

**H720
power supply and
mounting box
manual**

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CHAPTER 1

INTRODUCTION

This manual provides the user with information on the PDP-11 Power Supply and Mounting Box: their system configurations and installation procedures.

The H720 Power Supply is described in Chapter 2, which provides the user with the theory of operation and circuit diagrams necessary for comprehension and maintenance. Both general and detailed descriptions of the power supply are included; the level of discussion assumes that the reader is familiar with basic electronic theory.

NOTE

Sections of this manual refer to specific engineering drawings which are contained in the second volume entitled *H720 Power Supply and Mounting Box, Engineering Drawings*. The drawings in the above manual reflect the latest print revisions.

Chapter 3 comprises descriptions of the modular concept of the PDP-11 System and the four available mounting box models.

Installation procedures are covered in Chapter 4, which describes all applicable PDP-11 System configurations and planning requirements. The remainder of the chapter contains a series of data sheets on the six basic system configurations and the major hardware components, including a brief description of the item, specifications, and installation drawings.

CHAPTER 2

POWER SUPPLY

2.1 INTRODUCTION

The H720 Power Supply provides both regulated and unregulated ac and dc power for the PDP-11 System. This supply furnishes all power required by components mounted in either a basic or extension mounting box.

This chapter provides the theory of operation of the power supply and is divided into three major parts: general description, block diagram description, and detailed description. As it is beyond the scope of this chapter to present detailed maintenance procedures, emphasis is placed instead on how the power supply should function during normal operation. The user can then utilize this information when analyzing trouble symptoms to extrapolate necessary corrective action.

The physical dimensions and electrical specifications of the H720 Power Supply are given in the appropriate data sheet in Chapter 4 of this manual.

2.2 GENERAL DESCRIPTION

The H720 Power Supply provides both regulated and unregulated ac and dc power for the PDP-11 System. There are two basic versions of the power supply and two models of each version, as shown in Table 2-1.

Table 2-1
H720 Power Supply Models

Version	Model No.	Remarks
A & B	H720-A	Models A and B are identical except for input voltage requirements.
	H720-B	
C & D	H720-C	Models C and D are door-mounted versions of models A, B, E, or F. A metal frame accepts the entire power supply for use with some peripheral controllers.
	H720-D	
E & F	H720-E	Models E and F are identical except for input voltage requirements. Ac control and increased +5V current capabilities distinguish these models from the A and B models.
	H720-F	

The H720 Power Supply, designed to mount in the BA11 Mounting Box, furnishes all power required by components in either a basic or extension mounting box. The input voltage may be either 120V or 240V at 50/60 Hz. Regulated outputs of +5V at 16 amps (A and B version), or at 22 amps (E and F version), and -15V at 10 amps (both versions) are available.

Unregulated outputs of +8V at 1.5 amps and -25V at 1.5 amps are also available. In addition, a sine wave clipped both at ground and +5V (nominal) is provided for the line clock, and a pair of logic levels (AC LO and DC LO) are provided to warn the processor of imminent power failure.

Switching mode regulation, employed in the +5V and -15V supplies, offers the advantages of compactness and high efficiency over an analog-type regulator at the expense of a slightly greater circuit complexity. Dynamic over- and under-voltage protection and current-limiting are implemented on the two regulated voltages.

2.2.1 AC Power Distribution

Incoming ac power is applied through fuse F1 of the H720 Power Supply, and then routed above the fans to the OFF/POWER/PANEL LOCK switch on the front panel. (Both ac lines connect to this switch.) Power is then routed to the back of the supply where two accessory outlets are provided, and is then applied through fuse F2 to the primary winding of the power transformer. A split primary with jumpers is used to allow operation at either 120V or 240 Vac. One pair of fans is connected across each primary winding to ensure that the fans always receive 120 Vac.

Models E and F of the H720 have four features in the ac control section that distinguish them from the A and B models. These features are:

- a. The incoming ac line uses a circuit breaker rather than a fuse.
- b. The control portion permits switchable remote and local control to provide the capability of one unit controlling several others (see the schematic of the control portion).
- c. The POWER switch on the front panel of the computer switches only a single ground control line to activate the ac input, rather than switching both sides of the ac line as in the A and B version.
- d. A thermal detector is used to turn off the supply in the event of excessive temperature.

The remainder of the ac portion of the E and F versions is essentially the same as that of the A and B versions.

