

## CONVERTER/RECTIFIERS 11

The Converter/Rectifiers circuit provides the operating power for this instrument from an ac line-voltage source. This circuit includes a LINE VOLTAGE SELECTOR switch, located on the rear panel. Figure 3-40 shows a detailed block diagram of the Converter/Rectifier circuit. A schematic is provided on diagram 11 in the Diagrams section of this manual.

### Line Input

Power is applied through Line Filter FL1200, line fuse F1200, POWER switch S1200, and Line Selector switch S1212. The Line Filter is designed to keep powerline interference from entering the instrument and to keep the approximate 25 kilohertz Inverter signal from entering the power line. Components R1205, C1205, and C1206 suppress reverse-recovery transients of CR1215.

Line Selector switch S1212 allows the instrument to operate from either a 115 volt nominal or a 230 volt nominal line-voltage source. In the 115 volt position, rectifier CR1215 operates as a full-wave doubler with energy-storage capacitors C1216 and C1217, so the voltage across the two capacitors in series will be the approximate peak-to-peak value of the line voltage. For 230 volt operation, CR1215 is connected as a bridge rectifier and the voltage across C1216 and C1217 will be the approximate peak value of the line voltage. Thus, the dc voltage applied to the Inverter stage is about the same for either 115 volt or 230 volt operation.

Thermistors RT1209 and RT1213 limit the surge current when the power supply is first turned on. After the instrument is in operation, the resistance of these thermistors drops so that it has little effect on the circuit. When the instrument is turned off, the Inverter control stage turns off the Inverter which prevents it from discharging C1216

