INSTRUCTIONS

GEI-90845A
Supersedes GEI-90845

REGULATOR-AMPLIFIER TRAY FOR SILCOMATIC POWER CONVERSION EQUIPMENT

SWITCHGEAR DEPARTMENT
GENERAL ELECTRIC
PHILADELPHIA, PA.

CONTENTS

REGULATOR-AMPLIFIER TRAY FOR SILCOMATIC POWER CONVERSION EQUIPMENT

INTRODUCTION

Before installing or attempting to use this equipment, read these instructions thoroughly and carefully.

GENERAL DESCRIPTION

The regulator-amplifier tray is used to amplify small d-c signals and produce a d-c control signal to control one or two gate-pulse generator trays of silicon controlled rectifier (SCR) power conversion equipment. Other functions, such as bias and suppression circuits, are included on some trays.

The equipment in which these trays are used is generally identified as SILCOMATIC power conversion equipment.

RATING

Input Power: 115-volts, single-phase, at frequency specified in over-all equipment instructions and drawings.

Control Input: 0 to ±0.6 milliamperes d-c, or a part of this range as specified in over-all equipment instructions and drawings.

Control Input Impedance: Consists of resistance of series resistors in the tray. (The elementary diagram for the over-all equipment shows series resistors.)

Gain: 66 volts per milliampere.

Output: 0 to ±40 volts d-c at 40 milliamperes. (Will drive two gate-pulse generator and amplifier trays as used in SILCOMATIC equipment.)

Ambient: 0 to 55 degrees C.

RECEIVING, HANDLING AND STORAGE

Immediately upon receipt of the tray, examine it for any damage or loss sustained in transit. If injury or rough handling is evident, file a damage claim at once with the transportation company and notify the nearest General Electric Sales Office.

Unpack the tray as soon as possible after being received. Use care in unpacking to avoid damage. Be sure no loose parts are missing or left in the packing material. Carefully remove with vacuum or dry air any dirt or particles of packing material that may have accumulated on or in the tray.

If the tray is not installed at once, store it in a clean, dry place. Covering the tray will prevent accumulation of dust. Do not use moisture-absorbing covering material.

INSTALLATION

Regulator-amplifier trays either slide into position on metal tracks or are bolted in place. Ventilation space is required above and below the tray around the holes in the bottom (and/or side) and cover.

Connections are made either by special plugs or on terminal boards. The control input and output connections should be twisted shielded pairs. The average signal level is low so that, if other wires are used, electrical pick-up will be a problem. The a-c input and other control wires may be ordinary wiring.

Polarities of control input and output connections must be as shown on the equipment over-all elementary diagrams.

BASIC FUNCTIONS

The main function of the regulator-amplifier circuit is to amplify a small input signal which provides a control-signal voltage to one or two gate-pulse generator circuits. The input signal usually is the error signal developed between the reference and feedback of a regulator, but may be a control signal which is not large enough to drive the gate-pulse generator directly.

Auxiliary circuits (not included on all regulator amplifier trays) are a bias circuit and a suppression circuit.

The bias circuit is used in equipment for reversing drive applications, where silicon-controlled rectifier (SCR) trays are connected back-to-back (positive of one to negative of the other). The bias circuit turns off whichever (SCR) trays are not required to carry current at any given time during operation.

The suppression circuit is used in equipment where overcurrent stops SCR firing, thus shutting off the SCR equipment.

OPERATION

The following sections describe the operation of the various circuits. The figures show the circuits by sections, each figure showing only the circuitry necessary for understanding the particular section being described. For a single, complete diagram and for the location of devices within the tray, see the over-all drawings supplied with the equipment.

D-C POWER SUPPLY

The d-c power supply for the regulator-amplifier uses a full-wave rectifier and L-C filter to supply d-c voltage to zener diodes (which have a constant voltage drop when conducting) to establish d-c bus voltages. Series resistors limit the zener diode current.

