manual will define differences between other instruments and the Model 215A described herein. If the change sheets are missing, your ℌ Engineering Representative can supply the information.

1-6. INSTRUMENT DESCRIPTION AND USES.

1-7. MODEL 215A DESCRIPTION.

1-8. The Model 215A is a versatile pulse generator which provides an output pulse with a 1 nanosecond (1 ns = 10^{-9} second) rise and fall time. The maximum amplitude of the pulse output is 10 volts peak into a 50 ohm load or 20 volts peak into an open circuit. The Model 215A 50 ohm output impedance minimizes reflection problems. The amplitude of the pulse may be varied with a calibrated 1 to 12 db attenuator. The pulse width is also variable, from 2 to 100 ns. The trigger pulse may be varied, from 10 ns after, to 140 ns before, the output pulse. Output pulses from the Model 215A may be either positive or negative as controlled by a front panel switch. Trigger output pulses may be either positive or negative (also a front panel switch) with a rise time of 5 ns and an amplitude of at least 1 volt into a 50 ohm load. An external trigger may be used to initiate pulses from the Model 215A or an internal repetition rate generator will provide pulses of a frequency from 100 cps to 1 Mc. A manual control provides a single pulse out each time a button is pushed. A count-down feature allows the Model 215A to be synchronized with any trigger input signal up to 100 Mc. In gated operation, output pulses may be

obtained from the Model 215A only when an external gate input signal reaches a positive 1 volt level. The Model 215A power supply may be operated from either 115 vac or 230 vac (±10%) with line frequency at 50 to 60 cps.

1-9. MODEL 215A USES.

1-10. Fast pulse rise and fall time requirements are met by the Model 215A for use in research and design as well as for production line testing. The 1 ns rise and fall time of the pulse (with low pulse jitter) is useful for measuring transfer functions, such as switching and recovery time for semiconductor diodes, transistors, logic circuits and thin-film computer memory elements or to find the step response of a circuit. Storage time for semiconductor diodes and transistors may be checked. Also, because of the positive or negative pulse output (with identical characteristics), either npn or pnp type transistors may be checked with equal convenience. The shape of the generated pulse is not affected by the load placed on the output and the output impedance appears as 50 ohms (see paragraph 4-29). The Model 215A may be used in determining transmission line characteristics. The electrical distance to a discontinuity in a line is measured by transmitting the pulse from the Model 215A and observing on an oscilloscope the time delay before a reflection appears from the discontinuity. Another application for the Model 215A is for checking small inductance or capacitance such as the inductance of a diode package, the series inductance of a capacitor or the shunting capacitance of an inductor.

SECTION II

PREPARATION FOR USE

2-1. INITIAL INSPECTION.

2-2. Upon receipt of the Model 215A, verify that the contents are intact and as ordered. Inspect the instrument for any physical damage such as a scratched panel surface, broken knob or connector, etc., incurred in shipping. To facilitate possible reshipment, keep the original packing material (if foam) until a satisfactory operational check is completed. If damage is found, file a claim with the freight carrier and refer to the warranty page in this manual.

2-3. AC POWER CONSIDERATIONS.

2-4. POWER SOURCE REQUIREMENTS.

2-5. The Model 215A may be operated from an ac source of 115 or 230 volts (±10%) at 50 to 60 cps. With the instrument disconnected from the ac power source, move the slide switch (located on the rear panel) until the desired voltage numbers are visible. A narrow-blade screwdriver may be used to operate the switch. The fuse, F1, should be 1 amp for 115v operation and 1/2 amp for 230v.

2-6. THREE-CONDUCTOR POWER CABLE.

2-7. For the protection of operating personnel, National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. The Model 215A is equipped with a detachable three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The round pin on the power cable connector is the ground connection. To retain the protection feature when operating the instrument from a two-contact outlet, use a three-conductor to two-conductor adapter and connect the adapter wire to a suitable ground.

2-8. TEMPERATURE LIMITS.

2-9. The Model 215A is designed to operate within its specifications over a temperature range of 0°C to 55°C. An exhaust fan on the rear panel provides the cooling needed to dissipate any heat generated within the instrument. The instrument should not be installed in a space which obstructs the fan air flow. Since the Model 215A circuitry is primarily solid state devices (transistors, diodes), internal heat generated is low but an external source of heat near the instrument could affect operation.

2-10. RACK/BENCH INSTRUCTIONS.

2-11. The Model 215A is shipped with the plastic feet and tilt stand in place, ready for use as a bench-type instrument (unless ordered specifically as a rack-type model) The hp modular instrument enclosure system allows easy conversion from bench to rack model and vice versa. A kit is shipped with the instrument allowing rack or bench conversion. Instructions are included with the kit. The rack version of the Model 215A is an EIA standard width of 19 inches.

2-12. REPACKAGING FOR SHIPMENT.

2-13. If an instrument is being packaged for shipment, use the original packing material (only if foam type) if available or contact your authorized hp Engineering Representative for assistance. Original packing materials which are a cardboard "accordion-like" filler are not recommended for shipment since the useful cushioning qualities are usually gone after one use. If a foam type packing material is not available, first protect the instrument surfaces with heavy paper or with sheets of cardboard flat against the instrument. Then protect the instrument on all sides (use approximately 4 inches of new packing material designed specifically for package cushioning), pack in a durable carton, mark carton clearly for proper handling, and insure adequately before shipping.

2-14. If an instrument is being returned to hp for service or repair, attach a tag to the instrument specifying owner, desired action, model number, and serial number. Ship the instrument to the hp Customer Service department at the address on the warranty page. All correspondence should refer to an instrument by model number and the full (eight-digit) serial number.

SECTION III

OPERATING PROCEDURES

3-1. GENERAL.

3-2. Figure 3-1 indicates the location of, and briefly explains the function of, the Model 215A front panel controls, adjustments, switches, and connectors. For a circuit description of how the output pulse is formed and controlled, see Section IV. In addition to operating procedures, more detailed information is included about use of the count-down (synchronizing to input) mode in paragraph 3-8, and on bias voltages at the pulse output connector in paragraph 3-11.

3-3. SELECTING TRIGGER SOURCE.

3-4. EXTERNAL TRIGGER.

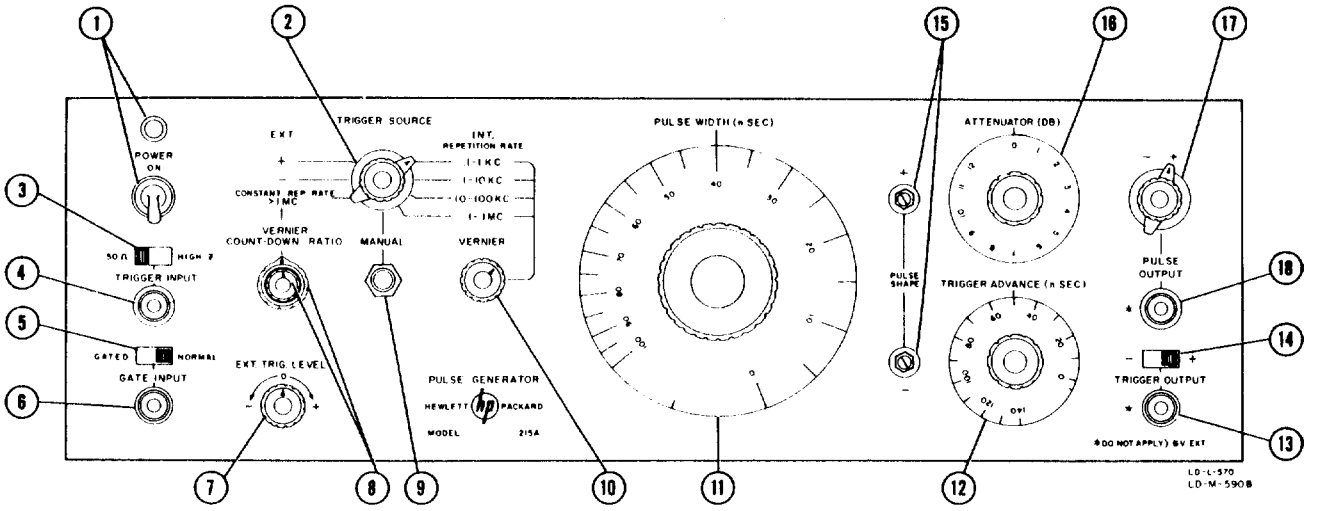
3-5. External trigger signals may be used to initiate the pulses of the Model 215A. Trigger signals which will cause one pulse out for each trigger in, may be either of two types: (1) sine waves from 10 cps to 1 Mc or (2) pulses from 0 pps to 1 Mc. An external trigger must be at least 1.0 volt peak-to-peak and triggering pulses must be at least 30 nsec wide. The Model 215A will also sync and count-down for a trigger input up to 100 Mc if the amplitude is at least 2 volts rms. In count-down operation, the Model 215A output frequency will always be less than 1.3 Mc (see paragraph 3-8). The trigger input impedance may be set to 50 Ω for low trigger source impedance or to HIGH Z if source impedance is high. Note that the instrument input impedance on HIGH Z depends on whether triggering is set to occur on a + or - slope: 100K Ω on -, 50K Ω on +. To trigger the Model 215A externally, follow this procedure:

a. Turn Model 215A POWER switch to ON. Allow about one minute for warmup.

b. Set TRIGGER SOURCE to EXT. (external) position. If set to +, a pulse is generated on a positive trigger slope, and vice versa for a - setting. (Refer to paragraph 3-8 which explains use of the Model 215A for synchronizing to an external trigger frequency above 1 Mc).

c. Adjust the EXT. TRIG. LEVEL control to set the desired voltage level for triggering the Model 215A. Select input impedance and connect trigger signal to TRIGGER INPUT.

d. The Model 215A output may be gated by an external signal. Move the front panel slide switch to GATED and apply the gating signal to the GATE INPUT connector. Outputs then occur only when the gate signal is at a +1 volt level or greater (maximum of 50 v peak, 20 v rms). If gating is not used, set switch to NORMAL.



1. POWER switch and indicator (lights when switch is in ON position).
2. TRIGGER SOURCE switch selects an external or internal source for triggering the Model 215A to generate a pulse.
3. TRIGGER INPUT switch selects input impedance (50 Ω or HIGH Z) to obtain best match to impedance of external trigger source.
4. TRIGGER INPUT connector accepts BNC-type connector.
5. GATE INPUT switch set to GATED if Model 215A output is desired only at a time interval controlled by a gating voltage input.
6. GATE INPUT connector accepts BNC-type connector.
7. EXT. TRIG. LEVEL selects point on input waveform at which triggering occurs. For positive slope triggering TRIGGER SOURCE must be set to EXT +; for negative slope set to EXT -.
8. COUNT-DOWN RATIO synchronizes Model 215A to a sub-multiple of an input above frequency of 1MC. Used only for CONSTANT REP. RATE >1MC setting of TRIGGER SOURCE.
9. MANUAL provides a single pulse out when button is pushed (TRIGGER SOURCE set to MANUAL).
10. VERNIER (for INT. REPETITION RATE) controls frequency of internal repetition rate generator within limits of TRIGGER SOURCE setting.
11. PULSE WIDTH (nSEC) sets the length of the output pulse in nanoseconds.
12. TRIGGER ADVANCE (nSEC) sets the time interval in nanoseconds between the trigger output and the pulse output.
13. TRIGGER OUTPUT connector accepts BNC-type connector. Observe caution against applying > 5V externally.
14. TRIGGER OUTPUT switch allows selection of a positive (+) or negative (-) signal for synchronizing with a test instrument such as an oscilloscope.
15. PULSE SHAPE screwdriver adjustment to obtain best + and - output pulse shape.
16. ATTENUATOR (DB) controls the pulse output amplitude over a 12 db range.
17. PULSE OUTPUT switch sets polarity of pulse.
18. PULSE OUTPUT connector accepts BNC-type connector. Observe caution against applying > 5V externally.

Figure 3-1. Front Panel Description

e. Adjust the PULSE WIDTH control to desired setting.

f. If the TRIGGER OUTPUT connection is used (e.g. to synchronize an oscilloscope), set the TRIGGER ADVANCE control to the number of nanoseconds desired for the trigger to precede (or follow, up to 10 ns) the output pulse. Move TRIGGER OUTPUT slide switch to + or - setting.

CAUTION

Do not connect the TRIGGER OUTPUT or the PULSE OUTPUT to a bias source which will develop more than 5 volts peak across the connector (50Ω). If this maximum voltage is exceeded, damage to circuit components may result. See paragraph 3-11 for information on the effect of dc bias on the pulse shape and suggested methods for connecting the output pulse.

g. Set the PULSE OUTPUT switch to + or - position.

h. Set the ATTENUATOR switch to the 12 db position.

i. Attach a coaxial cable, 50 ±0.5 ohms, to the PULSE OUTPUT connector. The 50 ohm impedance of the Model 215A should be extended by matched impedance cable (hp Accessory No. 10120A) to the actual load connection. It is not necessary to match the load since load reflections will be completely absorbed by the Model 215A if no discontinuity exists at the PULSE OUTPUT connector.

j. Change the ATTENUATOR setting to obtain a pulse of desired amplitude.

Note

A front panel adjustment, PULSE SHAPE, may be made if the Model 215A output pulse requires it. Section V gives the procedure for making and checking this adjustment.

3-6. INTERNAL REPETITION RATE TRIGGER.

3-7. The Model 215A may be triggered by an internal circuit which is controlled by the TRIGGER SOURCE switch in the INT. REPETITION RATE positions. Operation with the internal trigger source is similar to that with external trigger. Proceed as follows:

a. Turn Model 215A POWER switch to ON. No warmup time is required when using internal triggering.

b. Set TRIGGER SOURCE to an INT. REPETITION RATE position. Set the VERNIER to obtain the frequency wanted between the limits indicated by the TRIGGER SOURCE setting. In the MANUAL position the Model 215A will generate a pulse out each time the button is pushed.

c. The Model 215A may be gated when using INT. REPETITION RATE. Gating is explained in step d of paragraph 3-5.

d. Follow steps e through j of paragraph 3-5. The same limit applies for a maximum of 5 volts applied to either the PULSE OUTPUT or TRIGGER OUTPUT connectors (see paragraph 3-11).

3-8. COUNT-DOWN MODE.

3-9. The Model 215A is capable of synchronizing to a sub-multiple of an external trigger input frequency between 1 Mc and 100 Mc. For input frequencies between 1 and 10 Mc, merely use the EXT. + or EXT. - setting of TRIGGER SOURCE, and the EXT. TRIG. LEVEL control the same way as for lower frequencies. For input trigger signals above 10 Mc, best operation is obtained by using the CONSTANT REP. RATE > 1 MC position, and adjusting the COUNT-DOWN RATIO and EXT. TRIG. LEVEL controls together to obtain synchronization. First set the EXT. TRIG. LEVEL for a free-running condition of the Model 215A, then vary EXT. TRIG. LEVEL and COUNT-DOWN RATIO to get synchronization.

3-10. To determine proper synchronization proceed as follows:

a. Set the Model 215A for a 1 Mc internal repetition rate. Using 50 ohm coaxial cable, connect the Model 215A output trigger to an oscilloscope trigger input. Adjust the oscilloscope controls for proper triggering.

b. Connect the external trigger signal to the Model 215A TRIGGER INPUT and to the oscilloscope input.

c. Change the Model 215A TRIGGER SOURCE to an external position, and view the trigger input waveform on the oscilloscope. Adjust Model 215A COUNT-DOWN RATIO and/or EXT. TRIG. LEVEL; when proper synchronization is reached, the waveform will remain stationary and stable on the oscilloscope screen.

d. When counting down with trigger input signals near the 100 Mc limit of the Model 215A, occasionally recheck for proper synchronization. The repetition rate may drift slightly and continue to free-run at a non-synchronized frequency.

3-11. EXTERNAL DC BIAS AT OUTPUT.

3-12. GENERAL.

3-13. In some applications of the Model 215A it is desirable to have the pulse base line at a constant dc voltage rather than at ground. Examples of this application are as a holdoff bias for transistors, cutoff bias for tubes, etc. The following paragraphs cover the more common situations and provide information for reducing the effect of fixed bias.

3-14. SHUNT FEED WITH BLOCKING CAPACITOR.