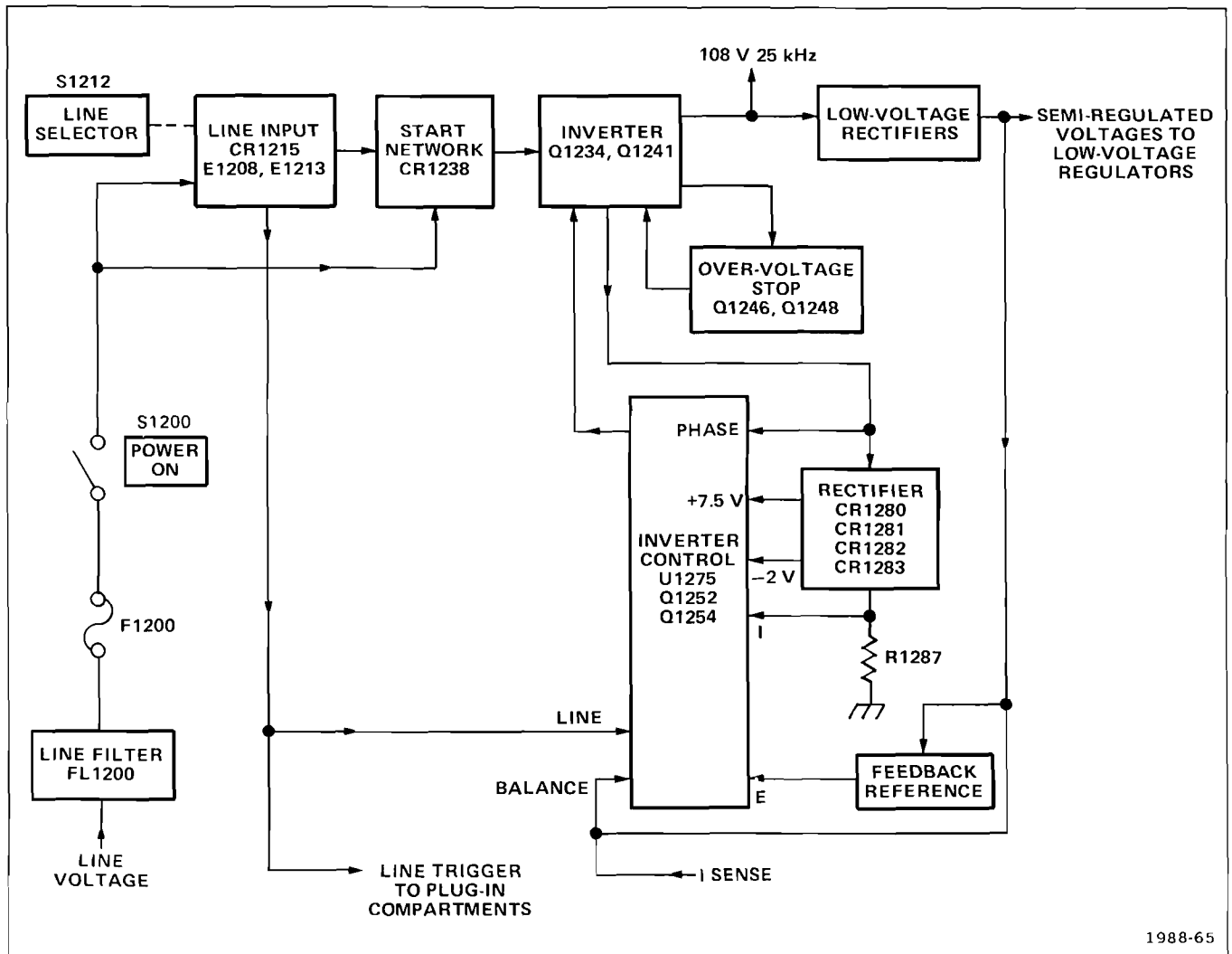


Figure 3-40. Detailed block diagram of Converter/Rectifiers circuit.

and C1217; C1216 and C1217 discharge slowly through R1221 to allow for thermistor thermal-recovery time. This ensures sufficient thermistor resistance to limit the turn-on surge current to a safe level. Since C1216 and C1217 discharge slowly, dangerous potentials exist within the power supply for several minutes after the POWER switch is turned off. The presence of voltage in the circuit is indicated by the relaxation oscillator R1219, C1219, and DS1219. Neon bulb DS1219 will blink until the potential across C1216 and C1217 drops to about 80 volts.

Spark gap electrodes E1208 and E1213 are surge-voltage protectors. When the Line Selector switch is in the 115 volt position, only E1208 is connected across the line input. If a peak voltage greater than 230 volts is present on the line, E1208 will conduct and quickly open line fuse F1200 to interrupt the input power before the instrument can be damaged. In the 230 volt position, E1208 and E1213 are connected in series across the line input to provide protection for peak voltages greater than 460 volts.

Transformer T1208 provides a sample of the line voltage to the plug-in connectors for triggering at line frequencies. This line-frequency signal is also connected to the Inverter control stage to sense when line voltage is present.

### Start Network

Network R1210, R1242 and C1242 is connected between the input line (ac) and the negative side of C1217 (through T1225). C1242 charges on each cycle of the input line voltage. When the charge on C1242 reaches about 32 volts, trigger diode CR1238 conducts providing base drive to turn on Q1241 through C1239. When Q1241 turns on, it shock-excites series-resonant network L1237 and C1237 to generate a damped oscillation. This damped oscillation provides the drive necessary to start the Inverter switching action. After the Inverter is operating, the recurrent waveform at the collector of Q1241 keeps C1242 discharged through CR1242, thus disabling the Start Network while the instrument is on.

### Inverter

The Inverter stage converts the dc voltage across C1216 and C1217 to a sine-wave current to drive Power Transformer T1310. Once the Inverter has been started by the Start Network, transformer T1230 provides feedback to the bases of Q1234 and Q1241 to sustain oscillation. These transistors operate at a forced beta of 4 due to the turns ratio of T1230. Also, T1230 provides a 60-turn, center-tapped winding for pre-regulation and fault protection shut-down. The Inverter Control stage short circuits one-half of this winding to either delay the turn-on of Q1234 and Q1241 or to completely stop their switching action.

The switching action of Q1234 and Q1241 generates a square-wave voltage with an amplitude approximately equal to the dc voltage at the input to this stage. The square-wave voltage at the emitter of Q1234 supplies the drive necessary to maintain a sine-wave current in the series-resonant network of L1237 and C1237. Diodes CR1234 and CR1241 provide paths for series-resonant current when Q1234 and Q1241 are held off for pre-regulation.

To aid in understanding circuit operation, Figure 3-41(A) shows a representation of the Inverter stage as a switch. The three possible states of the Inverter are depicted by the three possible switch positions: Q1234 is on in position (a); Q1241 is on in position (c); or both transistors are held off for pre-regulation in position (b). In the composite current waveform of Figure 3-41(B), the relative phase and amplitude of each component of  $I_t$  is shown for periods  $T_a$ ,  $T_b$ , and  $T_c$  corresponding to the three switch positions. Figure 3-41(C) and Figure 3-41(D) show the relationship of the Inverter voltage and primary winding voltages with respect to the current waveform.