2.2.2 Unregulated DC Supply

The basic ± 25 Vdc are developed from a pair of full-wave bridge rectifier circuits connected to the center-tap of the secondary winding of the power transformer. A 22,000 μ F capacitor on each dc voltage leg provides filtering. In addition, there is a pair of taps (approximately 8V rms) on either side of the center tap. This voltage is full-wave rectified but unfiltered, and provides power for the console indicator lamps.

2.3 BLOCK DIAGRAM DESCRIPTION

This section presents a brief review of switching mode regulation and a block diagram description of the H720 Power Supply. Since the +5V and -15V regulators are nearly identical, only the +5V regulator is covered in detail. This is followed by a description of the crowbar circuits and the AC LO and DC LO logic circuits.

2.3.1 Switching Mode Regulation

Figure 2-1 is a highly simplified schematic diagram of the regulator used in the +5V supply. Figure 2-2 shows the waveforms taken at points A and B in Figure 2-1.

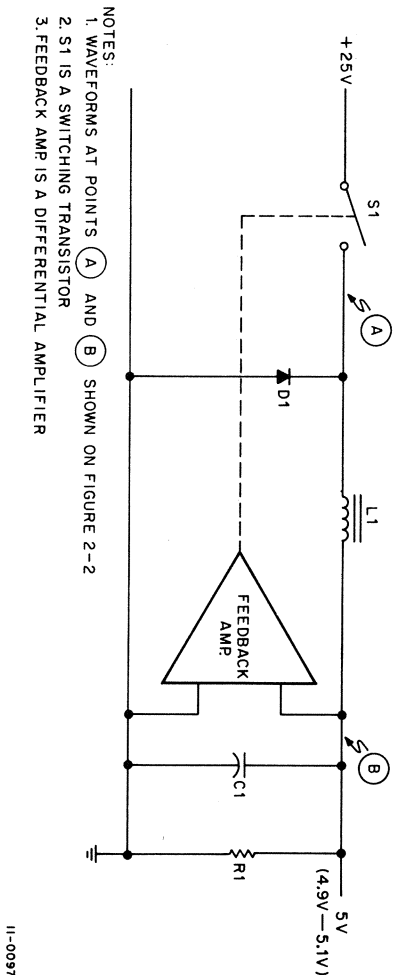


Figure 2-1 +5 Volt Regulator (Simplified Schematic)

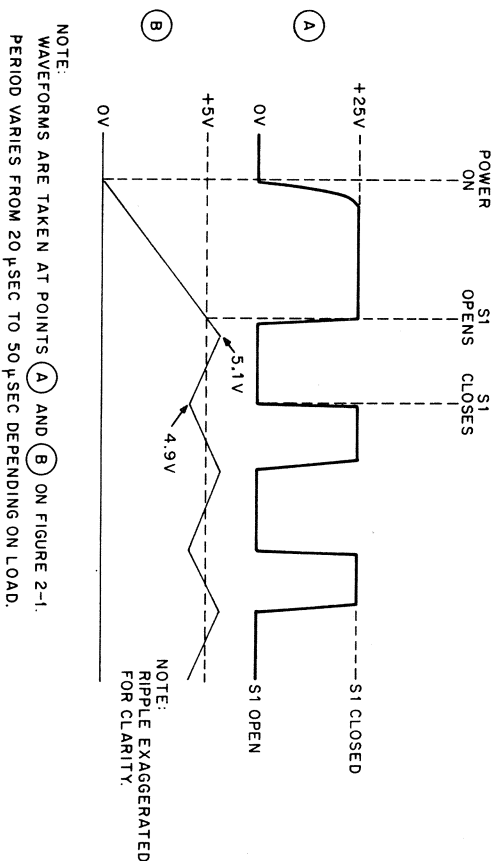


Figure 2-2 +5 Volt Regulator Waveforms

When power is first applied, switch S1 is closed and the output voltage starts to rise toward +25V. However, due to the combined action of choke L1 and capacitor C1, this voltage rise is relatively slow, as shown in waveform B.

When the output voltage reaches 5.1V, the feedback amplifier opens switch S1. At this point, the field around choke L1 begins to collapse, maintaining a flow of current through load resistor R1 into ground (when S1 is open, the current path is completed through diode D1 to the other side of the choke). The output voltage decays, however, and when it reaches +4.9V, the feedback amplifier closes switch S1 and the output again starts to rise toward 5.1V. The power supply continues to oscillate in this manner, although the output voltage actually fluctuates between 4.9 and 5.1V, it maintains an *average* output of 5.0V.