3-15. Use of a blocking capacitor has the advantage of not passing dc current back through the generator, hence is especially useful when the required bias exceeds the 5 volts (100 ma into 50 ohms) maximum that can be safely impressed across the Model 215A output. Figure 3-2 illustrates a typical circuit setup. Unexpected voltage shifts, caused by incomplete recovery of the capacitor voltage between pulses, can change the pulse current into the load, especially at higher repetition rates. This will occur to some extent even with a linear load since the pulse output contains an average (dc) component which the capacitor cannot pass. When driving a nonlinear load such as a semiconductor junction, a peak rectifying action occurs that can charge the capacitor to a much different voltage than intended. Because of this, care must be taken in interpreting the results of changing to a different repetition rate or pulse width in the circuit of figure 3-2.

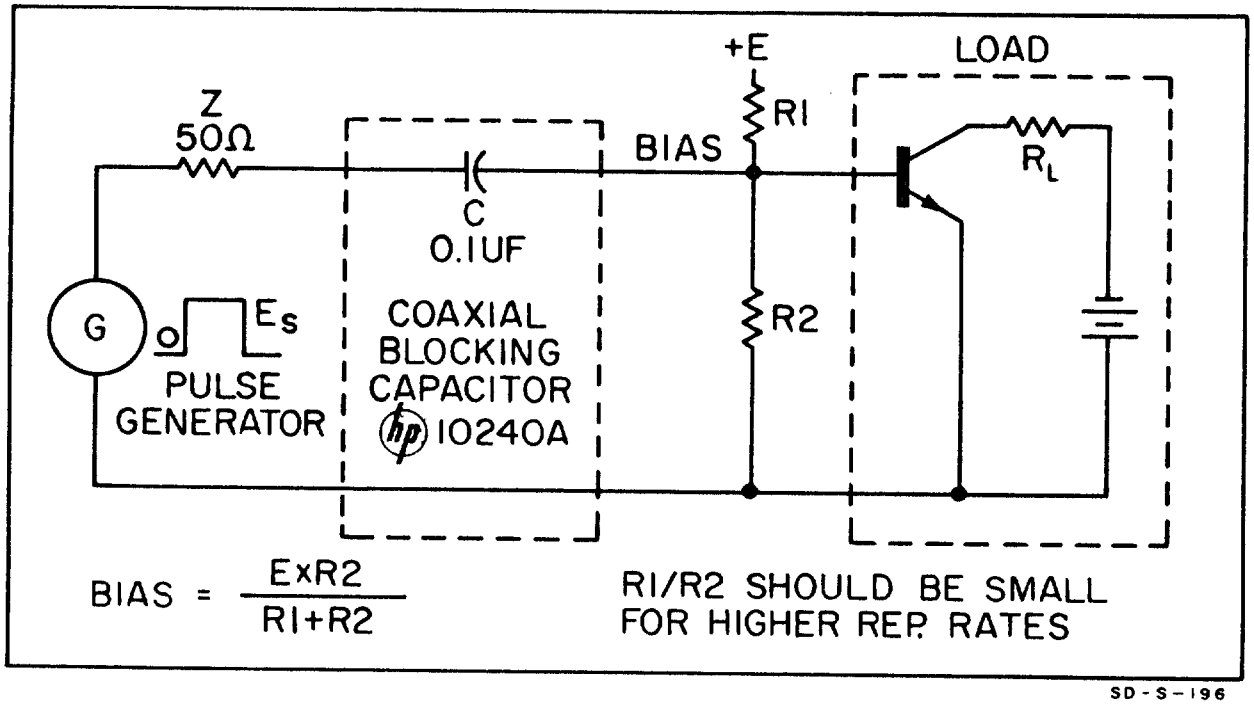


Figure 3-2. Typical Circuit Using Shunt Feed Blocking Capacitor

CAUTION

Avoid sudden application of a large dc bias (over 15 volts), even with the blocking capacitor. The resulting excessive charging current may damage the Model 215A.

3-16. DIRECT SHUNT FEED.

3-17. Use of direct shunt feed is usually best for a bias level below 1 volt, especially with low impedance, high current loads. Figure 3-3 is a typical circuit using this method and also shows the equivalent circuits including the bias. This method completely eliminates recovery problems with a change in repetition rate or pulse width. Since the equivalent circuit is known, and is not repetition rate sensitive, the pulse current into the load is easily calculated by measuring the load pulse voltage, E_L, and the pulse generator open circuit voltage, E_{oc}. The equation for pulse current is

$$I_{pulse} = \frac{E_{oc} - E_L}{50 \text{ ohms}}$$

CAUTION

With direct shunt feed, do not exceed a bias current of 100ma (5 volts across 50) into the instrument output or damage to internal components may result.

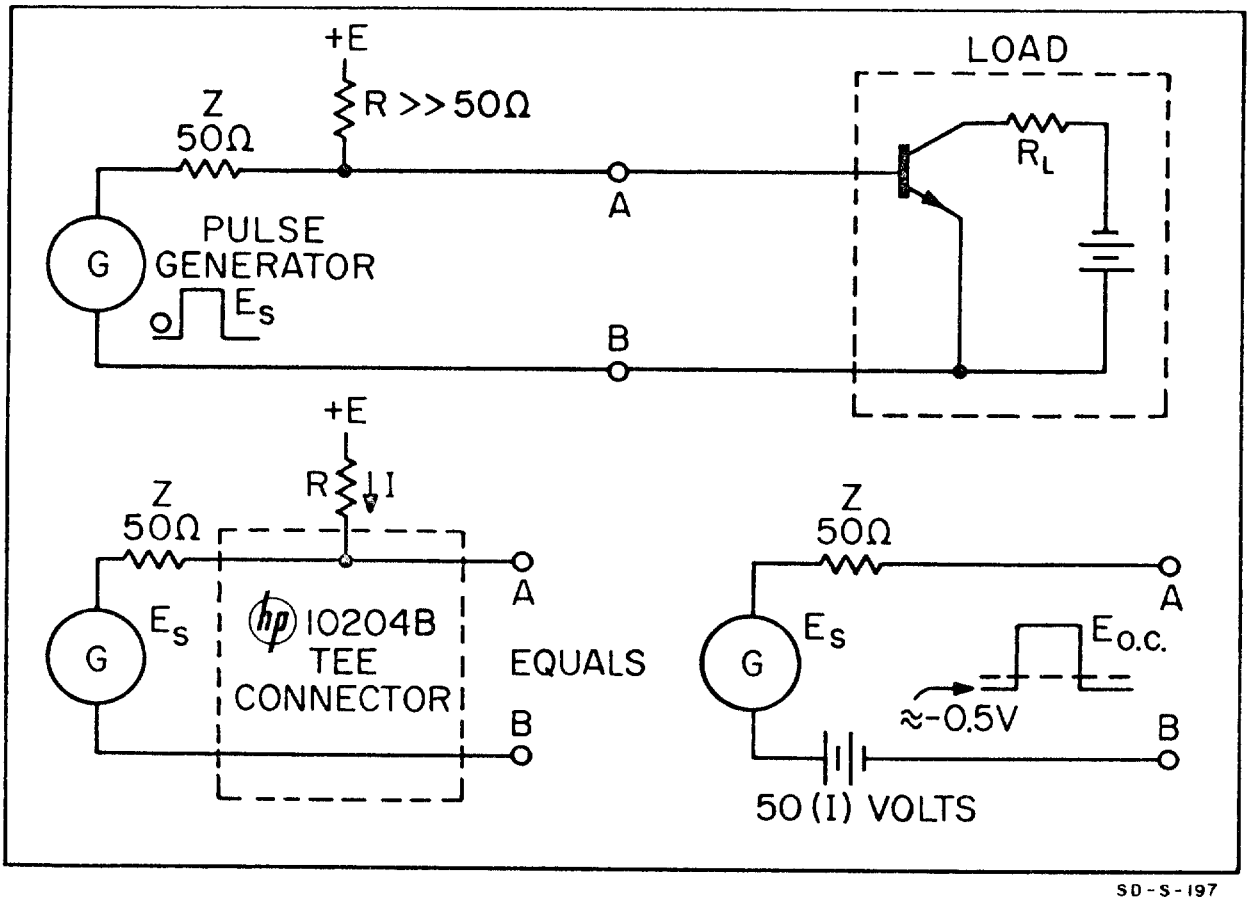


Figure 3-3. Typical Circuit Using Direct Shunt Feed

3-18. External bias current fed into the output connector will cause a change in the output pulse shape. The effect on the pulse increases with the bias and is greatest when the ATTENUATOR is set to 0 db. Figures 3-4 through 3-7 illustrate the effect on pulse shape with different bias conditions and attenuation. Generally, the pulse shape (with zero attenuation) remains within specifications up to 0.2 volts bias. For a bias up to about 1 volt, the pulse may be returned to specifications by adjusting the PULSE SHAPE controls. With a positive pulse, first adjust + PULSE SHAPE for a flat top, then adjust - PULSE SHAPE for best trailing edge. With a negative pulse, first adjust - PULSE SHAPE for a flat top, then adjust + PULSE SHAPE for best trailing edge. Increased bias will have less effect on the pulse as attenuation is increased. No damage to the Model 215A will occur for a bias below 5 volts.

