VOLTAGE REGULATOR
(MULTI-LOOP CONTROLLER)

I. GENERAL DESCRIPTION

The multi-loop controller voltage regulator module provides the reference shaping networks used with C-56 basic regulators for motor armature Thyristor Power Supplies as described in IL 16-800-126. Three variations of the module design provide a fixed current limit, externally adjustable current limit or tapered current limit adjustment feature. Each module provides a droop adjustment or IR compensation feature and can be used in either regenerative (DUAL CONVERTER) or uni-direction (SINGLE CONVERTER) drive applications.

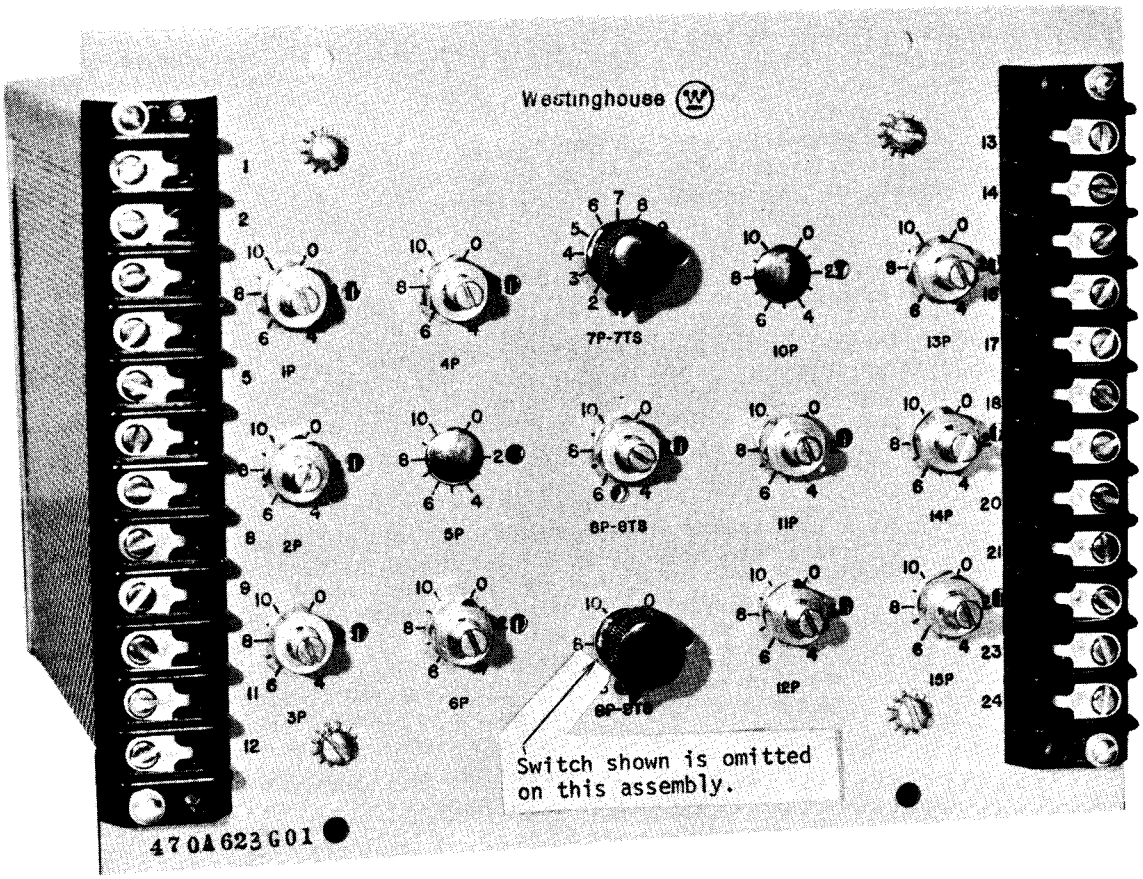

FIGURE #1

The module shown in Figure 1, contains P101A operational amplifiers (IL 16-800-24) their associated function boards, limiter circuit boards and sequencing relay boards extending from a 9" x 7" faceplate on which are mounted front accessible adjusting potentiometers, selector switches and screw type terminals to which all external connections are made.

