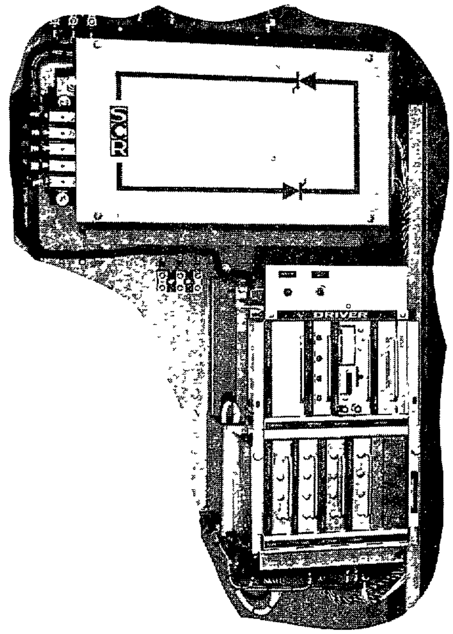
INSTRUCTIONS

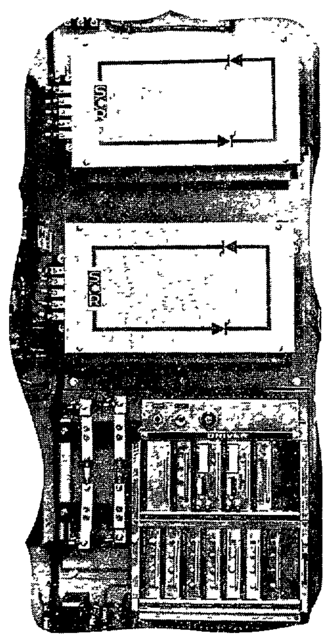
GEK-11014A

SCR CONVERSION ASSEMBLIES FOR SILCON VI* SCR DRIVES

OPERATION – ADJUSTMENT – TROUBLE SHOOTING



NON-REVERSING SCR
CONVERSION ASSEMBLY
(Single Conversion Module)



REVERSING SCR
CONVERSION ASSEMBLY
(Back-to-Back Conversion Modules)

GENERAL ELECTRIC

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WARNING

<u>HIGH VOLTAGE.</u> ELECTRIC SHOCK CAN CAUSE SERIOUS OR FATAL INJURY. WHETHER THE AC VOLTAGE SUPPLY IS GROUNDED OR NOT, HIGH VOLTAGES TO GROUND WILL BE PRESENT AT MANY POINTS WITHIN THE SCR DRIVE. EXTREME CARE MUST BE EXERCISED IN THE SELECTION AND USE OF TEST INSTRUMENTS.

OPERATORS SHOULD NOT STAND ON GROUNDED SURFACES OR BE IN CONTACT WITH GROUND WHEN APPLYING TEST INSTRUMENTS TO TEST POINTS. TEST INSTRUMENTS SHOULD NOT HAVE CHASSIS GROUNDED WHILE TESTS ARE BEING MADE. THUS THEIR CHASSIS WILL BE AT A HIGH VOLTAGE WITH RESPECT TO GROUND DURING TESTING. EXTREME CARE SHOULD BE TAKEN WHILE ATTEMPTING TO ADJUST, TROUBLESHOOT OR MAINTAIN ANY DRIVE SYSTEM DESCRIBED HEREIN.

SCR CONVERSION ASSEMBLIES
FOR
SILCON VI* SCR DRIVES

INTRODUCTION

The SCR conversion assembly is a combination of power and control building blocks which, when connected together, converts three phase A-C power into adjustable voltage D-C power. This assembly accepts a D-C reference signal from the regulator to control the D-C output voltage for driving a motor armature.

The power building block is the SCR conversion module which may be used alone or in combination. The control building block is the driver module which may be either the nonreversing or the reversing type. Different combinations of these building blocks form SCR conversion assemblies which are capable of one, two or four quadrant operation of a D-C motor.

The SCR conversion assembly contains regulating, logic and protective circuitry and components to insure its proper operation under a wide variety of operating conditions. It has a very fast speed of response and has linear gain over its operating range.

RATINGS AND SPECIFICATIONS

1. A-C Power Input

(a) Voltage—three phase;
low voltage—230 volts +10%, −5%;
high voltage—460 volts +10%, −5%

(b) Frequency—60 cps standard, 50 cps special

(c) Current—0.82 times D-C current

2. D-C Power Output

(a) Voltage—controllable over the following rated voltage ranges:

Conversion Type	Rated D-C Voltage Range Nonreversing	Reversing or Regenerative
Low Voltage	0 to 250 volts	−250 to +250 volts
High Voltage	0 to 550 volts	−500 to +500 volts

(b) Current—rated to match NEMA D-C motor horsepower ratings, with 1.0 service factor and standard overload rating of 150% for one minute at maximum ambient of 40°C (outside enclosing case); higher overload ratings, service factors or ambient temperatures are obtainable by derating the horsepower rating.

3. Control Input

(a) Reference voltage—0 to 10 volts D-C, positive for first and second quadrant operation and negative for third or fourth quadrant operation.