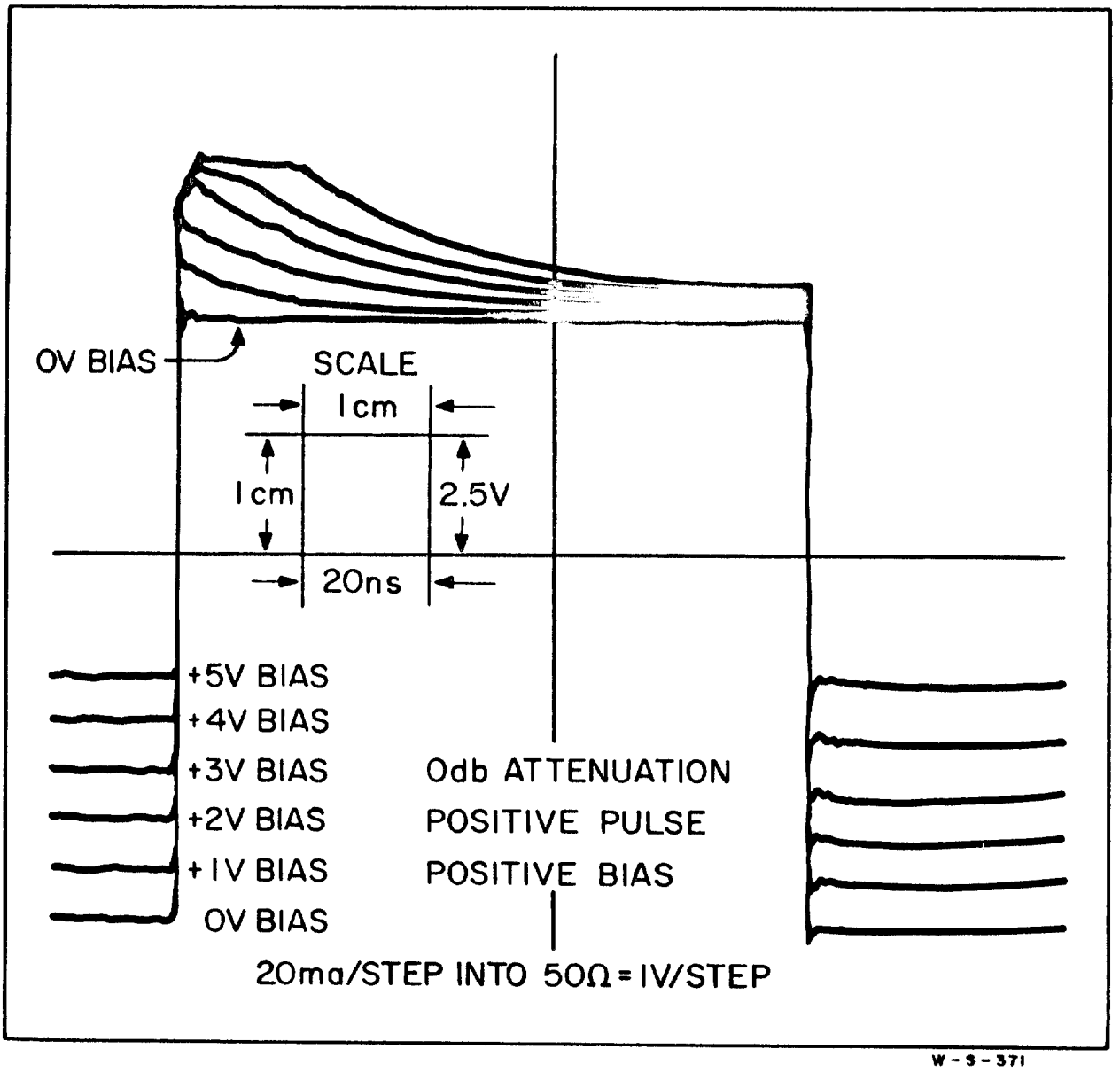


Figure 3-4. Positive Bias Effect With No Attenuation

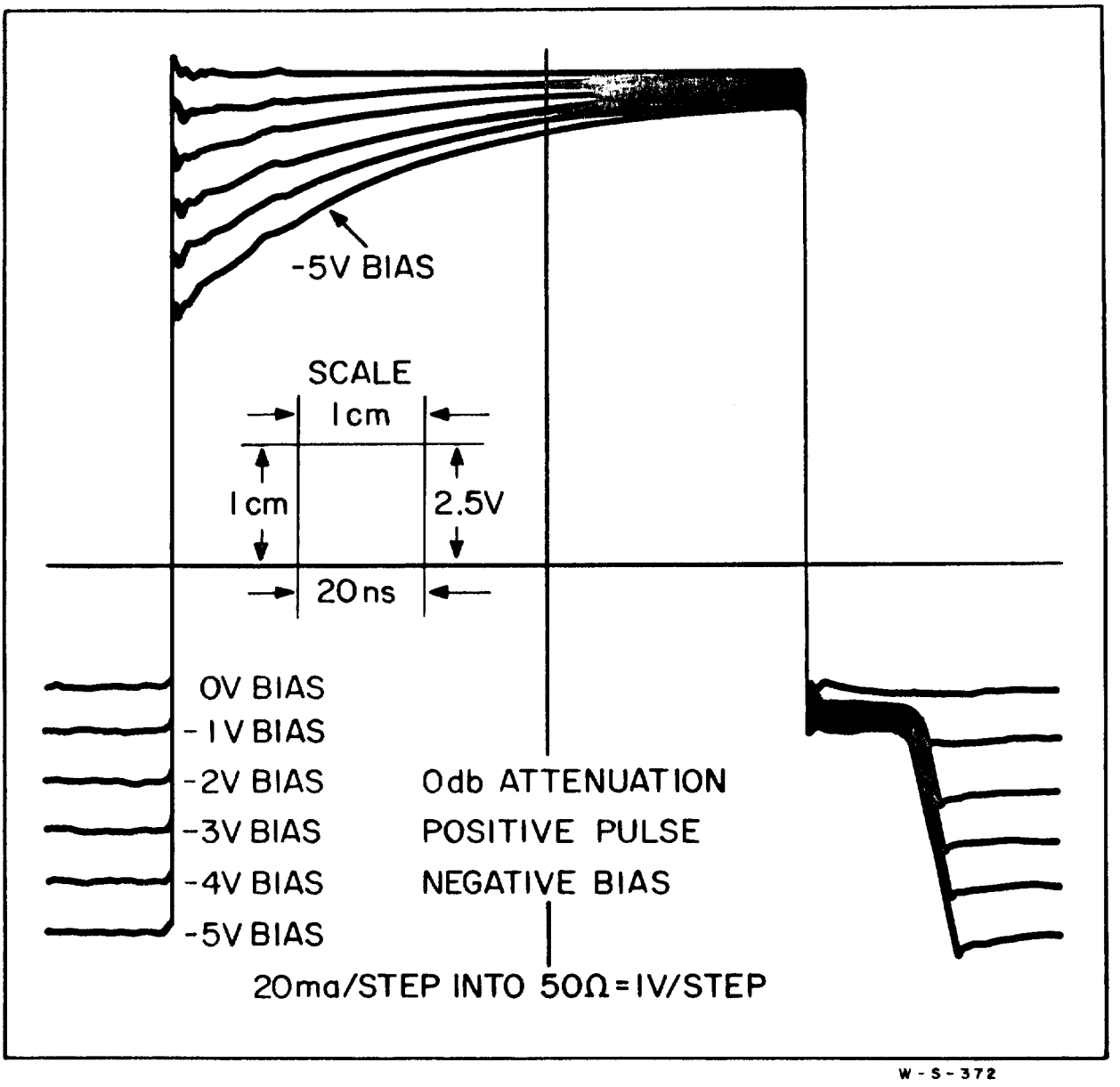


Figure 3-5. Negative Bias Effect With No Attenuation

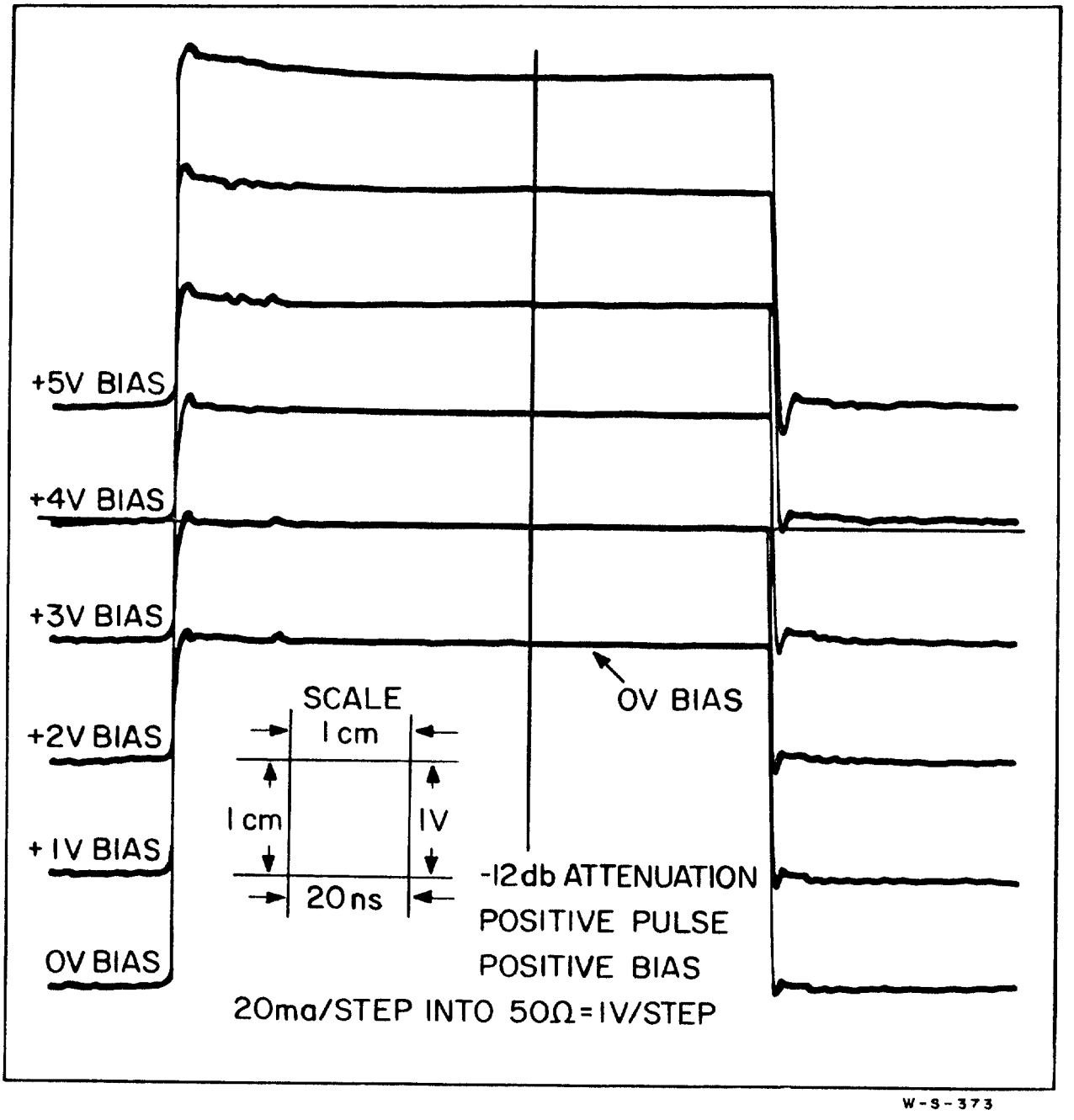


Figure 3-6. Positive Bias Effect With -12 db Attenuation

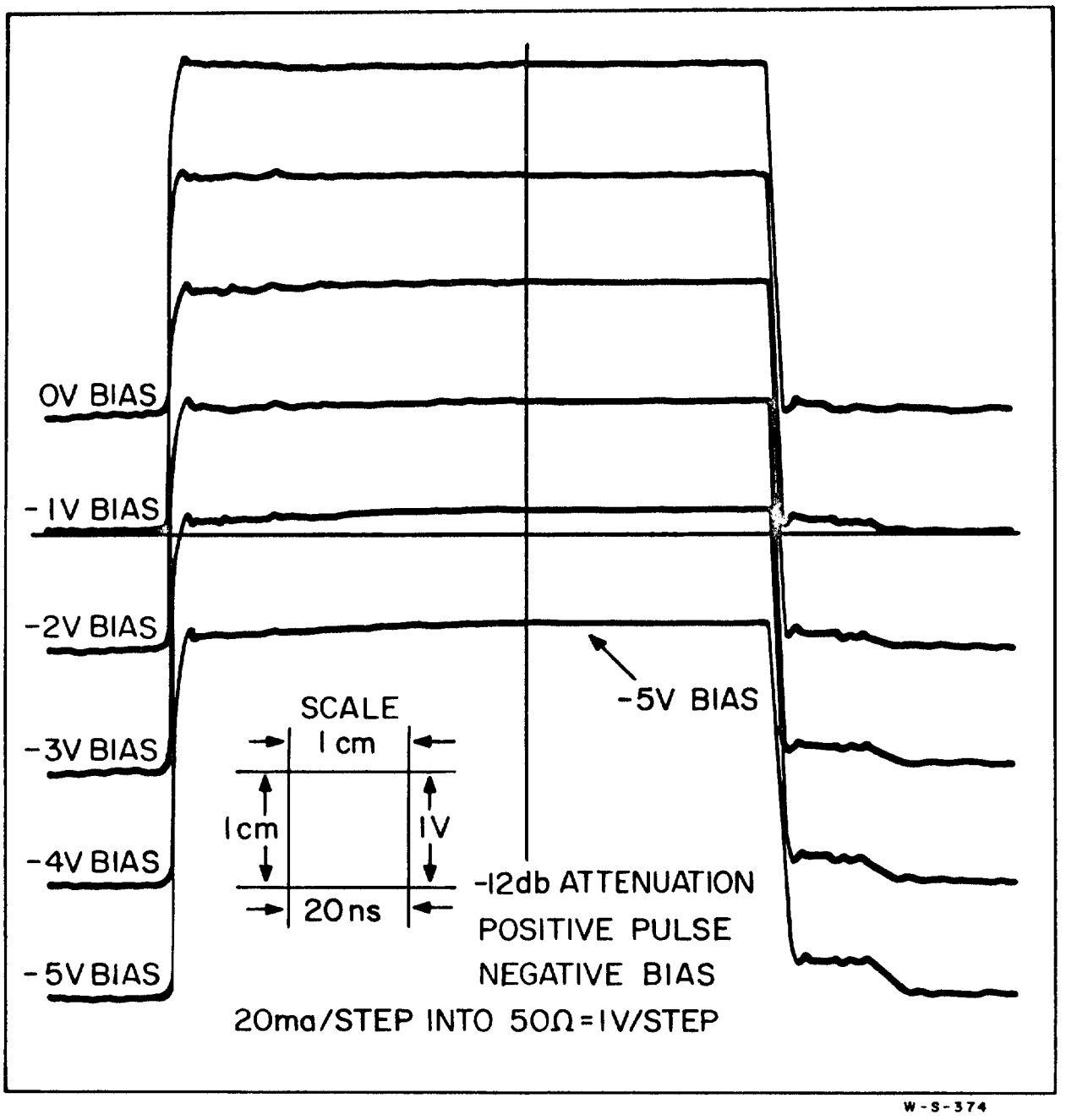


Figure 3-7. Negative Bias Effect With -12 db Attenuation

3-19. SERIES VOLTAGE BIAS.

3-20. The series voltage bias method is similar to using a blocking capacitor except that the capacitor voltage is fixed by a dc source. Figure 3-8 shows a typical application. This eliminates dc shifts which may occur when using only the blocking capacitor. This series voltage bias technique works best with high impedance loads and for higher bias voltages since it keeps the developed voltage at the generator low, and reduces the current drain on the bias supply.

CAUTION

Avoid shorting the load, as this would place a high bias directly across the Model 215A output. Observe normal precautions against shock hazard when using high voltages.

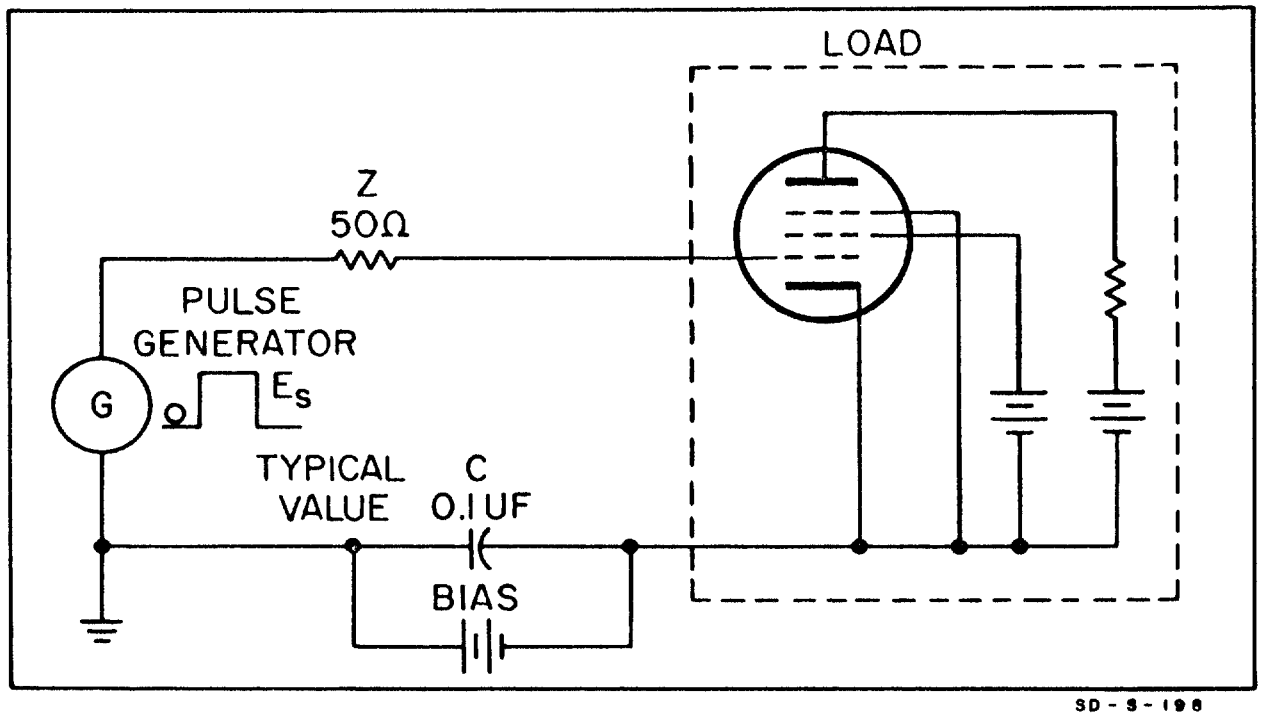


Figure 3-8. Typical Circuit Using Series Voltage Bias

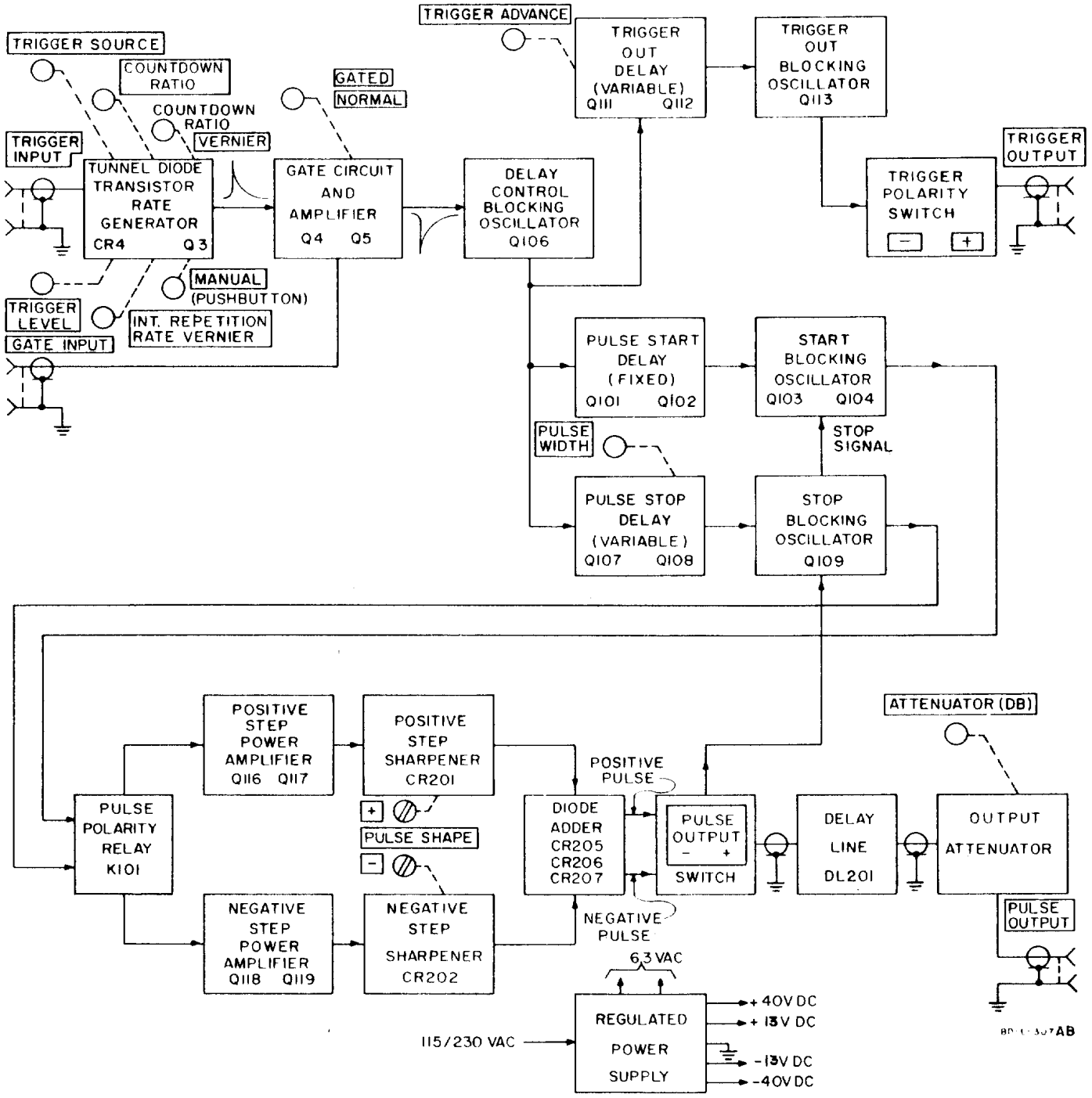


Figure 4-1. Model 215A Block Diagram

SECTION IV

PRINCIPLES OF OPERATION

4-1. GENERAL.

4-2. The Model 215A achieves fast rise and fall time pulse characteristics by the following general sequence: 1) generating a pulse from a parallel tunnel diode-transistor circuit, 2) using this pulse to trigger three delay generators which 3) drive blocking oscillators with 4) the output of two b.o.'s driving output power amplifiers (a third b.o. is the trigger output), and 5) using step recovery diodes for the output pulse formation. The following circuit description is intended to clarify some basic principles involved as well as describe the sequence of events in forming the pulse output. The circuitry for the Model 215A may be divided into three sections (corresponding to the three schematic diagrams, figures 5-5 , 5-6 , and 5-7): sync and rate circuit, logic circuit, and output circuit. Refer also to figure 4-1 for a block diagram of the Model 215A.