II. SCOPE OF APPLICATION

The multi-loop controller voltage regulator can be used on all drive applications which use the C-56 basic regulator as motor armature supply.

The reference voltage representing rated output voltage of the C-56 basic regulator must be 10 volts or higher.

III. ELECTRICAL SPECIFICATIONS

Power Supply Requirements.

VOLTAGE: +24/0/-24 VDC

REGULATION: ± 1%

CURRENT: 190 mA

IV. DESCRIPTION OF OPERATION

The following description covers all the features available in the multi-loop voltage regulator module, it is recommended that the reader check the Regulator Systems Diagram and Regulator Signal Distribution Diagram of the customer's schematic for the features required for his application. The schematic diagram for fixed current limit applications is shown in Figure 2; the schematic for externally adjustable current limit applications is shown in Figure 3; the schematic for tapered current limit applications is shown in Figure 4.

The multi-loop voltage control consists of a current and voltage controller connected in series. The current controller output feeds directly into the inner voltage loop while the voltage controller output acts as an input to the current controller.

The current controller is a PI controller with a fixed lead in the current feedback. The lead of The PI controller is fixed and is necessary in order to cancel the delay associated with the inner voltage loop. The four inputs to the current controller, terminals #1, #2, #3 and #4, are as follows.

Terminal #1 is for the current feedback signal, and is composed of a lead of 25 ms and a small delay of 1 ms.

Terminal #2 is connected to terminal #20, the output of the voltage controller, and potentiometer 3P is used for current limit adjustment.

Terminal #3 is a spare input.

Terminal #4 is not used for this application.

For control of current zero, relay 1CR should be de-energized, thereby removing all inputs from the current controller except current feedback. Relay 2CR is an initial condition relay which will be picked up once the current loop has been closed and the thyristors energized. This is to prevent the output of the current amplifier from drifting from its zero position.

Dynamic adjustment of the current loop is by means of pot 2P and switch 7TS. Switch 7TS changes the values of resistances associated with pot setting 2P, and has the same effect on the integrating time constant as changing the capacitance in the feedback of the amplifier. Switch 7TS and pot 2P are used to change the crossover frequency of the current loop without changing the response of this loop.

The current controller has a symmetrical limiter using a single Zener Diode, ensuring that the limit in the positive and negative direction are very close to one another.

The voltage controller has basically a proportional response. Each input of the voltage controller has a time constant associated with it. In order to operate as a voltage controller, the input to the inverter amplifier terminal #13 and #14, is connected to the output of the current controller terminal #9. (For single drives, terminals #13 and #14 should be jumpered. For duplex drives, the output from the two current controllers should be applied to terminals #13 and #14).

Three inputs to the voltage reference controller (terminals #15, #16 and #17) are brought to the terminal block, the fourth is internally connected to the inverter amplifier and is used as the voltage feedback signal. Terminal #15 is where the voltage reference is applied with potentiometer 14P for adjustment of magnitude. Terminal #16 is for IR compensation with pot 15P for adjustment, and terminal #17 is a spare input. Dynamic adjustment of the voltage loop is by means of potentiometer 12P (for voltage loop crossover frequency) pot 13P (droop adjustment) and pot 15P (IR compensation).

For drives using the Tapered Current Limit feature, the bus voltage signal ($+V_b$) is connected to terminal #5. When using the Externally Adjustable Current Limit feature, the required control voltages are connected to terminal #5 and #6.

V. START-UP PROCEDURE

The following assumes the basic regulator is working.

