Instruction Manual

Installation
Operation
Maintenance

Voltage Regulator
KCR 560
50/60 Hertz

Publication
INSR-23-71A (May 1974)

KATO ENGINEERING™

Kato Engineering, Inc. | P.O. Box 8447 | Mankato, MN USA 56002-8447 | Tel: 507-625-4011
KatoEngineering@mail.nidec.com | www.KatoEngineering.com | Fax: 507-345-2798

This instruction manual includes information pertinent to operation and maintenance of Kato Engineering Company Model KCR 560 Voltage Regulators.

Copy the following information from the data plates attached to the voltage regulator and generator set.

Voltage Regulator System Model No. KCR 560 ______________________

Voltage Regulator Part Number ________________________

Generator Serial No. ___________________ Model _______________ Type ___________

The following precaution is repeated from the text.

CAUTION

DANGEROUS VOLTAGES ARE PRESENT IN THIS EQUIPMENT WHEN UNIT IS OPERATING. CONTACT WITH THESE VOLTAGES COULD RESULT IN SERIOUS ELECTRICAL SHOCK OR ELECTROCUTION. BE EXTREMELY CAREFUL TO AVOID CONTACT WITH LIVE CONDUCTORS WHEN REPAIRING UNIT OR MAKING ADJUSTMENTS.

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LIST OF ILLUSTRATIONS

1.1 GENERAL

1.1.1 The KCR560 voltage regulator consists of transistors, silicon diodes, zener diodes, silicon controlled rectifiers, resistors, capacitors and transformers. The regulators are not subject to wear from moving parts and are relatively unaffected by humidity, temperature, vibration or shock.

1.1.2 This unit regulates the generator voltage by controlling the current it supplies to the generator or the exciter field. The regulator can be used on any generator system within its rating. This includes rotary exciters or directly into the generator field. (See Table 1-1).

TABLE 1-1 LEADING PARTICULARS

Manufacturer	Kato Engineering Company
Model Number	KCR560 plus designator letters for requested options and accessories (see page 1-2)
Electrical Specifications	
Frequency	For 50 to 70 HZ Generators
Minimum Field Resistance	9 Ohm Minimum
Output: Continuous	65 VDC Full Load, 7 Amps
1 Minute Forcing	100 VDC, 10 Amps
Sensing	120/208/240/416/480 VAC, 50 to 70 HZ. Single Phase Standard, 3 Phase Sensing, volts-per-cycle sensing and volts-per-cycle underfrequency limit, 600 VAC, dc sensing and tachometer sensing optional.
Power	Single Phase 120 VAC, 50 to 70 HZ

NOTE: IF CORRECT VOLTAGE IS NOT AVAILABLE FOR POWER INPUT, A SUITABLE POWER TRANSFORMER MUST BE SELECTED

Regulation	± ½% No Load to Full Load Steady State
Response	Approximately 1 cycle
Voltage Adjust Range	± 10% of Nominal Voltage
Operating Temperature Range	0 to 50 degrees C., Standard Drift ± 1%. Extended temperature range available
Parallel Compensation	Available as optional feature
(Terminals CT1, CT2)	5 Amps at 25 VA, Droop Adj. to 4%
Field Flashing (See paragraph 2.2.1 a. and b. pgs. 2-5 and 2-6)	Flashing Relay for flashing from generator residule included. External flashing module optional
RFI Suppression	Available as optional feature

1) Standard Commercial: Includes RFI filter for conducted RFI suppression
2) Radiated and Conducted Suppression: Built to meet Mil Standard 461, Mil-I-26600, Mil-I-16910C, Mil-G-55301, Mil-6181D. Mil Standard 826. Includes RFI filter, regulator cover (option F) and when necessary, RFI ground and isolation transformer (option G).

NOTE: RFI will meet specification given in purchase order.

Dimensions & Weight
Dimensions: 11½" long, 8 3/8" wide, 5" high
Weight: Approximately 20 lbs.

Finish:	Heavy cadmium plating on chassis and cover. Plating also serves as electrical conducting shield to radio interference.

1.2 OPTIONAL FEATURES AND ACCESSORIES

1.2.1 The optional features which can be included in the regulator are listed below. They are designated by letters as follows:

KCR 560 ___ ___ ___ (Designating letters for options or accessories)

NOTE: NO DESIGNATING LETTER IS ASSIGNED FOR SINGLE PHASE 120-480 volt SENSING. SINGLE PHASE SENSING IS STANDARD. OTHER TYPES OF SENSING ARE OPTIONAL AND ARE IDENTIFIED IN MODEL NUMBER BY THEIR DESIGNATING LETTER.

DESIGNATING LETTER	OPTION
A	Three Phase Sensing.
AD	Single Phase Sensing with Volts-Per-Hertz Underfrequency Limit.
D	Single Phase Volts-Per-Hertz Sensing.
A1	240 VDC Sensing.
A2	Tachometer Sensing Speed Regulator - Voltage Inversely Proportional to Speed. For use with Bucking Control Field.
A3	Tachometer Sensing Speed Regulator with Constant Amplifier Power Supply.
A4	24-240 VDC Sensing with Constant Amplifier Power Supply.
A5	48VAC Sensing with Constant Amplifier Power Supply.
A6	600 VAC Sensing.
B	Parallel Compensation Components (For either reactive droop or reactive cross current compensation)
C	Standard Commercial RFI Filter (See Table 1-1).
F	Regulator Cover.
K	High Reliability Non Electrolytic Capacitors

1.2.2 Accessories which can be included in the regulator system are as follows:

DESIGNATING LETTER	ACCESSORIES
E	Motor Starting Assist Assembly.
*G	Isolation Transformer.
H	Regulator Power or Field Circuit Breaker.
I	External Field Flashing Module (See paragraph 2.2 1b page 2-6).
J	Auto Manual Module.
L	Current Limit Sensing Assembly.
M	Tachometer Sensing Speed Regulator - Voltage Proportional to Speed. For use with Aiding Field .
N	Remote Sensing or Remote ON-OFF Control

* If correct voltage is not available for power input a suitable power transformer must be used.

SECTION 2

PRINCIPLES OF OPERATION

2.1 FUNCTIONAL CIRCUITS

2.1.1 The voltage regulator illustrated in figure 6-3 senses the generator voltage, compares a sampled portion of that voltage with a reference voltage and supplies the field current required to maintain the predetermined ratio between the generator voltage and the reference voltage. The KCR 560 Voltage Regulator consists of five basic circuits. These are a sensing circuit, an error detector and error signal amplifier, an SCR phase control circuit, a single phase double SCR/diode power bridge and a stabilization network. All of these circuits except the sensing transformers and the SCR power bridge are contained on an etched circuit board assembly.

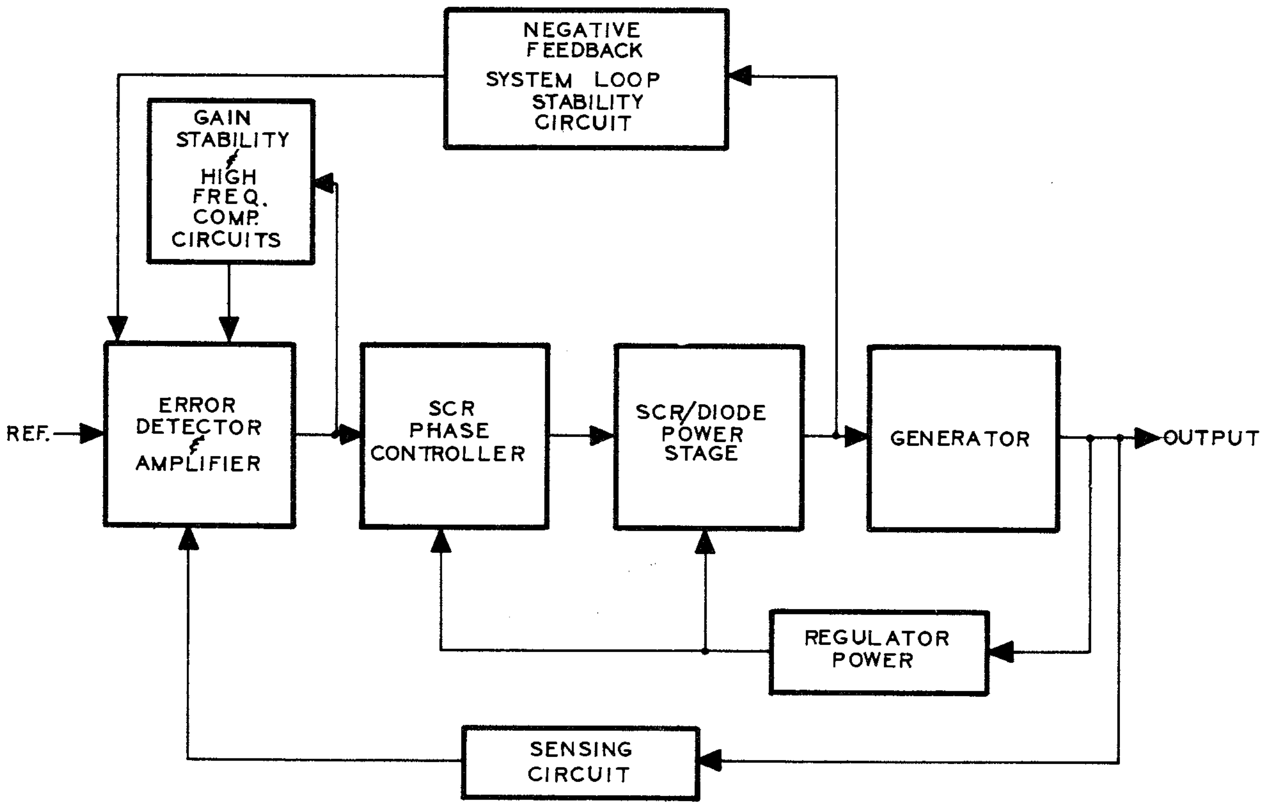
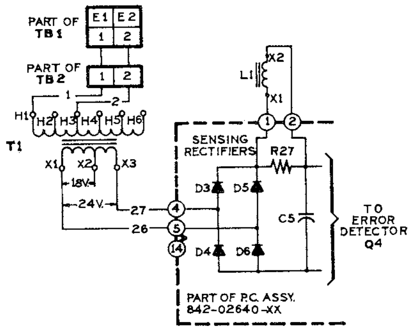


Figure 2-1 OVERALL BLOCK DIAGRAM

2.1.2 Sensing Circuit

2.1.2.1 This circuit consists of the sensing transformer(s), a full wave rectifier bridge and filter circuit comprised of resistor R27, capacitor C5 and choke L1. All components except the sensing transformer(s) and filter choke L1 are contained on an etched printed circuit board. The sensing circuit will sense the generator voltage, rectify and filter this and apply the resultant DC signal to the error detector and error amplifier.

a. Single Phase Sensing -- Sensing circuitry consists of sensing transformer T1, a rectifier bridge consisting of diodes D3, D4, D5, D6 and a filter circuit comprised of resistor R27, capacitor C5 and choke L1. Refer to figures 2-2 and 6-3.



VOLTAGE T1 TAPS

WIRE# & TAP	VAC @ 60HZ
1 TO H1, 2 TO H2	120
1 TO H1, 2 TO H3	208
1 TO H1, 2 TO H4	240
1 TO H1, 2 TO H5	416
1 TO H1, 2 TO H6	480

Figure 2-2 Interconnection Diagram, Single Phase Sensing (Basic KCR 560 Voltage Regulator)

b. Single Phase Sensing with Parallel Compensation -- Sensing Circuitry consists of sensing transformer T1, a parallel compensation circuit, a rectifier bridge D3, D4, D5, D6 and a filter circuit comprised of resistor R27, capacitor C5 and choke L1. The parallel compensation circuit is comprised of transformer T3, droop resistor R2 and a current transformer installed in a generator line. The output of transformer T1 and T3 add vectorially. The resultant voltage is rectified by D3 through D6 and filtered by R27, C5 and L1.

c. Three Phase Sensing -- Sensing circuitry consists of transformer T1, T2, rectifiers D3 through D8 and a filter circuit comprised of resistor R7, capacitor C5 and choke L1.

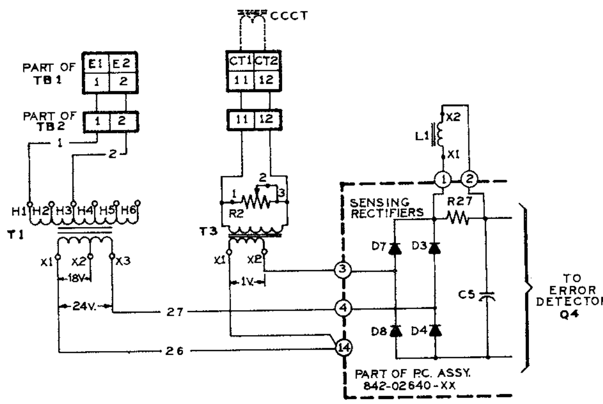


Figure 2-3 Interconnection Diagram, Single Phase Sensing Circuit with Paralleling Components (Option B)

d. Three Phase Sensing with Parallel Compensation -- Sensing circuitry consists of transformers T1, T2 a parallel compensation circuit, a full wave rectifier bridge consisting of diodes D3 through D8 and a filter circuit comprised of resistor R27, capacitor C5 and choke L1. The parallel compensation circuit is comprised of transformer T3, droop resistor R2 and a current transformer installed in a generator line. The output of transformer T3, adds vectorially to the output of sensing transformers T1, T2. The resultant voltage is rectified by a full wave three phase rectifier bridge consisting of diodes D3 through D8.