4-3. SYNC AND RATE.

4-4. GENERAL.

4-5. A tunnel diode, CR4, and transistor, Q3, are triggered either by an external signal through differential amplifier V1 and V2, or by a signal from an internal rate generator through Q1 and Q2. Figure 4-2 is a typical tunnel diode curve. Diode CR4 is biased at point A, and Q3 is normally off. As the current through CR4 is increased, the operating point moves to B, then jumps to point C. This increased voltage at the base of Q3 causes the transistor to conduct suddenly, and the positive voltage pulse at the collector is used to drive the rest of the Model 215A circuitry. In either external or internal operation, when the current through CR4 decreases enough, the operation changes from C to D to E, where Q3 cuts off and the circuit returns to normal. The setting of the exact bias and characteristics of the tunnel diode-transistor circuit is a critical adjustment and should not be attempted without following the maintenance procedure in Section V. A compensating diode, CR5, has the opposite voltage change with temperature as Q3 base voltage change with temperature. Resistor R43 biases CR5 into a higher conductance region and R42 to ground compensates for the dc voltage drop across CR5. The current through R42 is adjusted by R64 (Offset Voltage Adj.) and this is the critical adjustment for the correct tunnel diode-transistor characteristic.

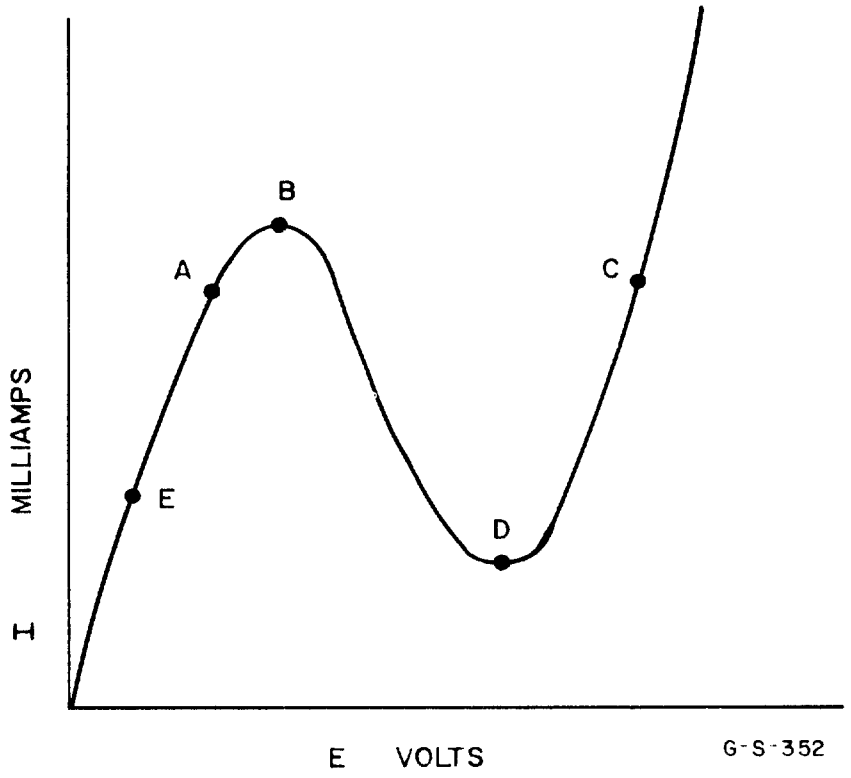


Figure 4-2. Typical Tunnel Diode Curve

4-6. EXTERNAL TRIGGERING.

4-7. For external triggering, increased current through CR4 is obtained by increasing the plate current through V2. Triggering the differential amplifier (V1 and V2) on a positive or negative input is accomplished by changing the connections of a balun-type transformer, T1, with TRIGGER SOURCE switch, S2. Capacitor C14 (EXT. MAX.RATE ADJ.) limits the maximum repetition rate (1MC) in EXT. + and EXT. - modes. EXT. TRIG. LEVEL, R9, changes the bias on V2 and sets the point on the slope at which triggering occurs (see front panel description, figure 3-1). Resistor R50 (Peak Curr. Comp. Adj.) sets the voltage at Q1 base (about 32 v). With V2 cut off, this biases the tunnel diode at about 4 ma, or 1 ma below its peak current at point B in figure 4-2. With V2 conducting, its quiescent plate current of nearly 1 ma is added and CR4's operating point moves almost to point B. An external trigger which slightly increases V2 plate current flips CR4 from point B to C. With Q3 now on, CR7 conducts causing CR8 to cutoff and, allowing CR9 to conduct. The current through CR9 also flows through CR4 along with the V2 plate

current, moving the operating point down from C toward D. This total current (CR9 plus V2) almost allows CR4 to move back to point E, but not until the input trigger reduces V2 plate current sufficiently. Resistor R63 (Ext. Trig. Sens. Adj.) sets the amount of current through CR9, consequently the sensitivity of the circuit. Counterclockwise is the most sensitive setting for R63, as this lowers the current through CR9 and less reduction in V2 plate current is then required to move from point D to E on the tunnel diode curve.

4-8. INTERNAL RATE GENERATOR.

4-9. When switch S2, TRIGGER SOURCE, is set to an INT. REPETITION RATE position, V1 and V2 are cutoff. The internal rate generator starts by charging a rate capacitor (C10, C11, C12, or C13 depending on the setting of S2) toward -40 volts through R28, R31, R35, and R37. Emitter followers Q1 and Q2 apply this voltage to R41, R44 and R45 (through S2C and S2D) and to the cathode of CR4, causing the current through the tunnel diode to increase. This increasing current then causes CR4 to change operation from point A to B to C, switching Q3 on as with external triggering. As Q3 comes on, CR7 conducts and allows the rate capacitor (C10-C13) to discharge until CR4 returns from D to E and then to operating point A. Resistor R37 (1 kc Max. Rep. Rate Adj.) sets the maximum repetition rate for all ranges except for .1-1MC. Capacitor C10 (1 Mc Max. Rep. Rate Adj.) allows setting of the maximum rate at 1 Mc. VERNIER control, R28 allows a front panel setting of the repetition rate within the limits of the TRIGGER SOURCE setting. When S2 is in the MANUAL position and the front panel button is pushed, C17 charges slowly, causing an increase in current through R41 until the tunnel diode-transistor combination pulses once. When S2 is in the CONSTANT REP. RATE > 1MC position V1 and V2 are again a part of the circuit. The internal rate generator is free-running somewhere below 1 Mc and will become synchronized at some sub-multiple of an input frequency which is above 1 Mc. The free-run frequency is set at the exact sub-multiple needed for synchronizing by R30, COUNT-DOWN RATIO, and by R29, VERNIER.

4-10. GATING CIRCUIT.

4-11. External gating of the pulse is accomplished by allowing an output from the sync and rate circuit only when the gate signal reaches a certain level. Transistor Q4 is normally saturated and Q5 is cut off by +40 v through R71, S4, and R69 to the base. Diode CR11 limits the base voltage to about +1 volt. As a pulse from Q3 hits Q4 base, Q4 is cut off and if Q5 is also off, a negative signal goes to Q106 in the logic circuit. When switch S4 is changed from NORMAL to GATED, Q5 is on until a positive signal of at least 1 volt into J2, GATE INPUT, turns Q5 off and allows a pulse to pass.

4-12. LOGIC CIRCUIT.

4-13. INPUT BLOCKING OSCILLATOR.

4-14. The signal from the gate circuit triggers a blocking oscillator, Q106, saturating the transistor on. The voltage impressed on the winding of T101 in Q106 collector circuit causes a signal feedback through the base secondary of T101 and through CR127 to hold Q106 on even after the signal from Q5 is removed. The collector current of Q106 rises linearly to a value just above what the transistor can supply. This pulls Q106 out of saturation and a regenerative action turns Q106 off again. Resistor R128 (B.O. Pulse Width Adj.) determines the extent of saturation for Q106 and hence the length of the pulse (clockwise for a longer pulse). Diode CR127 in the feedback winding is a step recovery diode which is initially back biased by the negative trigger to the base of Q106. The principle of a step recovery diode is that there is a buildup of current carriers at the junction of the two semiconductor materials. When the forward current in a semiconductor diode is suddenly reversed, these stored carriers allow reverse current flow and the diode behaves as a short circuit for a brief time. When the carriers are gone, the current ceases very abrupty. If CR127 were an ordinary diode, the feedback of a positive signal (from the regenerative action) to the base to turn Q106 off would be blocked. However, the carrier storage characteristics of CR127 allow reverse current to flow long enough to turn Q106 off.

4-15. DELAY CHANNELS.

4-16. The secondary windings of T101 drive three delay channels which are similar in operation. The channel consisting of Q101 through Q104 will be referred to as the start output channel, Q107 through Q109 as the stop output channel, and Q111 through Q113 as the trigger output channel.

4-17. START OUTPUT CHANNEL. Ramp generator, Q101, is normally on and a positive voltage on its collector is also present at the ramp capacitor, C101. The positive voltage on C101 is determined by the setting of R103 (START CHANNEL DELAY ADJ). Since Q101 is cut off during the pulse from Q106, C101 is charging through R105 toward -40v. Since the ramp slope is fixed, the positive voltage at which the ramp capacitor starts, determines the time delay before CR103 conducts and turns on Q102, the Pick Off Stage. When Q102 first turns on, CR111 (another step recovery diode) passes reverse current, allowing it to flow through L101 (thus storing energy). When this current reaches a certain point (approximately 100 ma) CR111 suddenly opens and the inductive kick from L101 tends to make the collector of Q102 very negative. Diode CR114 breaks down as Q102 collector reaches -10v and passes current to the base of Q104, turning it on. A winding of T102 in the collector circuit of Q104 couples the collector output of Q104 to the polarity relay K101 in the output stage. Because of the length of pulse width of Q104 blocking

oscillator, a feedback winding in the base circuit is necessary to sustain the oscillation. To stop the pulse from Q104, a transistor Q103 amplifies a turn off signal through T103 coming at the start of the pulse from Q109.

4-18. STOP OUTPUT CHANNEL. The operation of this channel is essentially the same as that of the start output channel. The positive voltage on C136, the ramp capacitor, is set by a front panel control, PULSE WIDTH, R140. Pulse width is effectively set since R140 controls the time between when Q107 cuts off and when the ramp capacitor voltage passes through the point at which CR136 conducts turning on Q108. Internal adjustments, R141 (Max Width Adj.) and R144 (Min. Width. Adj.) set the maximum and minimum width of the pulse, respectively. The action of the pick off stage Q108 in turning on Q109 is the same as Q102 turning on Q104. Transformer T103 couples the collector output of Q109 to K101 in the output stage and also sends the stop signal to blocking oscillator Q104. Note that Q109 has no feedback winding in its base circuit. The pulse from Q108 which drives Q109 into saturation is so large that Q109 remains saturated long enough for the required pulse. Before Q109 drops out of saturation, a stop signal in the form of a positive pulse, arrives at the base. This stop signal comes from T104 through S201B in the output circuit (see paragraph 4-27).

4-19. TRIGGER OUTPUT CHANNEL. Operation of this channel is similar to the other two channels. Ramp generator, Q111, has adjustments in the emitter circuit which set the amount of advance between the trigger output and the pulse output. TRIGGER ADVANCE, R160, is a front panel control to set the time separation within maximum and minimum limits adjusted by R161 (Max, Advance Adj.) and R164 (Min. Advance Adj.). These variable settings again determine the initial charge on the ramp capacitor, C152, hence the point where the capacitor starts on a ramp toward -40 volts. The output from the pick off stage, Q112, is taken from the emitter instead of collector as with Q102 and Q108. Another step recovery diode, CR161, conducts like a short circuit from the time Q112 turns on until approximately 50 ma of reverse current through CR161 is reached. At this point, CR161 suddenly becomes an open circuit. However, due to stored base charge in Q112, the collector current continues flowing, now through C156, to the base of Q113. The current flows long enough to trigger Q113 blocking oscillator and the trigger output is impressed across T105.

4-20. OUTPUT CIRCUIT.

4-21. GENERAL.

4-22. The explanation of the output circuitry (including the positive and negative step amplifiers and diode output circuit) will cover principles involved and the adjustments. At the input to the step amplifiers, relay K101 (actuated by setting

of switch S201B) determines which logic channel (start or stop) goes to which amplifier (positive or negative). Switch S201B is shown in the position for a positive pulse out, and the explanation here is for this condition. Operation for a negative pulse is analogous to the positive pulse mode. Similarly, the operation of the negative step amplifier is analogous to that for the positive step amplifier and only the latter will be fully explained. Since Q116 and Q117 are connected in parallel, as are Q118 and Q119, they act as one transistor and will be referred to as Q116/117, or Q118/119, as appropriate.

4-23. POSITIVE STEP AMPLIFIER.

4-24. In a steady state condition, CR201 (a step recovery diode) is forward conducting, CR206 is reverse biased, both ends of L176 are at about -13.7v, Q116/117 is cut off, and current flows to -40 volts through R185 and R186. This steady state condition is changed when Q104 turns on and the resulting pulse from T102 causes Q116/117 to turn on and saturate. This now puts the transistor side of L176 at +12 v and a current ramp starts in L176 which is a reverse current in the step recovery diode, CR201. The amount of stored charge in CR201 is adjusted by R185, +PULSE SHAPE, and this stored charge is just dissipated as the L176 current ramp passes approximately 1/2 amp. At this instant, CR201 opens and the current switches through CR206 to PULSE OUTPUT switch, S201B. The rise time of the output pulse has thus been sharpened by the fast switching action of CR201. This has now produced a pulse with a fast rise time and the fast fall time is yet to be accomplished by the negative step amplifier.

4-25. NEGATIVE STEP AMPLIFIER.

4-26. The negative step amplifier, Q118/119, is initially off and is turned on into saturation by a signal from the blocking oscillator, Q109. The time delay before Q118/119 comes on is determined by the PULSE WIDTH control in the stop output channel (see paragraph 4-18). Amplifier Q118/119 is symmetrical to Q116/117 except for a capacity balance adjustment (Cap. Bal.), C191 (shunted by C190). This adjustment compensates for some added capacitance to ground in Q116/117 (due to relay K101 and the secondary winding of T102) and ensures that the waveforms (and delays) are the same for both amplifiers. Step recovery diode, CR202 sharpens the "leading" edge of the negative pulse, producing an effective fast fall time, to be combined with the output of the positive step amplifier as explained in paragraph 4-27.

4-27. COMBINING STEP AMPLIFIER OUTPUTS.

4-28. The step amplifier outputs are finally combined to produce a pulse having the same rapid rise as fall time. One output determines the polarity of the pulse and the other output returns the pulse to zero. The following explains how the step amplifier outputs are combined in producing a positive pulse output from the

Model 215A. The anode of CR202 is connected through CR205 to the cathode of CR201. CR205 is not conducting while the positive step amplifier is in action since its cathode is at about +13.7v and the anode goes to only +12v. When the positive going pulse has formed, the negative step amplifier comes on and as the current through CR202 reaches about 1/2 amp (this occurs in the same way as explained for CR201 in paragraph 4-23) this step recovery diode opens and switches the current into CR205. This current then bucks the positive output current going through L176 and CR206 (see paragraph 4-23) and causes the pulse to end with a fall time sharpened by CR202. Just after the time the output is dropped to zero by bucking out the positive pulse, Q103 turns off Q104, hence turning Q116/117 off. Both sides of CR205 are now made negative by Q118/119 and L177. This back biases CR206 and CR207 conducts taking its anode negative. Here S201B diverts this signal to T104 which first turns Q109 off and subsequently turns Q118/119 off. The output circuit is then ready for the next pulse from the logic circuit.

4-29. OUTPUT IMPEDANCE AND ATTENUATION.