1.0 Balance of Amplifier

1.1 Disconnect leads from terminals #1, #2, #3, #4, #13, #14, #15, #16 and #17.

1.2 Turn pots 2P, 3P, 4P, 12P, 13P, 14P, 15P and switch 7TS full CCW.

1.3 Check AC power indicating light on.

1.4 Check PSN & PSP indicating light on.

1.5 Connect terminals #13, #14, #15, #16, #17 to PSC.

1.6 Adjust 8P such that the voltage between terminal #18 and PSC is zero volts.

1.7 Energize relay 3CR and adjust pot 11P for zero output.

1.8 De-energize relay 3CR.

1.9 Remove wire connecting #13, #14, #15, #16 and #17 to PSC.

2.0 Check Basic Regulator

2.1 Disconnect input to inner voltage loop terminal #10 and connect variable voltage source in its place.

2 2 Apply power to thyristors and slowly increase reference so that machine turns over.

2.3 Connect one terminal of Simpson multimeter to PSC with the other lead check polarity of current feedback signal removed from terminal #7 and reference signal feeding inner voltage loop removed from terminal #10. These must be of the same polarity.

2.4 De-energize thyristor power supply. Reconnect current feedback to terminal #1 and input to inner voltage controller to terminal #10.

CAUTION: The following tests are carried out without field on the motor, take care to continually monitor the speed of the drive to prevent if from taking off. Also, do not linger while passing armature current through stalled motor. Return armature current to zero and allow adequate cooling time if necessary.

3.0 Adjustment of Inner Current Loop

3.1 Remove motor field supply.

3.2 Energize thyristors and relay 2CR.

3.3 Adjust pot 1P for zero current.

3.4 Energize relay 1CR.

3.5 Apply +10 volt signal into terminal #2.

3.6 Slowly increase 3P CW till rated current is flowing in armature circuit.

3.7 Apply step reference to terminal #2 and record current responses.

3.8 Turn 7TS and 2P CW till current response starts to oscillate then turn 7TS one position CCW.

3.9 The current loop is now dynamically adjusted.

4.0 Adjustment of Gate Pulse Suppression

For gate pulse suppression adjustment, do not circulate armature current for more than 25 seconds, allowing at least two minutes for cooling after current is reduced to zero.

4.1 On current sensor (CS) board of basic regulator turn gate pulse suppression pots 4P, 5P full CW.

4.2 Apply +15 volts into terminal #2 and increase pot 3P CW until 115% current limit is reached.

4.3 On current sensor (CS) board of basic regulator turn gate pulse suppression pot 4P (forward converter) slowly CCW until GPG suppresses pulses.

4.4 Turn 3P full CCW.

For dual converter drives.

4.5 Apply (-) 15 volt signal to terminal #2, and increase pot 3P CW to 115% current limit.

4.6 On current sensor (CS) board of basic regulator turn gate pulse suppression pot 5P (reverse converter) slowly CCW until GPG suppresses pulses.

4.7 Turn 3P full CCW.

4.8 Remove reference from terminal #2.

4.9 Reconnect voltage controller output to terminal #2.

5.0 Current Limit Adjustment

5.1 Fixed current limit

5.1.1 Apply -10 volts in to terminal #15

5.1.2 Turn 14P full CW.

5.1.3 Energize relay 3CR and check output terminal #20 for approximately +10 volts.

5.1.4 Turn 3P slowly CW till current limit is reached.

For dual converter drives.

5.1.5 Reverse polarity of reference to termina #15.

5.1.6 Turn 6P slowly CW till current limit (reg nerative) is obtained.
NOTE. Asymmetrical dual converters have unequal current limit values.

5.1.7 Turn 14P full CCW.

5.2 Externally Adjusted Current Limit (using P811 Limiter)

The positive and negative limits of the Voltage Reference Controller TOA are separately controlled by positive (E+) and negative (E-) control voltages connected to terminals #5 and #6. These control voltages can be obtained from potentiometers, amplifier outputs or any other voltage source having a source impedance of 10K ohms or less.

5.2.1 Apply a positive signal to terminal #5 whose magnitude is to represent stall current limit.

5 2.2 Apply -24 volt reference to terminal #17

5.2.3 Energize relay 3CR.

5.2.4 Check the output terminal #19 with Simpson, the voltage should be equal to the voltage applied to terminal #5.

5.2.5 Adjust pot 3P CW to obtain desired current limit.

For dual converter drives.