If the load should increase, the output voltage decays at a faster rate and switch S1 closes sooner. In other words, the frequency (and, therefore, the duty cycle) of the waveform at point A increases. This is the method the regulator uses to respond to a decrease in input voltage or an increase in load current. Conversely, at higher input voltages or smaller loads, the frequency (and duty cycle) drops. In this manner, the regulator maintains the output voltage at a constant value.

In the actual circuit employed in the power supply, switch S1 is a switching transistor and the feedback amplifier is a differential amplifier followed by several stages of amplification. However, because the transistor is either saturated or cut off, the average dissipation is kept low.

2.3.2 Basic Regulators

The heart of both the +5V and -15V regulators is a driver (see Figure 2-3 for A and B version, Figure 2-4 for E and F version). The driver controls the base of the switching transistor, holding it either in saturation or at cut-off. There are three inputs to the driver. For the +5V regulator, these three inputs are: the +5V differential amplifier output, the output of an overcurrent-sensing circuit, and the output of the overvoltage crowbar circuit. For the -15V regulator, the three inputs are: the -15V differential amplifier output, the output of the overcurrent-sensing circuit, and the output of the +5V low-sensing circuit.

2.3.3 +5V Regulator

Under normal operating conditions, the only active input to the +5V driver is the output of the differential amplifier. The differential amplifier compares the regulator output voltage with a zener-regulated reference voltage and provides an output representing the difference between the two voltages. When the +5V line approaches 5.1V, the differential amplifier signals the driver to cut off transistor Q1 (the switching transistor on the heat sink) until the output decays to 4.9V, at which time the amplifier signals the driver to turn on Q1 again. This oscillation continues as described under switching mode regulation, Paragraph 2.3.1. Thus, the feedback loop during normal operation is from the +5V input, to the differential amplifier, to the driver, and finally, to the switching transistor which controls the +5V level applied to the differential amplifier.

2.3.3.1 Overcurrent Protection – The amplitude of the current drawn by the load through the switching transistor is sensed by monitoring the voltage drop across 0.05Ω of resistance that is in series with the unregulated +25V supply. If the current (and, therefore, the voltage drop across the resistance) becomes too high, the overcurrent-sensing circuit signals the driver to turn off the switch (this signal overrides the input from the differential amplifier). Due to the time constants in the overcurrent-sensing circuit, the switch remains off until the current drops nearly to zero. At this time, normal feedback through the differential amplifier is resumed. If the condition producing excessive current is still present, the overcurrent-sensing circuit again overrides the differential amplifier and cuts off the switching transistor. While the overcurrent condition remains, this action continues. The regulator continues to oscillate, but in a different mode and at a somewhat lower frequency. Short circuit current is limited to approximately 30 amps in this mode.

NOTE
Overcurrent sensing in the +5V line is not used in the E and F models.