4-30. The apparent true 50 ohm output impedance of the Model 215A is achieved with delay line DL201, diode CR206, and resistor R203 for positive pulses (DL201, CR207, and R204 for negative pulses). The arrangement makes the Model 215A appear to be a true 50 ohm source between pulses, when load reflections could affect measurements. Because of DL201 any load reflections cannot arrive back at R203 before a delay of 120 nanoseconds (60 ns each way). The maximum pulse width of the Model 215A is 115 ns so the pulse is always over before the load reflections can arrive and since CR206 is reverse biased any reflection is completely absorbed in R203. Diode CR206 is sufficiently back biased to prevent forward biasing even with 100% negative reflection from a shorted load. The ATTENUATOR (DB) switch controls the output pulse amplitude over a calibrated 12 db range. This attenuator has a 50 ohm impedance from either end. Special high accuracy 50 ohm cables are used throughout the Model 215A to minimize reflections.

4-31. POWER SUPPLY.

4-32. The Model 215A power supply operates from 115 vac or 230 vac (switched by S302) which is rectified and regulated to provide a +40v, -40v, +13v, and -13v supply for the instrument circuits. A secondary winding of T301 also provide the 6.3 vac to filaments of tubes V1 and V2. The -40v supply is independent of the others and the positive side is grounded. Control transistor Q312 has a dc voltage for its collector from a doubler supply (CR313, CR314, etc.). Diode CR316 provides the reference for the -40v supply with its temperature coefficient balanced against voltage changes with temperature in Q113 and the voltage divider. The -40v supply is used as the reference for all the other supplies. Transistors Q306 and Q316 are Shunt Regulators drawing current from the +40v and -40v supplies, respectively. Diode CR317 protects Q313 in case the -40v supply is shorted. For 115 vac operation use a 1 amp fuse, and for 230 vac use a 1/2 amp fuse.

Table 5-1. Required Test Equipment

Description	Important Specifications	Recommended Equipment
DC Voltmeter	Voltage Range: Measure up to ±40 volts Input Impedance: 10 megohms Accuracy: ±1% of full scale reading.	℗ Model 412A DC Vacuum Tube Voltmeter (or Model 405 Digital DC Voltmeter)
AC Voltmeter	Voltage Range: Measure 1 mv to 10 v. Accuracy: ±1% of full scale reading.	℗ Model 400H Vacuum Tube Voltmeter
Oscilloscope	Basic oscilloscope with dual trace vertical amplifier for differential operation, i. e. channel A minus channel B.	℗ Model 175 Oscilloscope with ℗ Model 1750A Dual Trace Vertical Amplifier
Oscilloscope	Basic sampling oscilloscope with dual channel vertical amplifier. High input impedance about 100K ohms. Rise time of 0.5 nanosecond. Delay control for observing any portion of trace.	Model 185B Oscilloscope, with ℗ Model 187B Dual Trace Vertical Amplifier
Oscillator	Signal source of 10 and 100 cps, 2 v rms output, accuracy ±2%.	℗ Model 200CD Oscillator
Probe Divider	Allow measurement of signals with 20 volts peak-to-peak.	℗ 187B-76C 10:1 Divider
Load Termination	SWR of 1.05 or less, 1/2 watt.	℗ 908A 50Ω Termination
T Connector	Low swr and insertion loss.	℗ 187B-76E 50Ω Tee
Oscillator	1 volt output at 1.05 MC.	℗ Model 211A Square Wave Generator
Attenuator Pad	±0.1 db accuracy from nominal at dc.	Weinschel Model 50-30 30 db type N Attenuator

SECTION V

MAINTENANCE

5-1. CALIBRATION AND ADJUSTMENT.

5-2. GENERAL.

5-3. The following adjustment and calibration procedures are to be used only if a check has shown that the instrument is definitely not meeting the published specifications. The procedures for calibrating a given circuit section of the Model 215A are to be followed in the step sequence given. If an improper indication is noted when making an adjustment, the fault may be that another adjustment has been made improperly. See paragraph 5-12 for troubleshooting hints and procedures.

5-4. POWER SUPPLY.

Note

Use the negative side of C307 for all power supply checks and adjustments. Do not use chassis for ground.

a. With the dc voltmeter measure the voltage at the junction of R357 and R351, If necessary adjust R344 to obtain -40 ±0.1 volts.

b. Measure the voltage at the junction of R327 and R312. If necessary adjust R313 to obtain +40 ±0.1 volts.

c. Check the voltage at the opposite end of R357. If necessary adjust R352 to obtain -13 ±0.1 volts.

d. Check the voltage at the opposite end of R327. If necessary adjust R322 to obtain +13 ±0.1 volts.

e. Measure regulation of all supplies. Voltage should change less than 0.2v for ±10% line variation.

f. Set Model 215A TRIGGER SOURCE to MANUAL. Measure the ripple (with the ac voltmeter) of all power supply voltages as the line voltage is varied ±10% from normal. Ripple should not exceed 0.5 mv rms.

g. Measure the filament voltage between pins 5 and 6 of T301. Voltage should be 6.3 ±0.2 volts rms at normal line.

5-5. RATE GENERATOR.

a. Set the Model 215A TRIGGER SOURCE to INT. REPETITION RATE .1-1KC, VERNIER fully ccw, and the GATE INPUT switch to GATED.

b. Using the Model 175A Oscilloscope and the Model 1750A Dual Trace Amplifier (or equivalent equipment meeting specifications in table 5-1) with the hp AC-21M Voltage Divider Probe make the following settings: channel A and B to .1 volts/cm, AC coupled, POLARITY to +UP; channel selector to A-B; TRIGGER SLOPE to +; TRIGGER SOURCE to INT.; SWEEP MODE to PRESET; SWEEP TIME to 2 msec/cm. HORIZONTAL DISPLAY to X1; all VERNIERS in calibrated position.

CAUTION

Extreme care is required for steps c through f or damage to circuit components may result.

Note

For consistent and most accurate waveshapes, use the metal bracket at the rear of S2 (TRIGGER SOURCE) as a ground reference for measurements.

c. Connect channel A probe to the junction of R41 and switch S2C (silk screened "X" on circuit board); channel B probe to the tunnel diode (CR4) side of R44 (silk screened "Y"). The waveform should be about 3.3 volts peak-to-peak sawtooth shape No adjustment will be necessary at this time if the peak-to-peak voltage is between 3.0 and 4.0. The height of the waveform is measured at the intersection of the lines (disregarding any overshoot).

d. If no waveform is observed or if limits in step c are not met, turn R64 (Offset Voltage Adj.) fully ccw and then turn cw until desired waveform appears. Do not change the setting of R64 unless necessary to meet these specified conditions.

e. Change oscilloscope channel selector to A and move the channel A probe to measure the collector to ground waveform of Q3. Change scope SENSITIVITY to .2 v/cm and adjust the scope SENSITIVITY VERNIER for a 5 cm display. Change scope SENSITIVITY to .05 v/cm and the waveform should appear as in figure 5-1 with h equal to 1 to 3% (0.2 to 0.6 cm) of the total height, t, of the waveform. If not, adjust R64 to the nearest of these two limits. If the waveform is within specifications shown in figure 5-1, do not adjust R64. Return VERNIER to CALIBRATED.

f. Recheck the sawtooth waveform as in step c. It should have a height of 3.0 to 4.0 volts peak-to-peak.

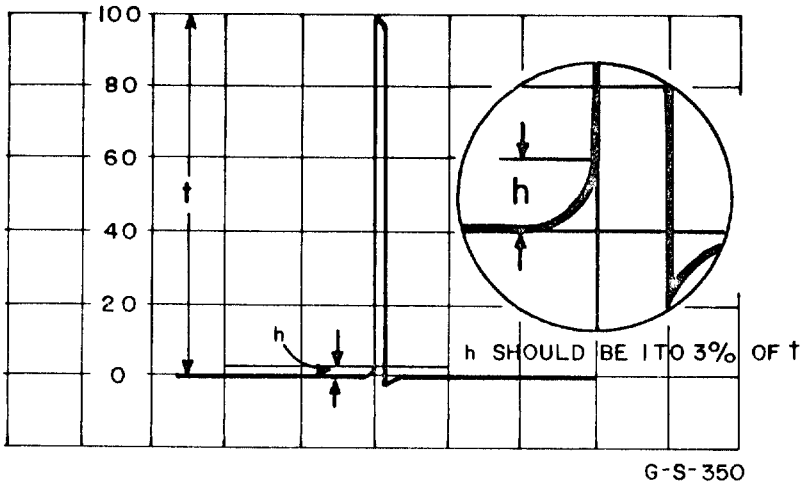


Figure 5-1. Q3 Collector Waveform

g. Remove channel B probe and place channel A probe on collector of Q3. Set the scope SWEEP TIME to .1 msec/cm,AC coupled,SENSITIVITY to .5 volts/cm. Set the Model 215A INT. REPETITION RATE VERNIER fully cw.

h. Adjust R37 (1 kc Max. Rep. Rate Adj.) for a 0.77 millisecond period (i.e. 7.7 cm between pulses). This represents a 1.3 kc rep rate.

i. Change scope SWEEP TIME to 1 usec/cm and the Model 215A TRIGGER SOURCE to INT. REPETITION RATE .1-1MC.

j. Adjust C10 (1 Mc Max. Rep. Rate Adj.) for 11 cycles/10 cm as displayed on the scope. This represents a 1.1 Mc rep rate.

k. Check all positions of INT. REPETITION RATE switch with the VERNIER control to insure that there is a continuous frequency coverage according to table 5-2. The waveform amplitude should remain constant ±1 v with no unstable conditions.

Table 5-2. VERNIER Limits Check

TRIGGER SOURCE Setting	Frequency With VERNIER Fully CW	Frequency With VERNIER Fully CCW
.1-1MC	1.1 Mc	below 100 kc
10-100KC	above 100 kc	below 10 kc
1-10KC	above 10 kc	below 1 kc
.1-1KC	above 1 kc	below 100 cps

5-6. EXTERNAL TRIGGER.

a. Set the Model 215A TRIGGER SOURCE to EXT. -, and EXT. TRIG. LEVEL fully ccw. Connect a dc voltmeter between junction of R41 and S2C ("X" on circuit board), and ground.

b. Turn R50 (Peak Curr. Comp. Adj.) fully cw and then turn back ccw slowly to decrease the voltage. Note the level of the voltage just before the voltage jumps (i.e. where oscillation starts). Set R50 back cw to give reading 1 volt higher than the level just before the voltage jump occurs.

c. Make the following settings on the Model 175A and Model 1750A: channel A to .2 v/cm AC; channel B to .1 v/cm; DC coupled; channel selector to ALTERNATE; SWEEP TIME to 2 msec/cm; and TRIGGER SOURCE to EXT. AC.

d. Set the Model 215A TRIGGER INPUT switch to HIGH Z.

e. Apply a 0.5 volt peak-to-peak, 100 cps signal from the Model 200CD to the Model 215A TRIGGER INPUT, to the Model 175A TRIG. INPUT, and directly to channel B INPUT of the scope (no probe used).

f. Connect the channel A probe to the anode side of CR9 (at blue wire on switch wafer S2D) and adjust the Model 215A TRIGGER LEVEL control to obtain a square wave scope trace (should be same frequency as the sine wave).

g. Adjust R63 (Ext. Trig. Sens. Adj.) while adjusting the TRIGGER LEVEL to maintain triggering. Stop when the circuit just triggers at only one position of the TRIGGER LEVEL control (turning R63 ccw increases sensitivity). The circuit should not free-run (i.e. when Model 215A TRIGGER INPUT is removed) and the square wave should be clean and sharp.

h. Set the Model 200CD to provide 1 volt peak-to-peak at 10 cps. The Model 215A should synchronize to the signal.

i. Set the Model 175A and Model 1750A as follows: SWEEP TIME to 1usec/cm; channel switch to ALTERNATE; channel A SENSITIVITY to 1 v/cm; channel B SENSITIVITY to .2 v/cm.

j. Set the Model 215A TRIGGER SOURCE to EXT. +, TRIGGER INPUT to 50 Ω, GATE INPUT switch to GATED, and turn EXT. TRIG. LEVEL fully ccw.

k. Connect the 75Ω OUTPUT of the hp Model 211A to (1) the Model 215A TRIGGER INPUT, (2) the oscilloscope TRIG. INPUT, and (3) directly to scope channel B.

m. Adjust the Model 211A to provide 1 volt out (5 cm on scope), and set the frequency to 1.05 Mc (10 cycles/9.5 cm on scope).

n. Place the scope channel A probe on Q3 collector. Carefully adjust the Model 215A EXT. TRIG. LEVEL clockwise until the first stable triggering point occurs from the Model 215A (i.e. when trace first appears stable on the scope.

p. Set C14 fully cw (maximum capacity) and then back off ccw until the frequency from the Model 215A is the same as that of the Model 211A, i.e. the scope shows one cycle from Model 215A for each cycle from the Model 211A. Leave C14 set so Model 215A triggers at only one position of EXT. TRIG. LEVEL.

5-7. LOGIC CIRCUIT.

5-8. The procedures for calibrating the Logic Circuit assume use of the Model 185B Oscilloscope, the Model 187B Dual Trace Vertical Amplifier, and the Model 187B-76C 10:1 Divider, with the necessary connecting cables and adapters. If substitute equipment is used it must meet the minimum specifications listed in table 5-1.

a. Set the Model 215A TRIGGER SOURCE to EXT. +, TRIGGER INPUT switch to 50 Ω, and GATE INPUT switch to NORMAL.

b. Set the Model 185B TIME SCALE MAGNIFIER to X2 and the TIME SCALE to 100 ns/cm, (leave Calibrated), channel selector to A, SENSITIVITY to 200 mv/cm, and MODE to FREE RUN. Connect a 50 ohm coaxial cable from the Model 185B SYNC PULSE OUTPUT to the Model 215A TRIGGER INPUT.

c. Place the channel A probe (with 10:1 divider) to measure the collector to ground waveform of transistor Q106. Adjust the Model 215A EXT. TRIG. LEVEL until the trace appears on the scope. Position the waveform by adjusting the DELAY control of the Model 185B. The pulse width should be 280 ns as shown in figure 5-2. If necessary adjust R128 (B.O. Pulse Width Adj.) to obtain the correct pulse width.

d. Check the following characteristics of the pulse: rise time ≈ 15 ns; fall time ≈ 40 ns; amplitude ≈ 6.5 v; peak-to-peak amplitude ≈ 24 v maximum; total time ≈ 700 ns.

Note

The starting point of a waveform when making all checks and adjustments on the Model 215A is defined as shown in figure 5-3.

e. Set the Model 215A PULSE WIDTH fully cw. Set the Model 185B TIME SCALE to 100 nsec/cm (leave VERNIER in CAL.) and TIME SCALE MAGNIFIER to X5 (i.e. 20 ns/cm).

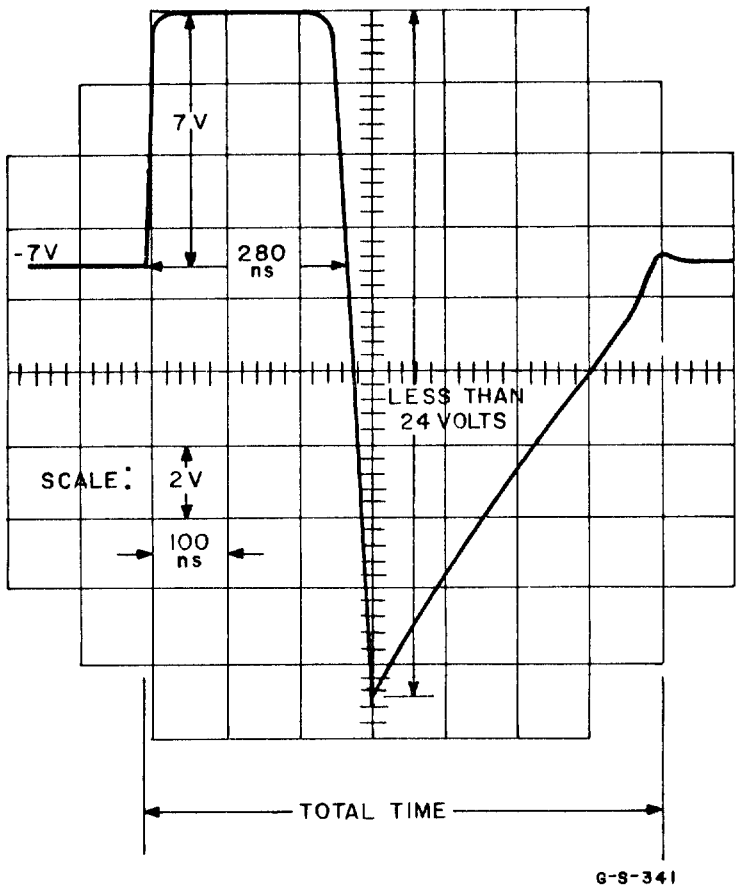


Figure 5-2. Q106 Collector Waveform

f. With the channel A probe, measure the collector to ground waveform of Q106. Adjust the Model 185B DELAY control to position the start of the waveform at the left edge of the graticule. Move scope probe to Q104 collector. Adjust R103 (Start Channel Delay Adj.) until start of Q104 waveform occurs 148 ns (7.4 cm) after the start of Q106 waveform. With the probe on Q104 collector, set R122 (B.O. Feedback Adj.) for a flat top on the waveshape.

g. Position start of Q104 collector to ground waveform at the left edge of the graticule. Place probe on Q109 collector and adjust R141 (Max. Width Adj.) until start of Q109 waveform occurs 115 ns (5.75 cm) after the start of Q104 collector waveform.

h. Turn the Model 215A TRIGGER ADVANCE fully ccw and set TRIGGER OUTPUT switch to +. Position start of Q104 collector waveform at left edge of graticule. Move probe to TRIGGER OUTPUT jack and adjust R164 (Min. Advance Adj.) until start of TRIGGER OUTPUT waveform occurs 104 ns (5.2 cm) after the start of Q104 collector wave form.