5.2.6 Reverse the polarity of signal into terminal #17.

5.2.7 Slowly increase the negative signal applied to terminal #6 until desired current limit is obtained.

5.3 Tapered Current Limit (using P810 Limiter)

The symmetrical positive and negative limits of the Voltage Reference Controller TOA are controlled by the absolute value of a positive or negative control voltage connected to terminal #5.

5.3.1 With motor field disconnected and armature loop closed, turn pot 10P full CCW.

5.3.2 Energize relay 3CR.

5.3.3 Apply (-)ive reference to terminal #15 and turn 14P full CW.

5.3.4 Check the output of the voltage reference controller terminal #19. The voltage should be limited to approximately +10 volts.

5.3.5 Slowly adjust pot 3P CW until current limit is reached.

5.3.6 Turn pot 14P full CCW.

5.3.7 Apply 10 volt signal to terminal 5 and turn 14P CW.

5.3.8 Adjust pot 10P (P810 Limiter) CW until current limit is obtained.

5.3.9 Remove signal feeding into terminal #5.

For asymmetrical dual converters.

5.3.10 Reverse polarity of signal feeding into terminal #15.

5.3.11 Slowly adjust 6P CW until current limit (regenerative) is obtained.

5.3.12 Turn pot 14P full CCW.

6.0 Droop Adjustment

6.1 With motor field disconnected and armature loop closed, pot 13P full CCW.

6.2 Energize relay 3CR.

6.3 Apply (-)ive reference to terminal #15 and slowly turn pot 14P CW until armature current is at its rated value.

6.4 Measure bus voltage V_{BM} and turn 14P full CCW.

6.5 Calculate $D = \frac{V_{BM}}{V_R}$

6.6 Calculate $I_X = \frac{D}{(PI_{R/\%})} I_R.$

where D = % natural droop

PI_R = % droop desired as percentage of top speed at rated load.

6.7 Slowly turn pot 14P CW until rated current obtained, then turn pot 13P CW to reduce armature current to I_X.

7.0 IR Compensation Adjustment

7.1 With motor field disconnected and armature loop closed, energize relay 3CR.

7.2 Reverse polarity of signal feeding into terminal #16.

7.3 Apply (-)ive reference to terminal #15 and slowly turn 14P CW until rated current is obtained.

7.4 Adjust pot 15P CW until armature current is reduced to 50% for 100% IR compensation. Take correspondingly less pot setting for lower percentage IR compensation.

7.5 Reverse polarity of signal feeding into terminal #16.

8.0 Adjustment of Dynamics of Voltage Loop

8.1 De-energize thyristor power supply.

8.2 Reconnect motor field, energize relay 3CR and apply thyristor power.

8.3 Apply (-)ive reference to terminal #15 and slowly turn 14P CW until 5% voltage is reached.

8.4 Apply step reference to terminal #15 and record response of terminal #9.

8.5 For faster response adjust 13P CW. Ensure drive does not go into current limit for this adjustment.

9.0 Reference Calibration

9.1 Apply reference voltage to terminal 15 and turn 14P till rated voltage is reached.

9.2 Remove reference.

THE DRIVE IS NOW BASICALLY ADJUSTED.

VI. SERVICE

Using the procedure outlined in Section V, any problem can be isolated to either a component on a function board or a faulty A101A transistorized operational amplifier. Our component board designs, utilizing stand-off terminals, facilitate the replacement of components using the proper sized (wattage) soldering iron. However, proper servicing of the A101A TOA requires instruments and techniques particular to transistorized, low-noise level circuits. Customers without the proper facilities are advised to return the defective unit to:

Westinghouse Electric Corporation
Industrial Systems Division
P. O. Box 225
Buffalo, New York 14240