The normal sequence of operation is as follows: Assume that  $I_t$  is passing through zero and is increasing in the direction which forward biases CR1241 to conduct  $I_1$  as shown in Figure 3-41(B). When the Inverter current crosses through zero the Inverter Control stage holds off Q1234 and Q1241. At a time determined by the Inverter Control stage, Q1234 is allowed to conduct  $I_2$  which reverse biases CR1241. Q1234 conducts as  $I_2$  goes through its peak and back to zero. At zero crossing, the Inverter Control stage again holds off Q1234 and Q1241. During this hold-off time, CR1234 conducts  $I_3$ . Next, Q1241 is turned on to conduct  $I_4$  which reverse biases CR1234. Q1241 conducts as  $I_4$  goes through its peak and back to zero. The cycle then repeats itself.

During conduction of Q1234, power is delivered to the series resonant circuit L1237-C1237, and to T1310. Part of this power, stored in the resonant circuit, is returned to the supply when diode CR1234 conducts. Pre-regulation is achieved by varying the holdoff of the inverter transistors,  $T_b$  in Figure 3-41(B), thereby determining the net power delivered to T1310.

### Over-Voltage Stop

Whenever the voltage across the primary of T1310 exceeds a safe level, the Over-Voltage Stop stage stops the Inverter to protect Inverter components from damage. For example, this stage activates whenever the normal voltage regulating path through Q1252 and T1230 is inoperative.

Capacitor C1243 charges through CR1244 to the peak voltage across the primary of T1310. If this voltage exceeds a safe level, VR1246 conducts to trigger SCR Q1248 into its forward-conduction state. Capacitor C1243 then discharges through C1249, R1249, R1248, and Q1248 into the base-emitter junction of Q1246. Q1246 turns on, short-circuits the base-drive winding of T1230 and stops the Inverter switching action. Since CR1249 becomes forward biased when Q1248 is triggered on, C1242 in the Start Network is prevented from charging to the breakdown voltage of CR1238, thus preventing the Inverter from starting. Transistors Q1248 and Q1246 continue to conduct until the discharge current of C1243 through R1248 drops below the

holding current of Q1248. After Q1248 returns to its forward-blocking state, CR1249 continues to inhibit the Inverter Start Network while C1243 charges through R1247 and R1210 in the Inverter Start Network. When the voltage on C1243 is sufficient to fire CR1238, the Inverter will start.

**Inverter Control**

The Inverter Control stage, made up of primarily U1275, provides pre-regulation and fault protection functions. For pre-regulation purposes, U1275 varies the hold-off time ( $T_b$ , in Fig. 3-41B) of the Inverter switching transistors.