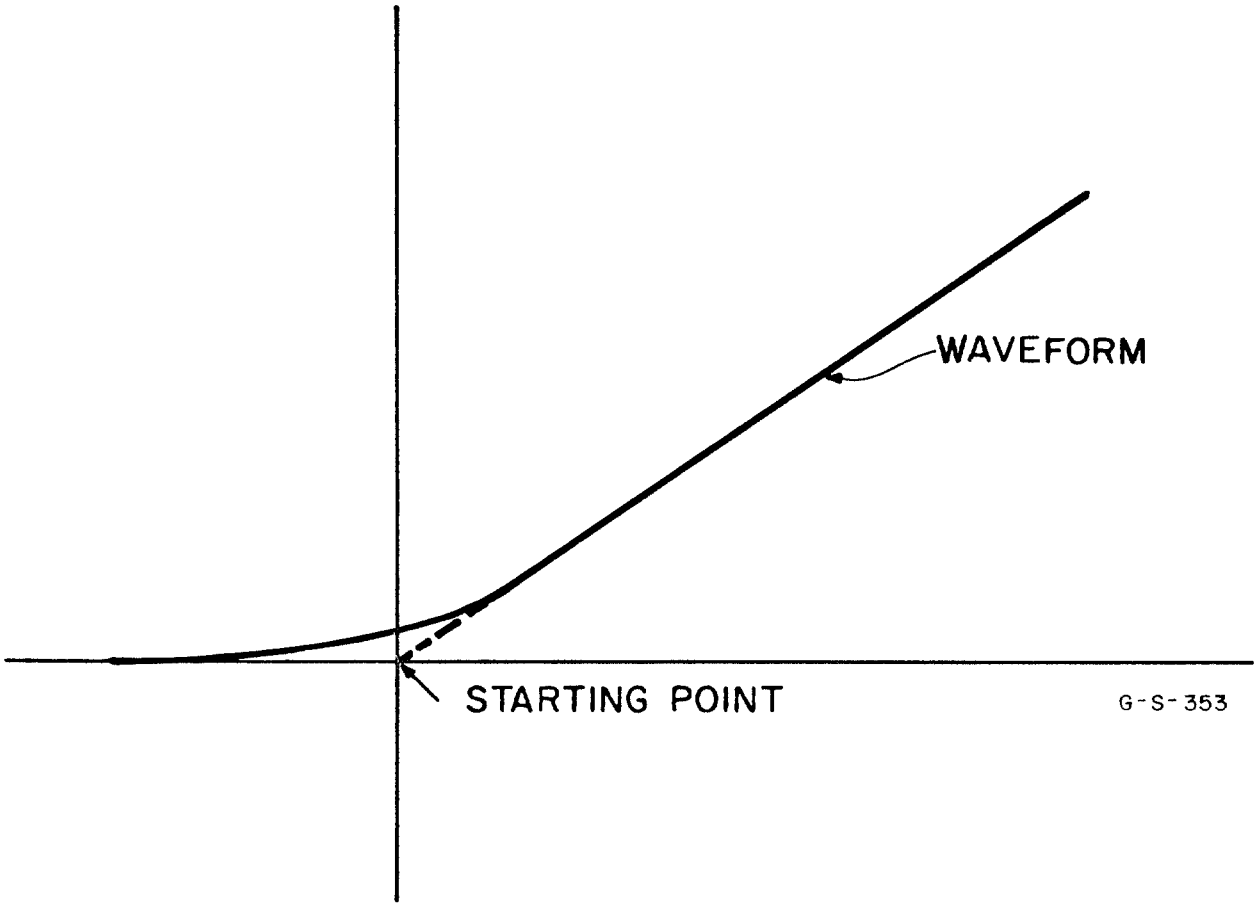


Figure 5-3. Waveform Starting Point Defined

i. Turn Model 215A TRIGGER ADVANCE fully cw. Set the Model 185B TIME SCALE MAGNIFIER to X10 (now scale is 10 ns/cm) and move probe to Q104 collector. Position the start of Q104 waveform to right edge of graticule. Move probe to TRIGGER OUTPUT jack and adjust R161 (Max. Advance Adj.) until start of TRIGGER OUTPUT occurs 66 ns before the start of Q104 waveform.

j. Set Model 215A PULSE WIDTH (nSEC) fully cw. Change Model 185B TIME SCALE MAGNIFIER to X50 (making scale 2 ns/cm). Place scope probe on Q104 collector and position start of waveform to right edge of graticule. Set Model 215A PULSE WIDTH fully ccw. Move probe to Q109 collector and adjust R144 (Min. Width Adj.) until start of Q109 waveform occurs 5 ns (i. e. 2. 5 cm) ahead of start of Q104 waveform.

5-9. OUTPUT STAGE.

5-10. The checks and adjustments of the Model 215A output stage require the use of the Model 187B, and Model 187B-76C or equivalent equipment as indicated in table 5-1.

a. Set the Model 215A ATTENUATOR (DB) to 0, PULSE WIDTH (nSEC) fully cw PULSE OUTPUT to +, TRIGGER SOURCE to EXT. +, and TRIGGER INPUT to 50 Ω.

b. Connect a Weinschel 30 db type N attenuator (see table 5-1) to the Model 215A PULSE OUTPUT. Connect Model 187B-76E T Connector to the attenuator pad, Model 908A Coaxial Termination to the T Connector, and insert the scope probe directly into the T.

c. Set the Model 185B MODE to FREE RUN, TIME SCALE to 100 ns/cm and TIME SCALE MAGNIFIER to X5. Connect a 50 ohm coaxial cable between the Model 215A TRIGGER INPUT and the Model 185B SYNC PULSE OUTPUT.

d. Adjust the Model 215A EXT. TRIG. LEVEL and Model 185B DELAY control to get pulse on scope. Set the Model 187B SENSITIVITY to 50 mv/cm and adjust VERNIER for a 10 cm display.

e. Adjust the Model 215A + PULSE SHAPE (R185) for a flat top on the pulse. Note the amplitude.

f. Change the Model 215A PULSE OUTPUT to — and adjust — PULSE SHAPE (R195) for a flat top on the pulse.

g. Adjust R352 (-13 volt power supply) until the amplitude of the negative pulse equals the amplitude of the positive pulse. Readjust — PULSE SHAPE for a flat top on the pulse.

h. Set the Model 187B SENSITIVITY to 100 mv/cm and leave uncalibrated. Change the Model 185B TIME SCALE MAGNIFIER to X50. Set Model 215A PULSE OUTPUT to + and ajust PULSE WIDTH to give about 2 ns observed on the scope. Adjust the Model 187B to set the waveform base line at the center of the graticule.

i. Change the Model 215A PULSE OUTPUT switch to —. Compare with width of positive pulse. Adjust C191 (Cap. Bal.) to obtain equal width for positive and negative output pulses.

j. Set Model 215A PULSE WIDTH fully cw and PULSE OUTPUT to +. Set scope SENSITIVITY to 200 mv/cm and TIME SCALE MAGNIFIER to X20. Ground the scope probe with divider and center the trace vertically on the graticule

k. Use the scope probe with 10:1 divider to measure the waveform to ground at junction of R203 and CR206 (this point is on top of the square-shaped post, nearest CR206 silk screen marking, on the diode output board). Adjust the scope controls to center the trailing edge of the waveform horizontally on the graticule.

m. Move the scope probe to the emitter of Q117. Adjust R122 (B.O. Feedback Adj.) until the trailing edge of the Q117 waveform crosses zero volts (at center of graticule) 20 ns after the trailing edge of the waveform at R203.

5-11. PULSE WIDTH AND TRIGGER ADVANCE CALIBRATION.

a. Set the Model 215A TRIGGER SOURCE to EXT. +, TRIGGER INPUT switch to 50Ω, ATTENUATOR (DB) to 0, and PULSE WIDTH to 100.

b. Connect a Weinschel 30 db attenuator (see table 5-1) to the Model 215A PULSE OUTPUT. Connect Model 187B-76E T Connector to the attenuator, Model 908A Coaxial Termination to the T, and insert the channel A scope probe directly (without divider) into the T.

c. Set the Model 185B MODE to FREE RUN, channel selector to A, TIME SCALE to 100 ns/cm and TIME SCALE MAGNIFIER to X10. Connect a 50 ohm coaxial cable between the Model 215A TRIGGER INPUT and the Model 185B SYNC PULSE OUTPUT. Check Model 185B TIME SCALE calibration with the 50 Mc calibrator.

d. Adjust the Model 215A EXT. TRIG. LEVEL and Model 185B DELAY control to get pulse on scope. Adjust the scope SENSITIVITY for a 10 cm display.

e. Adjust R141 (Max. Width Adj.) to obtain a pulse width of 100 ns at the half amplitude (5 cm) points.

f. Turn Model 215A PULSE WIDTH control to zero.

g. Adjust R144 (Min. Width Adj.) to obtain a spike waveform that is 1/2 the pulse amplitude set in step d.

h. Recheck the positive and negative pulse output as in paragraph 5-9, steps a through g, making the adjustments only if necessary.

i. Return scope and Model 215A to same setup as required for step g above, except change the scope TIME SCALE MAGNIFIER to X1.

j. Turn Model 215A PULSE WIDTH fully ccw (below "0") and check for a "hump" appearing in the baseline about 100 ns after the usual pulse position (ignore small, fast ripples near usual position). If the "hump" is present, turn R122 slightly ccw

until "hump" is eliminated. If necessary, adjust R122 slightly to improve baseline just after trailing edge of pulse. If R122 is turned, recheck for a flat top on the pulse at maximum PULSE WIDTH setting.

k. Set scope channel selector to A & B, SENSITIVITY of both channels to 200 mv/cm, CALIBRATED, and TIME SCALE MAGNIFIER to X5. Set Model 215A TRIGGER ADVANCE to 140 ns. PULSE WIDTH fully cw.

m. Using the scope controls, position the leading edge of Model 215A output pulse at 2 cm from right edge of scope graticule.

n. Connect scope channel B probe with 10:1 divider to the Model 215A TRIGGER OUTPUT.

p. Adjust R161 (Max. Advance Adj.) until the leading edge of the TRIGGER OUTPU waveform occurs 140 ns (7 cm) ahead of the PULSE OUTPUT waveform.

q. Set Model 215A TRIGGER ADVANCE to 0. Adjust R164 (Min. Advance Adj.) until the start of the TRIGGER OUTPUT pulse coincides with the start of the PULSE OUTPUT. A slight interaction between R161 and R164 may occur, so repeat steps p and q if necessary.

5-12. TROUBLESHOOTING.

5-13. GENERAL.

5-14. The information in the troubleshooting paragraphs is intended to help isolate the trouble first to a section of the Model 215A circuitry, and then to a specific component or adjustment. Refer also to the schematic diagrams, block diagram figure 4-1, and circuit description of section IV. A check of dc voltages at transistors and other elements should aid in isolating a faulty circuit or component. Table 5-3 provides dc voltages and gives the conditions for measuring these voltages. Table 5-4 is a sequence and description of the waveforms throughout the Model 215A. Do not change adjustments without following the procedures given in paragraphs 5-1 through 5-11.

5-15. SYNC AND RATE.

5-16. Operation of circuits up to and including Q4 and Q5 may be checked as follows:

a. Use the Model 175A and Model 1750A (table 5-1). Set SWEEP MODE to TRIGGER; channel selector to A; SENSITIVITY to .1 v/cm, dc coupled; and SWEEP TIME to .1 us/cm.

b. Set the Model 215A TRIGGER SOURCE to INT. REPETITION RATE, 10-100 KC VERNIER at mid-point; and GATE INPUT switch to NORMAL.

Table 5-3. DC Voltage Checks

NOTE: Voltages are measured with a high input impedance dc voltmeter. Indicated voltages may vary ±10% but relationship to another voltage must remain essentially the same. That is, if table 5-3 indicates -0.3 volts difference between base and emitter, this relationship should remain although base and emitter voltages may vary from nominal value given. For measurements, the Model 215A TRIGGER SOURCE is set to MANUAL, COUNTDOWN RATIO and VERNIER are set fully ccw. Other settings are given by symbols and notes. If a control or switch is not mentioned, the setting or position is unimportant.

B = Base; E = Emitter; C = Collector; A = Anode; Ca = Cathode

Designator	Element	Voltage
V1	Ca	+6.1*, +11.7#
V2	Ca	+6.0*, +12.5#
Q1	B	+20.0
Q1	E	+21.3
Q1	C	+38.7
Q2	B	+21.3
Q2	E	+21.5
Q2	C	+21.5
Q3	B	+38.7
Q3	E	+38.7
Q3	C	+20.0
CR5	Ca	+38.7
CR5	A	+39.0
Q4	B	-0.37
Q4	E	0
Q4	C	-0.1
Q5	B	+0.49►, -0.26@
Q5	E	0
Q5	C	-0.1
Q101	B	+7.6
Q101	E	+7.9
Q101	C	+7.8
Q102	B	+0.96
Q102	E	+0.71
Q102	C	-7.25
Q103	B	+1.9
Q103	E	+1.9
Q103	C	+0.1
Q104	B	+0.1
Q104	E	0
Q104	C	-14.3
Q106	B	+0.25
Q106	E	0
Q106	C	-7.1
Q107	B	+16.1Δ, +7.1●
Q107	E	+16.7Δ, +7.4●
Q107	C	+16.4Δ, +7.3●
Q108	B	+0.93
Q108	E	+0.68
Q108	C	-7.1
Q109	B	+0.25
Q109	E	0
Q109	C	-14.3
Q111	B	+0.96ψ, +5.1ϕ
Q111	E	+1.25ψ, +5.4ϕ
Q111	C	+1.2ψ, +5.3ϕ
Q112	B	+0.9
Q112	E	+0.8
Q112	C	-7.1
Q113	B	+0.25
Q113	E	0
Q113	C	-7.1
Q116	B, E	-14.0
Q116	C	+12.9
Q117	B, E	-14.0
Q117	C	+12.9
Q118	B, E	-13.1
Q118	C	+14.0
Q119	B, E	-13.1
Q119	C	+14.0
CR201	A	-13.1
CR201	Ca	-14.0
CR202	A	+14.0
CR202	Ca	+13.1

* = EXT. TRIG. LEVEL ccw
\# = EXT. TRIG. LEVEL cw
► = In NORMAL position
@ = In GATED position

Δ = PULSE WIDTH at "100"
● = PULSE WIDTH at "0"
ψ = TRIGGER ADVANCE at "140"
ϕ = TRIGGER ADVANCE at "0"

Table 5-4. Waveform Checks (External or Internal Trigger)