(b) A-C control power—115 volts ±10%, single phase for power supply.

4. Control Output

(a) Power supply—+20 volts at 200 milliamps and −20 volts at 200 milliamps power supply for auxiliary regulator usage.

(b) Fault relay interlock—normally open interlock on a fault relay that is energized during normal operation, for external magnetic fault circuitry usage.

PRINCIPLES OF OPERATION

NONREVERSING SCR CONVERSION ASSEMBLY

The operation of this assembly is best understood by referring to the schematic block diagram of Figure 1. This diagram shows the important parts of the total assembly in functional block form. A more detailed description of these blocks can be found later in these instructions.

The D-C reference is fed into the driver amplifier where it is compared with a voltage feedback signal from the SCR conversion module. This voltage feedback is first sent through an isolator to isolate the control circuitry from the power circuit. The error between reference and voltage feedback is amplified and fed into the gate pulse generators. (The block on the diagram actually represents three gate pulse generators.) The gate pulse generators produce six gate signals, synchronized to the A-C voltage, which are fed to the six SCR's in the SCR conversion module, represented by one block on the diagram. The gate pulses are fed to the SCR's through pulse transformers which provide isolation of the control circuitry from the power circuit. The SCR conversion module rectifies the three phase A-C power into adjustable voltage D-C power, the voltage being proportional to the reference input. Current transformers in the SCR conversion module feed back a current signal to the driver which is used for current limit and instantaneous overcurrent tripping. A-C control power is fed to synchronizing transformers in the driver module to synchronize the production of gate pulses with the A-C voltage. A cooling fan is included if forced cooling of the SCR conversion module is required.

The closed loop characteristic (output voltage vs reference voltage) of this assembly is shown in Figure 2. The solid line portion covers positive voltage or motoring operation whereas the dotted line portion covers negative voltage or regenerating operation, since the output current can only be positive under all operating conditions. Operation in the regenerative quadrant is possible only if the load drives the motor in the negative direction from the normal motoring direction.

The open loop characteristic (output voltage vs error voltage) of this assembly is shown in Figure 3. Again the solid and dotted portions of the line represent motoring and regenerating operation respectively.

The closed loop transfer function of this assembly is as follows:

$$\frac{\text{Output voltage}}{\text{Reference voltage}} = \frac{K}{1+Tp}$$

where the gain K is 24 for a 250 volt D-C drive and is 56 for a 500 volt D-C drive. The time constant T is approximately .002 seconds, but may vary from .001 to .005 seconds.

The nonreversing SCR conversion assembly is normally required to operate only in the first quadrant as a nonregenerative drive. All of the control circuitry however is capable of controlling and protecting this assembly when operating in the fourth quadrant as a regenerative drive. All that is required is to add a fast acting fuse in the D-C armature loop to protect against inverter faults which can occur only during regenerative operation.

REVERSING SCR CONVERSION ASSEMBLY

The operation of this assembly is best understood by referring to the schematic block diagram of Figure 4. This diagram shows the important parts of the total assembly in functional block form. A more detailed description of these blocks can be found later in these instructions.

The D-C reference is fed into the driver amplifier where it is compared with a voltage feedback signal from the SCR conversion module. This voltage feedback is first sent through an isolator to isolate the control circuitry from the power circuit. The error between reference and voltage feedback is amplified and fed into the gate pulse generators. A positive error drives the forward set of three gate pulse generators whereas a negative error drives the reverse set of three gate pulse generators (each set being represented by one block on the diagram). The amplifier is biased such that the two sets of gate pulse generators cannot be turned on together. Each set of gate pulse generators produces six gate signals, synchronized to the A-C voltage, which are fed to the six SCR's respectively in each of the forward and reverse SCR conversion modules. The gate pulses are fed to the SCR's through pulse transformers which provide isolation of the control circuitry from the power circuit. Each SCR conversion module rectifies the three phase A-C power into adjustable voltage D-C power, the voltage being proportional to the reference input, dependent on polarity. The forward and reverse SCR conversion modules have their D-C outputs cross-connected such that the forward module produces a positive output and the reverse module produces a negative output. This connection is made through two D-C armature fuses whose function is to protect against inverter or circulating current faults. Current transformers in each SCR conversion module feed back current signals to the driver which are used for lockout, current limit and instantaneous overcurrent tripping. (The lockout function prevents one SCR conversion module from being turned on if current is present in the other.) A-C control power is fed to the synchronizing transformers in the driver module to synchronize the production of gate pulses with the A-C voltage. A cooling fan is included if forced cooling of the conversion modules is required.

The closed loop characteristic (output voltage vs reference voltage) of this assembly is shown in Figure 5. The solid line portions cover motoring action of each SCR conversion module, or first and third quadrant operation. The dotted line portions cover regenerating action of each SCR conversion module, or second and fourth quadrant operation. Current can only be unidirectional in each SCR conversion module.