Figure 1 shows the d-c power supply and the three d-c voltages (-11 v, -20 v, and -68 v) with respect to zero reference voltage.

AMPLIFIER

GENERAL

The amplifier is a conventional transistor amplifier with two balanced sections to minimize drift caused by line voltage variations and ambient temperature changes. With zero input, the amplifier is in a quiescent state, each section developing the same voltage. Because the net output is the difference between the voltages of the two sections, the net output is zero.

Signal voltage of one polarity increases the output voltage of one section and decreases that of the other section, giving a net output in one direction. Reversing the signal voltage unbalances the section voltages to produce a net output in the other direction.

An internal feedback loop is used for each amplifier section to obtain constant gain and stabilization.

(See Fig. 3 and the following sections for more complete details.)

TRANSISTOR OPERATION

The high forward gain of the amplifier is attained by several stages of transistor circuits. A transistor has the property of carrying high collector-emitter current relative to low base-emitter current, so several stages can give a very high amplification.

Two types of transistors are used; these are shown in Fig. 2.

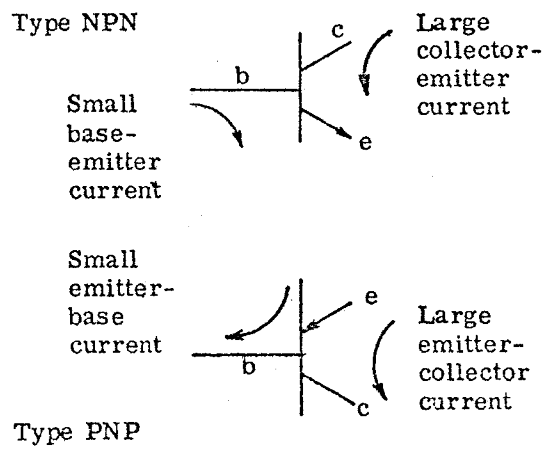


Fig. 2. Types of transistors

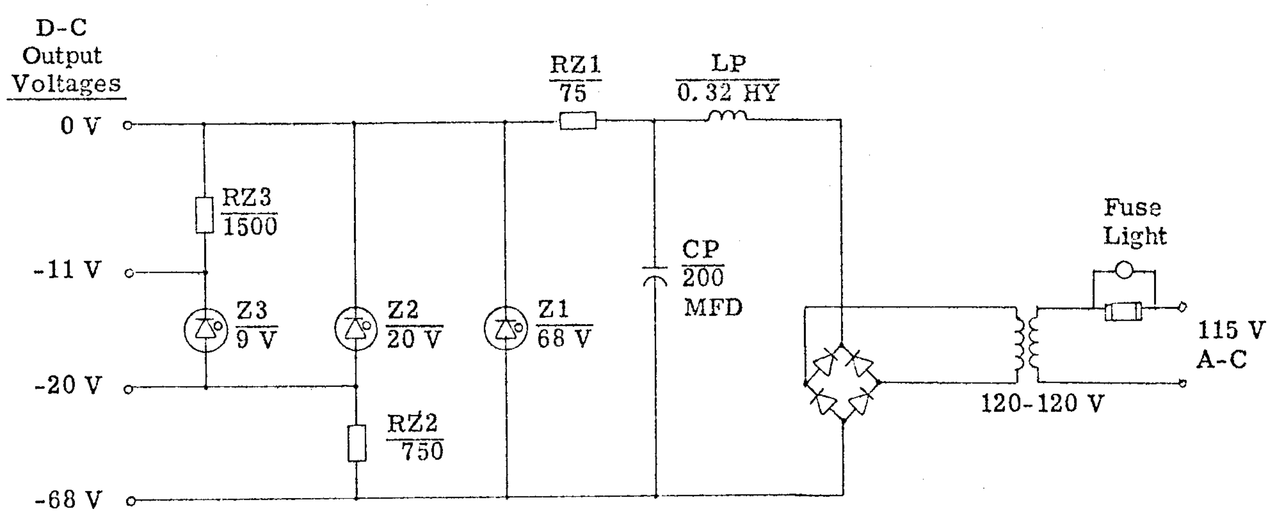
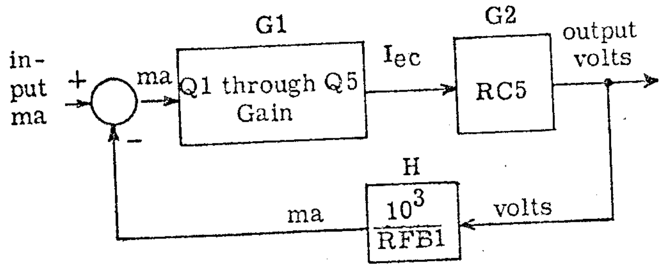