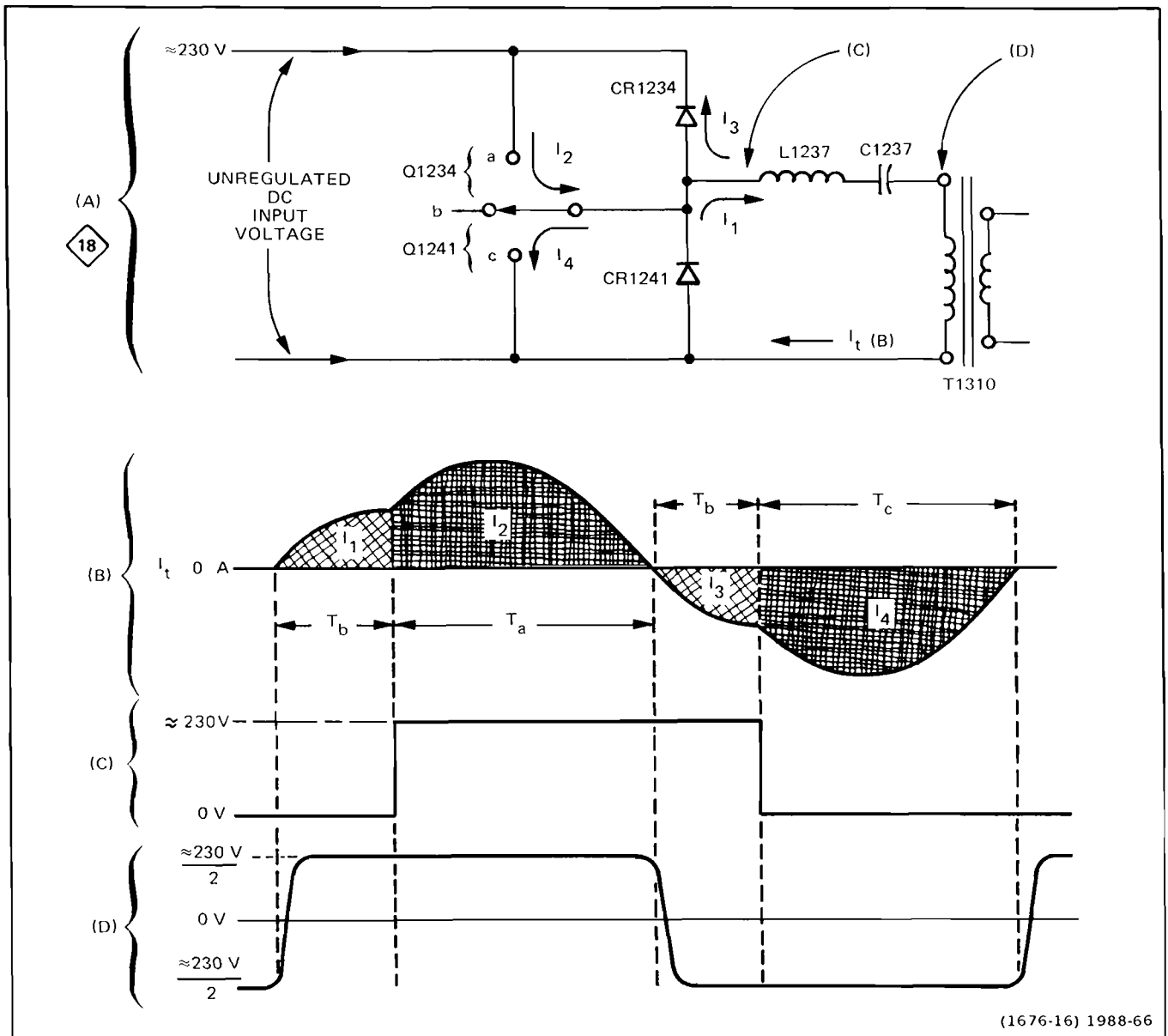


Figure 3-41. (A) Representation of Inverter stage. Idealized waveforms of (B) total inverter current,  $I_t$ , (C) voltage of CR1234 and CR1241, and (D) voltage across primary.

Under normal operating conditions, only the E Sense input at pin 15 controls the hold-off time. However, various fault conditions can affect hold-off time or stop Inverter operation altogether. The operation of each individual function of the Inverter Control stage is described in the following discussion.

### Pre-Regulator

The Pre-Regulator operation of U1275, maintains constant voltages at the outputs of the Low-Voltage Rectifiers. It also provides constant peak-to-peak voltage to the High-Voltage supply.

Transformer T1235 provides Inverter phase information and power to U1275. The phase information is connected to pins 10 and 11 through C1275 and C1276. Bridge rectifier CR1280, CR1281, CR1282, and CR1283, provides positive and negative operating voltages to U1275. A shunt regulator in U1275 maintains +7.5 volts at pin 6. The -2 volt (nominal) supply connected to pin 7 is unregulated. Zener diode VR1279 is for protection against open circuit condition (U1275 removed) and is normally not conducting.

Pin 15 is the voltage sensing (E Sense) point of the Pre-Regulator circuit. Zero volts at pin 15 indicates proper regulation. Zener diode VR1297 provides a stable reference voltage for the sensing-divider resistors R1290, R1291, R1293, R1294, and R1296. Resistor R1293 in this divider adjusts the ratio of the divider to adjust the output of the +108 volt supply. Outputs of the other supplies are then set by the turns ratio of T1310.

