6.1 POWER SUPPLY #8790021, 38W
(ASTEC #AA11320)

6.1.1 General

One of the power supplies used in the Model 4 is a 38W switching mode power supply utilizing the flyback method of power conversion. This supply has built-in EMI filter and has over-voltage and over-current protection as well as regulation over line and load variations.

6.1.2 Theory Of Operation

PRIMARY

Power is taken from a 115 volt AC line. A UL approved fusable resistor, R25, limits inrush current as well as acting as a system fuse. The AC current is taken through an EMI filter which suppresses power supply and system noise that would otherwise be reflected back into the power lines.

After the EMI filter, the signal goes to a full-wave bridge rectifier (DB1) then into a capacitive input filter. The combination of these last two items produces a 165 volt DC B+ line from which a DC-DC converter is run.

The DC-DC converter consists of a transistor (Q2) which is used to chop the B+ line at approximately 20 kHz. D2, R9, C8, C9, and D3 are all part of a snubber network designed to protect Q2 as well as suppress ringing which would contribute to line conducted EMI.

SECONDARY

When the power transistor (Q2) is 'ON', energy is stored in the core of the power transformer (T2). The secondary windings are polarized so that the output rectifiers do not conduct while Q2 is ON. When Q2 turns 'OFF', it causes the transformer to 'flyback' which causes the polarity on the output windings of T2 to reverse, allowing the output rectifiers to conduct and deliver energy to the output and output capacitors.

A pi filter consisting of capacitors on either side of a series filter choke is used to smooth the output waveform, deliver energy during the ON time, and reduce ripple.

FEEDBACK AND CONTROL

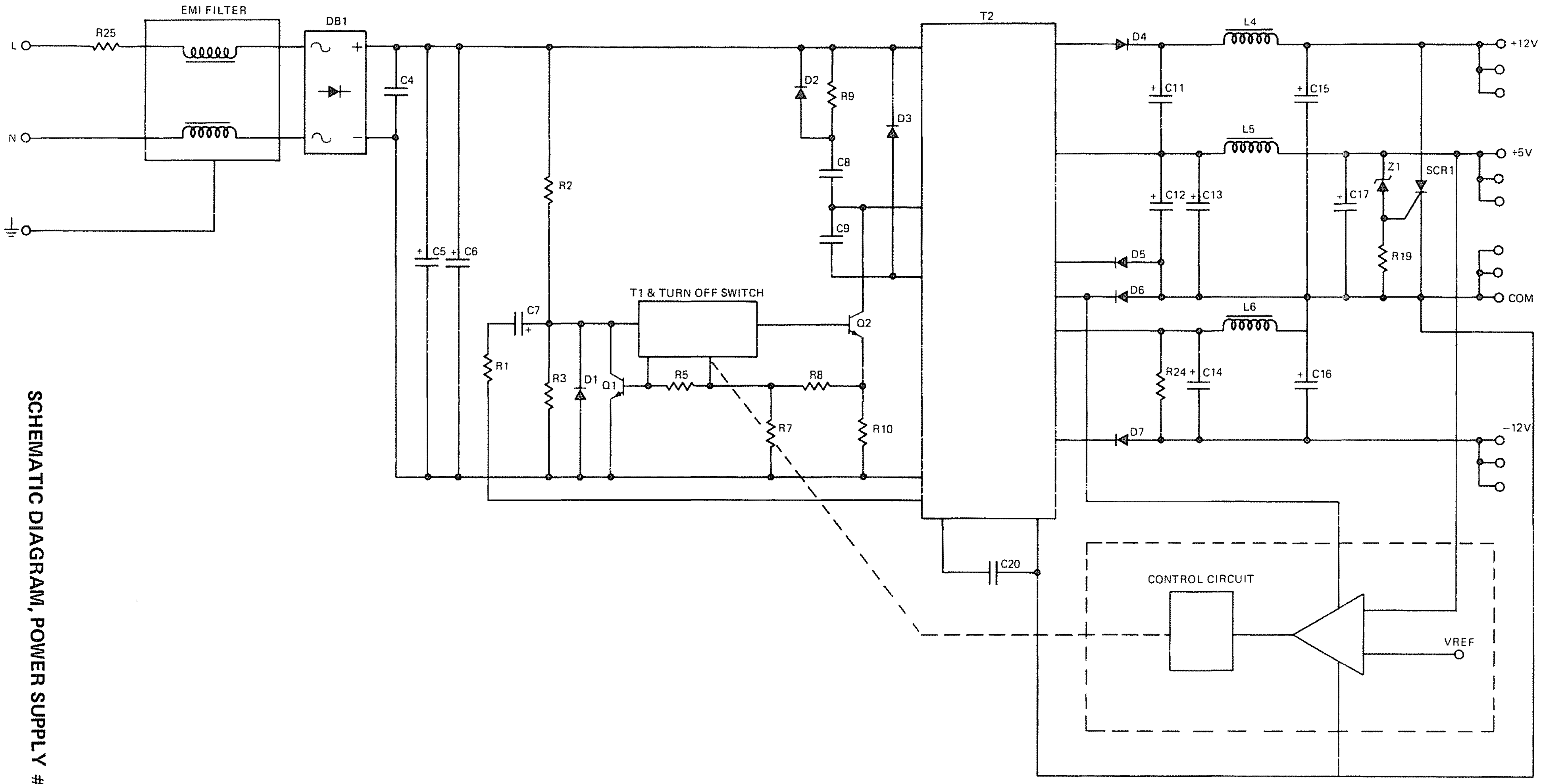
On this power supply the only regulated voltage is the +5 volt output. The +12 volt and -12 volt outputs are simply additional secondary windings stacked on top of the +5 volt winding. They track the +5 voltage close enough to provide sufficient regulation to run the circuitry requiring +12 or -12 volts.