Fig. 1. D-c power supply for amplifier



$$\text{closed loop gain} = \frac{\text{output volts}}{\text{input MA's}} = \frac{G_1G_2}{1+G_1G_2H} = \frac{1}{H} = \frac{V}{MA}$$

$$H = \frac{10^3}{33.2 \times 10^3} = \frac{1}{33.2}\frac{MA}{V}$$

total closed loop gain = (2) (33.2) = 66.4 volts/MA

Fig. 4. Amplifier block diagram (one-half)

voltage. A positive signal increases Q1 (b-e) and (c-e) current, and RC5 voltage is raised as described in the preceding section (see Table II). Increasing RC5 voltage tends to decrease the current from Q1 emitter to RC5 (through RFB1), thus tending to lower RC5 voltage. This action balances out to determine an output voltage always at a fixed ratio to input voltage.

Expressed in terms of regulators, the amplifier has a very high forward gain, G, which varies with base current and with ambient temperature. It also has a fixed, accurate feedback gain, H, which does not change. Over-all gain is expressed by G/(1 + GH), which, because GH is much larger than 1, reduces to G/GH, or 1/H. Thus, changes in G have almost no effect on gain.

The size of RFB1 and RFB6 should always be 33.2K. However, the stabilizing R-C circuit in parallel with RFB1 and RFB6 will vary among amplifiers. See the drawings supplied with the equipment for actual component values.

CIRCUIT ACCESSORIES

Series input resistors RS1 and RS2 (on Fig. 3) determine gain in terms of volts per volt. The volts per ma gain (see section above) divided by series input resistance in kilohms gives volts per volt gain. For the quantity and resistance of the series resistors see the drawings supplied with the equipment. (Series resistors should always be used in pairs -- one of each pair in each input leg -- to maintain balance.)

Diodes D6 and D7 are connected across the input as shown to prevent overdriving the amplifier.

BIAS CIRCUIT

For reversing power supplies where the positive end of one rectifier connects to negative end of the other (and vice versa), some means is required to turn off one rectifier when the other is carrying current. The two rectifiers must also be "phased apart" under all conditions to avoid excessive circulating currents between them.

The bias circuit introduces constant voltages in series with the amplifier output to each rectifier gate-pulse generator circuit. These voltages control phasing as shown in Fig. 5. (Point A positive turns Rectifier #1 on, point A negative turns #1 off. Point D positive turns #2 on, point D negative turns #2 off.) Figure 6 shows the filtered d-c power supplies used as bias voltage sources.