The open loop characteristic (output voltage vs error voltage) of this assembly is shown in Figure 6. The characteristic on the right or positive error side is for the forward conversion module, while the characteristic on the left or negative error side is for the reverse conversion module. The two characteristics are biased to prevent both from being operative at the same time.

The solid and dotted portions of the two lines represent motoring and regenerating operation respectively.

The closed loop transfer function of this assembly is as follows:

$$\frac{\text{Output voltage}}{\text{Reference voltage}} = \frac{K}{1+Tp}$$

where the gain K is 24 for a 250 volt D-C drive and is 56 for a 500 volt D-C drive. The time constant T is approximately .002 seconds, but may vary from .001 to .005 seconds.

The reversing SCR conversion assembly can operate in all four quadrants because it contains two back to back connected SCR conversion modules, each capable of two quadrant operation. The control circuitry in the driver senses which mode of operation is required at all times. If a quadrant change, requiring a change in the operating SCR conversion module, is required, the driver quickly turns off the one and turns on the opposite SCR conversion module. The fast response voltage regulating loop enables the driver to switch operating SCR conversion modules with a minimum of off time so as not to interfere with drive operation. The dead band biasing and lockout circuitry prevent both forward and reverse SCR conversion modules from being fired at the same time. Since these lockout circuits have practically instantaneous response, misoperation is prevented even though the transfer operation from one SCR conversion module to the other is extremely fast.

SCR CONVERSION MODULE

The SCR conversion module is the power building block in the SCR conversion assembly. It consists of a three phase, full wave SCR bridge rectifier circuit, protective components and circuitry, firing circuitry and feedback circuitry, all mounted together in one package. One of these modules is required for a nonreversing SCR conversion assembly whereas two modules, connected back to back, are required for a reversing SCR conversion assembly.

The SCR conversion module is described in detail in Instruction GEK 11015A.

DRIVER MODULE

The driver module is the control building block in the SCR conversion assembly. It consists of a synchronizing transformer assembly and a driver rack which contains all the printed circuit cards required to perform the control functions. There are two types of driver modules, one for nonreversing SCR conversion assemblies and one for reversing SCR conversion assemblies. The driver module is described in detail in Instruction GEK 11016A.

COOLING

SCR conversion assemblies which have ratings up through 20 hp at 250 volts D-C, 40 hp at 500 volts D-C and 50 hp at 550 volts D-C are designed for convection cooling. As long as air flow in unrestricted and ambient temperature does not exceed 40°C (outside the enclosing case), no forced cooling means is provided or is required.

SCR conversion assemblies with higher hp ratings than those listed above normally have cooling fans for forced cooling of the SCR conversion modules, since convection cooling of these sizes would require derating. The fan and plenum chamber are located at the top, and force air down through the SCR conversion module ('s). The fan is driven by a three phase motor which is fused for short circuit protection.

D-C ARMATURE FUSES
(Reversing or regenerative operation only)

Fast acting fuses are placed in the D-C outputs of the SCR conversion modules on reversing SCR conversion assemblies. Their function is to protect against inverter faults and circulating currents. An inverter fault can be either a shoot-thru or a plugging fault which can only occur during regenerative operation. A shoot-thru occurs when any two SCR's in series across the D-C bus of a regenerating SCR conversion module are simultaneously fired. This produces a short circuit across the D-C motor armature which cannot be interrupted by A-C fault protection. A plug occurs when an SCR is not commutated off at the end of its normal conduction period during regenerative operation. If an SCR remains in the conducting state for the full cycle, the A-C supply voltage is connected to the D-C armature voltage in an additive instead of opposing direction and a high fault current results. A circulating current fault occurs when back to back connected SCR conversion modules are simultaneously fired. The fault current does not go through the D-C load but is circulated through both SCR conversion modules.

Inverter faults do not occur normally because of the protective lockout and logic circuits which are contained in the driver control, and the protective circuits contained in the SCR conversion modules.

However, if they occur, it is possible to blow D-C armature fuses without the instanteous overcurrent trip circuit operating to drop out the driver fault relay. If detection of blown D-C fuses is necessary to operate a brake or shut down other equipment, a fuse failure detector card can be provided in the driver module.

PARALLEL OPERATION

Paralleling of SCR conversion modules is required to provide higher current ratings than would be obtainable with the largest rated module. Only the largest SCR conversion module is paralleled, and these modules contain leg fuses and cell indicating lights not normally furnished on non-paralleled modules. The function of the leg fuse is to interrupt a short circuit caused by an SCR failure without damaging other cells, thus isolating the shorted leg. The indicating light, which is normally lighted, will go out when the SCR fails and the leg fuse blows.

Current sharing between paralleled SCR conversion modules is accomplished by firing all the modules from one set of gate pulse generators and by means of the leg chokes in each module.

OPERATION AND ADJUSTMENTS

Before operating the equipment, this instruction book and the SCR conversion module and driver module instruction books should be read and understood. This equipment has been operated in the factory to check performance and make adjustments. Only a limited amount of checking and adjustment will be required on initial start-up of the SCR conversion assembly portion of the drive.