VOLTAGE TRANSFORMERS T1 & T2

WIRE & TAP T1	WIRE & TAP T2	VAC @ 60 HZ
1 TO H1, 2 TO H2	3 TO H1, 4 TO H2	120
1 TO H1, 2 TO H3	3 TO H1, 4 TO H3	208
1 TO H1, 2 TO H4	3 TO H1, 4 TO H4	240
1 TO H1, 2 TO H5	3 TO H1, 4 TO H5	416
1 TO H1, 2 TO H6	3 TO H1, 4 TO H6	480

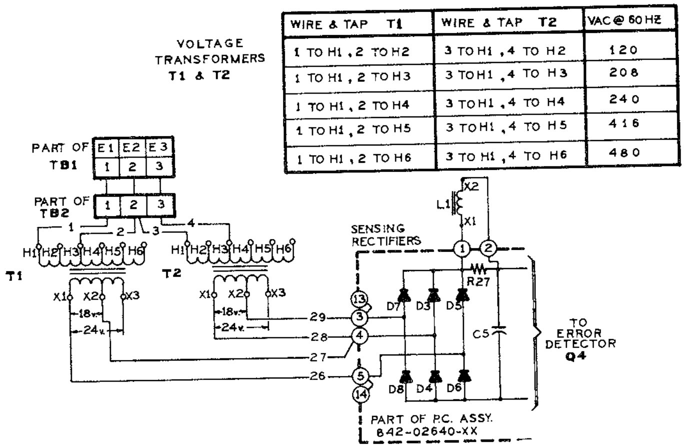


Figure 2-4 Interconnection Diagram, Three Phase Sensing Circuit (Option A)

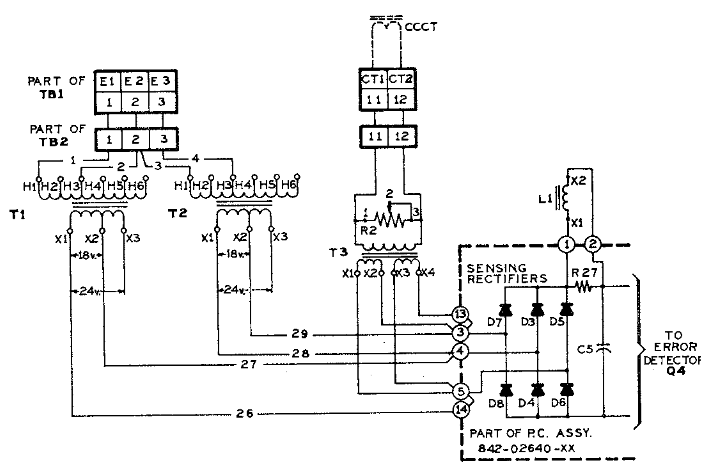


Figure 2-5 Interconnection Diagram, Three Phase Sensing Circuit with Paralleling Component (Options A and B)

e. Volts-Per-Hertz Sensing -- Volts-Per-Hertz Sensing option permits use of the KCR 560 regulator with variable frequency generators. The volts-per-hertz circuitry is incorporated in place of sensing transformer T1. The output of the volts-per-hertz assembly is rectified by a single phase rectifier bridge consisting of diodes D3 through D6. The resultant DC voltage is filtered by capacitor C5, resistor R27 and choke L1. The volts-per-hertz assembly is comprised of a multiple tap transformer, a reactor and variable resistor. Taps on the transformer permit 2.0, 4.0, 8.0 volts-per-hertz sensing.

VOLTAGE - PER - HERTZ

TRANSFORMER T4 H1 TO L2 TAP# TAP	VOLTS-PER-HERTZ	VAC@60 HZ
X2	2.0	120
X3	4.0	240
X4	8.0	480

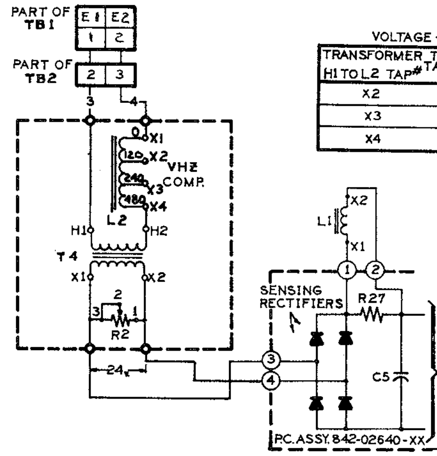


Figure 2-6 Interconnection Diagram Volts-Per-Hertz Sensing Circuit (Option D)

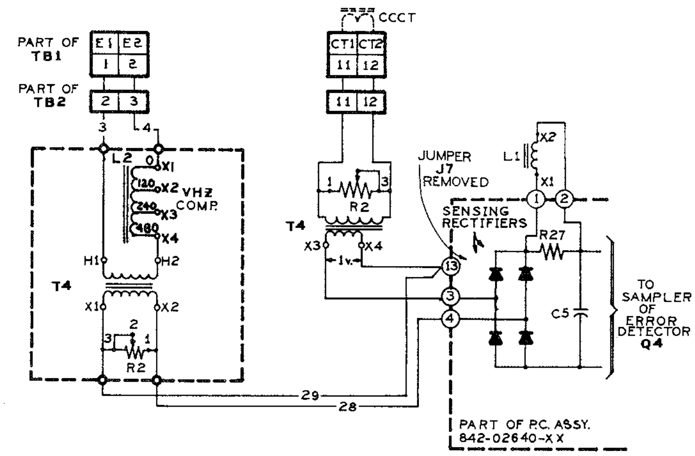


Figure 2-7 Interconnection Diagram, Volts-Per-Hertz Sensing Circuit with Paralleling Components (Options B and D)

f. Volts-Per-Hertz Limit for Underfrequency Protection -- The sensing circuitry consists of sensing transformer T1, a volts-per-hertz sensing module a full wave rectifier bridge comprised of diodes D1 through D8 and an RC filter circuit consisting of resistor R27 and capacitor C5. The volts-per-hertz assembly consists of transformer T4, reactor L2 and a variable resistor R2. At rated frequency the sensing transformer T1 and volts-per-hertz assembly function as a three phase sensing circuit. During underfrequency operation, however, the output of the volts-per-hertz assembly over rides the signal from the sensing transformer T1. The resultant rectified DC signal from the rectifier bridge appears as an overvoltage signal to the error detector. The regulator reacts by reducing phase angle of its output voltage which results in less average field current and a reduction in generator output voltage.

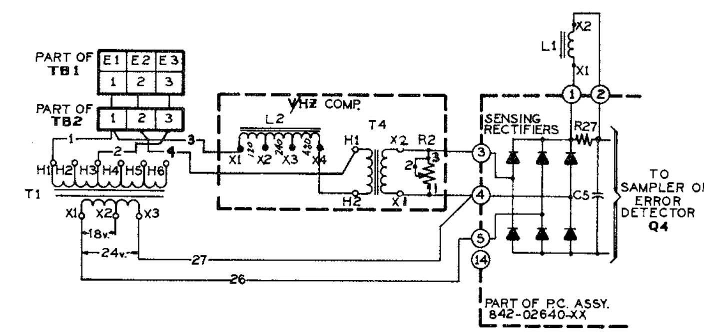


Figure 2-8 Interconnection Diagram, Single Phase Sensing Circuit with Volts-Per-Hertz Assembly for Underfrequency Limit (Option D)

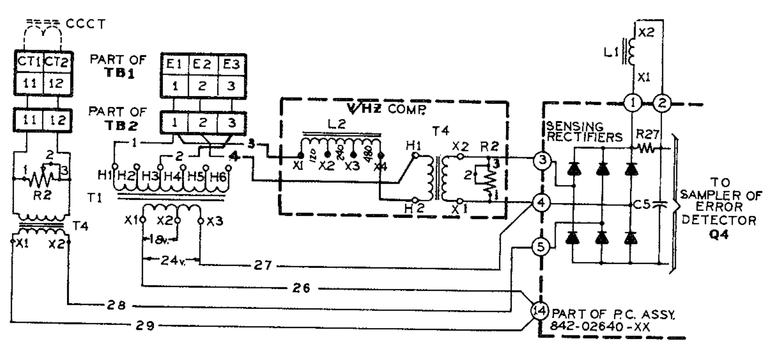


Figure 2-9 Interconnection Diagram, Single Phase Sensing Circuit with Paralleling Components and Volts-Per-Hertz Assembly for Underfrequency Limit. (Option AD and B)

2.1.3 ERROR DETECTOR

2.1.3.1 Components comprising the error detector are contained on the etched circuit board. The basic error detector circuit consists of the integrated circuit error detector and amplifier Q4, a reference voltage circuit comprised of zener Z2 and resistors R14, R18 and a voltage divider consisting of resistors R20, R21, R22, R23, R24 and external voltage adjust R1.

2.1.3.2 The integrated circuit Q4 is a high gain operational amplifier. It is used as a differential signal amplifier. A portion of the rectified sensing voltage at the slider of resistor R23 is applied as input voltage to pin #3 on Q4. Zener reference voltage is applied as a second input voltage at pin #2 on Q4. The resultant of the two input voltages constitutes an error signal. The amplified error signal drives the SCR phase control stage.

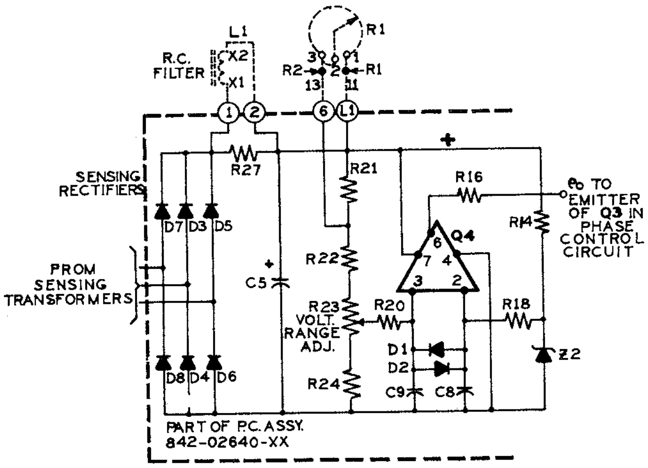


Figure 2-10 Error Detector and Amplifier

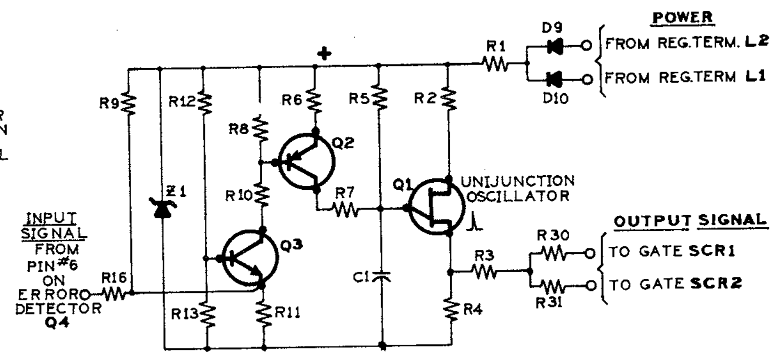


Figure 2-11 SCR Phase Angle Control Circuit

2.1.4 SCR PHASE CONTROL STAGE

2.1.4.1 All Components comprising the SCR phase control stage are contained on an etched circuit board. Unijunction transistor Q1, transistors Q2, Q3, capacitor C1, zener diode Z1, resistors R1 through R13, R30 and R31 and a rectifier bridge consisting of diodes D9 and D10 comprise this circuit. Refer to figure 2-11 and 6-3.

2.1.4.2 The SCR phase control stage is a relaxation oscillator. It controls the conduction angle of the regulator output by regulating the control or "gating" signal applied to the silicon controlled rectifiers in the SCR power bridge. The "ON" time of unijunction transistor Q1 is controlled by the charge rate of capacitor C1. The charge rate of C1 is regulated by the series resistance of R6, Q2 and R4. Transistor Q2 functions as a variable resistor. It is driven by transistor Q3. Transistor Q3 in turn is driven by the amplified error signal obtained from the output of error detector Q4. Zener diode Z1 is used as a "voltage clamping" device. Output of a rectifier bridge consisting of diodes D9 through D12 powers the SCR phase control stage.

2.1.5.1 Regulator output is taken from the SCR/Diode Power Bridge. The power stage consists of a single phase double SCR/Diode Power Bridge with a free wheeling diode for inductive loads and is comprised of thyristors (SCR'S) SCR1, SCR2, rectifiers CR1 and CR3 and free wheeling diode CR2. Average field current

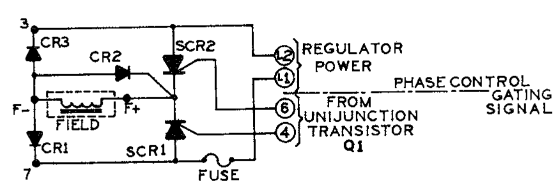


Figure 2-12 SCR/Diode Bridge Power Stage

is controlled by regulating the conduction angle of the SCR'S. The SCR control or "gating" signal (turn on Trigger) is obtained from the SCR phase control stage discussed in paragraphs 2.1.4 through 2.1.4.2. Free wheeling diode CR2 prevents inductive "Kickback" voltage. (See figures 2-12 and 6-3.)