The +5 volt output is fed into an error amplifier which compares it to a reference voltage. The output of this amplifier is fed into a control circuit which is magnetically coupled through T1 to the turn-off circuit. This output also controls the ON time of Q2 providing voltage regulation by variations of the duty-cycle.

OVERVOLTAGE PROTECTION

If a failure in the power supply causes the outputs to rise uncontrolled past a specified voltage limit, the power supply will automatically shut down. This is done by sensing the +5 volt output via a Zener diode. When the voltage limit is reached, the SCR is triggered and shorts the +12 volt output to ground. A short on any output will cause the supply to foldback and shut down.

SCHEMATIC DIAGRAM, POWER SUPPLY #8790021



PARTS LIST, POWER SUPPLY #8790021 (ASTEC #AA11320)

SYMBOL	DESCRIPTION
	CAPACITORS
C1	2200pF, 250VAC, metallized paper
C2	0.01μF, 1KV, ceramic
C3	2200pF, 250VAC, metallized paper
C4	0.22μF, 100V, polyester
C5	47μF, 250V, electrolytic
C6	100μF, 250V, electrolytic
C7	220μF, 10V, electrolytic
C8	4500pF, 1KV, ceramic
C9	0.01μF, 1KV, ceramic
C10	0.22μF, 100V, polyester
C11	1000μF, 25V, electrolytic
C12	1000μF, 25V, electrolytic
C13	1000μF, 25V, electrolytic
C14	330μF, 16V, electrolytic
C15	2200μF, 16V, electrolytic
C16	330μF, 16V, electrolytic
C17	470μF, 25V, electrolytic
C18	0.022μF, 50V, polyester
C19	0.22μF, 100V, polyester
C20	3900pF, 400VAC, ceramic
C21	0.1μF, 250VAC, metallized
	DIODES
D1	RGP10A, rectifier
D2	RGP10D, rectifier
D3	RGP10J, rectifier
D4	Rectifier assembly
D5	Rectifier assembly
D6	Rectifier assembly
D7	RGP15B, rectifier
D8	1N4606, silicon
D9	1N4606, silicon
D10	1N4606, silicon
DB1	W06, bridge rectifier
Z1	5.6V, 5%, 1W, zener
	INDUCTORS
L1	Common mode choke assembly
L2	Base choke
L3	1.5mH, choke
L4	Choke coil assembly
L5	Choke coil assembly
L6	Choke coil
	INTEGRATED CIRCUIT
IC1	Regulator
	RESISTORS
R1	47 ohm, 5%, metal oxide film
R2	150K, 5%, carbon film
R3	1K, 5%, carbon film
R4	Not used
R5	82 ohm, 5%, carbon film
R6	27 ohm, 5%, carbon film
R7	3.3 ohm, 5%, carbon film
R8	10 ohm, 5%, carbon film
R9	27 ohm, 5%, metal oxide film
R10	75 ohm, 5%, 1W, metal film
R11	270 ohm, 5%, carbon film
R12	82 ohm, 5%, carbon film
R13	270 ohm, 5%, carbon film
R14	8.2 ohm, 5%, carbon film
R15	560 ohm, 5%, carbon film
R16	56 ohm, 5%, carbon film
R17	56 ohm, 5%, carbon film