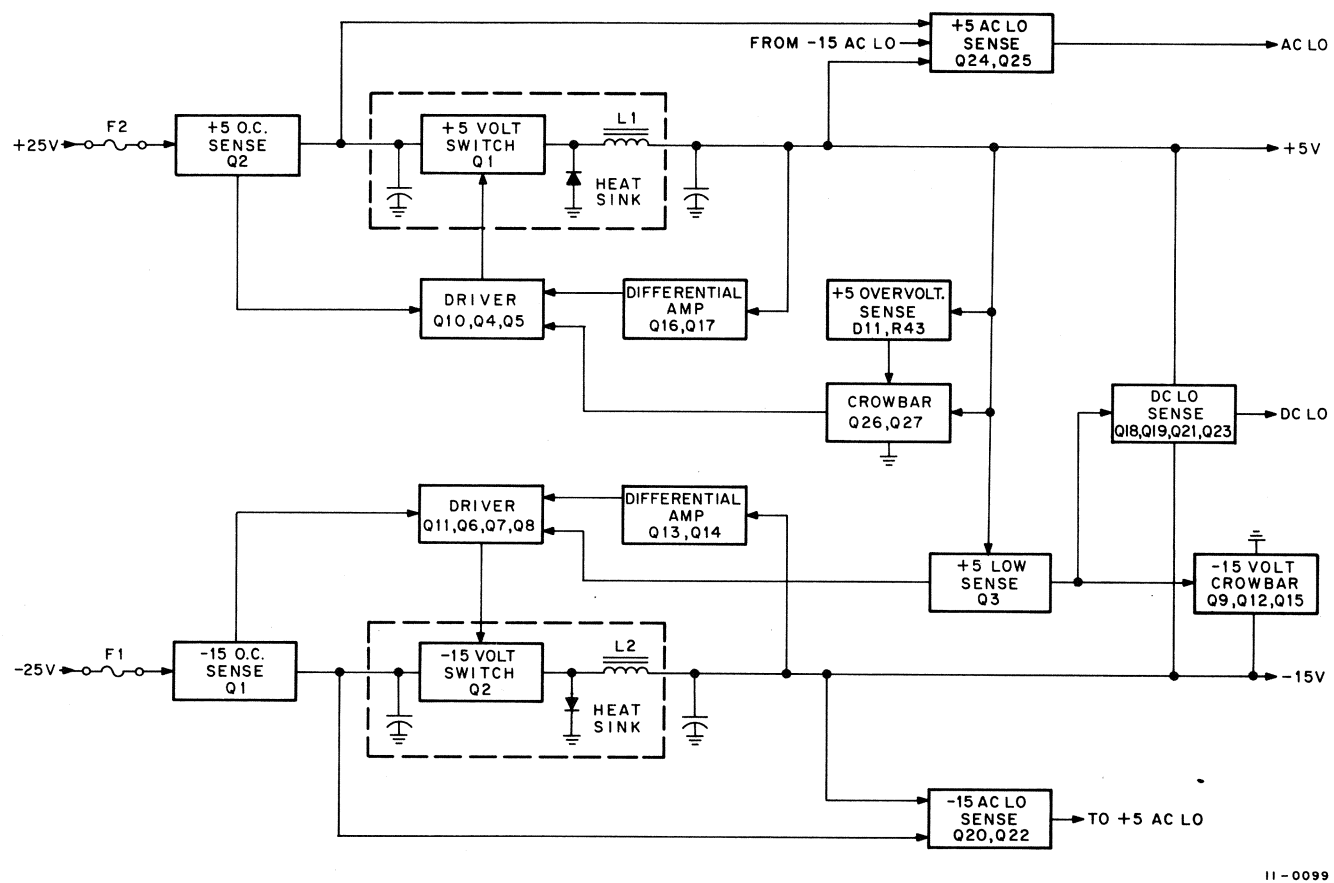


Figure 2-3 H720 Block Diagram (A and B Version)