FLIP-FLOP CIRCUIT

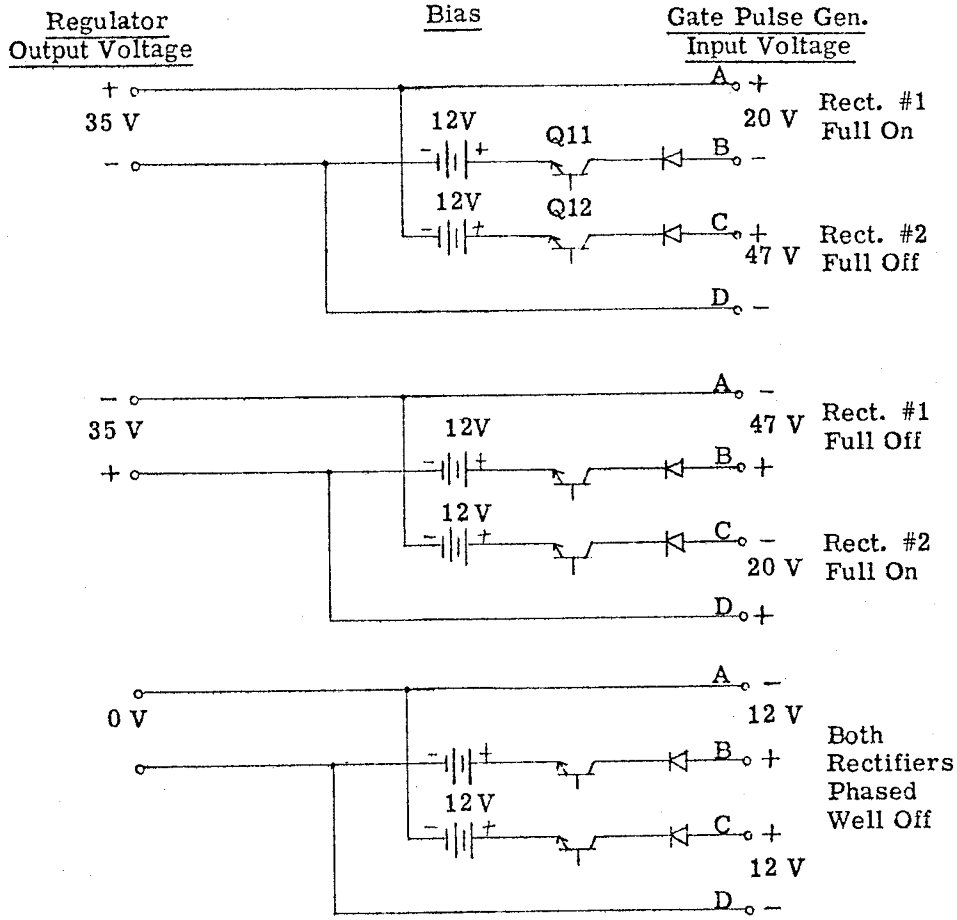
The flip-flop circuit as shown in Fig. 7 functions to prevent the Forward gate-pulse generator from being phased on while d-c current is still being supplied by the Reverse power supply, and vice-versa. Transistor Q11 serves as an "open-close" switch in the regulator output to the Forward gate-pulse generator. When turned off it has a very high impedance between collector and emitter, and acts like an open circuit. Since current flow into the Forward gate-pulse generator then is essentially zero, no gating pulses are generated and the Forward rectifier is phased full-off.

Under normal operating conditions and with less than one percent current being supplied from the Reverse rectifier, transistor Q11 is turned on by bias current supplied through resistor RS4, diode D13, and resistor RF2. In the turned-on state, the transistor offers little impedance to current flow from collector to emitter, and the Forward gate-pulse generator provides gating pulses in response to the level of d-c signal output from the regulator.

At any time when approximately one percent or more current is being supplied through the three CT's located in the a-c feed to the Reverse rectifier, there is sufficient signal voltage across resistor RF1 to overcome the bias and turn-off Q11, thus phasing the Forward rectifier full off. In like manner transistor Q12 controls the output signal for the Reverse rectifier.

EXCITATION SUPPRESSION CIRCUITS

The excitation-suppression circuits are used to turn the flip-flop transistors off, usually in response to an overcurrent or other fault signal. Opening the amplifier output shuts off the SCR's and turns off the rectifier. Contacts are also available to trip breakers and operate alarms when shut-off occurs.