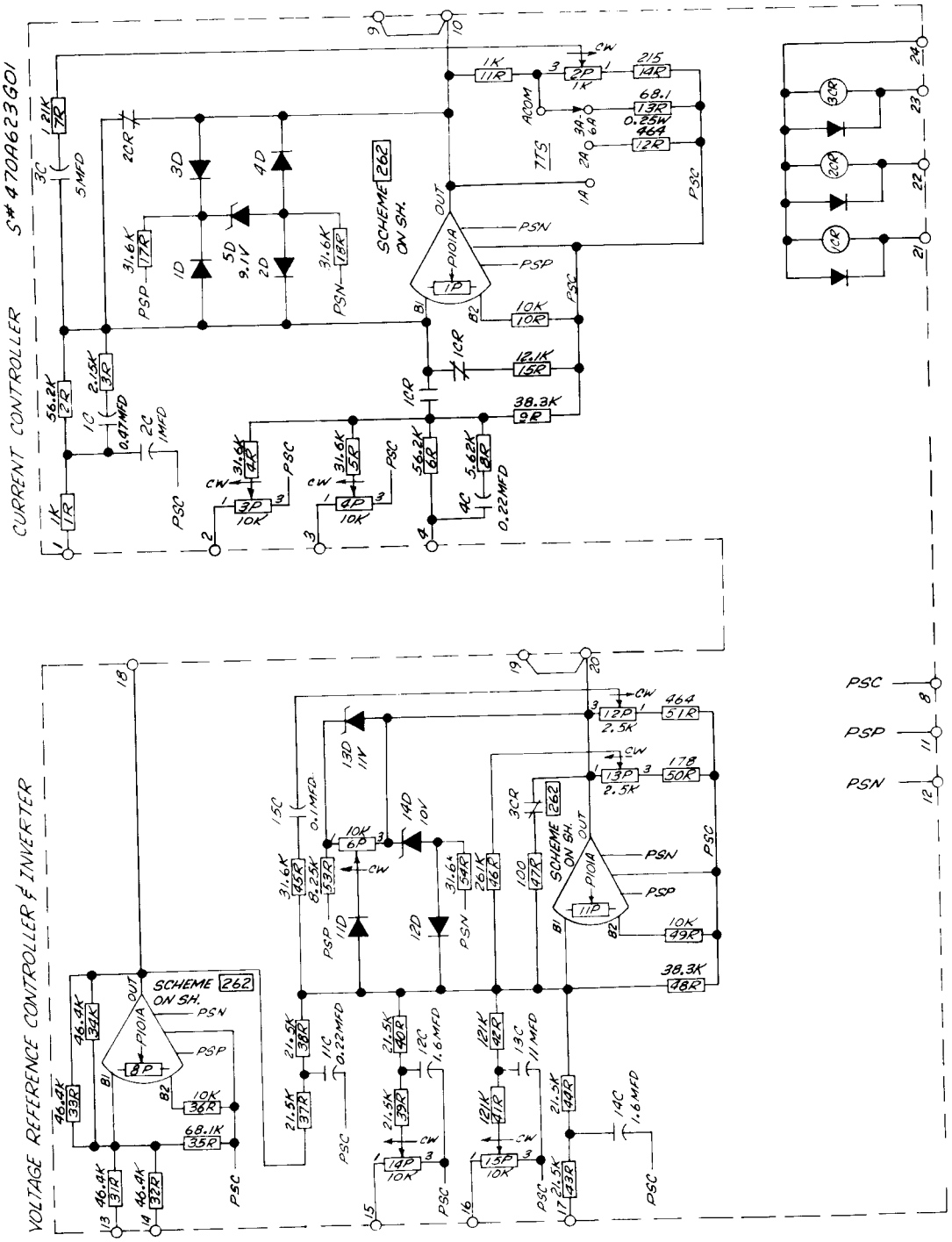

FIGURE #2

VOLTAGE REGULATOR
FIXED CURRENT LIMIT