2.1.6 STABILIZATION CIRCUITS

2.1.6.1 The stabilization circuits provide stable operation under all operating conditions. All components comprising the stabilization circuits are contained on the etched circuit board. Two separate stability circuits are incorporated in the KCR 560 voltage regulator. They are; a AC negative feedback circuit and a negative feedback system loop stability circuit. (See figures 2-13, 2-14 and 6-3.)

a. AC Negative Feedback Circuits -- The AC negative feedback circuits prevent unwanted amplification of signals other than the amplified error signal. They consist of RC loop R22 and C4 connected to pins 1 and 8 of the error detector amplifier Q4, capacitor C3 connected to pins 5 and 6 of Q4, and RC circuit, R15, R17 C2 connected to pins 6 and 2 of Q4. The circuits prevent amplifier oscillations from developing due to high gain of the error detector Q4, stray capacitance and inductance, and noise in the error detector input signal. Resistor R15 in addition to providing AC negative feedback for frequency compensation is a negative DC feedback circuit reducing the high gain amplifier output signal to the desired amplified DC error signal level.

b. Negative Feedback System Loop Stability -- The negative feedback system loop stability circuit is a two stage RC loop consisting of resistors R25, R26, R28 capacitors C6, C7 and stability adjust potentiometer R18. The RC network injects a stabilizing signal from the regulator output into the error detector Q4 to prevent oscillations (hunting). Adjustment of potentiometer R18 determines the amount of stability signal applied to the error detector.

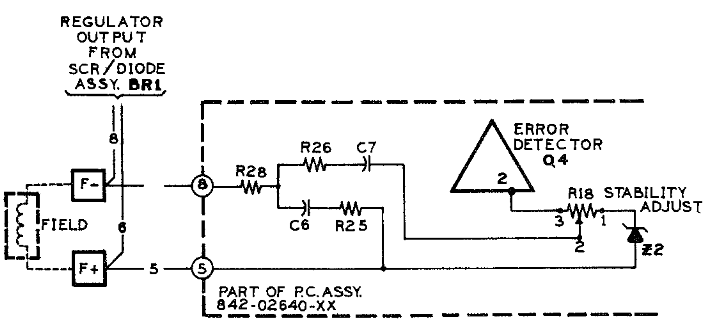


Figure 2-13 Negative Feedback System Loop Stability Circuit

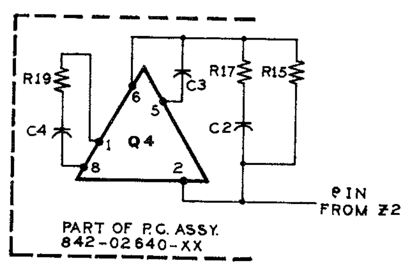


Figure 2-14 AC Negative Feedback Gain Stability and High Frequency Gain Compensation Circuits

2.2 AUTOMATIC VOLTAGE BUILDUP

2.2.1 The relay (RY1), contains two normally closed contacts. The relay can be used for either automatic voltage buildup from generator residual or as a flashing disconnect relay in applications where external field flashing is used. (See figures 2-15, 2-16,6-3 and 6-4.)

a. Automatic Voltage Buildup from Generator Residual -- Refer to figure 2-15. Normally closed contacts provide a current path around the control rectifiers (SCR1 and SCR2) to allow the generator residual voltage to be converted to DC by diodes D9, D10, CR1, CR2 and applied to the exciter field. When the generator voltage reaches approximately 75% of rated, the relay pulls in allowing the control rectifiers to regulate the generator output voltage. Full wave rectified voltage for the coil of flashing relay RY1 is provided by diodes D9 and D10.

b. External Flashing -- Refer to Figure 2-16. External flashing voltage from a separate DC Source which may be either a battery or rectified AC is applied to regulator terminals B (-) and F+. Normally closed contacts in relay RY1 provide a current path around the control rectifiers (SCR1 and SCR2) to allow application of flashing voltage to the exciter field. When generator voltage reaches approximately 75% of rated, the relay pulls in allowing the control rectifiers to regulate generator voltage. Diode D4 is used as a blocking diode to prevent feedback of regulator voltage into the external flashing assembly. An RC circuit consisting of capacitor C11 and resistor R32 prevents contact arcing. Diodes D9 and D10 provide coil voltage.

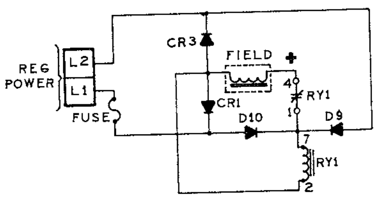


Figure 2-15 Residual Voltage Flashing Circuit

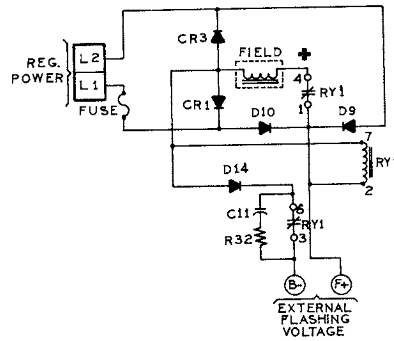


Figure 2-16 Regulator Flashing Circuit with External Flashing Voltage (Option I)

2.3 MOTOR STARTING ASSIST OR SHORT CIRCUIT FAULT CLEARANCE WITH BRUSHLESS ROTARY EXCITER OR STATIC EXCITER.

2.3.1 In brushless exciter or static exciter applications, the generator terminal voltage is reduced. Under heavy transient loads the addition of a motor starting assist option prevents collapse of generator excitation by providing sufficient power during heavy transient loads to start loads and ensure that protective overload devices will activate. (See figure 6-6)

2.4 PARALLEL COMPENSATION (VOLTAGE DROOP OR CROSS-CURRENT COMPENSATION)

2.4.1 When parallel operation is required, additional components are required in the regulating system. These are transformer T3, adjustable resistor R2 and a current transformer CCCT. Transformer T3 and resistor R2 are included in a parallel equipped regulator. Current transformer CCCT is a separate item. It must be installed in a generator line and connected to regulator terminals CT1 and CT2 as shown in figures 6-7 or 6-8.

2.4.2 The paralleling components allow the paralleled generators to share reactive load and reduce circulating reactive currents between them. The regulator sensing input voltage (terminals E1, E2 and E3) and the parallel compensation signal (terminals CT1 and CT2) must be connected to the generator system so as to provide correct phase and polarity relationship.

2.4.3 A current transformer CCCT is installed in line 2 of each generator. It develops a signal that is proportional in amplitude and in phase with the line current. This current signal develops a voltage across resistor R2. A slider on resistor R2 supplies a part of this voltage to the primary of transformer T3. The secondaries of T3 are connected in series with the leads from the secondary of the sensing transformer(s) and the sensing rectifiers located on the printed circuit board. The voltage applied to the sensing rectifiers is the vector sum of stepped down sensing voltage and the parallel CCCT signal supplied through transformer T3. The parallel CCCT signal is very small in relation to the signal supplied by the sensing voltage.

2.4.4 When a resistive (unity PF) load is applied to the generator, the voltage that appears across R2 and T3 windings leads the sensing voltage by 90 degrees. The vector sum of the two voltages is nearly the same as the original sensing voltage.

2.4.5 When a leading power factor (capacitive) load is applied to the generator, the voltage across R2 becomes out of phase with the sensing voltage and the vector sum of the two voltages results in smaller voltage being applied to the sensing rectifiers. The regulator reacts by increasing field excitation and, thus, generator output voltage.

2.4.6 When a lagging power factor (inductive) load is applied to the generator, the voltage across R2 becomes out of phase with the sensing voltage but in this case the vector sum of the two voltages is more than the sensing voltage. Voltage applied to the sensing rectifiers is increased and the regulator reacts by decreasing field excitation and, thus, generator output voltage.

2.4.7 When two generators are operating in parallel, if the field excitation of one generator should become excessive and cause a circulating current to flow between the generators, this current will appear as a inductive load (lagging power factor) to the generator with excessive field excitation and a capacitive load (leading power factor) to the other generator. The parallel compensation circuit will cause the voltage regulator to decrease the field excitation on the generator with the lagging power factor load minimizing the circulating currents between the generators. This action and circuitry is called parallel droop compensation and is illustrated in figure 6-7. It allows two or more parallelled generators to proportionally share inductive loads by causing a decrease or droop in the generator system voltage.

2.4.8 Parallel cross-current compensation allows two or more parallelled generators to share inductive reactive loads with no decrease or droop in the generator system output voltage. This is accomplished by the circuitry and action described for parallel droop compensation and the addition of cross connecting leads between the cross current compensation current transformer secondaries as illustrated in figure 6-8. By connecting the finish of the current transformer from one generator to the start of the current transformer of another generator, a closed series loop is formed which interconnects the cross current compensation current transformers of all generators to be paralleled. The signals from the interconnected current transformers cancel each other when the line currents are proportional and in phase. In the case of unbalance, the currents flow through the regulators to decrease the excitation of the generator carrying excessive reactive current and increase the excitation of the generators carrying low reactive current.

2.5 RFI

2.5.1 The circuits shown in figures 2-17 and 2-18 illustrate the two RFI filters available as options with the KCR 560 series voltage regulators. The RFI circuitry suppresses conducted RFI by conducting it to ground.

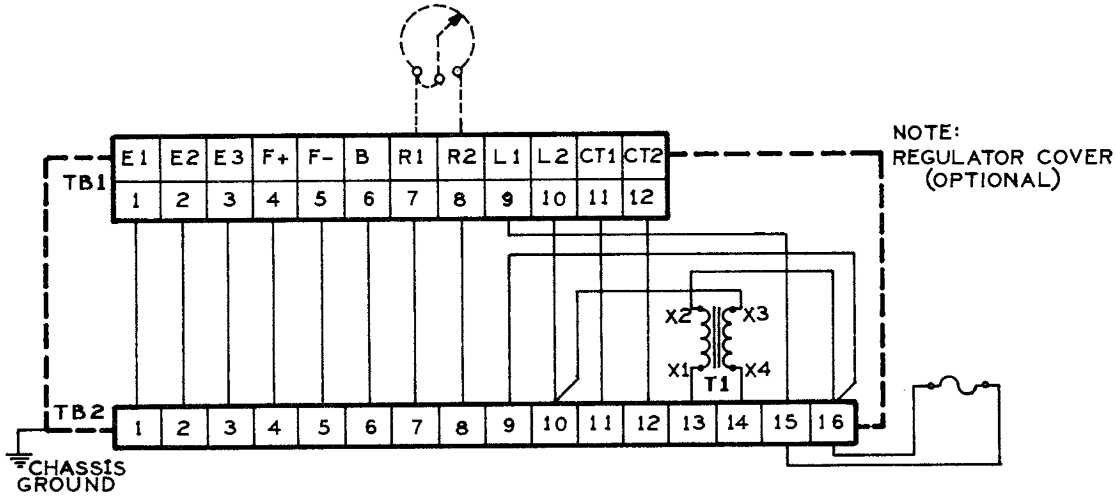


Figure 2-17 Interconnection, Commercial RFI Filter 514-00408-04

SENSING TAPS
H1 - H6 = 480
H1 - H5 = 416
H1 - H4 = 240
H1 - H3 = 208
H1 - H2 = 120

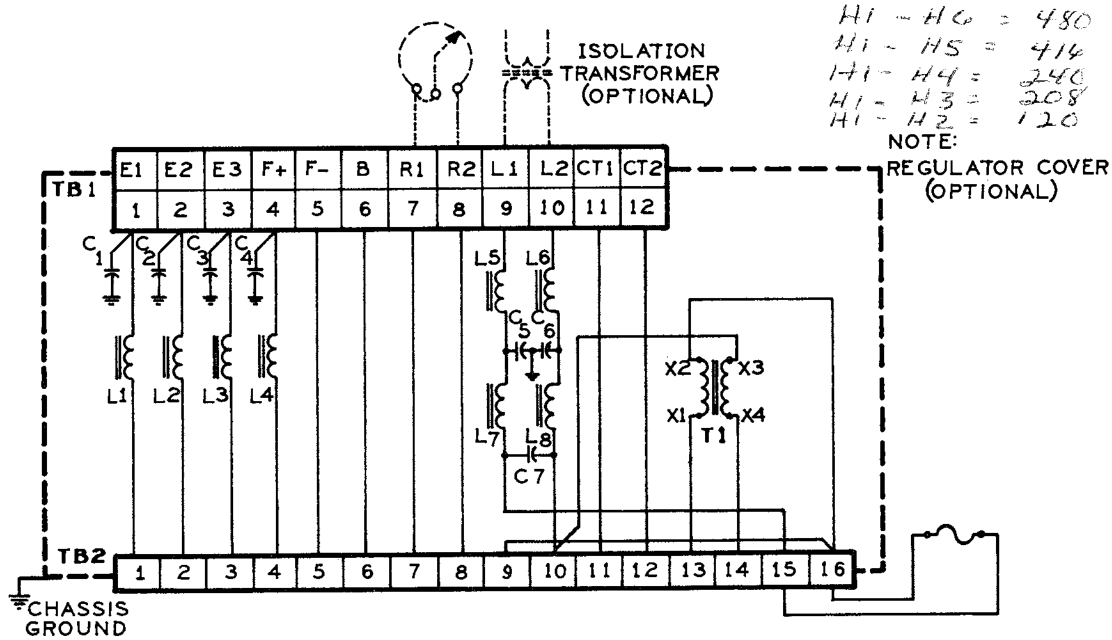


Figure 2-18 Interconnection, RFI Filter 514-00407-04

SECTION 3

INSTALLATION

3.1 MOUNTING

3.1.1 The voltage regulator can be mounted in any position without affecting its operating characteristics. The overall size of the voltage regulator and mounting dimensions are shown in figure 6-1. The regulator can be mounted in any location where the ambient temperature does not exceed its ambient operational limits (see Table 1-1). The regulator can be mounted in a control cabinet or, due to its rugged construction, directly on a generator. The enclosure should be of sufficient size to permit air flow about all sides of the voltage regulator.