PHASE SEQUENCE

It is necessary to connect the A-C supply to the power unit in the correct phase sequence for the SCR conversion assembly to operate properly. The fault relay in the driver monitor card will not pick up and the "loss of phase" indicating light, on the front of the driver monitor card, will light if phase sequence is incorrect. Interchange any two A-C supply leads and reapply A-C power to recheck phase sequence.

Before applying A-C power to a reversing conversion assembly, disconnect one end of pulse train cable 3CA from the driver.

INITIAL START-UP OF NONREVERSING CONVERSION ASSEMBLY

The drive should be checked out first before connecting the motor armature leads. If the drive operates as a voltage regulator, it can be checked out as a total drive with the motor disconnected. If the drive contains a speed or current regulator, the regulator must be disconnected to check out the SCR conversion assembly. This may be accomplished by disconnecting the reference input to driver terminal 7 and connecting driver terminal 7 to a temporary speed reference potentiometer of the correct polarity.

When A-C power is applied, the "power on" light mounted on the driver pot bracket will turn on. Unless a fault exists, the fault relay on the driver monitor card will immediately pick up, closing the interlock connected to driver terminals 11 and 12 for external magnetic circuit interlocking.

When positive reference voltage is applied to driver terminal 7, the SCR conversion module will produce D-C voltage, producing rated voltage at approximately 8 to 10 volts reference input. Using an instrument card in the driver test card position, go through the driver voltage check list and voltage wave shape check list given on the driver elementary diagram and in the "Trouble Shooting" section of the Driver Instructions GEK 11016A. Compare the voltages and voltage wave shapes read with those given on the elementary diagram and in the instruction book. These should look the same except for voltage and current feedback readings (selector positions 4 and 5) which will appear somewhat different due to the lack of output loading.

The output voltage should be fully controllable with the reference, and should be completely stable. If this is not the case, it may be necessary to load the output slightly with a loading resistor. This loading resistor should be rated to load the D-C output about 2 percent of rated amps at rated D-C volts.

If the SCR conversion assembly checks out properly as outlined above, the motor armature leads should be connected and the reference input to the driver should be returned to its original connection if it has been changed. The drive should be run and the SCR conversion assembly should be rechecked, paying particular attention to the voltage and current feedback wave shapes. These wave shapes should agree with those given in the driver instruction book.

INITIAL START-UP OF REVERSING CONVERSION ASSEMBLY

The drive should be checked out first before connecting the motor armature leads. If the drive operates as a voltage regulator, it can be checked out as a total drive with the motor disconnected. If the drive contains a speed or current regulator, the regulator must be disconnected to check out the SCR conversion assembly. This may be accomplished by disconnecting the reference input to driver terminal 8 and connecting driver terminal 7 to a temporary speed reference potentiometer of the correct polarity.

Before applying A-C power, disconnect one end of pulse train cable 3CA from the driver to the reverse SCR conversion module (or from the driver to the signal distribution assembly, if a paralleled drive). This will allow checking out the forward portion of the SCR conversion assembly separately. (Note: The feedback cable 4CA from the driver to the reverse SCR conversion module should not be disconnected).

The forward portion of the SCR conversion assembly should be checked out according to the procedure outlined for initial start up of the nonreversing assembly, up to the point of connecting the motor. If the forward portion checks out all right, the reverse portion should then be checked. This is accomplished using the same procedure as for the forward portion, except that pulse train cable 1CA is disconnected and pulse train cable 3CA is reconnected, a reverse reference is applied to driver terminal 7, and the instrument card is transferred from the forward test card position to the reverse test card position.

If both the forward and reverse portions of the SCR conversion assembly check out properly, the motor armature leads should be connected and the reference input to the driver should be returned to its original connection if it has been changed. Keeping pulse train cable 1CA disconnected, run the drive and recheck the reverse portion of the SCR conversion assembly, paying particular attention to the voltage and current feedback wave shapes. These wave shapes should agree with those given in the driver instruction book. The motor should be fully controllable in the reverse direction and operation should be completely stable. The "voltage limit" potentiometer, located on the driver pot bracket, has been factory adjusted to limit the motor armature voltage to 270 volts for a 250 volt rated drive, and to 540 volts for a 500 volt rated drive. (Note: It will be necessary to temporarily increase the regulator "max speed" adjustment, or equivalent, to check the voltage limit adjustment.)

If the reverse portion of the SCR conversion assembly checks out properly with the motor load, the forward portion should then be checked. This is accomplished using the same procedure as for the reverse portion, except that pulse train cable 3CA is disconnected and pulse train cable 1CA is reconnected, and the instrument card is transferred from the reverse test card position to the forward test card position.

If both forward and reverse portions of the SCR conversion assembly check out properly with the motor load, the drive should be checked with both forward and reverse portions operating together. Reconnect pulse train cable 3CA and run the drive both forward and reverse. Try running the drive through all four quadrants, watching voltage and current feedback wave shapes and comparing them with those given in the driver instruction book.