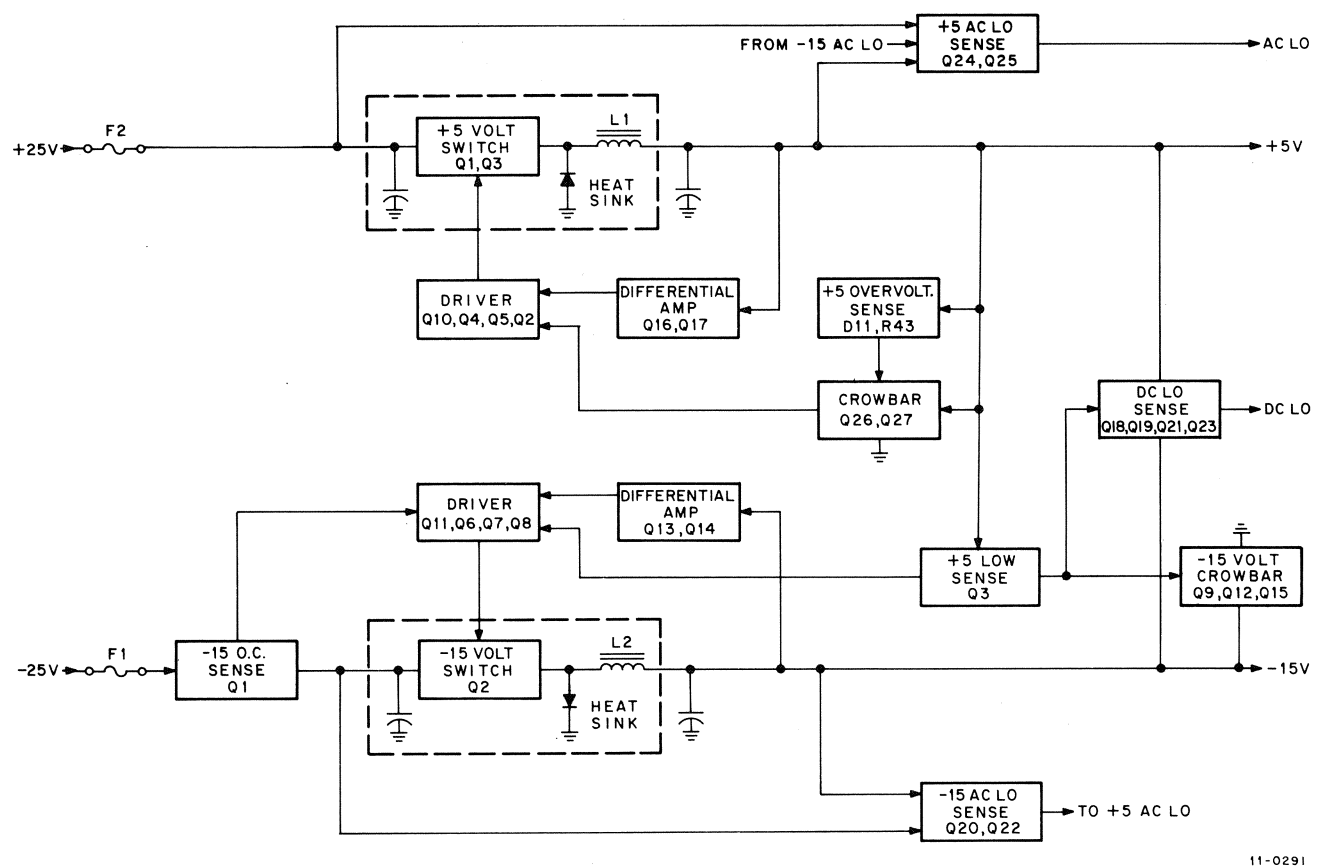


Figure 2-4 H720 Block Diagram (E and F Version)

2.3.3.2 Overvoltage Sensing and Crowbar – It is necessary to protect the logic from voltages in excess of +6V. For this reason, an overvoltage-sensing circuit triggers an SCR which short circuits the +5V line to ground if it rises above +6V. When the crowbar is triggered, a signal is sent to the +5V driver to turn off the switching transistor. This signal also overrides the normal feedback mode. Once triggered, the SCR does not stop conducting and the voltage across it (the output) drops to zero. When the voltage again rises to +6V, the crowbar again triggers and a third mode of oscillation occurs. If the malfunction causing the overvoltage condition is of such a nature that the switching transistor does not turn off (for example, it is shorted), then the SCR remains conducting and the overcurrent-sensing circuit attempts to turn off the transistor. If this fails, then fuse F2 (mounted on the regulator board) opens, breaking the circuit entirely.

2.3.4 -15V Regulator

It should be noted that the -15V regulator is nearly a mirror image of the +5V regulator (see Figure 2-3), and operation is very similar.

Normally, the -15V differential amplifier provides the signal to the -15V driver that controls switching transistor Q2 (on the heat sink), and the output voltage rises and falls between 14.9V and 15.1V. The regulator oscillates in exactly the same manner as described for the +5V regulator (Paragraph 2.3.3).

Overcurrent protection also functions in the same manner (refer to Paragraph 2.3.3.1). The voltage drop across 0.05 Ω of resistance, which is in series with the -25V line, is monitored. In this case, however, current limiting takes place at 14-16 amps.

The only major difference between this regulator and the +5V regulator is the third input to the driver. In this case, the input comes from a circuit which senses the +5V line and signals the driver to turn off the -15V switching transistor if the +5V line drops below approximately 4.5V. (The signal also triggers the -15V crowbar.) The purpose of this circuit is to protect the core memory, which cannot withstand -15V unless it is also provided with the full +5V level. No oscillation occurs in this case, and the switching transistor is simply held off until the +5V level is back to full operating voltage.