3.2 INTERCONNECTION REGULATOR SENSING (Terminals E1, E2 and E3)

3.2.1 The regulator sensing must be connected as detailed in this section and as shown in the basic interconnection diagrams contained in Section 2 and 6. Number 14 gauge wire (or larger) should be used. For precise voltage regulation, the sensing leads should be connected as close as possible to the point where regulation is desired. To verify sensing refer to model number on regulator data plate, Table 1-1 and paragraph 1.2. (Refer to regulator electrical schematics).

3.2.2 On standard single or three phase sensing models, the regulator has an internal sensing transformer (s) T1 (T2) provided with taps for input voltages of 120, 208, 240, 416 and 480 VAC. Volts-per-hertz sensing models utilize a transformer with taps for 2, 4 or 8 volts-per-hertz sensing. The taps on the volts-per-hertz assembly are shown on the regulator electrical schematic. They are marked 120 volts which is equal to generator voltage of 2 volts-per-cycle at 60 cycles, 240 volts or 6 volts-per-cycle at 60 cycles and 480 volts or 8 volts-per-cycle at 60 cycles. The regulator sensing load is less that 10 VA and correct polarity must be maintained to the regulator sensing input. Wires to primary windings on the sensing transformers and volts-per-cycle assembly must be connected onto taps which correspond to applied sensing voltage. (Refer to regulator electrical schematics).

3.2.3 On single phase sensing models, the voltage sensing leads are connected to terminals E1 and E2. Terminals E1, E2 and E3 are used for three phase sensing and applications where a volts-per-hertz assembly is used in conjunction with single phase sensing for underfrequency protection. Terminals E1 and E2 are also untilized for volts-per-hertz sensing.

3.3 INTERCONNECTION OF REGULATOR INPUT POWER (Terminals L1 and L2)

3.3.1 The nominal voltage applied to the regulator input power stage (terminals L1 and L2) must be 120 VAC. The input power may be taken from any generator lines which provide the correct voltage (line to line or line to neutral). On single phase sensing models it is recommended that input power be taken from a phase other than the one used for sensing.

3.3.2 In the event 120 VAC generator terminal voltage is not available, a power transformer must be used to match the generator output to the regulator input. If excessive voltage is applied to the regulator input (terminals L1 and L2) the SCR's and diodes in the power stage and the diodes in the phase control input circuit may be destroyed.

3.3.3 If the field or flashing circuit is grounded, a power transformer must be used to isolate the regulator input from ground. This isolation transformer may also be required in applications where RFI filtering must meet military standards or when regulator input power is taken from an AC source other than the generator output.

3.4 INTERCONNECTION OF FIELD POWER (Terminals F+ and F-)

3.4.1 The DC resistance of the field to which the regulator is connected must be equal to, or greater than, 9 ohms. Observe polarity, connect a wire from terminal F+ to exciter positive lead and connect a wire from terminal F- to exciter negative lead. Shielded wires are recommended.

3.4.2 When manual voltage control is desired, a manual voltage control option consisting of a separate DC power supply, AUTO-MANUAL switch and field rheostat is used. Connection of a typical AUTO-MANUAL module in the regulatory system is shown in figure 6-5.

3.5 INTERCONNECTION OF FIELD FLASHING

3.5.1 In applications where flashing using generator residual voltage is desired, flashing relay RY1 contained in the voltage regulator provides the flashing circuit.

3.5.2 In applications where external flashing is desired connect wire from the negative terminal of an external flashing assembly to regulator terminal B- and connect wire from the positive terminal of the flashing assembly to regulator F+. Relay RY1 incorporated in the voltage regulator will automatically open the flashing circuit at approximately 75% of rated voltage. In order to limit flashing current an adjustable resistor should be incorporated in one of the lines from the flashing assembly to the regulator flashing terminals.

3.6 INTERCONNECTION OF PARALLEL COMPENSATION (Terminals CT1 and CT2)

3.6.1 When it is required to operate the regulator in parallel, first verify the regulator is equipped with parallel provisions (see Table 1-1).

3.6.2 In addition to the regulator provisions a 25 VA current transformer (CCCT) is required. This current transformer is connected in a generator line and should deliver from 3 to 5 amps secondary current at rated load. See figures 6-7 and 6-8.

3.6.3 The phase relationship of the CCCT signal to the sensing voltage must be correct or the systems will not parallel properly. On single phase sensing models it must be installed in the line which does not supply sensing to the regulator. For three phase sensing models the CCCT must be installed in the line that supplies sensing voltage to regulator terminal E2.

3.6.4 The typical system interwiring drawings contained in Section 6 of this manual show the correct CCCT polarity for L1-L2-L3 phase rotation. If the phase sequence is other than L1-L2-L3 the CCCT secondary leads must be interchanged.

3.6.5 Proper CCCT connection for parallel voltage droop and cross current compensation are shown on the interconnection diagrams contained in Section 6. For cross currenct compensation, in applications where all generators are not on the load bus, a unit-parallel switch should be installed in the CCCT secondary circuit of each regulator. If the switch is not used, a voltage droop will be introduced into the system. This is due to the unloaded generator parallel CCCT not supply its compensating signal, but allowing a voltage drop to occur across it. This drop will also cause the voltage of the incoming generator to fluctuate prior to paralleling. The unit-parallel switch may not be required on parallel droop compensation applications where a voltage drop is not objectionable.

OPERATION

4.1 GENERAL

4.1.1 The initial operating procedures are outlined in paragraphs 4.3 through 4.6. The following procedures should be reviewed before initial operation is attempted.

4.2 WIRING

4.2.1 Before initial operation is attempted, verify the regulator is connected for the applicable operation. Refer to drawings contained in Section 6 and the wiring diagrams supplied with the generator set.

4.3 OPERATION AT REDUCED SPEEDS

4.3.1 Prolonged operation at speeds lower than normal can cause destruction of the voltage regulator and/or exciter field. If operation at reduced speeds is essential, input power should be removed from the regulator or a volts-per-hertz sensing assembly should be added to the system. (See paragraph 2.1.1 f. and Table 1-1).

4.3.2 The regulator may be equipped with a switch or circuit breaker to allow removal of excitation in an emergency or when the generator prime mover must be operated at reduced speed. When used, this switch should normally be installed in the input power line to the regulator (terminal L1 and L2). The switch may be installed in the field circuit providing a field discharge diode is used in conjunction with the switch.

4.4 ADJUSTMENTS

4.4.1 The following adjustments pertaining to the regulator and system operation should be made during initial operation.

a. Generator Voltage Adjust R1 -- This adjustment is provided to control generator voltage. It is mounted either on the voltage regulator chassis or on the generator control panel. When adjusted to its full clockwise position, maximum generator voltage is obtained. Minimum voltage is obtained by turning R1 to its extreme counter clockwise position.

NOTE: If generator voltage decreases when turning R1 clockwise, reverse wires to potentiometer at terminals R1 and R2 on regulator terminal board TB1 (Terminal board TB2, at terminals 7 and 8 if potentiometer is mounted on regulator chassis).

b. Nominal Voltage Range Adjust R23 -- This adjustment is provided to vary the limits of Voltage Adjust R1. Normally R23 is set to provide R1 with an adjustment range of ± 10% of rated. Potentiometer R23 is located on the printed circuit board, accessable through a hole in the regulator cover.

c. Volts-per-hertz Sensing Resistor R2 -- Disconnect sensing from regulator and apply nominal rated voltage and frequency from seperate source to regulator V/H sensing terminals E1 and E2. Measure voltage across terminals X1 and X2 on transformer T4. Adjust R2 for 26 to 28 volts. Disconnect voltage source and connect lines from generator to sensing terminals on regulator. Apply generator voltage at rated nominal frequency. Adjust voltage adjust R1 and range adjust R23 for desired voltage and range.

d. Volts-per-hertz under frequency limit resistor R2 -- This resistor is incorporated on units which have single phase sensing and a volts-per-hertz assembly for frequency limiting. Adjust as follows:

1) Set R2 for minimum resistance.

2) Disconnect wire from terminal E2 on terminal board TB1.

3) Apply generator voltage at rated frequency. Set voltage adjust R1 and if necessary range adjust R23 to obtain desired voltage. Reconnect wire to terminal E2.

4) Reduce frequency. Three to five cycles below rated is recommended minimum difference.

5) Increase resistance of volts-per-hertz limit resistor R2 to point where generator output voltage begins to droop.

6) Increase frequency to rated. Check for rated voltage. If below rated voltage,decrease resistance of R2 slightly.

e. Field Flashing Current Limit Adjust -- This resistor is used in applications where a separate flashing assembly is mounted external of the voltage regulator. It is generally located either on the flashing assembly or within the generator set control panel. Decreasing resistance will increase excitation and voltage build up. Minimum resistance setting may result in excessive field current. Set with maximum resistance that will provide voltage build up.

f. Manual Voltage Adjust Rheostat -- This resistor is incorporated in the regulatory system when an AUTO-MANUAL Module option is included. It is mounted external to the voltage regulator. When adjusted to its full clockwise position, maximum generator voltage is obtained. Turn the rheostat counter clockwise to decrease generator voltage.

NOTE: If voltage decreases when turning the rheostat clockwise reverse wires connected to the extreme ends of the resistor but do not remove jumper wire to the slider..

g. Stability Adjustment R18 -- This adjustment provides for stable generator operation and is located on the printed circuit board. The stability adjust potentiometer controls the amount of feedback that is applied to the error amplifier stage. Normally it is factory set during factory test of the voltage regulator. It should be adjusted only in the event instability or poor response should occur during operation of the generator set. Maximum feedback is obtained by turning R18 to the extreme clockwise position. This setting normally assures stability, but tends to slow down the response of the generator. Turning it counter clockwise results in faster system response. However, if turned too far counter clockwise the generator voltage may hunt (oscillate). It should be set clockwise above the point where oscillating occurs and the system tested for stability at no-load and with load applied. If a setting is desired that provides the fastest possible voltage response with good generator stability, an oscilloscope or some voltage recording device should be used.

4.5 INITIAL OPERATING INSTRUCTIONS FOR SINGLE UNIT OPERATION

4.5.1 Before attempting system operation, locate all controls and adjustments pertinent to system operation.

a. Open the generator set output circuit breaker or contactor. Initial start up should be made with no load applied.

b. Start the prime mover and bring up to rated speed. If a voltage shutdown switch is used, close switch to apply excitation.

NOTE: If voltage does not build up field flashing may be required. Flashing relay RY1 option when incorporated in the regulator provides field flashing from generator residual voltage. In applications where generator residual voltage does not exist, an external flashing voltage applied to terminals B(-) and F+ may be used.

c. Verify generator voltage. Any of the following conditions may occur.

(1) No voltage build up -- If this condition exists, field flashing may be required.

(2) Voltage builds Up and Collapses -- If this condition exists, stop the prime mover and determine the cause of collapse. If necessary, refer to trouble shooting procedures.

(3) Overvoltage -- If this condition exists, immediately open the shutdown switch or stop the prime mover. Determine the cause of overvoltage. Check for proper connection of sensing transformers and adjustment of voltage adjust and voltage range adjust potentiometers. If overvoltage condition still exists, refer to trouble shooting procedures.

(4) Undervoltage -- If this condition exists, stop the prime mover and determine cause of undervoltage. Check for proper connection of sensing transformers and adjustment of voltage adjust and voltage range adjust potentiometer. If undervoltage condition still exists, refer to trouble shooting procedures.

(5) Oscillating Voltage (Hunting) -- If this condition exists, turn the stability adjust potentiometer R18. Turning R18 clockwise improves stability. However, excessive clockwise rotation can result in slow generator response.

NOTE: Voltage hunting can also be caused by an unstable prime mover. Instability can also occur when the no load field requirements of the generator or exciter is near the minimum working voltage of the regulator.

d. The voltage regulator is now ready for load test. Test as follows:

(1) Close unit parallel switch, when used.