Point A positive turns Rectifier #1 on (phase advanced)
Point D positive turns Rectifier #2 on (phase advanced)
Point A negative turns Rectifier #1 off (phase retarded)
Point D negative turns Rectifier #2 off (phase retarded)

(Note - Receptacle point letters are typical. For actual designations, see drawing supplied with equipment.)

Fig. 5. Bias circuit operation

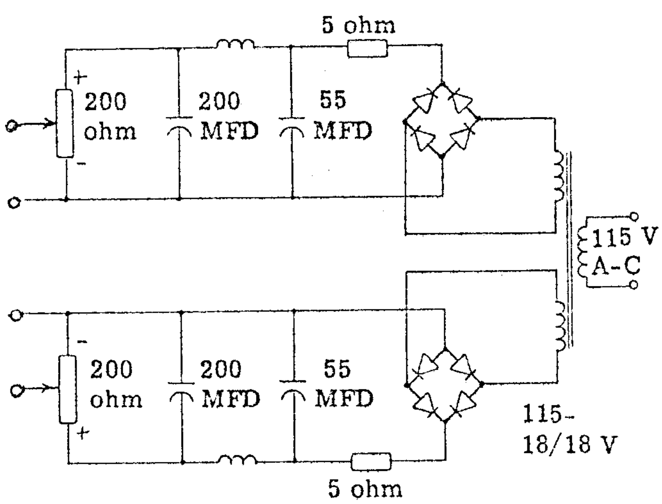


Fig. 6. Bias circuit for regulator amplifier tray

Figure 7 shows the suppression circuit with a typical external circuit -- current transformers with loading resistors. The CT current develops a voltage across the loading resistors which is rectified and (adjustable by RHS) applied to the zener diode ZS10. When the CT current exceeds a predetermined amount, enough voltage is developed to break down ZS10, which conducts current to the SCR gate and fires the SCR. Current flow in the SCR circuit picks up the 95 relay and biases the flip-flop transistors off, thus phasing both rectifiers full off.

Once the suppression SCR has been fired, it will continue to conduct current until the "Reset" pushbutton PB is depressed.

SIGNAL AMPLIFICATION

At zero input, the amplifier is in its quiescent state with output transistors Q5 and Q10 each carrying equal currents (emitter to collector) of about 100 ma. These currents develop equal voltages (about 35 volts) across resistors RC5 and RC10, and produce a net voltage of zero at the output terminals. Table I summarizes the maximum and minimum parameters for all the amplifier stages.