Designator	Element	Description
Q3	Collector	Positive pulse as in figure 5-1
Q5	Collector	Negative pulse, 4-6 volts amplitude in NORMAL, 0.4 volts in GATED
Q106	Collector	Pulse as shown in figure 5-2
Q106	Base	Waveform as in figure 5-4, check for negative portion shown dotted. See paragraph 5-17b
Q101 Q107 Q111	Collector	Negative going ramp ending no lower than -8 volts, with pick-off discontinuity at about 0 ±1 volt
Q104 Q109 Q113	Collector	Positive pulse: Q104 and Q109 about 13 v amplitude, Q113 about 6.5 v
Q117	Emitter	About 26 v positive pulse with PULSE OUTPUT +.
Q119	Collector	About 26 v negative pulse with PULSE OUTPUT -.

c. Connect the channel A scope probe to the collector of Q4 or Q5. The observed pulse should be negative, from 30 to 70 ns (0.3 to 0.7 cm) wide at its base, and greater than 4 volts (4 cm) in amplitude.

d. Change the Model 215A to GATED and the amplitude should drop below 0.4 volts (0.4 cm) peak.

e. Apply +1 volt dc at the GATE INPUT connector. The pulse should be the same as observed in step c.

f. Change TRIGGER SOURCE to EXT. + or EXT. −, GATE INPUT switch to NORMAL. Apply an external trigger signal to the Model 215A and repeat steps c through e.

g. If the proper pulse is observed for the internal repetition rate but not for external trigger, check the circuit of V1 and V2. Also note that CR9 is a part of

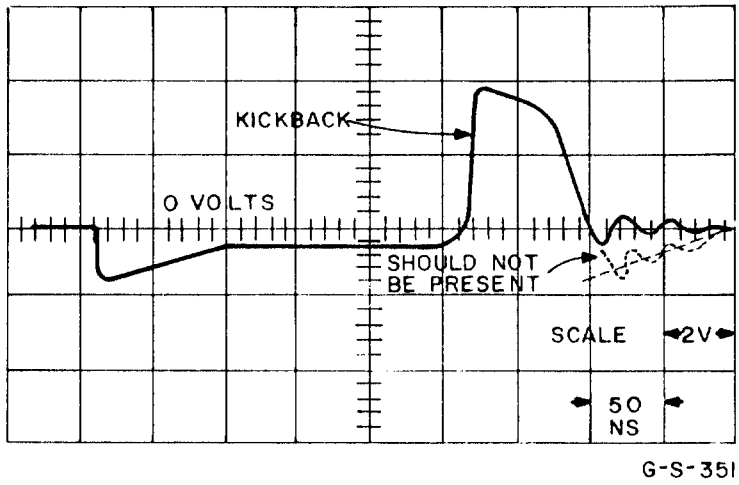


Figure 5-4. Q106 Base Waveform

the circuit only for EXT. + or EXT. −. Except for MANUAL, all modes of the TRIGGER SOURCE involve Q1 and Q2. Elements common to all trigger modes include CR4, Q3, Q4, and Q5.

h. If improper operation is indicated in the sync and rate circuit, check dc voltages of table 5-3 and waveforms of table 5-4.

5-17. LOGIC.

5-18. The logic circuit operation may be checked by observing the following:

a. A trigger output which is within specifications of table 1-1 and which agrees in frequency with the setting of TRIGGER SOURCE indicates that Q106 and the trigger channel (Q111-Q113) are functioning (this would also indicate an operating sync and rate circuit).

b. Check the waveform at Q106 base as shown in figure 5-4. If the negative portion (dashed line) is present, CR127 is probably defective.

c. If an output pulse is present, but does not track with the PULSE WIDTH control, trouble is indicated in the stop pulse channel, Q107-Q109.

d. Check dc voltages of table 5-3 and waveforms of table 5-4 to further isolate a trouble.

5-19. OUTPUT.

5-20. The following checks and observations should help locate a trouble in the output circuit.

a. As PULSE OUTPUT is slowly moved from + to − or − to +, relay K101 contacts should be heard operating. This would indicate that the +40 v and -40 v are present at the relay and that a signal from the logic circuit is being properly switched to the output step amplifiers.

b. Rise and fall time of the pulse output is primarily a function of CR201 and CR202 step recovery diodes.

c. If the pulse output width changes when switched between + and −, an unbalance in the output circuit is indicated. This may be caused by misadjustment of C191 (see paragraph 5-9) or a mismatch of L176-L177, R203-R204, or CR201-CR202.

d. A small difference in plus and minus pulse amplitude indicates the -13 volt power supply is misadjusted (see paragraph 5-9).

e. Check the dc voltages of table 5-3 and waveforms of table 5-4.

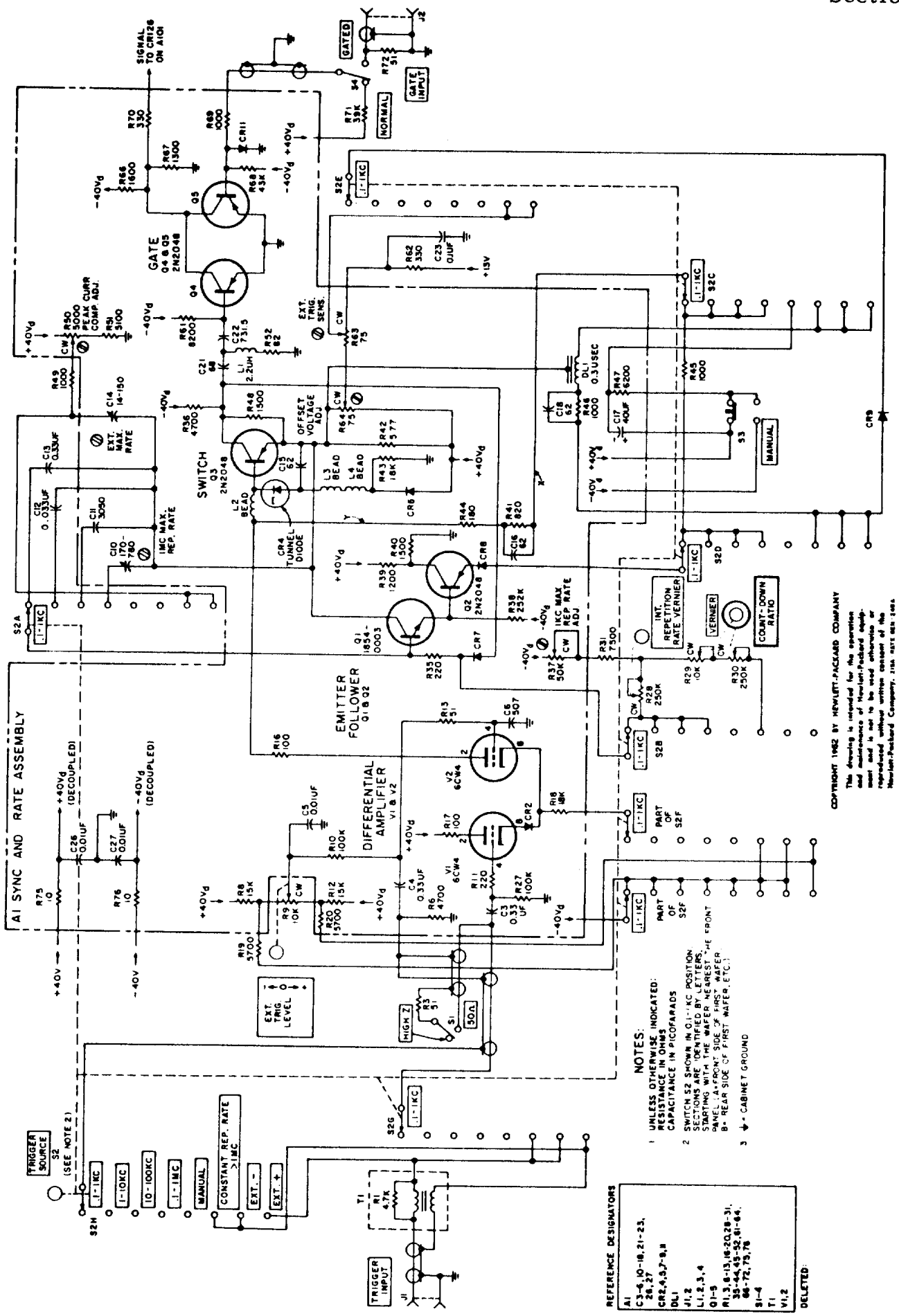


Figure 5-5. Model 215A Sync and Rate Circuit

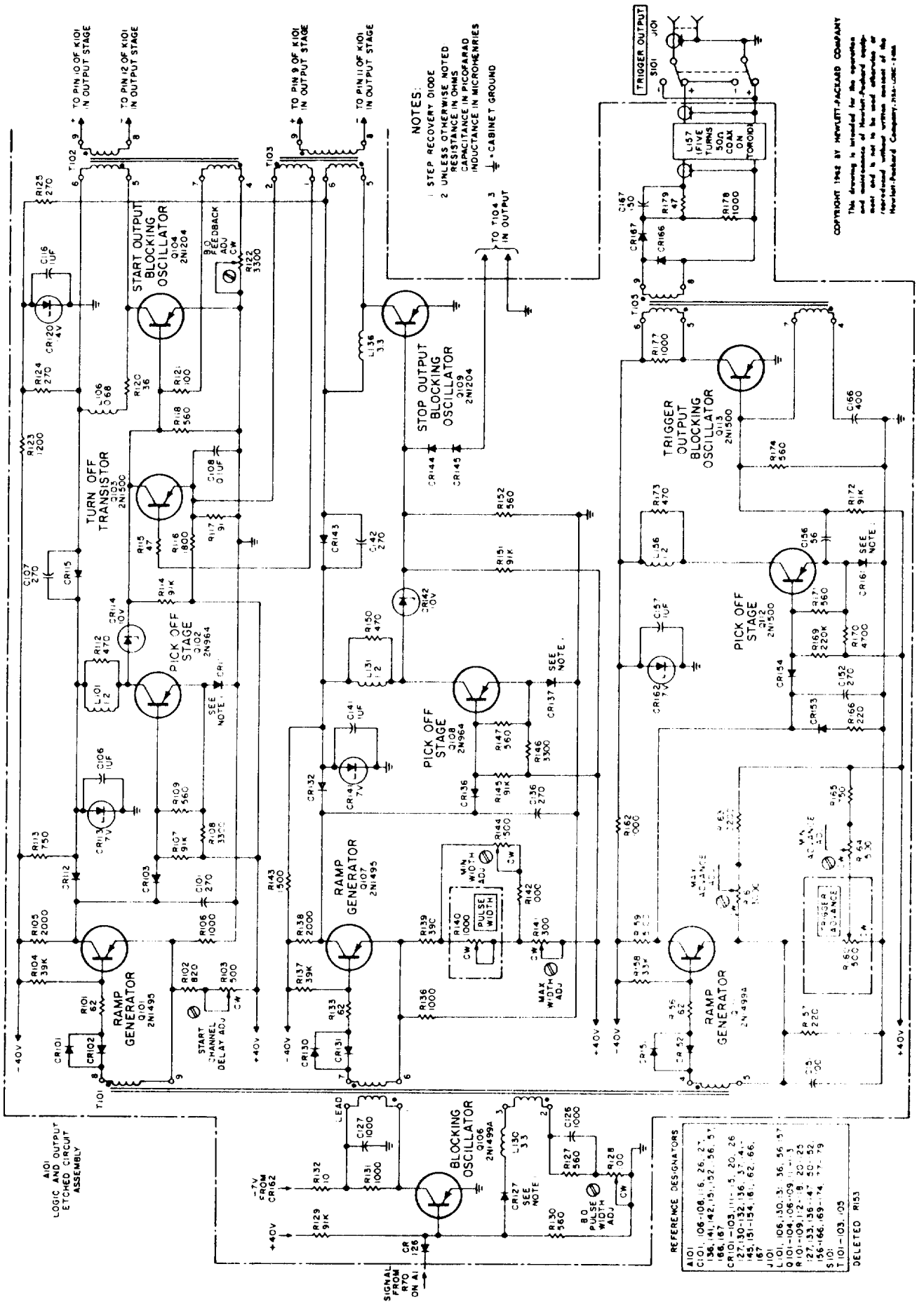


Figure 5-6. Model 215A Logic Circuit

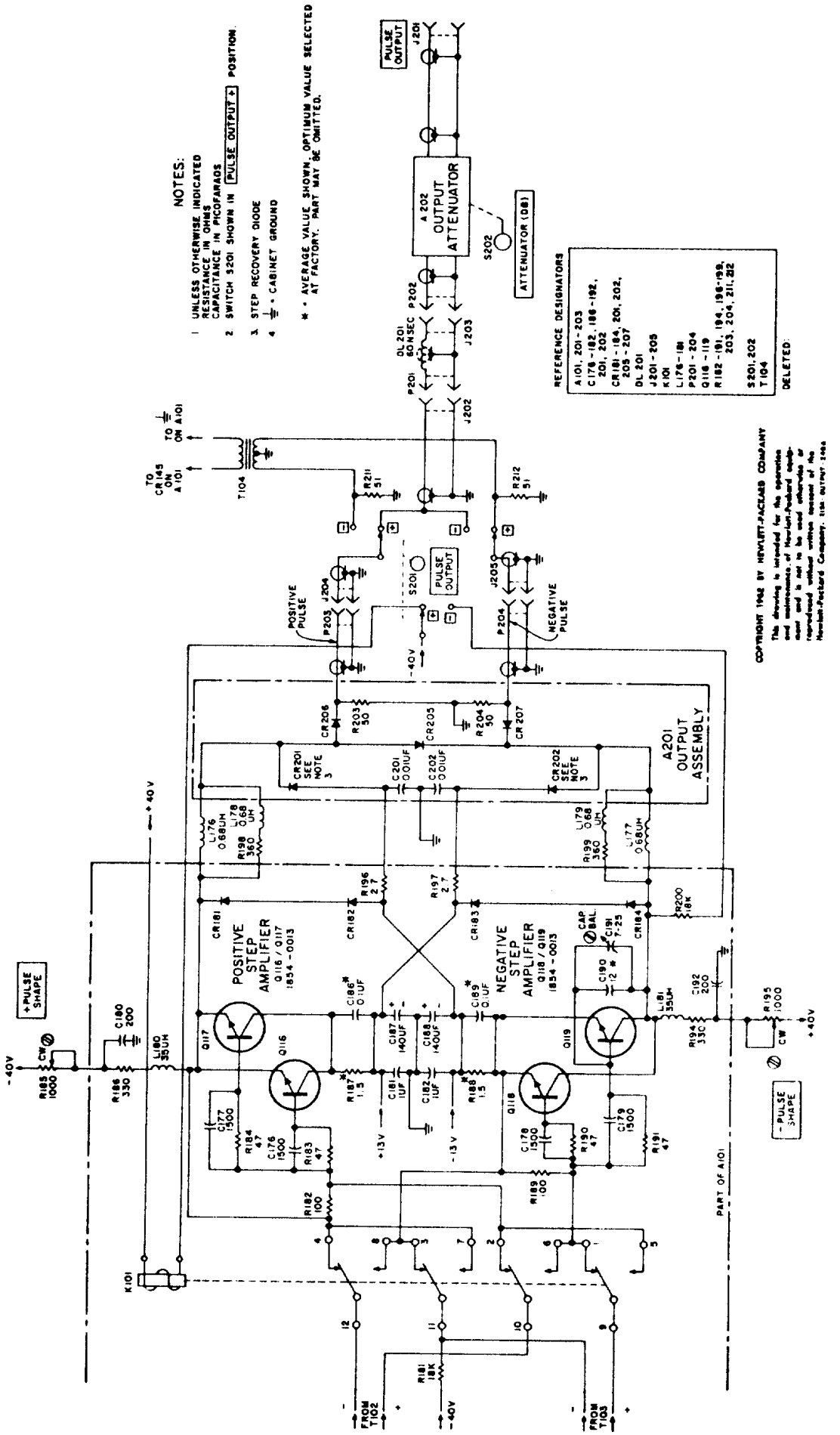
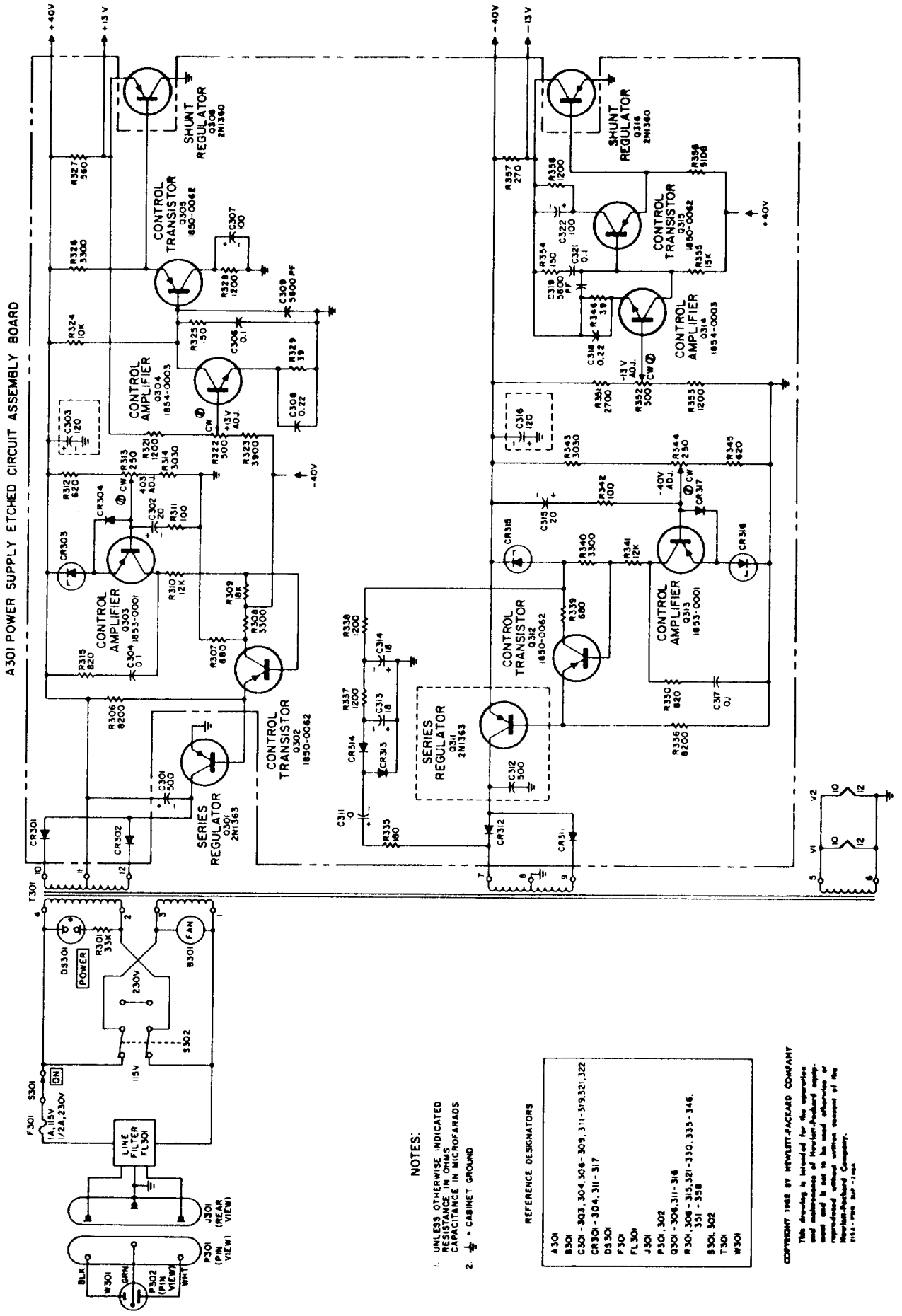