(2) Close output circuit breaker or contactor and apply load.

(3) Verify the voltage regulation is within ± 1/2%. If it is not within these limits, refer to the trouble shooting procedures.

(4) Alternately remove and apply load to determine if generator voltage is stable. If the generator voltage becomes unstable, adjust R18 for stable operation (See paragraph 4.5.c. step (5)).

4.6 INITIAL OPERATING PROCEDURES FOR PARALLEL OPERATION

4.6.1 In order to ensure proper parallel operation, the following requirements must be met.

a. The speed governing system must make the generators share the total KW load.

b. The voltage regulating systems must cause the generators to share the total KVAR load.

4.6.2 In order to initiate paralleling and to check for proper parallel operation, all generators should be equipped with the following monitoring equipment.

a. Synchroscope or a set of lights. (Indicates an in-phase condition)

b. AC Voltmeter

c. Frequency Meter

d. AC Ammeter

e. Selector Switches to allow monitoring voltage on all phases and current on each line.

f. KW Meter

g. KVAR or Power Factor Meter

h. Field Current Ammeters

4.6.3 Preliminary Instructions -- It is recommended before proceeding that the components internal and external to the voltage regulator which facilitate parallel operation be reviewed (See 4.4.1a thru f). The following items should be given special attention.

a. The paralleling signal at terminals CT1 and CT2 of the regulator must have the proper phase relationship with that of the sensing voltage. Refer to paralleling instructions contained in paragraph 2.4 through 2.4.8 and the wiring diagrams contained in Section 6.

b. Verify the paralleling CCCT secondary is not shorted. Unit parallel switch open (in Parallel position). In applications where cross current compensation is used, the unit parallel switch on only the generator in operation should be open. Switch on generators not on system bus should be closed.

c. Prior to parallel operation, the slide adjustment of droop resistor R2 on all regulators should be set to identical positions. R2 provides for maximum droop of about 6%, adjusting R2 for 4% droop is typical.

4.6.4 Preliminary Operation -- Before attempting to parallel two or more generator sets, it is recommended individual sets be tested to verify that the paralleling devices function properly. The following test may be used.

a. Place each set in operation in accordance with paragraph 4.4.1 steps a. through d.

b. Verify the paralleling CCCT is not shorted. (See paragraph 4.5.3 step B.)

c. Apply a 25% to 100% unit power factor load to the set under test. Generator voltage should change less than 1%.

NOTE: In engine driven generator set applications, the frequency will decrease if governor is set for droop operation.

d. Apply a 25% to 100% 0.8 power factor inductive load. Voltage should droop from approximately 4% to 6% with rated load, depending on setting of droop resistor R2. If the voltage rises instead of drooping, reverse the CCCT sensing leads at regulator terminals CT1 and CT2.

e. During the preceeding tests, verify voltage and speed do not drift erratically.

4.6.5 Paralleling Generators -- The following steps contain the proper procedures to be followed for paralleling generators. The best adjustment is obtained when all paralleled generators are supplying the same percent of rated current, the KW (or power factor) readings are equal, or the sum of the ammeter currents is minimum.

a. Start generator set No. 1.

b. Open unit parallel switch when used (Parallel position).

c. Close the circuit breaker or contactor connecting it to the system bus.

d. Adjust its voltage and frequency.

e. Apply load. If possible, load should be 10% or more of its KW rating.

f. Start generator set No. 2. Adjust its voltage and speed. Speed, when possible, should be slightly higher than generator set No. 1. Set unit parallel switch when used to Parallel open position.

g. Observing the synchroscope or synchronization lights, close its output circuit breaker when the set is in phase with generator set No. 1.

h. Immediately after closing the circuit breaker, verify the indication on the ammeter for set No. 2. They should read well within the rating for the generator. If line current exceeds generator rating, shut down the system and refer to trouble shooting procedures.

NOTE: Upon closing the circuit breaker for set No. 2 high line current may cause the circuit breaker to open due to current overload or it may be opened by the reverse power relay. In order to isolate the problem to a faulty voltage or speed regulating system parallel the generators as described in preceeding steps a through h. Immediately after closing the circuit breaker, observe the KW or power factor meters. The following conditions may occur:

1) A high ammeter reading accompanied by a large KW unbalance. When this condition exists, the speed regulating system is at fault .

2) A high ammeter reading accompanied by a KVAR unbalance. When this condition exists, the voltage regulating system is faulty.

i. Adjust the speed of generator set No. 2 to point where each generator is carrying the desired share of KW load.

j. Adjust the voltage of generator set No. 2 until the ammeter readings of both sets are near minimum. If KVAR or power factor meters are available, adjust voltage adjust devices for equal or proportional KVAR or power factor readings.

NOTE: If the sets are equipped with power factor meters instead of KW meters, alternately adjust the speed and voltage on set No. 2 until the AC ammeter readings are proportional and the power factor readings are equal.

NOTE: To obtain the best results, make final adjustments with full load on the bus.

k. With full load applied, readjust the speed and voltage of generator set No. 2 until the desired load division is obtained.

NOTE: The best adjustment is obtained when all paralleled sets are supplying the same percent of rated current, the KW or power factor readings are equal, or the sum of the AC ammeter currents is minimum.

l. Paralleling three or more generators -- The preceeding steps shown for paralleling generator set No. 2 should be followed for all additional sets to be paralleled.

SECTION 5

MAINTENANCE, COMPONENT TEST PROCEDURES, AND TROUBLE SHOOTING

5.1 PREVENTIVE MAINTENANCE

5.1.1 Periodic inspection should be made on this unit to insure it is kept clean and free from dirt and moisture. Also, it is recommended the wiring between the regulator and the system be inspected for general condition (absense of worn or frayed insulation). Connections should be checked and tightened at this time.

5.2 CORRECTIVE MAINTENANCE

5.2.1 Repairs to the regulator can be made following the diagrams in Section 6. Procedures for testing the regulator and its various components are contained in Section 5.5 through 5.15. Due to the protective coating, repair on the printed circuit board is difficult and should not be attempted.

5.3 SAFETY SUMMARY

5.3.1 The following precautions should be followed whenever making internal adjustments or repairs on the voltage regulator. Failure to observe these precautions can result in serious injury or electrocution or/and damage to the equipment.

CAUTION

DANGEROUS VOLTAGES ARE PRESENT IN THIS EQUIPMENT WHEN GENERATOR SET IS RUNNING. ALL WIRES AND CONNECTIONS SHOULD BE CONSIDERED CONDUCTORS OF VOLTAGE DANGEROUS TO PERSONNEL. CAPACITORS AND CIRCUITS INCLUDING CAPACITORS SHOULD BE CONSIDERED "LIVE" AT ALL TIMES.

CAUTION

DO NOT TEST REGULATOR WITH HIGH POTENTIAL TEST EQUIPMENT. WHEN TESTING GENERATOR WINDINGS WITH HIGH POTENTIAL TEST EQUIPMENT SUCH AS MEGGERS, FIRST DISCONNECT ALL WIRES INTERCONNECTING VOLTAGE REGULATOR AND GENERATOR SET.

CAUTION

DO NOT TEST Q4 (INTEGRATED CIRCUIT LM709C) WITH EITHER HIGH OR LOW VOLTAGE TEST EQUIPMENT. THIS INCLUDES OHMMETERS, MULTIMETERS AND TEST LIGHTS.

5.4 TROUBLE SHOOTING

5.4.1 The more common generator system malfunctions and appropriate repair procedures are listed in Table 5-1.

TABLE 5-1 TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Voltage does not build up to rated value.	Voltage Adjust R1 and/or Voltage Range Adjust R23 require adjustment.	ADJUST. Turn clockwise to increase voltage.
	Voltage Adjust R1 wired incorrectly.	Verify wiring.
	Low residual or incorrect polarity relationship between regulator output and field.	Verify wiring. Flash field if due to low residual.
	Voltage shutdown switch, when used, in OFF position.	Set to ON or close position.
	Prime mover not at rated speed.	Increase speed to rated.
	No voltage or improper voltage to terminals L1 and L2.	Verify wiring and voltage. Should be 120 VAC.
	No or poor connections to F+, F-.	Verify wiring.
	Defective or improperly wired exciter or generator.	Verify exciter and generator operation or connections. Refer to generator operating instructions manual and wiring diagrams.
	Improper connections or defective sensing transformers.	Verify primary and secondary connections are appropriate for sensing voltage applied. Test for open or shorted windings. Replace if defective.
	Defective regulator	Check PC Board, SCR/diode bridge, flashing relay. Replace defective parts or regulator assembly.

SYMPTOM	PROBABLE CAUSE	REMEDY
Voltage builds up until flashing relay RY1 actuates and then decays.	No firing pulse to SCR gate, SCR(s) and diodes defective or defective components on PC Board.	Test components in SCR/diode bridge and on PC board. Replace defective parts.
	Improper connection of sensing transformer(s).	Verify wiring.
	Shorted voltage adjust potentiometer R1.	Test for short circuit.
	Shorts or open in sensing circuitry comprising sensing rectifiers, sensing voltage filter components or resistors in voltage divider at pin 3 side of error amplifier Q4.	Test components. Replace defective PC board.
	Defective PC board.	Test components. Replace defective PC Board.
	Improper voltage to terminals L1, L2.	Verify wiring. Input power should be 120 VAC, 60 HZ.
Voltage high. Controlable with voltage adjust potentiometer.	Prime mover overspeed	Reduce speed to rated.
	Voltmeter inaccurate	Verify operation.
	Voltage range adjust R23 set too high.	Adjust. Counter clockwise rotation decreases voltage.
	Volts-per-hertz Limit Adjust R1 set too high (models with volts-per-hertz sensing)	Adjust.
	Sensing transformer set to wrong voltage tap.	Verify wiring.
	Faulty PC board.	Replace PC board or replace regulator.
Voltage high, uncontrolable with voltage adjust potentiometer.	No sensing voltage terminals E1, E2 and E3.	Verify wiring.
	Sensing transformer(s) set to wrong tap.	Verify wiring.
	Faulty Flashing relay RY1	Replace relay.

TABLE 5-1 CONT.

SYMPTOM	PROBABLE CAUSE	REMEDY
Voltage high, uncontrol-able with voltage adjust potentiometer. (CONT.)	AUTO-MANUAL switch, when used, in MANUAL position.	Set to AUTO position.
	SCR's defective.	Replace SCR's or replace regulator.
	Faulty PC Board.	Replace PC board.
Voltage low, control-able with voltage adjust potentiometer.	Voltage range adjust R23 set too low.	Adjust clockwise to increase voltage.
	Sensing transformer(s) set to wrong tap.	Verify wiring.
	Volts-per-hertz limit resistor R1 set to low (when volts-per-hertz sensing is used.)	Adjust.
	Prime mover not up to rated speed.	Increase speed to rated.
	Voltmeter inaccurate.	Verify operation. Replace if defective.
Voltage low, uncontrol-able with voltage adjust potentiometer.	Shorts in sensing circuit.	Test sensing components. Replace defective components or replace regulator.
	No gating signal to SCRs (Defective PC board.)	Test PC components. Replace defective PC board or replace regulator.
	SCR's or diodes in power stage BR1 open.	Test. Replace defective components or regulator.
	Defective error detector circuit or zener diode Z2 shorted.	Test components. Re-place faulty PC board or replace regulator.

SYMPTOM	PROBABLE CAUSE	REMEDY
Poor Regulation	Generator Overload	Reduce load to rated.
	Volts-per-hertz under frequency limit resistor set to limit voltage at frequency too close to rated frequency. (On units with Volts-Per-Hertz under-frequency limit option only.)	Set for volts-per-hertz limit at lower frequency. A minimum of 3 to 5 cycles below rated frequency is typical
	Exciter or generator full load field requirements exceed maximum regulator output.	If regulator application is beyond the limits specified in Table 1-1, consult KATO Engineering Company. List generator field requirements.
	Voltage at terminals L1 and L2 too low at nominal generator voltage.	Input voltage should be 120 VAC.
	Unit-parallel switch (when used) in PARALLEL position.	Place switch in closed (UNIT) position, except during parallel operation.
	Unbalanced load with three phase sensing.	Balance load. Unit averages all three phases.
	Prime mover speed low or fluctuating.	Verify speed. Check governor operation.
	Fault in exciter or generator.	Verify operation. Refer to generator instruction manual.
	Faulty SCR's or diodes.	Replace faulty components or replace regulator.
	Faulty PC Board.	Replace faulty PC board or replace regulator.
Poor Voltage Stability	Frequency unstable	Adjust prime mover governor.
	Stability Adjust R18 improperly adjusted.	Adjust. Turning R18 clockwise increases negative feedback which improves stability. Excessive clockwise rotation can, however, result in slow response.

TABLE 5-1 CONT.