Integrated circuit U1275 regulates the Inverter by varying the hold-off time of the switching transistors, Q1234 and Q1241. A variable pulse-width monostable multivibrator in U1275 is triggered at pins 10 and 11 whenever the Inverter current changes direction. The pulse width holds off the Inverter by turning on transistor Q1252 through pin 9 of U1275, thus shorting out the base drive to Q1234 and Q1241. The pulse width and therefore hold-off is controlled by a ramp at pin 12. If the voltage at the E Sense input, pin 15, is too low, the ramp is not allowed to rise very high and the pulse width and hold-off are short. As the E Sense voltage rises, the ramp is allowed to rise to a higher voltage level, increasing the hold-off time.

### Fault Protection

The fault-protection portions of U1275 provide protection for the power-supply components from damage due to short circuits, turn-on surge currents, and other malfunctions. When a fault is detected at the Bal Sense input (pin 2) or I Sense input (pin 13), a current from the Fault Holdoff Time output (pin 1) charges C1264. If the detected fault lasts longer than about 10 milliseconds, C1264 will charge positive enough to initiate a positive output at pin 8. This output is applied through U1278B and U1278C to turn on Q1254 and Q1252 which turns off the Inverter. The Invert-

er will remain off while C1259 discharges through R1261 which keeps Q1254 and Q1252 turned on. The Inverter restarts in roughly 500 milliseconds when the current through R1261 is insufficient to keep Q1254 and Q1252 turned on. When the inverter restarts C1259 is recharged through CR1259 and R1259. This cycle repeats until the fault is corrected, with the Inverter on for about 10 milliseconds, and off for about 500 milliseconds.

### Inverter Current Limiter

The Inverter current limiter provides protection for the Inverter components from damage due to excessive turn-on current or short circuits. Operation of this stage is similar to the Pre-Regulator (voltage regulation). The Inverter current limiter takes control of the Inverter hold-off time whenever pin 13 starts to go negative. T1235 is a current step-down transformer. The current is rectified and flows through R1287, the current-sensing resistor. The voltage across R1287 is negative and proportional to the Inverter current. The I Sense input at pin 13 is normally held positive through divider R1285 and R1286. The Inverter current limiter takes control of regulation when pin 13 approaches zero volts. Peak Inverter current is limited to about 5 amperes. If the voltage at pin 13 remains near zero for more than about 10 milliseconds, pin 8 will go positive to turn off the Inverter.

### Balance

The Balance portion of U1275 provides overload protection for the +5 volt light supply, +108 volt supply, +130 volt supply, +600 volt supply, focus supply and cathode supply, as well as backup protection for several regulated supplies. The +5 volt, +108 volt and -17 volt supplies are applied to the Bal Sense input at pin 2 of U1275 through resistive network of R1303, R1304, and R1305. Other inputs are from a network on the Low-Voltage Regulator board and current sensing resistors on the Focus board. During normal operation, the voltage at the Bal Sense input remains near zero. If one of the inputs changes sufficiently to cause this voltage level to vary about 200 millivolts (positive or negative) for more than about 10 milliseconds, a positive output is produced at pin 8 of U1275 to stop the Inverter.

### Line Stop

The Line Stop portion of U1275 stops the Inverter when the POWER switch is turned off. The Line Stop stage will also stop the Inverter if the ac line voltage falls below a minimum value.

The line-frequency signal from transformer T1208 is connected to pin 4, the Line Stop Sense input of U1275. During normal operation, the line-frequency signal causes the Line Stop Timer terminal (pin 3) to periodically discharge to ground. When the line-frequency signal is interrupted or falls below a minimum value, C1267 will charge to approximately +0.7 volt causing the Line Stop stage to produce a positive output at pin 8 of U1275 to stop the Inverter.

## Power On Logic

The Power On Logic provides a signal to the Storage circuitry. When the instrument is first turned on the Power On circuit produces a low state output for about 2 seconds after which time a high state is produced indicating that power is on. The low state is produced by the 7.5 volt supply rising and turning on U1278A through CR1266, R1265, C1263, CR1265 and R1265. The high state is produced after 2 seconds, when C1263 changes through R1260, turning on CR1261 and thus removing base drive to U1278A.

When the instrument is turned off, this circuit produces a low state output before the regulated power supply voltages begin to drop. The inverter stop signal, pin 8 of U1275, goes high allowing U1278B to turn on, thus turning on U1278D through U1278E.

## LV (LOW-VOLTAGE) REGULATORS

The Low-Voltage Regulators convert semi-regulated voltages from the Converter/Rectifiers circuit to stabilized, low-ripple output voltages. The regulators are series type, using the  $-50$  volt supply as a reference. Figure 3-42 shows a detailed block diagram of the Low-Voltage Regulator circuits. A schematic is provided on diagram 12 in the Diagrams section of this manual.