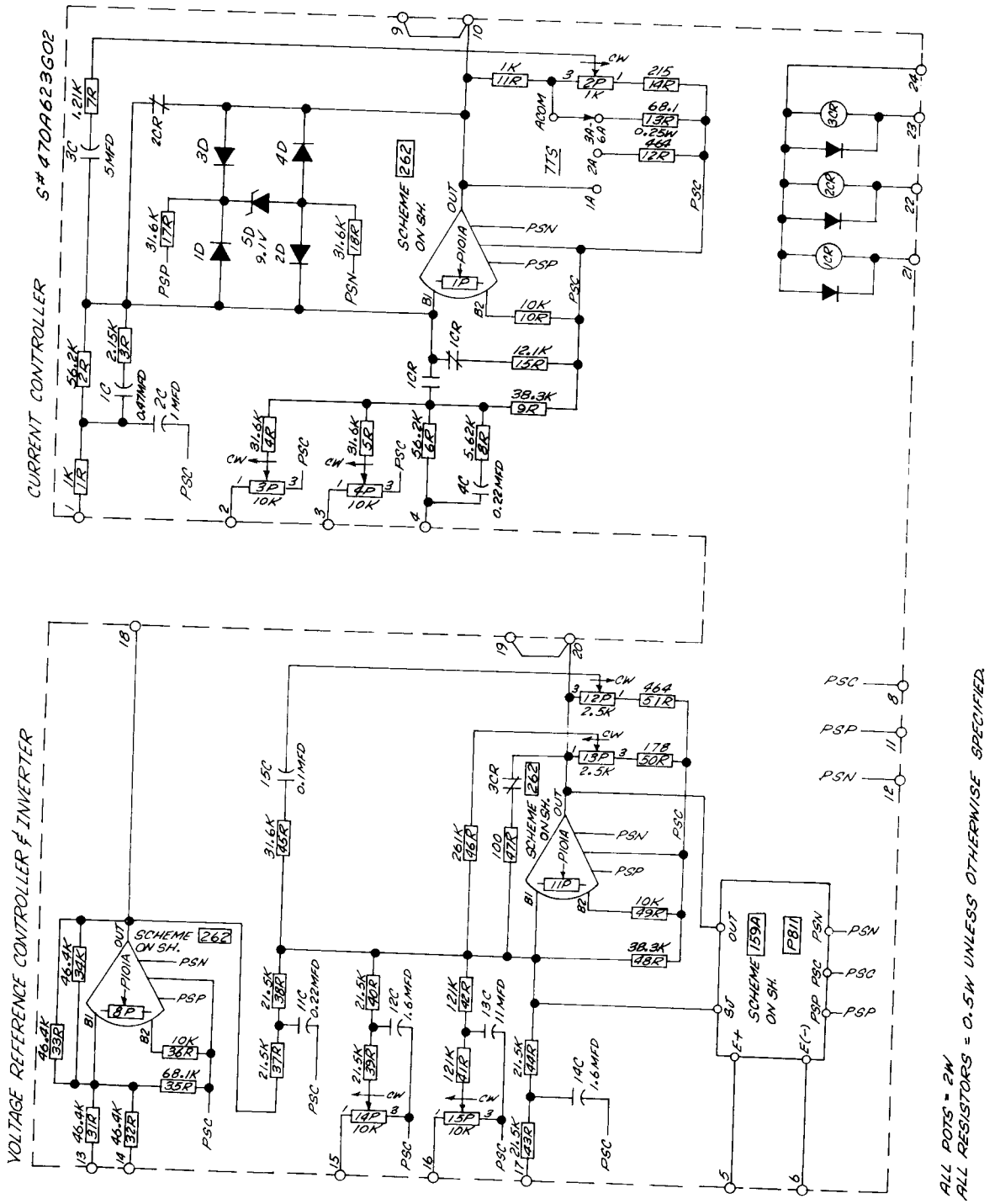

FIGURE #3

VOLTAGE REGULATOR
EXTERNALLY ADJUSTED CURRENT LIMIT