CURRENT LIMIT (Protective)

The protective current limit potentiometer in the driver is normally adjusted in the factory to limit armature current to 150% of rated, at rated voltage. The adjustment of this potentiometer, and the different ranges of adjustment available, is discussed in the "Operation and Adjustments" section of the Driver Instruction GEK 11016A. If a functional current limit is included in the regulator, this protective current limit may be set up as high as 200% of rated so that it does not interfere with the regulator current limit.

Normally, it is difficult to check the current limit setting on a drive. This may be accomplished at stall by disconnecting the motor field and locking the motor shaft by some means to prevent it from rotating. The current limit point at stall will be approximately 10 to 20 percent higher than at rated speed.

OTHER ADJUSTMENTS

There are a number of other adjustments which are contained in the driver. These are factory adjustments which should not require readjusting unless misoperation occurs. Refer to the "Operation and Adjustments" section of the Driver Instruction GEK 11016A for a description of these adjustments.

TROUBLE SHOOTING

GENERAL APPROACH

When incorrect operation is first noticed, it is often possible to reduce the overall servicing time by studying the symptoms in order to localize the trouble. A good understanding of the functional operation, as explained in the "Principles of Operation" section, will be very helpful in isolating the problem. A systematic check of voltages and voltage wave shapes and comparison of them with the correct readings, as given in the "Trouble Shooting" sections of the SCR Conversion Module Instruction GEK 11015A and the Driver Module Instruction GEK 11016A, should reveal the source of many malfunctions. If the trouble is localized to one of the above two modules, the trouble shooting notes in that instruction book should then be followed.

WARNING

HIGH VOLTAGE. ELECTRIC SHOCK CAN CAUSE SERIOUS OR FATAL INJURY. WHETHER THE AC VOLTAGE SUPPLY IS GROUNDED OR NOT, HIGH VOLTAGES TO GROUND WILL BE PRESENT AT MANY POINTS WITHIN THE SCR DRIVE. EXTREME CARE MUST BE EXERCISED IN THE SELECTION AND USE OF TEST INSTRUMENTS.

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The use of a good quality oscilloscope is required to properly trouble shoot this equipment. The information on selection and use of an oscilloscope in the general approach portion of the "Trouble Shooting" section of GEK 11015A should be followed when observing high voltage wave shapes.

If trouble occurs only when the motor is run (such as frequent or immediate IOC tripping), the motor armature leads should be disconnected and a resistor should be connected to the D-C power terminals to load the drive. This loading resistor should be rated to load the D-C output about 2 percent of rated amps at rated volts. It should then be possible to check out the SCR conversion assembly portion of the drive as outlined previously in the initial start-up portion of the "Operation and Adjustments" section of this instruction.

If trouble is experienced on a reversing SCR conversion assembly, it may be desirable to check out the forward and reverse sections separately to determine the trouble. This may be accomplished by disconnecting the pulse train cable (either 1CA or 3CA) from the driver to that SCR conversion module to be disabled.

CHECKING FOR MALFUNCTIONS

1. Drive shuts down or won't start

(a) Check driver monitor card indicating lights and fault relay interlock at driver terminals 11 and 12. If indicating light is lit or fault interlock is open, refer to trouble shooting notes in GEK 11016A.

(b) Check D-C armature fuses on reversing or regenerative drives. If blown, replace with fuses of the same type and ampere rating, restart drive and observe performance. Compare voltages and voltage wave shapes given in the trouble shooting notes of GEK 11015A and GEK 11016A.

(c) Check for presence of reference input to the driver, for A-C power to the SCR conversion module (s) and to the driver, for connection of cable receptacles at the driver and the SCR conversion module(s), and for the presence of D-C control power at driver terminals 4 and 5 with respect to terminal 1 (common). Run through voltage check list given in trouble shooting notes of GEK 11016A.

2. Drive voltage erratic and not controllable

(a) Check phase sequence of incoming A-C supply to SCR conversion module(s). It should be 1-2-3 for T1, T2, T3 terminals.

(b) Check A-C synchronizing and pulse train phase sequence in the driver. Also check for voltage feedback in the driver. Refer to the trouble shooting notes in GEK 11016A.

3. Drive will not put out rated voltage

(a) Check armature current level to see if SCR conversion assembly is in protective current limit. Check unijunction emitter voltage wave shape in driver trouble shooting notes for current limit condition. Refer to trouble shooting notes in GEK 11016A.

(b) Check voltage feedback wave shape for missing pulses or for fully turned on condition. Refer to trouble shooting notes in GEK 11015A if one or more pulses are missing. Check A-C line voltage for excessively low voltage.

(c) Check for reference input voltage to driver. It should be 8 to 10 volts for rated output voltage. Check setting of voltage limit adjustment. Refer to trouble shooting notes in GEK 11016A.

4. Drive output voltage or current unbalanced

(a) If some pulses are completely missing, refer to trouble shooting notes in GEK 11015A for failed SCR or missing firing pulses.

(b) Check adjustment of gate pulse generator biases as outlined in the "Operation and Adjustment" section of GEK 11016A. Also refer to the trouble shooting notes in GEK 11016A for other possible causes of pulse train unbalance.