### $-50$ Volt Supply

The Semi-Regulated  $-54$  volts from the Converter/Rectifiers circuit provides the unregulated voltage source for this supply. Transistors Q1508, Q1522, Q1534 and Q1538 operate as a feedback-stabilized amplifier to maintain a constant  $-50$  volt output level. Transistor Q1508 is connected as a differential amplifier to compare the feedback voltage at the base of Q1508B against the reference voltage at the base of Q1508A. The error output at the collector of Q1508B reflects the difference between these two inputs. The change in error output level at the collector of Q1508B is always in the opposite direction to the change in the feedback input at the base of Q1508B. Zener diode VR1505 sets a reference level of about  $-9$  volts at the base of Q1508A. A sample of the output voltage from the  $-50$  Volt Supply is connected to the base of Q1508B through divider network R1512, R1513, and R1514. Resistor R1513 in this divider is adjustable to set the output level of this supply. Notice that the feedback voltage to this divider is obtained from a line labeled  $-50$  V Sense. If the feedback voltage were obtained at the supply, the voltage at the load would not stay constant, due to the inherent resistance of the interconnecting cable between the supply and its load. The sense configuration overcomes this problem by sensing the voltage at the load. Since the current in the sense line is small and constant, the load voltage is held constant regardless of the load current.

Regulation of voltage occurs as follows: If the output level of this supply decreases (becomes less negative) due to an increase in load or a decrease in input voltage (as a result of line-voltage changes or ripple), the voltages across divider R1512, R1513, and R1514 decreases also. This results in a more positive level at the base of Q1508B than that established by the  $-50$  Volt Reference stage at the base of Q1508A. Since the transistor with the more positive base controls the conduction of the differential amplifier, the output current at the collector of Q1508B increases. This increase in current through Q1508B also causes successive increases in current through Q1522 and Q1534 resulting in increased conduction of Q1538, the  $-50$  V Series Regulator. The load current increases and therefore the voltage across the load also increases (becomes more negative) sufficiently to balance the input into differential amplifier Q1508A and Q1508B. The  $-50$  Volts adjustment, R1513, sets the output level of this supply.

The  $-50$  V Current Limiting stage (Q1526) protects the  $-50$  Volt Supply if excessive current is demanded from this supply. Since the load is connected to this supply through R1537, all current from the  $-50$  Volt Supply must flow through this resistor. Transistor Q1526 senses the voltage drop across R1537. Under normal operation there is insufficient voltage drop across R1537 to forward bias Q1526. However, when excessive current is demanded from the  $-50$  V Series Regulator due to a short circuit or similar malfunction at the output of this supply, the voltage drop across R1537 increases until it is sufficient to forward bias Q1526. The collector current of Q1526 results in a reduction of current through Q1522 and finally to limit the conduction of Q1538. This current limiting protects Q1538 from damage due to excess power dissipation.

Several protection diodes are also included in this circuit. Diode CR1539 prevents the output of this supply from going more positive than about  $+0.6$  volt if it is shorted to a positive supply. Zener diode VR1501 and diode CR1502 supply a turn-on voltage for Q1508 to start the  $-50$  Volt Supply when the instrument is first turned on. As soon as the  $-50$  Volt Supply turns on, CR1502 stops conducting.

### $-15$ Volt Supply

Basic operation of all stages in the  $-15$  Volt Supply is the same as for the  $-50$  Volt Supply. Reference level for this supply is established by divider R1463 and R1464 between ground and the  $-50$  V Sense voltage. The divider ratio of R1463 and R1464 sets a level of  $-15$  volts at the base of Q1406A. The level on the  $-50$  V Sense line is held stable by the  $-50$  Volt Supply. Any change at the output of the  $-15$  Volt Supply appears at the base of Q1406B as an error signal. The output voltage is regulated in the same manner as described for the  $-50$  Volt Supply. Diode CR1499 limits the output of this supply from going more positive than about  $+0.6$  volt if it is shorted to one of the more positive supplies. Diodes CR1468 and CR1469 provide reverse voltage protection for transistors Q1406B and Q1406A, respectively.