R18	12K, 5%, carbon film
R19	12 ohm, 5%, carbon film
R20	470 ohm, 5%, carbon film
R21	2.7K, 2%, metal film
R22	2.7K, 2%, metal film
R23	68K, 5%, carbon film
R24	220 ohm, 5%, 1W, metal oxide film
R25	2 ohm, 5%, fusing metal film
R26	22K, 5%, carbon film
SCR1	SCR C122F
	TRANSFORMERS
T1	Control assembly
T2	Power assembly
	TRANSISTORS
Q1	PE8050B
Q2	Transistor assembly
Q3	PE8550B

6.2 Power Supply #8790043, 65 Watt (Astec AA12090)

6.2.1 Test Set-Up

A. Equipment Needed

1. Isolation Transformer (minimum of 500 VA rating). Dangerously high voltages are present in this power supply. So, for the safety of the individual doing the testing, please use an isolation transformer. The 500 VA rating is needed to keep the AC waveform from being clipped off at the peaks. These power supplies have peak charging capacitors and draw full power at the peak of the AC waveform.
2. 0-140 V Variable Transformer (Variac). Used to vary input voltage. Recommend 10 amp. 1.4 KVA rating minimum.
3. Voltage meter – Needed to measure DC voltages to 50 VDC and AC voltages to 200 VAC. Recommend two digital multimeters.
4. Oscilloscope – Need x10 and x100 probes.
5. Load board with connectors – See Table 6-1 for values of loads required. The entry on the table for safe load power is the minimum power rating for the load resistors used.
6. Ohmmeter.

B. Set-Up Procedure

Set up test equipment as shown in Figure 1. You will want to monitor the input voltage and the output voltage of the regulated bus, which is the +5V output, with DVM's. Also monitor the +5V output with the oscilloscope using 50mv/div sensitivity. The DVM monitoring the +5V output can also be used to check the other outputs. See the **No Output** section for test points within power supply.

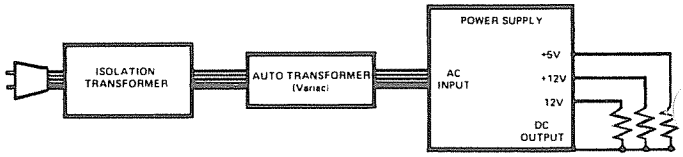


Figure 6-1. Test Set-Up

6.2.2 Visual Inspection

Check power supply for any broken, burned, or obviously damaged components. Visually check fuse, if any question check with ohmmeter.

6.2.3 Start-Up

Load power supply with minimum load as specified in Table I. Bring power up slowly with variable Transformer while monitoring +5V output with scope and DVM. Supply should start with approximately 40-60 VAC applied and should regulate when 90 VAC is reached. If output has reached +5 volts, refer to the **Performance Test** section. If there is no output, refer to the **No Output** section.