5. Misoperation during reversing or regeneration

(a) Check for operation of lockout circuits and for correct dead band in the driver module. Check voltage wave shapes in driver during regeneration. Check bias adjustment of gate pulse generators. Refer to trouble shooting notes in GEK 11016A.

(b) Check for high DV/DT voltage spikes across SCR's during regeneration with an oscilloscope. Refer to trouble shooting notes in GEK 11015A.

6. Cooling fan not operating

(a) Check for blown fuses inside fan plenum chamber. If blown, replace with the same type and ampere rating, reapply A-C voltage and check operation.

(b) Check for A-C voltage to fan fuses.

NONREVERSING SCR CONVERSION ASM.

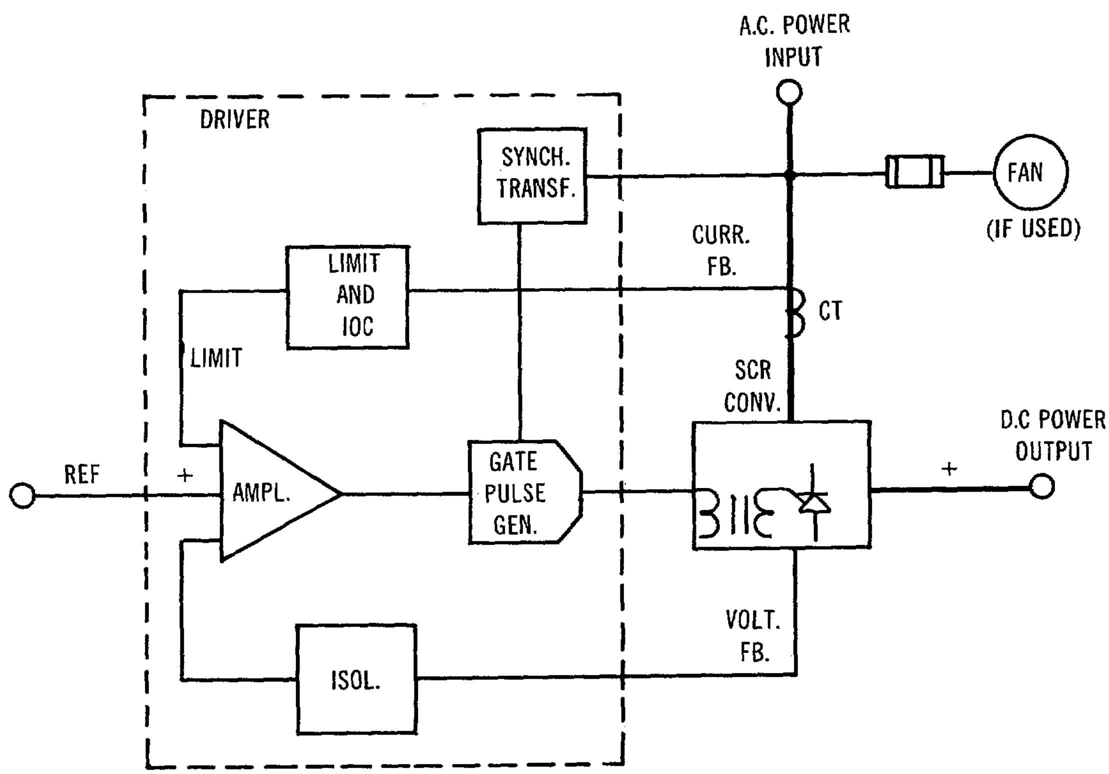

FIGURE 1

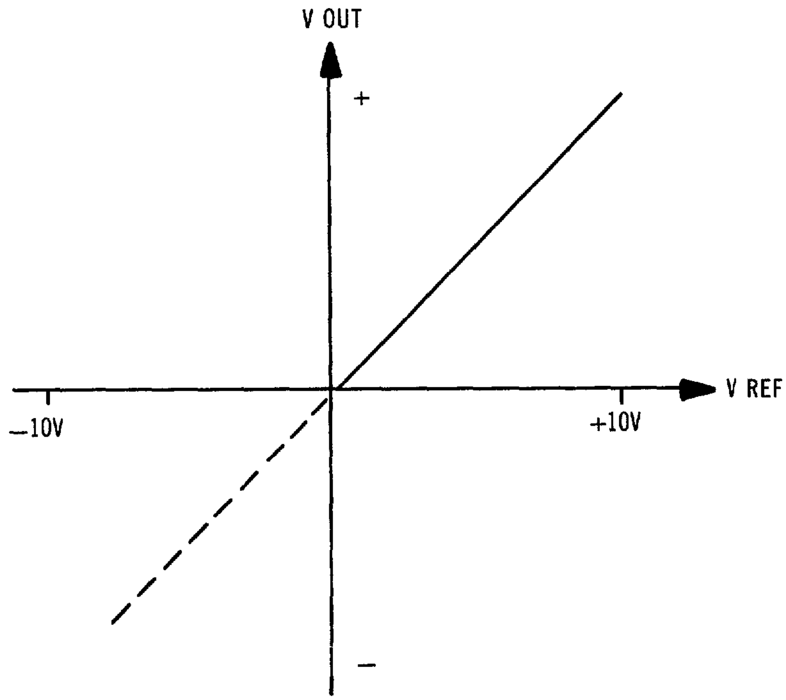

FIGURE 2

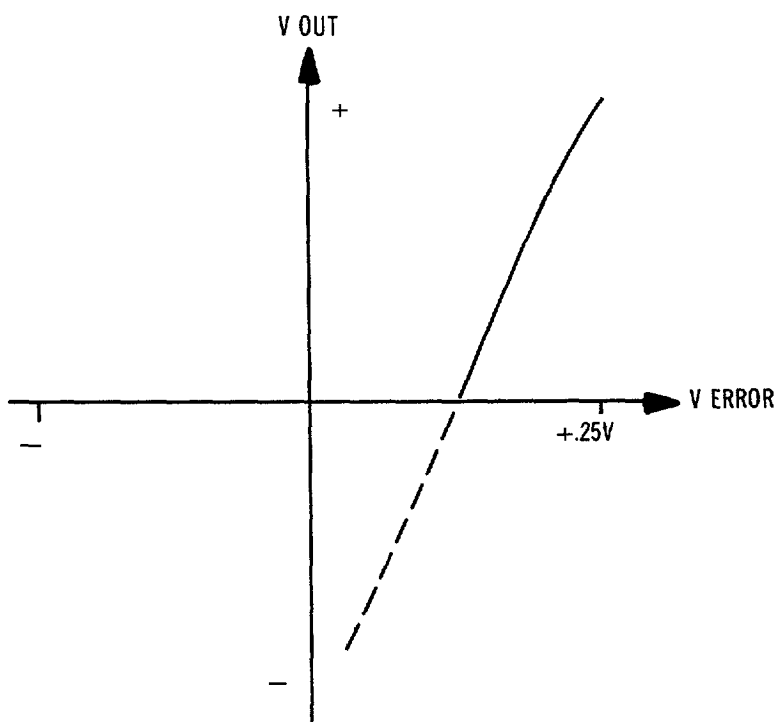

FIGURE 3

REVERSING SCR CONVERSION ASM.