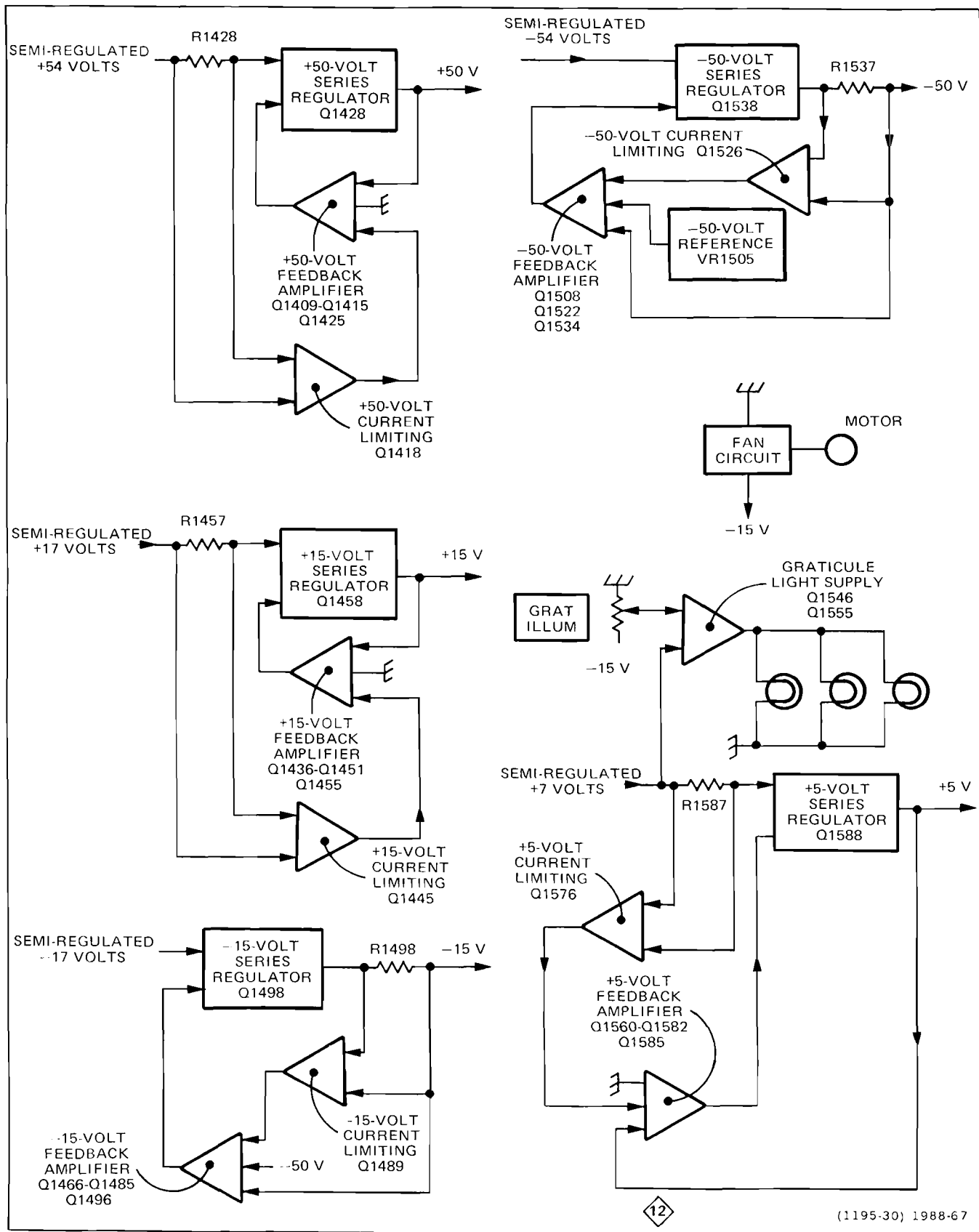


Figure 3-42. Detailed block diagram of the Low-Voltage Regulator circuit.

### +5 Volt Supply

The operation of the +5 Volt Supply is basically the same as described for the previous supplies. Error voltage to the base of Q1560B is provided by divider R1564 and R1565, referenced to the -50 V Sense line, from the +5 V Sense line. The divider ratio of R1564 and R1565 is 10:1, so the base of Q1560B is at zero volt when the supply is operating normally. The level on the -50 V Sense line is held stable by the -50 Volt Supply. Therefore, any change at the output of the +5 Volt supply appears at the base of Q1560B as an error signal. The output voltage is regulated in the manner described previously for the -50 Volt Supply. Diode CR1589 limits the output of this supply to about -0.6 volt if it is shorted to one of the negative supplies.