The -15V crowbar grounds the -15V line through a power transistor rather than an SCR. This power transistor is activated by the +5V sensing circuit only when the +5V line drops below 4.5V. The sensing circuit is activated if the +5V regulator goes into an overcurrent or overvoltage mode, and whenever power falls below the minimum required operating level. (Power falls below the minimum level not only when power is lost but also for a short interval during turn on and turn off of the system.) In other words, any condition that causes the +5V level to be less than 4.5V activates the -15V crowbar. (There is no overvoltage protection circuit on the -15V regulator.)

2.3.5 AC LO Circuit

The AC LO is a bus-type signal sent from the power supply to the processor. This signal, when asserted, indicates that power failure is imminent. From the time AC LO drops to ground, the supply has two ms of power left at full load.

The AC LO signal is developed by comparing each unregulated voltage with its corresponding regulated voltage. If either drops too close to the regulated level, AC LO is asserted. This occurs, for example, when the +25V line drops to approximately 18V and when the -25V line drops to approximately 20V. Both lines are sensed separately (as shown on the block diagram); however, if the -15V section detects a loss of voltage, it asserts AC LO by forcing the +5V detection circuits to become active, which actually asserts the level.

There is a small amount of hysteresis designed into each circuit to prevent “hunting” when voltages approach the threshold levels. For example, if AC LO is asserted at an input of 100 Vac, the input must rise to 103V before AC LO is negated.

2.3.6 DC LO Circuit

The DC LO level is another bus-type signal which, when asserted, indicates that one or the other of the regulated dc output levels is dropping. The DC LO signal is independent of the AC LO circuit, but follows AC LO within a few ms in the case of power shutdown. During power up, DC LO is negated before AC LO because the +5V and -15V levels are present before the +25V and -25V supplies are up to full voltage. It is possible to have only DC LO asserted if, for example, the +5V crowbar is triggered.

The DC LO-sensing circuits (see Figure 2-3) compare the +5V and -15V lines for a three-to-one ratio. If either voltage drops, the circuit asserts DC LO. The third input to the DC LO circuits comes from the +5V low-sensing circuit. The purpose of this input is to speed up the response to a low +5V condition, thus ensuring that DC LO is asserted at the same time the -15V crowbar is activated.

It should be noted that if the +5V and -15V levels drop at exactly a three-to-one ratio, the DC LO-sensing circuits do not assert DC LO. A DC LO signal, however, is required to indicate that the voltage is dropping, regardless of the ratio. The -15V line is then grounded by the +5V low-sensing circuit as soon as the +5V line drops to 4.5V, which in turn causes DC LO to be asserted.

2.4 DETAILED DESCRIPTION

A thorough understanding of the block diagram discussion (refer to Paragraph 2.3) should aid the user considerably in understanding the material presented in the following paragraphs. The circuit descriptions follow the same general outline used in the block diagram discussion: basic regulators, crowbar circuits, and AC LO and DC LO logic circuits.

For the following discussions, refer to the circuit diagram for the regulator board (5408475-0-1), in addition to figures specifically called out in the text.

2.4.1 +5V Regulator

As mentioned previously, the heart of each regulator is the driver. Based upon three inputs, the driver controls the state of the switching transistor. The driver stages for the +5V regulator are shown in Figure 2-5, and consist of transistors Q10, Q4, and Q5. Transistor Q5 drives the base of the series-switching transistor Q1, which is mounted on the heat sink.

When power is first applied, Q10 remains cut off because none of the three inputs shown on the figure are sufficiently positive to draw base current. Since Q10 is not conducting, base current flows in Q4 through resistor R18 to the +25V line (which starts at ground and rises very quickly to +25V when power is applied). When the base of Q4 reaches approximately 2.1V, it draws current through resistors R14 and R13. The drop across R14 forward-biases Q5, which in turn draws base current through Q1 and allows it to stay on while the output voltage is rising toward 5.0V.

When the output exceeds 5.0V, the differential amplifier pulls the base of Q10 positive to approximately +0.7V and draws base current through it. As Q10 turns on, its collector drops toward ground. When it drops below +2.1V, Q4 no longer conducts (diodes D2 and D3 raise the effective base voltage of Q4 to 2.1V: 0.7V in the transistor, and 0.7V forward drop through each diode). When Q4 cuts off, Q5 also cuts off because there is no path for base current flow. This in turn cuts off Q1, and its base returns to the same potential as the emitter, due to resistor R1.