6.2.4 No Output

General

If the power supply does not produce an output with the AC input applied to the L and N connections and the power switch ON, one or more components have failed. A no-output-fault condition is most likely caused by a shorted/open component on the primary side but may also be caused by a short on the secondary. To determine this, follow the steps below.

A. Check Fuse:

If fuse is blown, replace but do not apply power until cause of failure is found.

B. Preliminary Check on Major Primary Components:

Check Diode Bridge (DB1), Power Transistor (Q2) and Catch Diode (D3) for shorted junctions. If any component is found shorted, replace.

C. Primary Check on Major Secondary Components

Using Ohmmeter from output common to each output, with output loads disconnected, check for shorted rectifiers or capacitors. If +12V output is shorted, also check crowbar SCR (SCRI).

D. Check B+ with the Fuse Intact

Connect power supply as in Figure 1 and attach x100 scope probe ground to the anode of D1. Slowly turn up power and check for B+ on end of R14 nearest the transformer. With input at 95 VAC, this point should be between 260 and 270 VDC. If this is not correct, check resistor and DB1.

If R14 is open it was most likely caused by a shorted component that is fed power by R14. Check the following components for proper operation (Q2, Q1, D1, D3).

E. Check Q2 Waveforms

Using x100 probe on Q2 heat sink, check collector waveform. Transistor should be switching, correct waveform is shown in Figure 2.

If this is not present check for open junctions on Q2. If Q2 is ok, check to see if base voltage is being supplied to Q2, it should be 0.7 volts. If it is not present, check components (L3, Q1, D1, and R4).

6.2.5 Low Outputs

A. All outputs are Low

If all outputs are low at the same time, check to ensure that the voltage selection jumper is in the proper position.

B. +5V and +12V (V3) Outputs

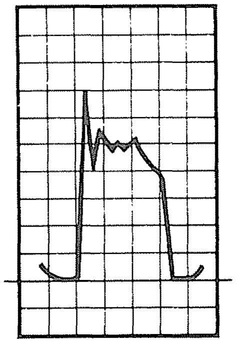
The power supply regulates off of the +5V and +12V (V3) outputs. If these outputs are low, it could cause the others to be low. If so, adjust +5V and +12V (V3) outputs by removing or adding R27 and R28.

C. Rectifier Check

If any one output is not present, first check the rectifier associated with that output and then the rest of the components in the circuit and the solder joints on the PCB.

6.2.6 Crowbar

If the crowbar is not operating, check Z1 and SCR1. If the crowbar is not triggering within the specified limits, change Z1.



50 V/DIV
5 μsec/DIV

Input – 120VAC
Loads – +5 @ 2A
+12 @ 1A
-12 @ 0.1A

Figure 6-2. Q2 Collector Waveform

1.0 V/DIV
5 μsec/DIV

Input and Loads
same as above.

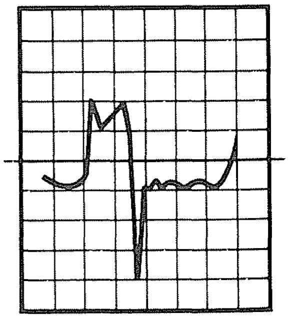


Figure 6-3. Q2 Base Waveform

6.2.7 Performance Test

Each of these test conditions should be set up and noted to be within the limits specified in Table 6-2.

Step	Input	+5V Load	+12V(V2)	+12V(V3)	–12V
1	90VAC	Max	Max	Max	Max
2	132	Max	Max	Max	Max
3	120	Max	Min	Min	Min
4	120	Min	Min	Max	Min
5	132	Min	Min	Min	Min
6	Test Crowbar Limits.				

If the power supply does not pass the above tests, refer to Section 6.2.4 and 6.2.5.