The +5 Volt Current Limiting stage (Q1576A and B) protects this supply from excessive output current. Transistors Q1576A and Q1576B are connected as a comparator to detect excessive current through R1587. With normal supply current through R1587, the voltage drop across R1587 is such that the base of Q1576B is more positive than the base of Q1576A; therefore, Q1576A is cut off. If the current through R1587 increases above a safe level, the base of Q1576B becomes more negative than the base of Q1576A. Now, Q1576B is cut off and Q1576A conducts. The collector current of Q1576A forward biases CR1576 and decreases the voltage on the base of Q1582. This limits the conduction of Q1588 to a safe current level.

### +15 Volt Supply

The +15 Volt Supply regulates in the same manner as the -50 Volt Supply; current limiting operates in the manner described for the +5 Volt Supply. Error feedback voltage to the base of Q1436B is provided through divider R1440 and R1459, referenced to the -50 V Sense line, from the +15 V Sense line. The divider ratio of R1440 and R1459 sets the base of Q1436B at zero volts. Any change in the output level of the +15 Volt Supply appears at the base of Q1436B as an error signal. This results in an opposite change at the collector of Q1436B. This change is conveyed to the +15 V Series Regulator stage through Q1455 to correct the error in the output voltage of the supply.

Diode CR1439 protects Q1436B against negative voltages if the +15 Volt Supply is shorted to ground. Diode CR1459 limits the output of this supply to about -0.6 volt if it is shorted to one of the negative supplies.

### +50 Volt Supply

Operation of the +50 Volt Supply is basically the same as described for the -50 Volt Supply; current limiting operates in a similar manner as described for the +5 Volt Supply. Error voltage to the base of Q1490B is provided by divider R1412 and R1429, referenced to the -50 V Sense line, from the +50 V Sense line. The divider ratio of R1412 and

R1429 sets the base level of Q1409B at zero volts when the output of this supply is correct. The protection diodes in this circuit operate similarly to those in the other supplies.

### Fan Circuit

The fan motor used in this instrument is a brushless dc motor, using Hall Effect devices. The 2 Hall Effect devices sequentially drive the 4 transistors (U1615 A, B, C, and D) which, in turn, control the current flow through the 4 field windings. The fan motor speed is regulated by limiting the current flow through Q1604. Diodes CR1611, CR1612, CR1613, and CR1614 rectify the back emf produced by the 4 field windings. This voltage is applied to the base of Q1603 through resistive divider network R1614 and R1613; the voltage developed by this circuit is proportional to the motor speed. If the motor speed starts to increase, the current drive to the base of Q1604 will decrease, reducing the current to the motor, thus maintaining a constant motor speed.

### Graticule-Light Supply

The Graticule-Light Supply provides power to illuminate the graticule lights. The front-panel GRAT ILLUM control controls the output of this supply to set the brightness of the graticule lights. Transistors Q1546, Q1555, and CR1549 form a pseudo differential amplifier. The output voltage at the collector of Q1555 follows the voltage set at the base of Q1546 by the divider made up of R1544, R1545, R1543, and the GRAT ILLUM control R917 (see Diagram 13). Resistor R1551 limits the output current from this supply to protect Q1555 from damage due to a short circuit.

## MAIN INTERCONNECT



The Main Interconnect diagram shows the signal and power interconnections between the Acquisition and Display Unit, diagram 13, in the Diagrams section of this manual.

## VERTICAL AMPLIFIER



The Vertical Amplifier circuit provides final amplification for the vertical signal before it is applied to the vertical deflection plates of the crt. The Vertical Amplifier also accepts inputs from the Readout System to block the vertical signal while readout information is displayed and to produce the vertical portion of the readout display. An input is provided for the BEAMFINDER switch to compress an over-scanned display within the viewing area of the crt. In addition, the Vertical Amplifier accepts the Auxiliary Y-Axis input from the Main Interface circuit. Figure 3-43 shows a block diagram of the Vertical Amplifier circuit and a schematic is provided on diagram 14 in the Diagrams section of this manual.