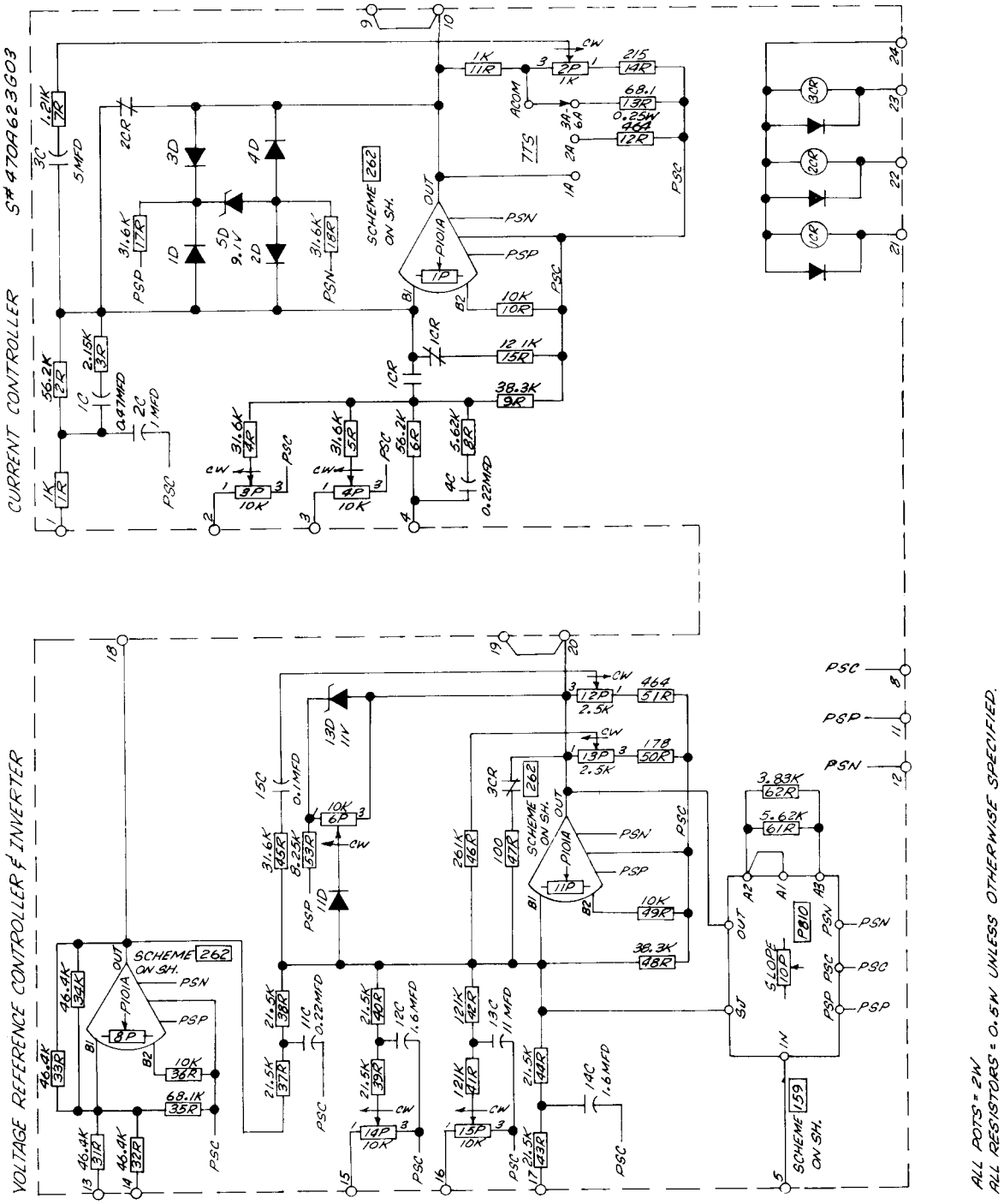

FIGURE #4

VOLTAGE REGULATOR
TAPERED CURRENT LIMIT