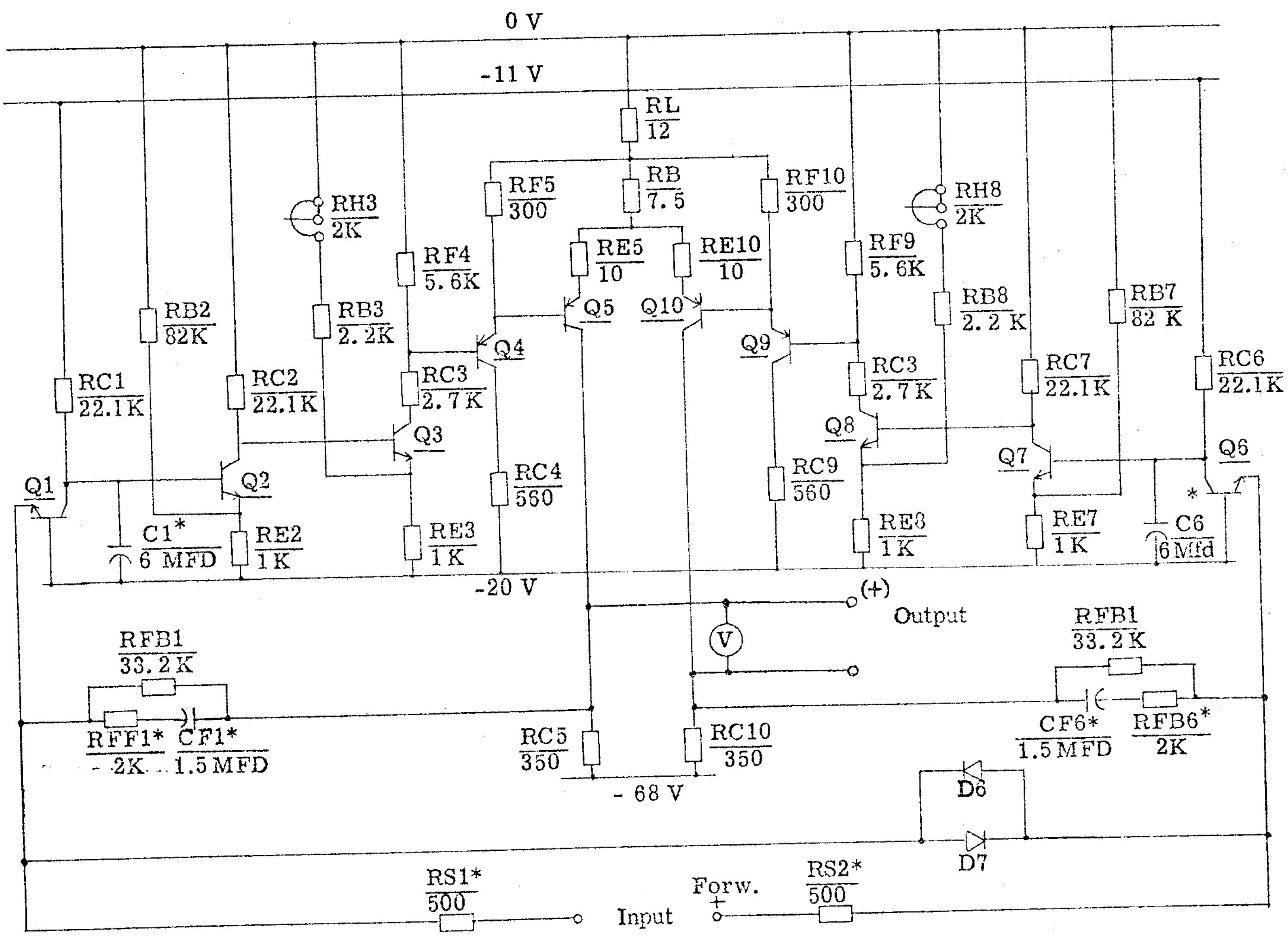
Assume that input voltage is applied having the polarity shown in Fig. 3. (Plus marks show relative polarity of output and input; if input polarity is reversed, output also reverses.) Emitter voltage of Q1 is reduced and that of Q6 raised; Q1 base-emitter (b-e) current increases, increasing its collector-emitter (c-e) current; Q6 (b-e) current decreases, decreasing its (c-e) current.

This process continues through the circuit. Example changes are tabulated in Table II for both positive and negative signals.

The amplitude of the input signal determines the amplitude of Q1 and Q6 (c-e) currents, and, through the other transistors, the amplitude of Q5 and Q10 (e-c) currents. The Q5 and Q10 (e-c) currents determine the relative voltages across resistors RC5 and RC10, thus determining amplitude as well as polarity of the output.

INTERNAL FEEDBACK

Resistors RFB1 and RFB6 are connected from output resistors RC5 and RC10 to Q1 and Q6 emitters. These resistors serve as internal negative feedback to regulate the amplifier voltage and maintain a constant ratio between input signal and output



*Typical - For actual values see over-all drawing supplied with equipment.