Table 6-1. Load Board Values

Output	Min Load	Load Resistance	Safe Load Power	Max Load	Load Resistance	Load Power
+5V	1.35A	3.7 ohms	12.5W	4.0A	1.25 ohms	50W
+12V-V2	0.40A	30 ohms	10 W	2.1A	5.7 ohms	50W
+12V-V3	0.60A	20 ohms	15 W	1.5A	8 ohms	35W
–12V	O A	1K ohms	1 W	0.1A	120 ohms	3W

Table 6-2. Voltage and Ripple Specifications

Output	Min	Max	Ripple (Max RP)
+5V	5V	5.25	50 MV
+12V	11.40V	12.60V	120 MV
+12V	11.40V	12.60V	120 MV
–12V	–11.40V	–12.60V	120 MV

Pin Assignments

AC Input:

TB1

Pin 1	Line
Pin 2	Neutral

DC Output:

TB2

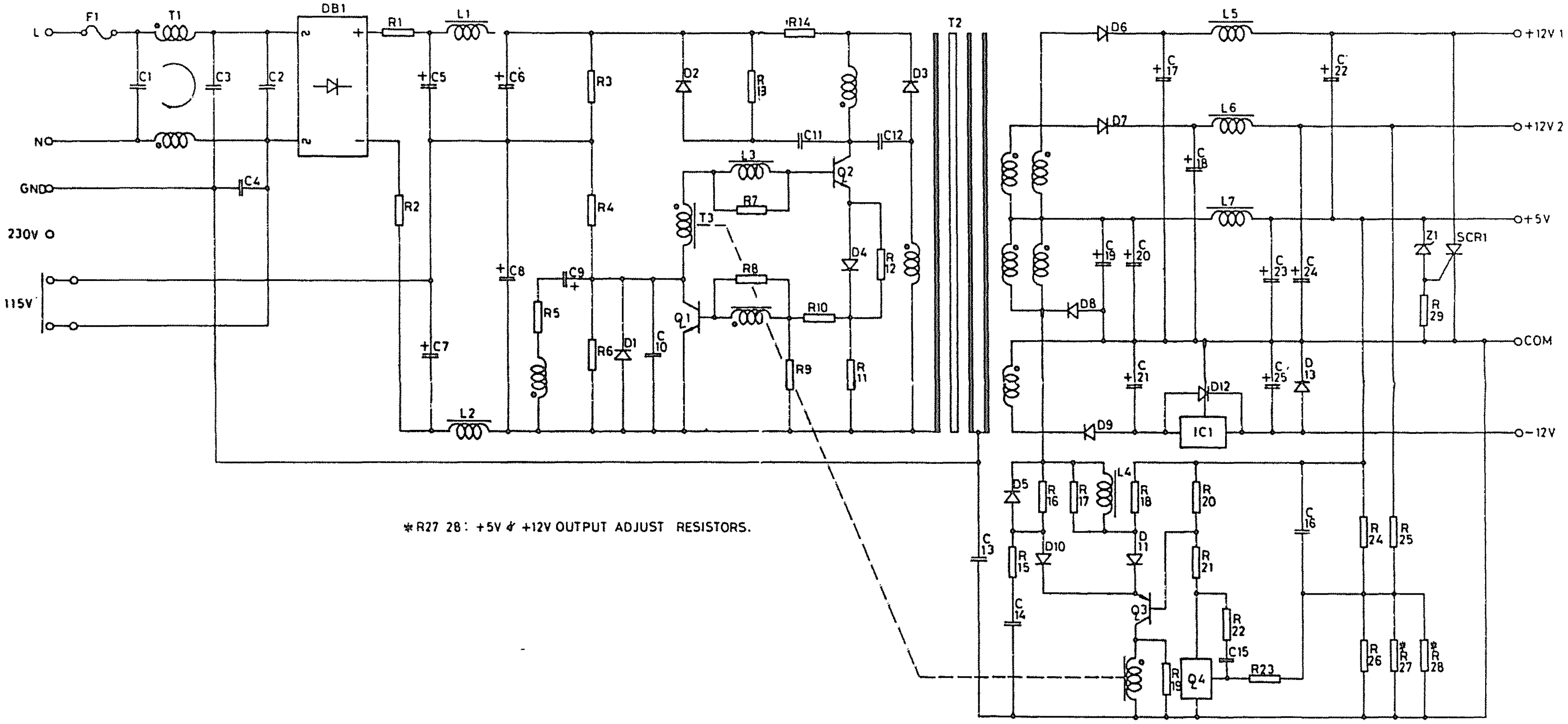
Pin 1	Common	
Pin 2	V2	+12V
Pin 3	Key	
Pin 4	V4	– 12V
Pin 5	V3	+12V
Pin 6	V3	+12V
Pin 7	V3	+12V
Pin 8	V1	+5V
Pin 9	V1	+5V
Pin 10	V1	+5V
Pin 11	Common	
Pin 12	Common	
Pin 13	Common	