SYMPTOM	PROBABLE CAUSE	REMEDY
Poor Voltage Stability (CONT.)	Fault in exciter or generator.	Verify operation. Refer to generator manual, when necessary.
	Faulty PC Board.	Replace defective PC Board or replace regulator.
	Faulty SCR's	Replace SCR's or replace regulator.
Voltage recovery slow with load changes.	Stability Adjust R18 maladjusted.	Turn counter-clockwise to improve response. NOTE: Excessive counter-clockwise rotation can result in instability.
	Slow prime mover response.	Adjust prime mover governor.
	Response characteristics of exciter or generator slow for application.	Consult generator manufacturer.
	Low regulator forcing capability.	Improper application of regulator. Consult Kato Engineering Co. List requirements for application and give generator set characteristics.
Voltage rises on application of inductive load.	Parallel CCCT secondary (when used) polarity wrong.	Verify parallel droop components are incorporated. Reverse parallel CCCT secondary leads at regulator terminals CT1 and CT2.
No droop compensation can be obtained for parallel generators.	Tap on droop resistor R2 set to minimum droop position.	Adjust to obtain desired droop. All generators operating parallel should be adjusted for identical voltage droop.
	Parallel CCCT does not supply required secondary current.	Consult Kato Engineering Co. List generator full load line current.

TABLE 5-1 CONT.

SYMPTOM	PROBABLE CAUSE	REMEDY
Parallel generators do not divide KW load equally.	Prime mover governor power sensing adjust requires adjustment.	Consult governor manual. Adjust governor.
Circulating reactive generators due to parallel generators not dividing reactive KVAR load equally.	Terminals CT1 and CT2 of regulator shorted by unit-parallel switch.	Open switch by setting to PARALLEL position.
	Tap on droop resistor R2 set for insufficient droop.	Adjust for increased voltage droop. ALL generators operating parallel should be set for same voltage droop.
	Parallel CCCT secondary reversed.	Interchange secondary leads on CCCT's. CAUTION: DO NOT OPEN SECONDARY WITH CIRCUIT ENERGIZED.
	Parallel CCCT not in proper generator line.	Verify wiring. On single phase sensing models, use phase other than phases used for sensing.
	Parallel CCCT does not supply required secondary current.	Contact Kato Engineering Co. List generator full-load line current.

5.5 COMPONENT TEST PROCEDURES

5.5.1 Paragraphs 5.6 through 5.14 describe general procedures for testing the various regulator components. Review and follow the safety precautions listed in paragraph 5.3, page 5-1 whenever testing or repairing the voltage regulator.

5.6 RECTIFIER TEST

5.6.1 Small brown surface marks, sometimes developed by rectifiers during normal operation, usually do not adversely affect rectifier operation. If the resistance is taken with rectifier leads connected in circuit, care should be taken that components in parallel do not affect readings. Test with ohmmeter or three-volt test light as follows:

(1) Connect ohmmeter or test light leads across rectifier. Observe ohmmeter reading or, if test light is used, observe if bulb lights.

(2) Reverse leads. Again observe ohmmeter readings; or, if test light is used, observe if bulb lights.

(3) A good rectifier will have high resistance in one direction and low resistance in the opposite direction. If a test lamp is used, the bulb should light in the direction where resistance is low, and should not light in the direction where resistance is high. If a low resistance is indicated in both steps (1) and (2), the rectifier is probably shorted. A high resistance in both steps (1) and (2) indicates an open rectifier.

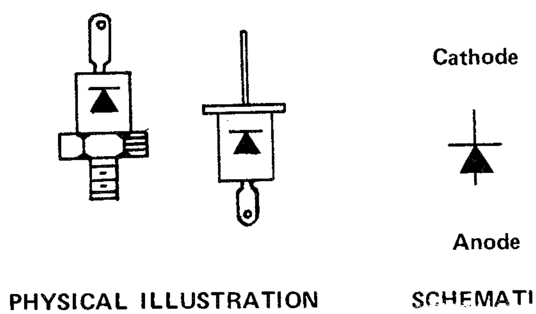


Figure 5-1 Silicon Rectifier (Diode)

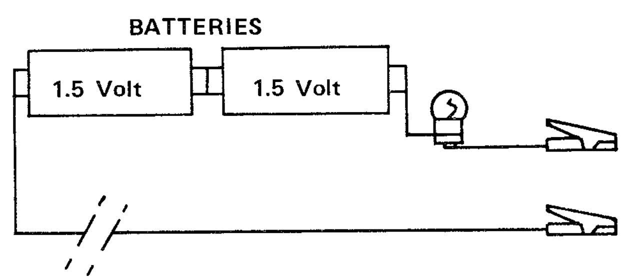


Figure 5-2 Three volt Test light

5.7 POWER TRANSFORMER TEST

5.7.1 Typical transformer defects are shorts between windings, open windings, and shorted turns. These usually may be detected by checking resistances and voltages. When the transformer overheats, and the existance of shorted turns cannot be proved by resistance measurement, check the no-load alternating current in the primary windings. This excitation current will be excessive if there are shorted turns. Test transformer as follows:

With rated voltage on the primary winding, check the secondary voltages. Measured voltages, taken when a transformer is unloaded, run up to about 10% higher than those taken when the transformer is wired into its circuit.

5.8 CURRENT TRANSFORMER TEST

5.8.1 Current transformers have a fixed ratio of current between primary and secondary. The ratio between these currents is determined by the turns ratio. The ratio of primary to secondary current is approximately the same as the ratio of secondary turns to primary turns. If secondary current is considerably less than it should be, shorted turns are indicated. The following test should be made for shorted turns:

(1) Load the generator to produce primary current in the transformer.

(2) Measure the secondary current.

CAUTION
DO NOT OPEN THE SECONDARY OF A CURRENT TRANSFORMER WHILE THE CIRCUIT IS ENERGIZED.

5.9 POTENTIOMETERS AND RESISTORS

5.9.1 Check resistance values with an ohmmeter. Potentiometers and adjustable resistors should be checked over their full range. Care should be taken to avoid damage to the fine wire when setting adjustment bands on adjustable resistors. The adjustment band should be loosened until it slides freely on the resistor tube.

NOTE

IF READINGS ARE TAKEN WITH RESISTOR CONNECTED IN CIRCUIT, CARE SHOULD BE TAKEN TO MAKE CERTAIN COMPONENTS IN PARALLEL DO NOT AFFECT READINGS.

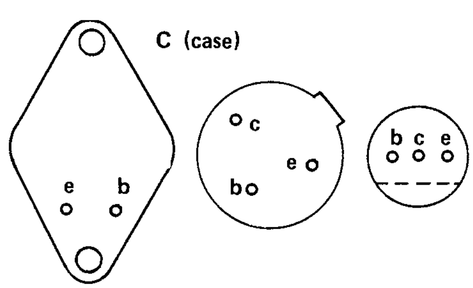
5.10 CAPACITOR TEST

5.10.1 Capacitors may be checked on a capacitor bridge to measure capacitance and leakage. Capacitance should not vary more than ± 10% of their rated values.

5.10.2 An approximate check may be made with an ohmmeter set to a high-resistance scale. The meter should initially indicate low resistance and then gradually increase until capacitor is fully charged.

5.11 PNP AND NPN TRANSISTOR TEST

5.11.1 Silicon transistors can be tested with a three-volt test light as detailed in Table 5-2. Test by test light method will normally indicate if a transistor is open or short circuited. Remove transistor from circuit to prevent other components in circuit from affecting readings. The light indications listed in Table 5-2 are those which should be observed if transistor is not shorted or open.



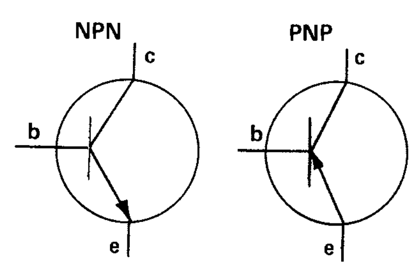


Figure 5-3. PNP and NPN Transistors.

TABLE 5-2 TRANSISTOR TEST CHART

TYPE TRANSISTOR	TEST LAMP NEGATIVE LEAD CONNECTED TO-	TEST LAMP POSITIVE LEAD CONNECTED TO-	LIGHT INDICATION
NPN	BASE BASE	EMITTER COLLECTOR	NO LIGHT NO LIGHT
	EMITTER COLLECTOR	BASE BASE	LIGHT LIGHT
PNP	BASE BASE	EMITTER COLLECTOR	LIGHT LIGHT
	EMITTER COLLECTOR	BASE BASE	NO LIGHT NO LIGHT

4.4.8 UNIJUNCTION TRANSISTOR TEST

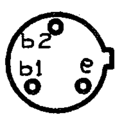
4.4.8.1 Test resistance with ohmmeter or multimeter as follows:

(1) Test b_1 to b_2 with meter positive lead on b_1. Resistance should be in the range of 2K ohms to 3K ohms.

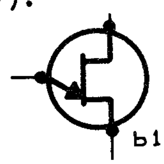
(2) Test b_1 to b_2 with meter positive lead on b_2. Resistance should be in the range of 5K ohms to 10K ohms. Read and record resistance readings.

(3) Place meter positive lead on emitter (e) and negative on b_1. Resistance should be approximately 1/2 of the resistance recorded in step 1.

(4) Reverse meter leads at (e) and b_1. Meter should read a high resistance (near infinity).



Physical



Schematic

FIGURE 5-4 Unijunction Transistor

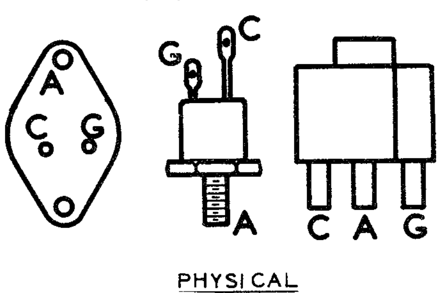
5.13 SILICON CONTROLLED RECTIFIER TEST

5.13.1 Using a three volt test light test as follows:

(1) Connect test light positive lead to anode.

(2) Connect test light negative lead to cathode.

(3) Momentarily jumper from anode to gate to trigger SCR. Light should come on and stay on until test light leads are removed from anode or cathode.



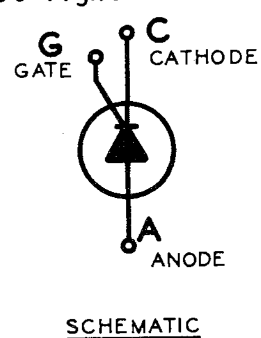


Figure 5-5. Silicon Controlled Rectifier (SCR)

5.14 ZENER DIODE TEST

5.14.1 A zener diode may be checked with an ohmmeter in much the same manner that a normal rectifier is checked or if a DC power supply is available a check on the actual operation of the zener may be performed (see figure 5-6). Utilizing the test setup illustrated in figure 5-6 the voltage across the diode will increase until it reaches the zener voltage. As the DC input voltage is increased the voltage across the diode will remain constant and the current through the diode will increase rapidly. Care should be taken not to exceed the current rating of the diode. The DC power supply should have a low ripple. A battery is perferred.

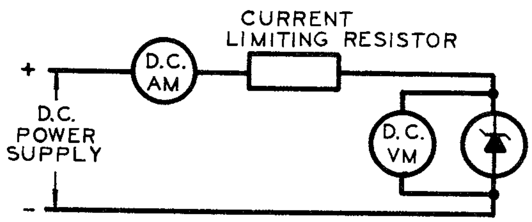


Figure 5-6 Zener Diode Test

5.15 REGULATOR VOLTAGE AND RESISTANCE MEASUREMENTS

5.15.1 Typical voltage and resistances across various circuits in the voltage regulator are listed in Tables 5-3 and 5-4. Voltage measurements should be taken with nominal sensing voltage and power applied to the regulator and with regulator working into a 10 ohm field with no load on the generator. Voltage measurements should be taken utilizing a Triplett model 630 NA multimeter or its equivalent.

TABLE 5-3 REGULATOR RESISTANCE MEASUREMENTS

POINT OF MEASUREMENT		RESISTANCE (Approx.)
Sensing Transformer T1 or T2 Terminal X1 to X3		4 ohm
Sensing Transformer T1 or T2 Terminals H1 to H3		170 ohm
Printed Circuit Terminal 6 to 7		2 k ohm
Q3 Collector To Printed Circuit Terminal 5		440 k ohm
Q2 Emitter To Printed Circuit Terminal 5		22 k ohm
Q1 (b_2) To Printed Circuit Terminal 5		25 K ohm
Across Capacitor C 5	Meter Positive Lead @ R27	2.4 k ohm
	Meter Negative Lead @ R27	3.6 k ohm
Across Diode D 12	Forward Polarity	11 k ohm
	Reverse Polarity	22 k ohm
Regulator Terminals F+ To F-(Regulator Disconnected From Generator Or Exciter Field)		33 ohm
Regulator Terminals L1 To L2 (Input Power Lines Disconnected)		18 k ohm
Regulator Terminals R1 To R2 (Voltage Adj. R1 Disconnected)		1500 ohm

TABLE 5-4 REGULATOR VOLTAGE MEASUREMENTS

POINT OF MEASUREMENT		VOLTS (APPROX.)
Terminal Board TB1 Terminals F+ To F-		15.6 VDC, 1.7 AMPS
Terminal Board TB1 Terminals L1 To L2		120 VAC
Terminal Board TB1 Terminals F+ To L1		38.6 VDC
Terminal Board TB1 Terminals F+ To L2		38.6 VDC
Terminal Board TB2 Terminals 10 To 14		2.8 VAC
Terminal Board TB2 Terminals 13 To 16		2.8 VAC
SCR Assy. BR1 Terminals 3 To 7		120 VAC
Transformer T1 Or T2 Terminal X1 To X3		24 VAC
Printed Circuit Terminal 2 (+) To 7 (-)		19.9 VDC
Printed Circuit Terminal 7 (-) 12 (+)		90 VDC
D 12 Anode (+) Cathode (-)		54 VDC
Q 2 Collector (+) P. C. Terminal 7 (-)		8.2 VDC
Q 1 (b2) (+) P. C. Terminal 7 (-)		15.9 VDC
Across Z1 Anode (+) Cathode (-)		24 VDC
Across Z2 Anode (+) Cathode (-)		6.2 VDC
Printed Circuit Terminal 7 (+), 8 (-)	R18 Full Clockwise	16.5 VDC Pulse
	R18 Full Counterclockwise	13-18 VDC Pulse(Unstable)

SECTION 6

DRAWINGS

6.1 GENERAL

6.1.1 This section contains drawings and diagrams to facilitate the installation, operation and maintenance of the voltage regulator.

a) Figure 6-1 Voltage Regulator Outline Drawing Including Component Location And Identification.

b) Circuit Board Assembly Component Location And Identification.

c) Schematic Diagram, KCR 560 AB Voltage Regulator.