Fig. 3. D-c amplifier circuits

TABLE I—AMPLIFIER STAGE PARAMETERS

CHARACTERISTIC	Q1, Q6	Q2, Q7	Q3, Q8	Q4, Q9	Q5, Q10
Quiescent collector current	375 microamp	580 microamp	800 microamp	12 milliamp	100 milliamp
Minimum current gain	0.971	13.4	13.4	13.5	15.5
Nominal current gain	0.980	15.5	15.5	16.5	20.0
Maximum current gain	0.989	17.8	17.8	19.0	25.5
Quiescent Vce	1.5 volts	6.0 volts	11.0 volts	9.0 volts	27.0 volts
Maximum Vce	2.0 volts	9.0 volts	20.0 volts	16.0 volts	50.0 volts

TABLE II—CHANGE OF TRANSISTOR OUTPUT WITH POSITIVE AND NEGATIVE SIGNALS

Polarity of Signal Voltage		Positive		Negative	
Transistors		Q1-Q5	Q6-Q10	Q1-Q5	Q6-Q10
Transistor current change:					
Q1 or Q6	b-e	more	less	less	more
Q1 or Q6	c-e	"	"	"	"
Q2 or Q7	b-e	less	more	more	less
Q2 or Q7	c-e	"	"	"	"
Q3 or Q8	b-e	more	less	less	more
Q3 or Q8	c-e	"	"	"	"
Q4 or Q9	e-b	more	less	less	more
Q4 or Q9	e-c	"	"	"	"
Q5 or Q10	e-b	more	less	less	more
Q5 or Q10	e-c	"	"	"	"
RC5 voltage		increases		decreases	
RC10 voltage		decreases		increases	
Net Output Voltage		positive		negative	

b = base, c = collector, e = emitter

(See Fig. 3 for circuit.)