Mating Connectors are:

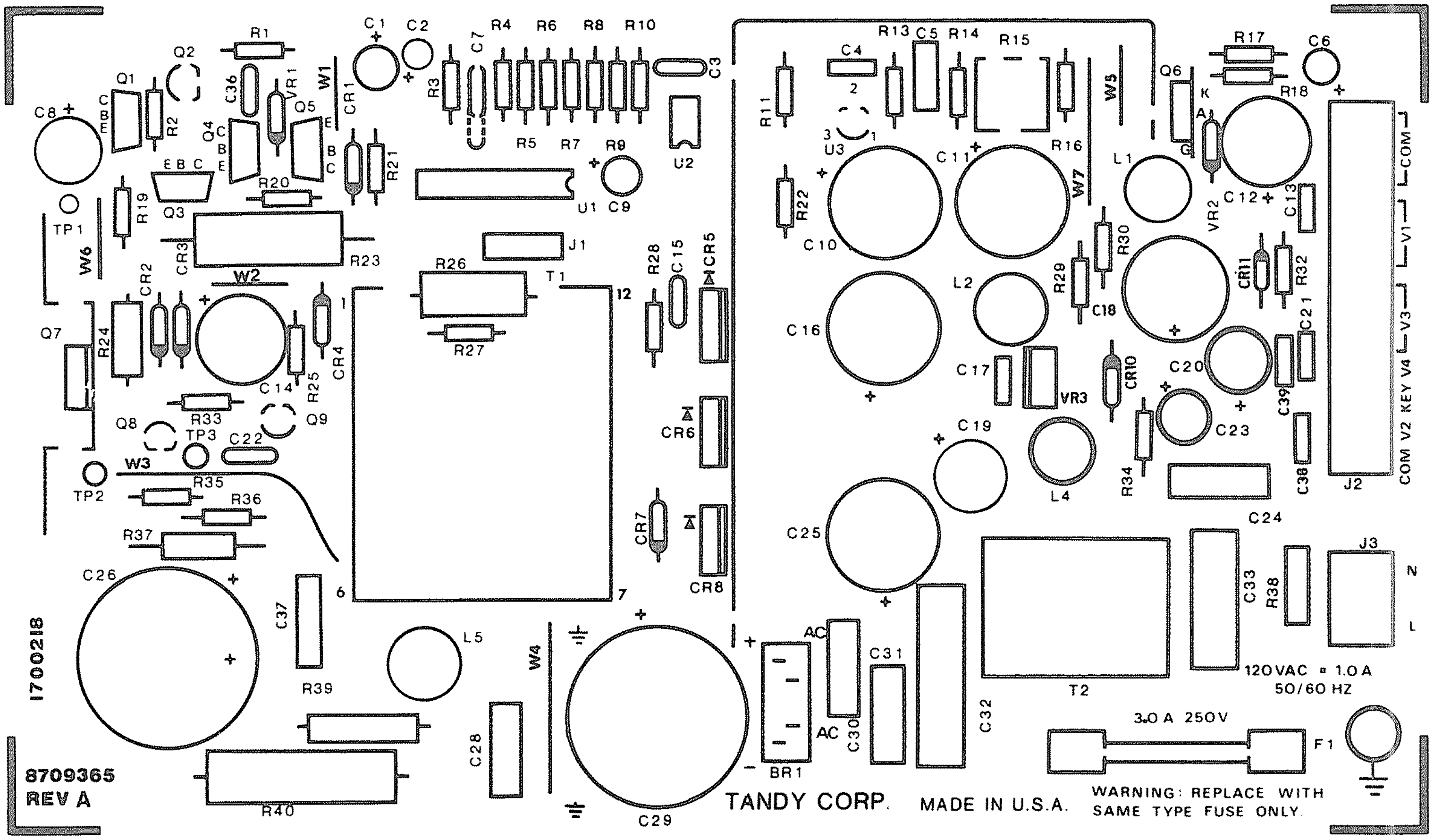
Molex Japan Co. Ltd.
AC Input (housing) 5239-09
DC Output (housing) 5265-12
Pin 5167