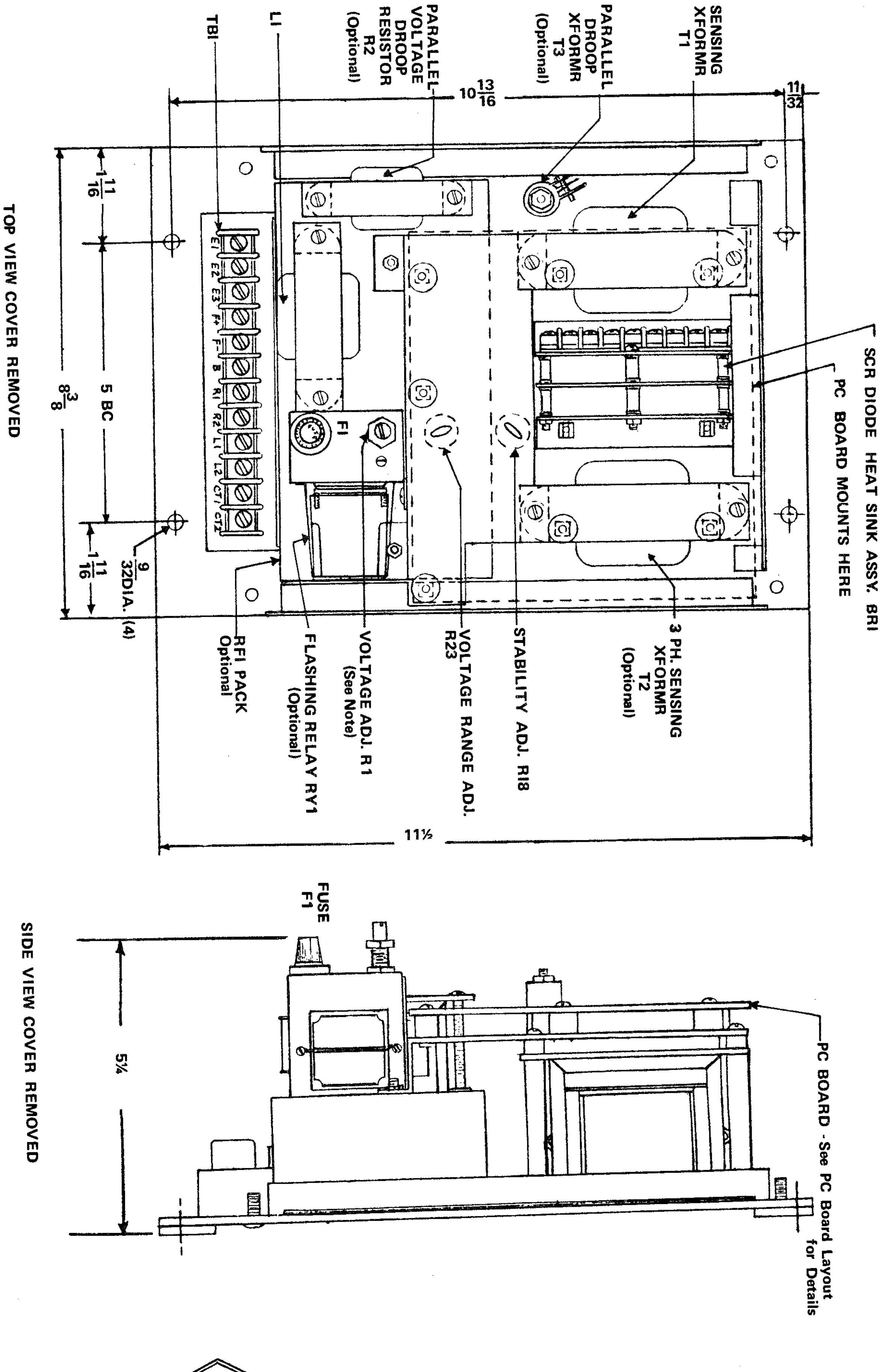
d) Typical Interconnection, KCR Regulator To Brushless Rotary Exciter (Or Static Exciter).

e) Typical Interconnection, KCR 560 Regulator And Auto-Manual Module Option To Brushless Rotary Exciter (Or Static Exciter).

f) Typical Interconnection, KCR 560 Regulator With Motor Starting Assist Option To Brushless Rotary Exciter (Or Static Exciter).

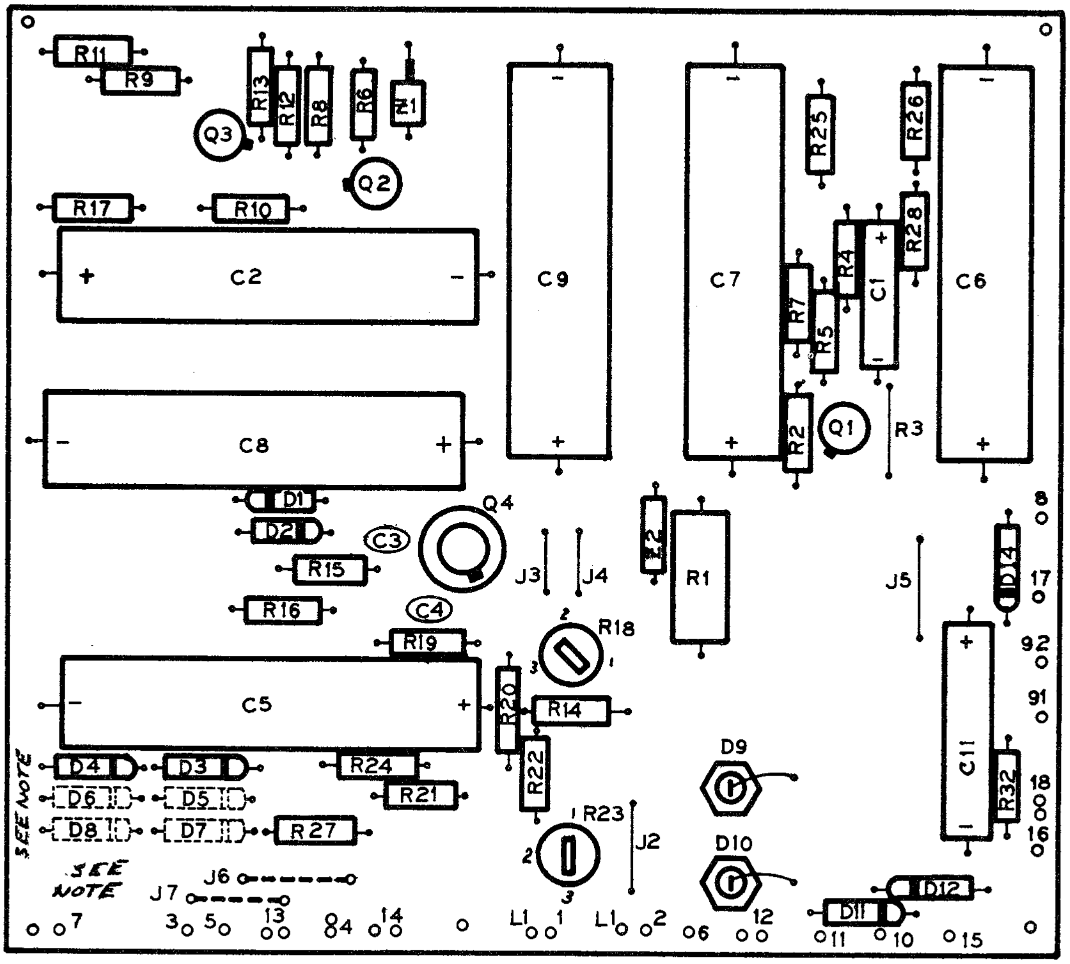
g) Interconnection, Parallel Voltage Droop Compensation.

h) Interconnection, Cross Current Compensation.



NOTE: Optional Location of Voltage Adjust, R1, Illustrated. Normal Location, Remote Mounting, External of Regulator Assembly.

Figure 6-1 Voltage Regulator Overall Drawing Including Component Location And Identification.

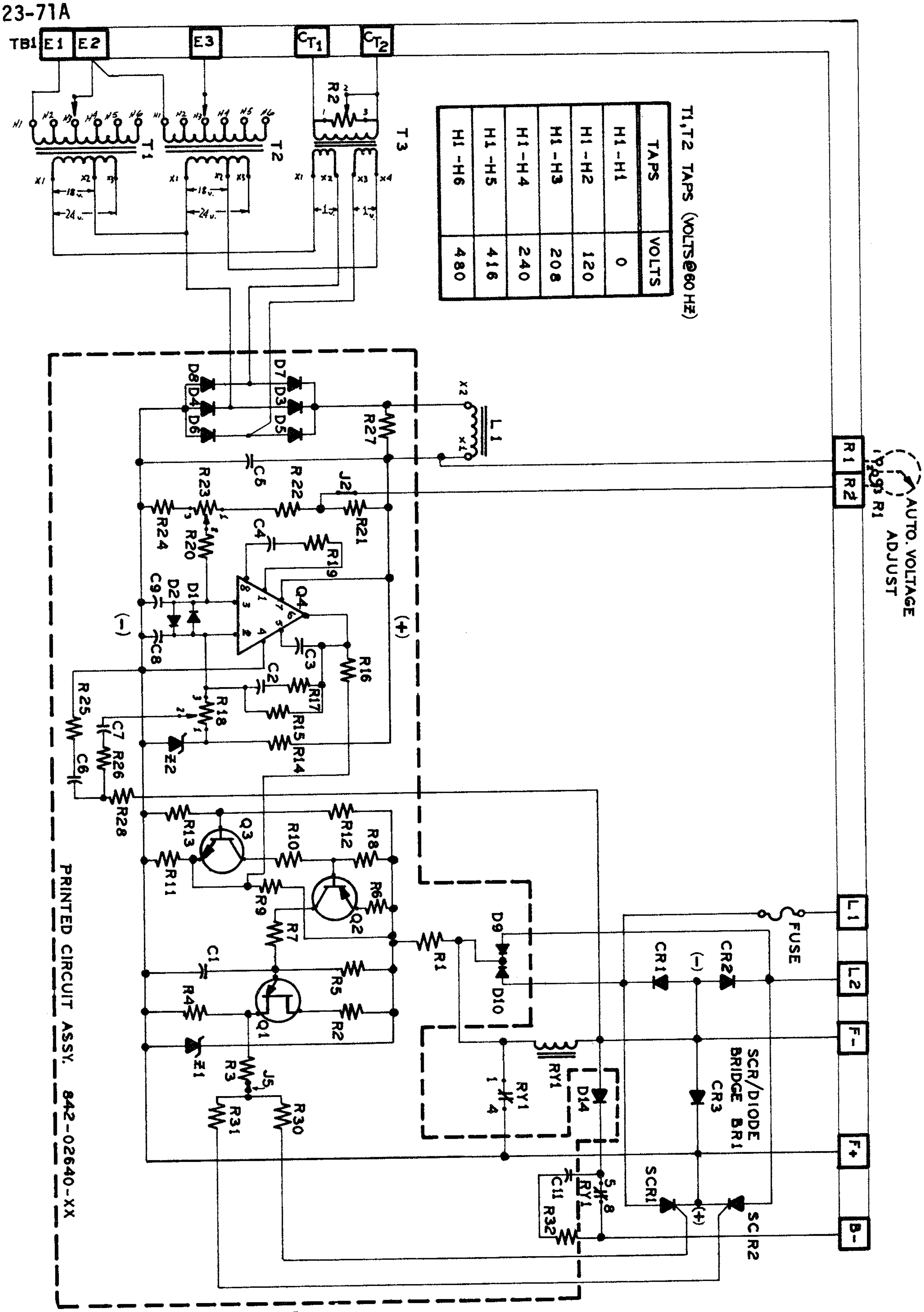


NOTE: REFER TO REGULATOR SCHEMATIC FIGURE 6-3 AND APPROPRIATE SENSING DRAWING CONTAINED IN SECTION 2 FOR THE FOLLOWING ITEMS:

1) RECTIFIERS UTILIZED FOR SENSING.