Note that transistors Q10, Q4, and Q5 are used in a common emitter configuration. Transistor Q1 in the +5V line is used in the common collector configuration (an emitter follower). Whenever Q10 is conducting, Q4, Q5, and Q1 are cut off, and when Q4, Q5, and Q1 are conducting, Q10 is cut off.

R3. This cuts off switching transistor Q2 on the heat sink, thereby stopping the current flow. Capacitor C2 must then charge through resistors R4 and R5. This keeps transistor Q1 turned on for a short period of time. When capacitor C2 is sufficiently charged, base current no longer flows in Q1 and normal operation is resumed. Capacitor C1 is a Miller capacitor used to slow down the circuit and improve noise immunity.

2.4.2.4 -15V Crowbar Circuit – The -15V crowbar circuit (see Figure 2-13) includes the +5V low-sensing circuit (Q3) to trigger the crowbar. The collector of transistor Q3 is connected through diode D22 to the DC LO circuit, and through diode D4 to the base of transistor Q6, to implement turn-off of the -15V regulator when transistor Q3 is conducting.

The base of transistor Q3 is normally very close to ground potential because diode D1 holds the base exactly 5V below the +5V level. When the +5V line drops, the base of Q3 shows a corresponding drop until base current flows through resistor R12 to the -15V line. This causes Q3 to conduct and draws current through resistors R17 and R16.

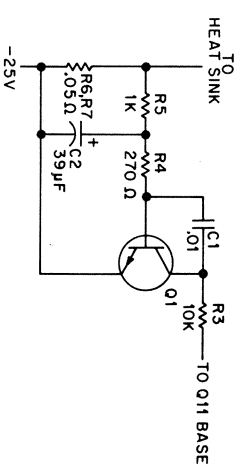


Figure 2-12 -15V Overcurrent Circuit

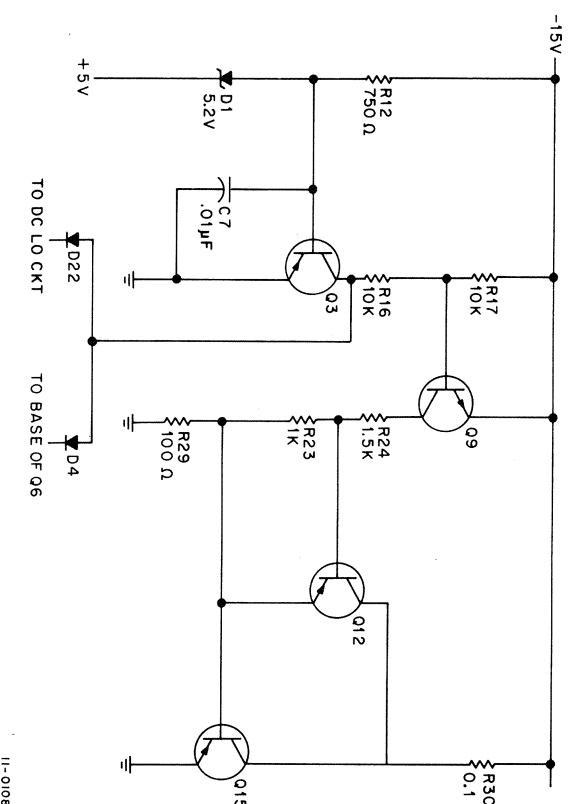


Figure 2-13

It is this action that introduces the previously mentioned hysteresis into the circuit. When Q25 is conducting, it also pulls the AC LO line on the Unibus to ground potential (asserted level).

The -25V portion of the AC LO circuit (see Figure 2-15) functions in the same manner as the +25V portion of the circuit, except that PNP transistors are used and the divider ratio is different, because failure of the -25V raw level must be detected sooner than failure of the +25V level. If the -25V circuit becomes active, it asserts AC LO by pulling the base of transistor Q24 more negative through resistor R58. This turns on Q24, which in turn causes transistor Q25 to conduct and assert AC LO as before.

Diode D27 allows the AC LO signal from all H720 Power Supplies in a given system to be ORed together on the Unibus to indicate a failure in any H720 in the system.

2.4.4 DC LO Circuit

Figure 2-16 is a simplified schematic of the detection portion of the DC LO circuits. Resistors R45, R39, R40, and R41 form a precision voltage divider between the +5V and -15V lines. As long as this divider maintains a one-to-three voltage ratio, the points on either side of diode D16 are a few tenths of a volt above and below ground. (The 0.7V forward drop of diode D16 splits almost evenly on either side of ground.)