Figure 5-7. Model 215A Output Circuit



NOTES:

1. UNLESS OTHERWISE INDICATED RESISTANCE IN OHMS CAPACITANCE IN MICROFARADS
2. ⏚ = CABINET GROUND

REFERENCE DESIGNATORS

A301
B301
C301 - 303, 304, 306 - 309, 311 - 319, 321, 322
CR301 - 304, 311 - 317
DS301
F301
FL301
J301
P301, 302
Q301 - 306, 311 - 316
R301, 306 - 315, 321 - 330, 335 - 346, 351 - 358
S301, 302
T301
W301

SECTION VI

REPLACEABLE PARTS

When ordering parts for the Model 215A Pulse Generator, always include the circuit reference and hp stock number from the following list, and the model number and serial number of the instrument. If the part is not listed, give a complete description of the function and location of the part.

Orders and inquiries may be addressed to your authorized Hewlett-Packard Sales Representative or to Customer Service, Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, California.

Ckt Ref.	Stock No.	
A1	215A-65B includes:	A3, C3 thru C6, C10, C11, C14, C16 thru C18, C21, C22, C26, C27, CR2, CR5, CR7, CR8, CR11, DL1, L1 thru L4, Q1, Q2, Q4, Q5, R6 thru R8, R10 thru R13, R16 thru R18, R20, R35 thru R44, R46 thru R48, R50 thru R52, R61, R63, R64, R66 thru R70, R75, R76, V1, V2, XV1, XV2
A2	215A-19B includes:	C12, C13, CR9, R19, R45, R49, S2
A3	215A-95B includes:	C15, CR4, Q3
A101	215A-65C includes:	C101, C106 thru C108, C116, C126, C127, C136, C141, C142, C151, C152, C156, C157, C166, C167, C176 thru C182, C186 thru C192, CR101 thru CR103, CR111 thru CR115, CR120, CR126, CR127, CR130 thru CR132, CR136, CR137, CR141 thru CR145, CR151 thru CR154, CR161, CR162, CR166, CR167, CR181 thru CR184, K101, L101, L106, L130, L131, L136, L156, L180, L181, Q101 thru Q104, Q106 thru Q109, Q111 thru Q113, Q116 thru Q119, R101 thru R109, R112 thru R118, R120 thru R125, R127 thru R133, R136 thru R139, R141 thru R147, R150 thru R152, R156 thru R159, R161 thru R166, R169 thru R174, R177 thru R179, R181 thru R184, R186 thru R191, R194, R196, R197, R200, T101 thru T103, T105
A201	215A-65D includes:	C201, C202, L176 thru L179, R198, R199, R203, R204
A202	215A-34A includes:	Parts not separately replaceable
A203	215A-19A includes:	R211, R212, S201, T104
A301	215A-65A includes:	C302, C304, C306 thru C309, C311, C313 thru C315, C317 thru C319, C321, C322, CR301 thru CR304, CR311 thru CR317, Q302 thru Q305, Q312 thru Q315, R306 thru R315, R321 thru R330, R335 thru R346, R351 thru R358

Ckt Ref.	Stock No.	Ckt Ref.	Stock No.	Ckt Ref.	Stock No.
B301	3140-0030	C5	0150-0012	C11	0140-0174
C3	0160-0137	C6	0140-0107	C12	0160-0180
C4	0160-0137	C10	0131-0003	C13	0170-0042

Ckt Ref.	Stock No.
C14	0131-0004
C15	part of A3
C16	0150-0087
C17	0180-0050
C18	0150-0087
C21	0140-0082
C22	0140-0150
C23	0150-0121
C26	0150-0012
C27	0150-0012
C101	0160-0139
C106	0160-0127
C107	0140-0206
C108	0150-0121
C116	0160-0127
C126	0140-0179
C127	0150-0050
C136	0160-0139
C141	0160-0127
C142	0140-0206
C151	0150-0073
C152	0160-0139
C156	0140-0191
C157	0160-0127
C166	0150-0071
C167	0140-0196
C176	0160-0141
C177	0160-0141
C178	0160-0141
C179	0160-0141
C180	0150-0072
C181	0160-0127
C182	0160-0127
C186	0160-0140
C187	0180-0080
C188	0180-0080
C189	0160-0140
C190	0160-0179
C191	0121-0037
C192	0150-0072
C201	0160-0142
C202	0160-0142
C301	0180-0047

Ckt Ref.	Stock No.
C302	0180-0049
C303	0180-0042
C304	0160-0168
C306	0160-0168
C307	0180-0039
C308	0160-0200
C309	0160-0158
C311	0180-0089
C312	0180-0047
C313	0180-0109
C314	0180-0109
C315	0180-0049
C316	0180-0042
C317	0160-0168
C318	0160-0200
C319	0160-0158
C321	0160-0168
C322	0180-0039
CR2	1901-0027
CR4	part of A3
CR5	1910-0016
CR7	1910-0016
CR8	G-29L-15
CR9	G-29L-15
CR11	1901-0025
CR101	1901-0041
CR102	1901-0041
CR103	G-29L-15
CR111	G-29J-14
CR112	1901-0042
CR113	1902-0043
CR114	G-29A-19
CR115	1901-0041
CR120	G-29G-6
CR126	1901-0042
CR127	G-29J-13
CR130	1901-0041
CR131	1901-0041
CR132	1901-0042
CR136	G-29L-15
CR137	G-29J-14
CR141	1902-0043
CR142	G-29A-19
CR143	1901-0041

Ckt Ref.	Stock No.
CR144	1901-0042
CR145	1901-0042
CR151	1901-0041
CR152	1901-0041
CR153	1901-0034
CR154	G-29L-15
CR161	G-29J-14
CR162	1902-0043
CR166	G-29L-15
CR167	G-29L-15
CR181	G-29L-15
CR182	G-29L-15
CR183	G-29L-15
CR184	G-29L-15
CR201	G-29J-11
CR202	G-29J-11
CR205	G-29L-60
CR206	G-29L-61
CR207	G-29L-61
CR301	1901-0026
CR302	1901-0026
CR303	G-31A-7L
CR304	1901-0025
CR311	1901-0026
CR312	1901-0026
CR313	1901-0033
CR314	1901-0033
CR315	1902-0043
CR316	G-31A-7L
CR317	1901-0025
DL1	9190-0004
DL201	215A-16B
DS301	1450-0048
F301 (1A)	2110-0001
(1/2A)	2110-0012
FL301	9110-0053
J1	1250-0118
J101	1250-0118
J201	1250-0140
J202	1250-0078
K101	0490-0042
L1	9140-0098
L2	9170-0029

Ckt Ref.	Stock No.
L3	9170-0029
L4	9170-0029
L101	9140-0046
L106	9140-0024
L130	9140-0143
L131	9140-0046
L136	9140-0076
L156	9140-0046
L176	9140-0147
L177	9140-0147
L178	9140-0147
L179	9140-0147
L180	9140-0027
L181	9140-0027
Q1	1854-0003
Q2	1850-0091
Q3	part of A3
Q4	1850-0091
Q5	1850-0091
Q101	1850-0067
Q102	1850-0099
Q103	1850-0051
Q104	1850-0073
Q106	1850-0093
Q107	1850-0067
Q108	1850-0099
Q109	1850-0073
Q111	1850-0093
Q112	1850-0051
Q113	1850-0051
Q116	1854-0013
Q117	1854-0013
Q118	1854-0013
Q119	1854-0013
Q301	1850-0082
Q302	1850-0062
Q303	1853-0001
Q304	1854-0003
Q305	1850-0062
Q306	1850-0094
Q311	1850-0082
Q312	1850-0062
Q313	1853-0001
Q314	1854-0003
Q315	1850-0062
Q316	1850-0094
R1	0683-4725
R3	0760-0012
R6	0683-4725
R7	0758-0053
R8	0758-0018
R9	2100-0234
R10	0758-0053
R11	0758-0015
R12	0758-0018
R13	0683-5105
R16	0758-0024
R17	0758-0024
R18	0757-0091
R19	0757-0168
R20	0757-0168
R28	2100-0333
R29	2100-0332
R30	2100-0332
R31	0758-0047
R35	0758-0015
R36	0764-0018
R37	2100-0094
R38	0727-0228
R39	0758-0070
R40	0758-0017
R41	0758-0032
R42	0727-0005
R43	0758-0019
R44	0758-0014
R45	0757-0089
R46	0757-0089
R47	0758-0046
R48	0758-0017
R49	0684-1021
R50	2100-0331
R51	0758-0037
R52	0684-8201
R61	0758-0048
R62	0813-0011
R63	2100-0326
R64	2100-0326
R66	0764-0017
R67	0758-0042
R68	0758-0051
R69	0758-0003
R70	0683-3315
R71	0758-0050
R72	0760-0012
R75	0687-1001
R76	0687-1001
R101	0683-6205
R102	0763-0013
R103	2100-0328
R104	0757-0093
R105	0763-0010
R106	0760-0014
R107	0758-0052
R108	0758-0010
R109	0683-5615
R112	0758-0029
R113	0763-0009
R114	0758-0052
R115	0683-4705
R116	0761-0010
R117	0758-0041
R118	0683-5615
R120	0683-3605
R121	0758-0024
R122	2100-0182
R123	0761-0009
R124	0758-0028
R125	0758-0028
R127	0684-5611
R128	2100-0108
R129	0758-0052
R130	0683-5615
R131	0684-1021
R132	0687-1001
R133	0683-6205
R136	0760-0014
R137	0757-0093
R138	0766-0033
R139	0763-0012
R140	2100-0341
R141	2100-0327

Ckt Ref.	Stock No.
R142	0758-0003
R143	0761-0015
R144	2100-0330
R145	0758-0052
R146	0758-0010
R147	0683-5615
R150	0758-0029
R151	0758-0052
R152	0683-5615
R153	0683-3605
R156	0683-6205
R157	0757-0087
R158	0757-0092
R159	0757-0095
R160	2100-0340
R161	2100-0356
R162	0764-0016
R163	0761-0005
R164	2100-0328
R165	0763-0009
R166	0758-0015
R169	0687-2241
R170	0758-0005
R171	0683-5615
R172	0758-0052
R173	0758-0029
R174	0683-5615
R177	0684-1021
R178	0684-1021
R179	0687-4701
R181	0758-0019
R182	0758-0028
R183	0683-4705
R184	0683-4705
R185	2100-0329
R186	0767-0023
R187	0727-0001
R188	0727-0001
R189	0758-0024
R190	0683-4705
R191	0683-4705
R194	0767-0023
R195	2100-0329
R196	0699-0001
R197	0699-0001
R198	0683-3615
R199	0683-3615
R200	0758-0019
R203	0730-0161
R204	0730-0161
R211	0757-0086
R212	0757-0086
R301	0687-3331
R306	0758-0048
R307	0684-6811
R308	0761-0011
R309	0684-1831
R310	0684-1231
R311	0684-1011
R312	0757-0088
R313	2100-0128
R314	0730-0020
R315	0758-0032
R321	0757-0077
R322	2100-0151
R323	0760-0017
R324	0758-0006
R325	0758-0007
R326	0758-0010
R327	0764-0015
R328	0758-0070
R329	0684-3901
R330	0758-0032
R335	0761-0014
R336	0758-0048
R337	0761-0009
R338	0761-0009
R339	0684-6811
R340	0758-0010
R341	0684-1231
R342	0684-1011
R343	0730-0020
R344	2100-0128
R345	0757-0088
R346	0684-3901
R351	0760-0016
R352	2100-0151
R353	0757-0077
R354	0758-0007
R355	0758-0018
R356	0758-0037
R357	0771-0001
R358	0758-0070
S1	3101-0011
S2	3100-0328
S3	3101-0014
S4	3101-0011
S101	3101-0011
S201	3100-0327
S301	3101-0036
S302	3101-0033
T1	215A-60C
T101	215A-60E
T102	215A-60D
T103	215A-60D
T104	215A-60A
T105	215A-60D
T301	9100-0163
V1	1921-0013
V2	1921-0013
W301	8120-0078
XF301	1400-0084
XV1	1200-0086
XV2	1200-0086

WARRANTY

All our products are warranted against defects in materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.

For assistance of any kind, including help with instruments under warranty, contact your authorized hp Sales Representative for instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service data or shipping instructions will be promptly sent to you. There will be no charge for repair of instruments under warranty, *except transportation charges*. Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

SHIPPING

On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

GENERAL

Your authorized hp Sales Representative is ready to assist you in any situation, and you are always welcome to get directly in touch with Hewlett-Packard service departments:

CUSTOMER SERVICE

Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California, U.S.A.
Telephone: (415) 326-1755
TWX No. PAL AL 117-U
Cable: "HEWPACK"

OR (In Western Europe)

Hewlett-Packard S.A.
54-54bis Route Des Acacias
Geneva, Switzerland
Telephone: (022) 42. 81. 50
Cable: "HEWPACKSA"