2) J6 JUMPERED OR OPEN, AND J7 JUMPERED OR OPEN.

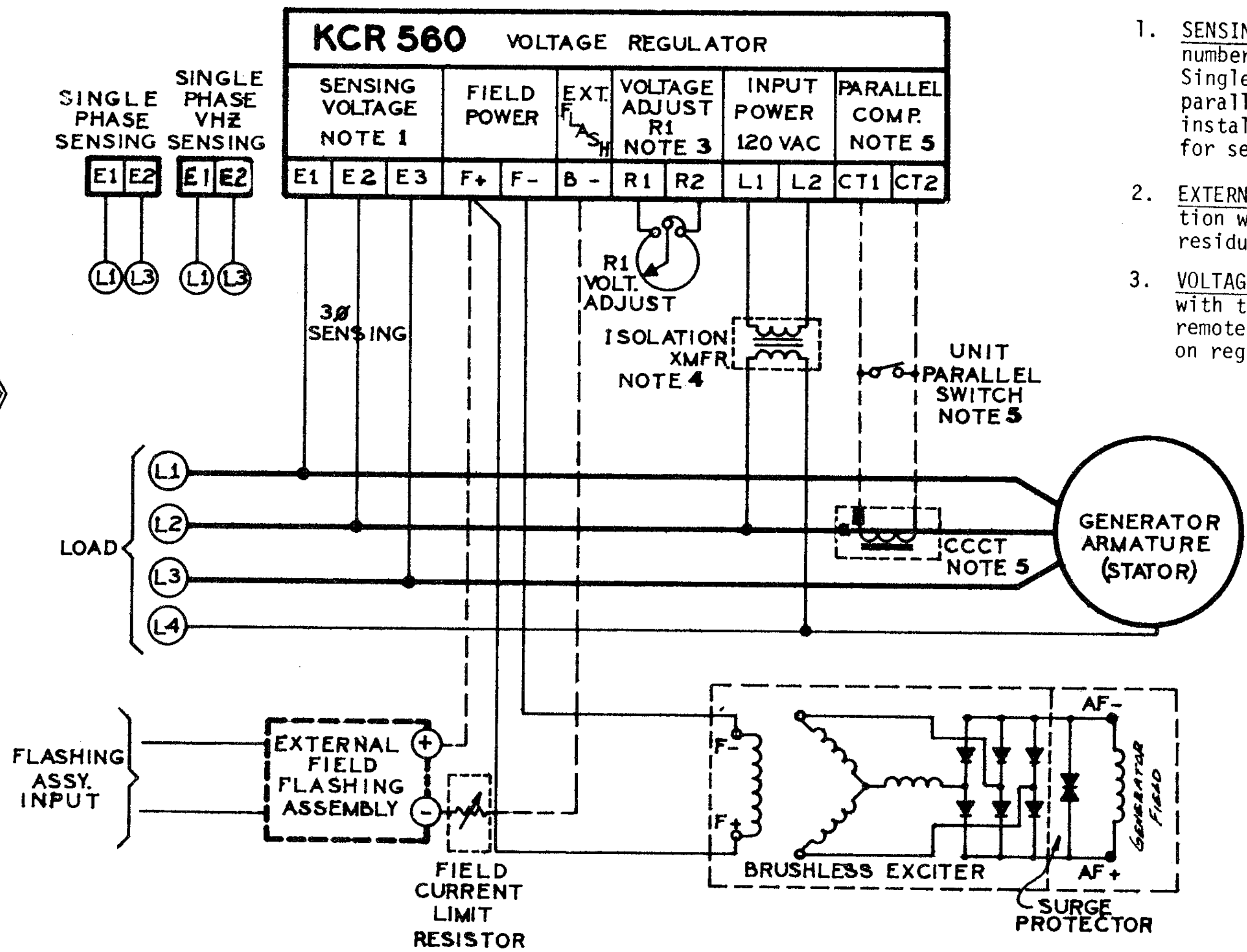
Figure 6-2 Printed Circuit Assembly Component Location and Identification



T1,T2 TAPS (VOLTS@60 HZ)

TAPS	VOLTS
H1-H1	0
H1-H2	120
H1-H3	208
H1-H4	240
H1-H5	416
H1-H6	480

Figure 6-3 SCHEMATIC, MODEL KCR560 VOLTAGE REGULATOR WITH THREE PHASE SENSING AND PARALLEL DROOP COMPENSATION OPTIONS.



NOTES

1. SENSING - Determine regulator sensing by model number. (See Table 1-1 and paragraph 1.2.) For Single phase or volts-per-hertz sensing models parallel compensation transformer CCCT should be installed in generator line other than those used for sensing.

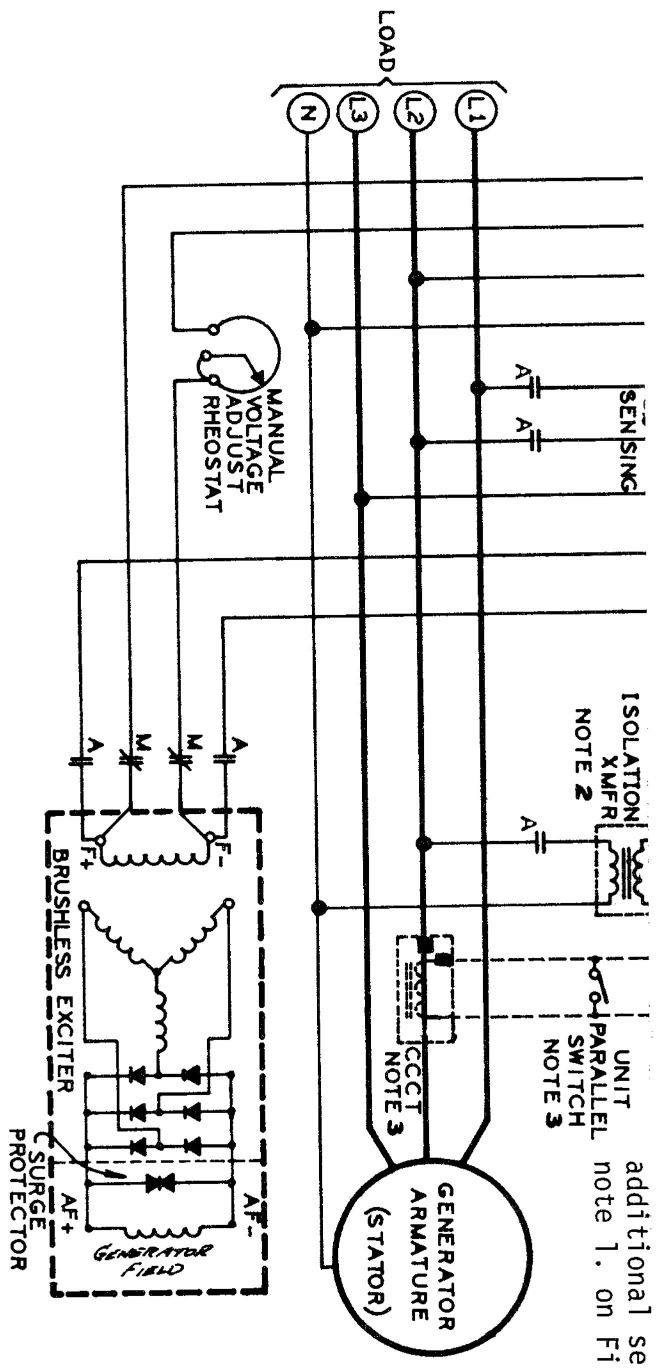
2. EXTERNAL FIELD FLASHING - Required only in application where generator or exciter does not retain residual magnetism. Retain polarity shown.

3. VOLTAGE ADJUST - This potentiometer is furnished with the regulator. Normally supplied loose for remote mounting. Optional location, when requested on regulator chassis.

4. ISOLATION TRANSFORMER - Required for voltage matching when 120 VAC is not available for regulator input power and for isolation when field and generator is grounded. An isolation transformer should be used when regulator power is taken from voltage source other than generator output. Isolation transformer also aids in surpression of conducted RFI.

5. PARALLEL COMPENSATION - Determine that regulator has parallel provisions (See Table 1-1 and paragraph 1.2). The polarity shown is for L1, L2, L3 phase rotation. Unit paralled switch should be used in cross current compensation applications where all paralled generators are not continually on system bus. (See Figure 6-8).

Figure 6-4 Typical Interconnection Diagram, KCR 560 Regulator To Brushless Rotary Exciter (or Static Exciter).



additional sensing information, refer to note 1. on Figure 6-4.

Figure 6-5 Typical Interconnection Diagram, KCR 560 Regulator With Auto-Manual Option With Brushless Rotary Exciter (or Static Exciter)

NOTE

WHEN MORE THAN 3
GENERATORS ARE TO
BE PARALLELED,
CONTINUE CONNECTIONS
AS SHOWN.

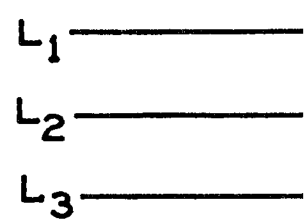
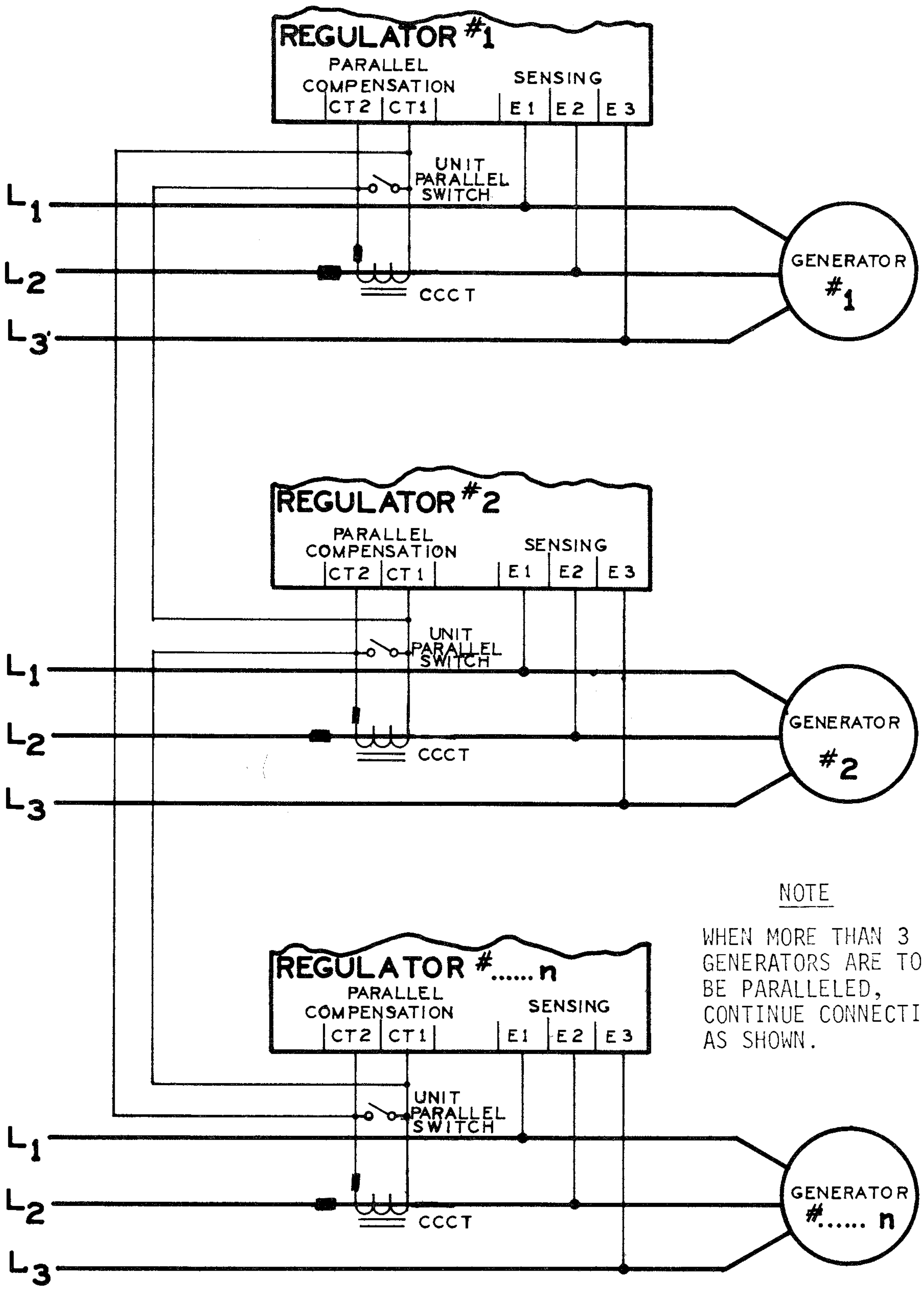


Figure 6-7 Parallel \



NOTE

WHEN MORE THAN 3 GENERATORS ARE TO BE PARALLELED, CONTINUE CONNECTIONS AS SHOWN.

Figure 6-8 Cross-Current Compensation CCCT's Interconnection

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