Assume now that the -15V level starts rising toward ground. Both the base of transistor Q18 and the base of transistor Q19 feel a more positive voltage, and Q19 becomes forward-biased. When Q19 conducts, it causes DC LO to be asserted.

If the +5V level drops, both bases (Q18 and Q19) feel a more negative voltage and Q18 becomes forward-biased. When Q18 conducts, it causes DC LO to be asserted.

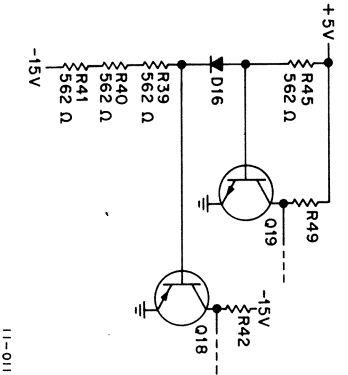


Figure 2-16 DC LO – Simplified Schematic

Figure 2-17 illustrates the entire DC LO circuit, including transistor Q3, which is the +5V low detection transistor. Normally, transistors Q18 and Q19 are cut off, transistor Q21 is biased through resistor R49, and transistor Q23 is off. If transistor Q19 conducts (indicating a low -15V line), it pulls the base of Q21 to ground, cutting it off. This raises the anode of diode D20 toward +5V through resistor R52, and base current flows in transistor Q23. When Q23 turns on, DC LO is pulled to ground potential (asserted).

Resistors R42, R56, and R57 are connected as a divider network between -15V and +5V. The junction of resistors R56 and R57 (anode of diode D19) is normally slightly negative. However, if transistor Q18 is conducting (low +5V line), the junction of resistors R56 and R42 goes to ground and the anode of diode D19 goes positive. This also forward-biases transistor Q23 and asserts DC LO.

Note that diodes D20 and D19 form an OR gate to the base of transistor Q23. Diode D18 is used to protect Q23 from high reverse bias, and capacitor C21 is a Miller integrator which increases noise immunity for Q23.

If transistor Q3 should conduct as a result of a low +5V line, this also grounds the junction of resistors R42 and R56 through diode D22, and turns on transistor Q23 to assert DC LO.

Diode D26 allows the DC LO signal from all H720 Power Supplies in a given system to be ORed together on the Unibus to indicate a failure in any H720 in the system.

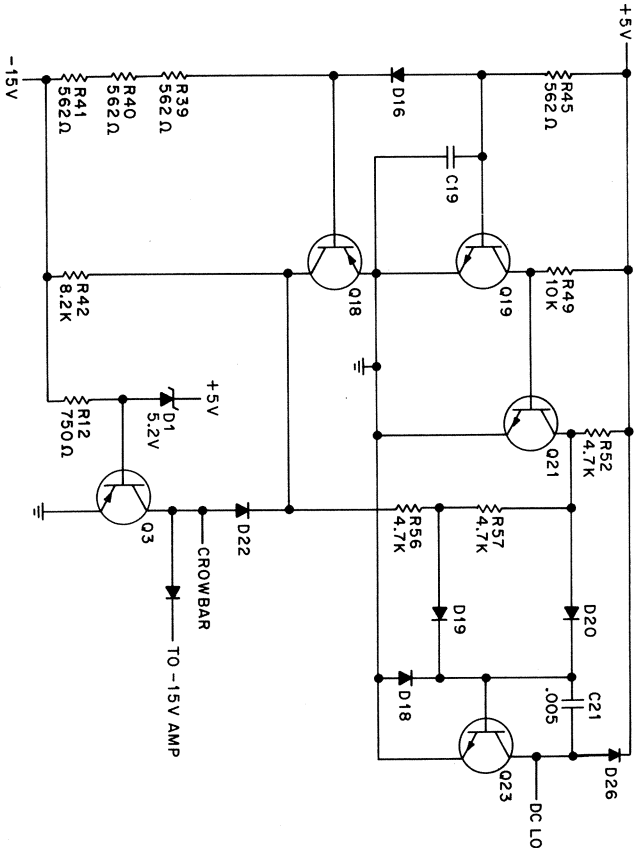


Figure 2-17 DC LO – Circuit Schematic