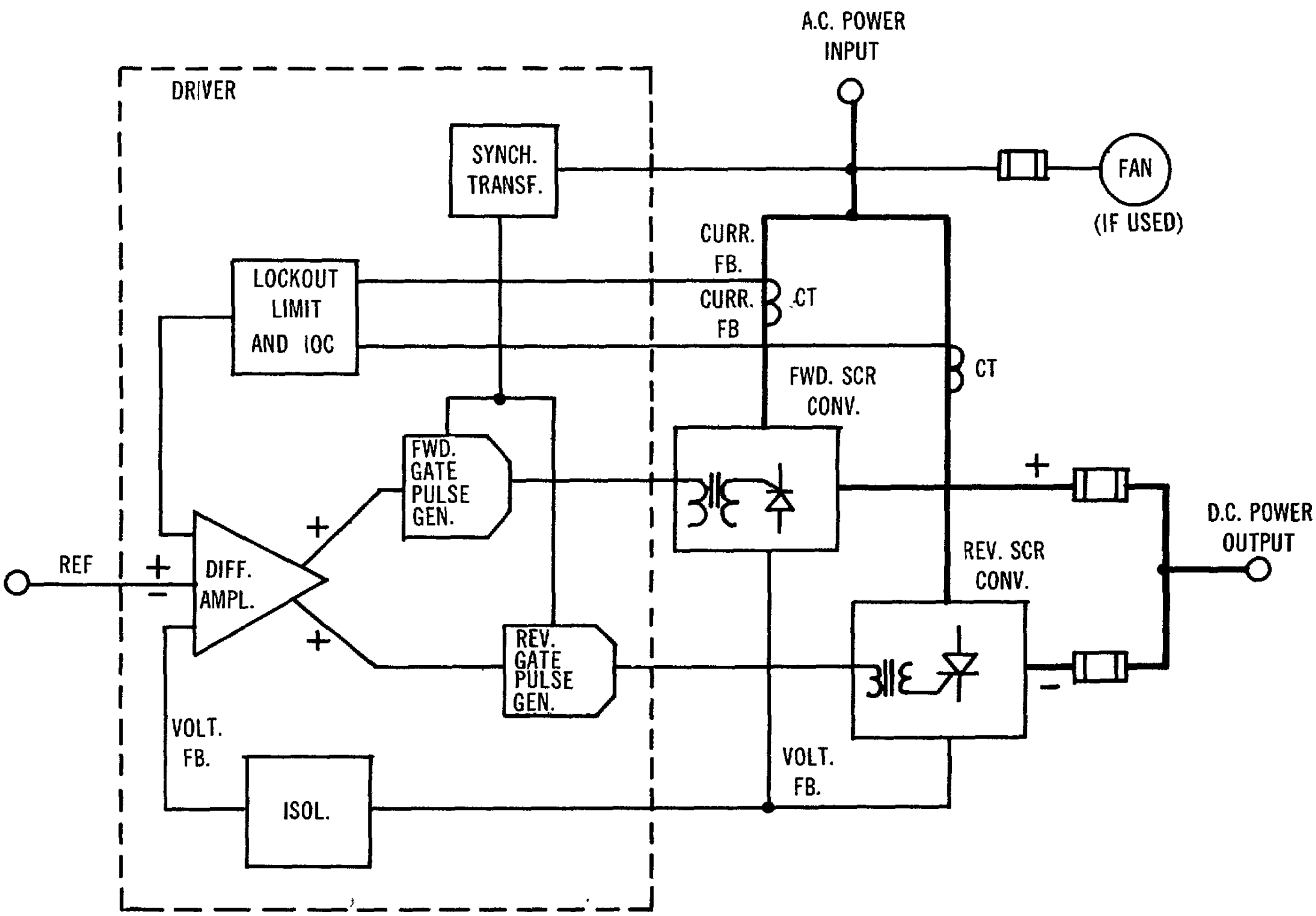

FIGURE 4

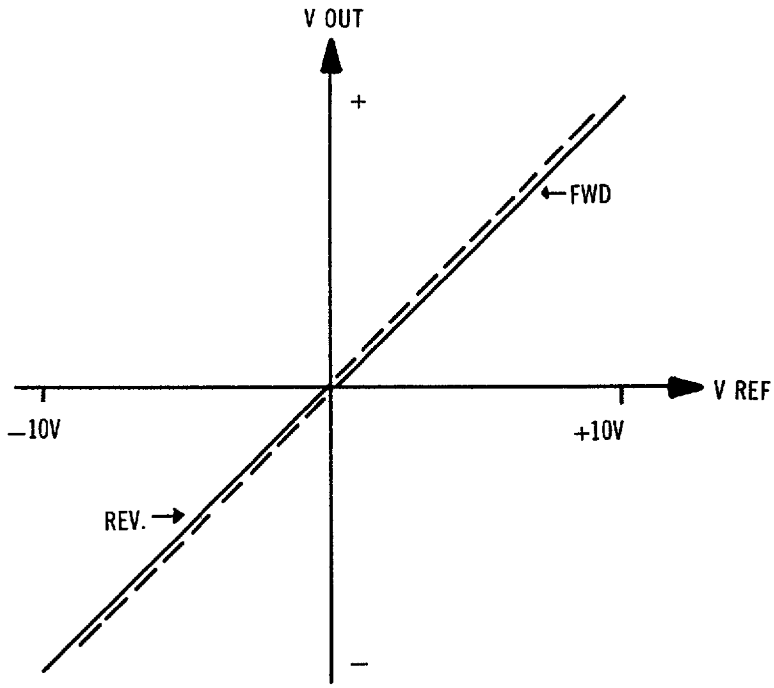

FIGURE 5

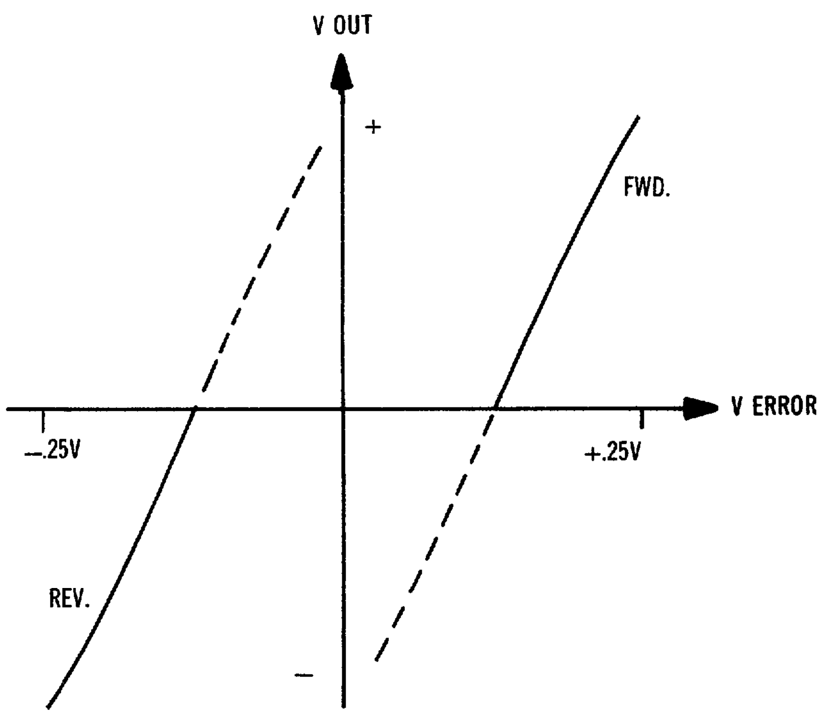

FIGURE 6

GENERAL ELECTRIC COMPANY – DC MOTOR & GENERATOR DEPARTMENT

SPEED VARIATOR PRODUCTS OPERATION
ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

GEK-11014A (5/79) 500 (F)