SCHEMATIC, POWER SUPPLY ASSEMBLY #8790043 (ASTEC AA12090)

R	R1,2 R5 R3,4,6 R13,7,8,14,9,10,11 R12 R15,16,17 R18 R19,20,21,22 R23 R24,26,25,27,29,28
C	C1 C3 C4 C2 C5,7 C6,8 C9 C10 C11 C12 C13 C14 C19,20,21 C17 C18 C15,23,25,24,16,22
T/L	T1 L1 L2 T3 L3 T2 L4 L5 L6 L7
D/Q	D1 D2 Q1 Q2 D4 D3 D5,10,8,6,7,9 D11 Q3 Q4 D12 D13
MISC	F1 DB1 IC1 Z1 SCR1



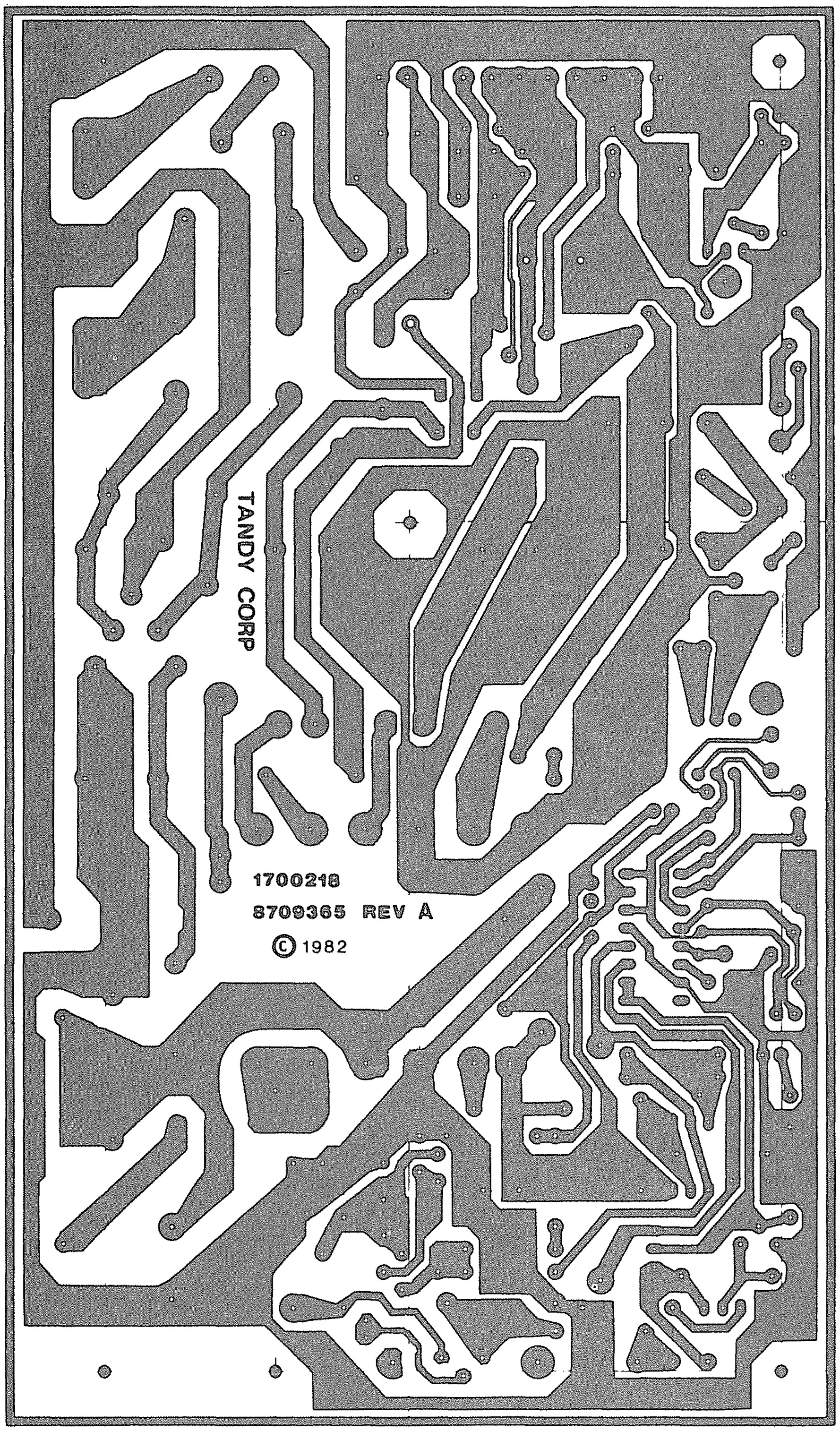
*R27 28: +5V & +12V OUTPUT ADJUST RESISTORS.