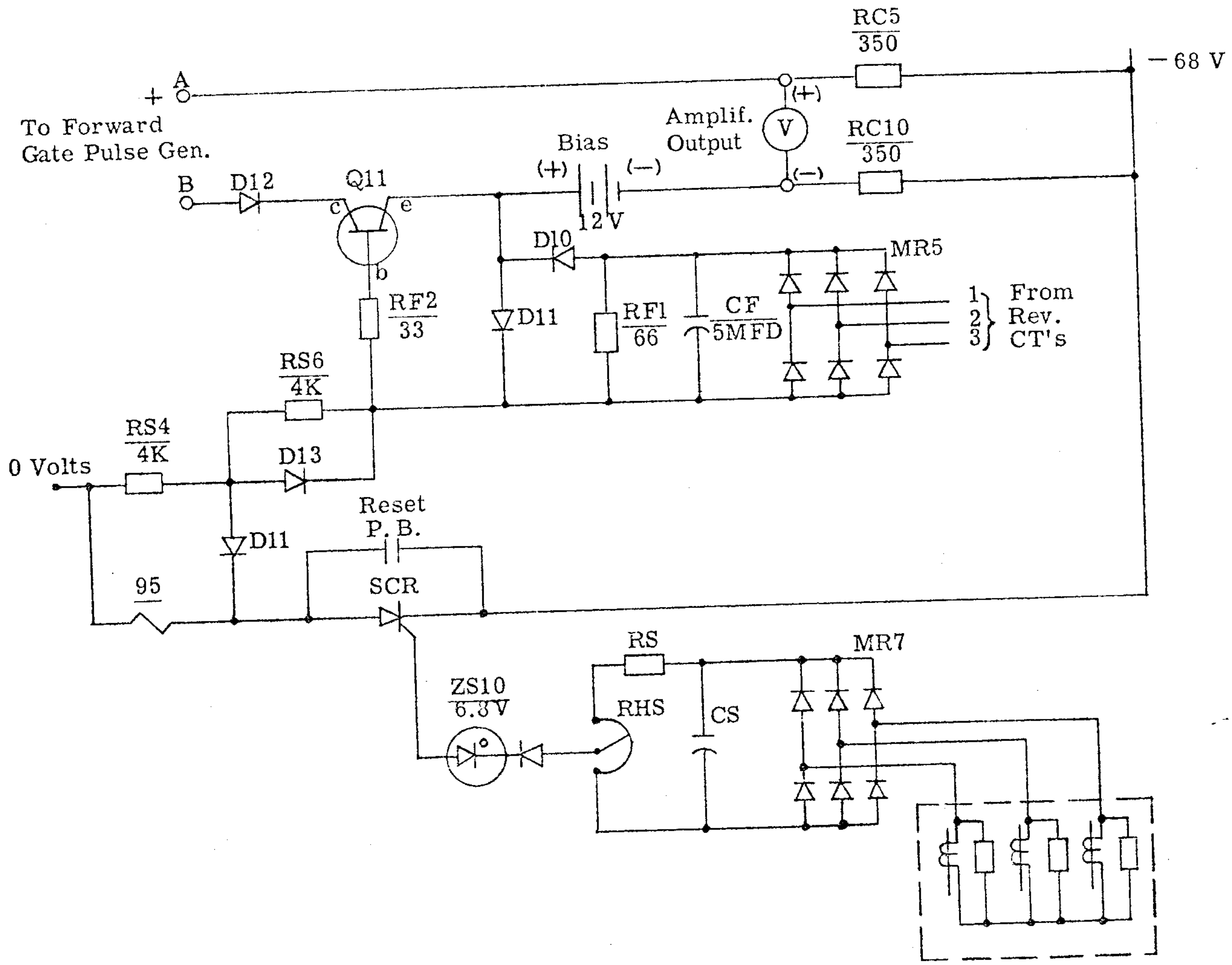


Fig. 7. Bias and suppression circuit with flip-flop

MAINTENANCE

Once installed, the regulator-amplifier tray should require little attention. Clean the tray of accumulated dust as required. Remove dust with a vacuum cleaner or carefully blow out with compressed air.

It is particularly important either to replace devices with those having the same catalog number or to substitute parts approved by the General Electric Company.

TROUBLE SHOOTING

NORMAL CONDITIONS

With 115 volts a-c applied, input signal terminals open, and a 1000 ohm, 10 w resistor across the amplifier output, the following voltages should be obtained, using a standard multi-meter (see Fig. 3).

1. -11 v, -20 v and -68 v bus voltages within ±5%

2. 35 v across RC5 and 35 v across RC10

3. Transistor collector to emitter voltages as tabulated in Table II.

4. Amplifier output voltage: less than 0.1 v.

5. Bias voltages: Approximately 12 v, both equal within ±5 percent. (Check drawings supplied with equipment to see if some other voltage is required.)

6. Input signal current versus amplifier output voltage should follow the curve of Fig. 8, with output voltage between 35 and 40 volts for input current of

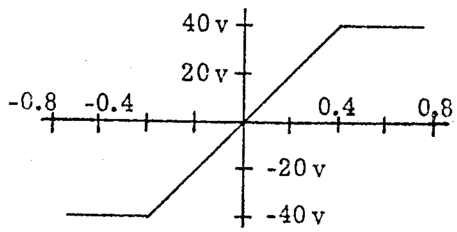


Fig. 8. Amplifier characteristic

0.6 ma in either direction. Saturation should occur above 40 volts.

MALFUNCTIONS

Output voltage with zero input may be caused by an open circuit or a faulty device. Check for normal voltages as described in the preceding section.

Varying output voltage with fixed input may be caused by a loose connection or an open internal feedback circuit.

SUPPRESSION ADJUSTMENT

If suppression must be readjusted, the following procedure should be followed:

1. Calculate the CT loading resistor voltage at which suppression is required from CT ratio, resistor ohms, and peak a-c current at which suppression is required.

2. Turn RHS (Fig. 7) to zero output position. Apply d-c voltage calculated in (1) to the voltage divider, and slowly turn RHS until the SCR fires. Relay #95 should pick up. A voltmeter across the SCR will indicate when the SCR fires by a considerable drop in voltage.

3. Remove the d-c battery voltage, and see that there is no change.

4. Operate the reset circuit to return circuits to their original condition.

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