COMPONENT LAYOUT #1700218, POWER SUPPLY ASSEMBLY #8790043

Parts List, Power Supply #8790043, (Astec AA12090)

Item	Sym	Description	Mfgr's Part No.
		Capacitors	
1	C1	0.01 ufd, +/- 20%, 250VAC, MPR	068-10300010-220
2	C2	0.1 ufd, +/- 20%, 250VAC, MPR	068-10400010-220
3	C3	4700 pfd, +/- 20%, 400VAC, Ceramic	055-47220001-189
4	C4	4700 pfd, +/- 20%, 400VAC, Ceramic	055-47220001-189
5	C5	100 ufd, +/- 20%, 250V, Electro.	057-10120170-141
6	C6	47 ufd, +/- 20%, 250V, Electro.	057-47020040-192
7	C7	100 ufd, +/- 20%, 250V, Electro.	007-10120170-141
8	C8	47 ufd, +/- 20%, 250V, Electro.	057-47020040-192
9	C9	220 ufd, +/- 20%, 10V, Electro.	057-22110300-190
10	C10	0.01 ufd, +/- 20%, 100V, Ceramic	055-10382125-111
11	C11	470 pfd, +/- 20%, 3kV, Ceramic	055-47167728-111
12	C12	0.01 ufd, +/-20%, 1kV, Ceramic	055-10368925-111
13	C13	0.01 ufd, +/- 20%, 250VAC, MPR	068-10300010-220
14	C14	0.22 ufd, +/- 10%, 100V, Polyester	058-22400240-189
15	C15	0.022 ufd, +/- 20%, 100V, Polyester	058-22300080-220
16	C16	0.22 ufd, +/- 10%, 100V, Polyester	058-22400240-189
17	C17	1000 ufd, +/- 20%, 16V, Electro.	057-10220100-192
18	C18	1000 ufd, +/-20%, 16V, Electro.	057-10220100-192
19	C19	1000 ufd, +/-20%, 16V, Electro.	057-10220100-192
20	C20	1000 ufd, +/- 20%, 16V, Electro.	057-10220100-192
21	C21	330 ufd, +/- 20%, 16V, Electro.	057-33120120-192
22	C22	2200 ufd, +/-20%, 16V, Electro.	057-22220070-192
23	C23	2200 ufd, +/-20%, 16V, Electro.	057-22220070-192
24	C24	2200 ufd, +/- 20%, 16V, Electro.	057-22220070-192
25	C25	330 ufd, +/-20%, 16V, Electro.	057-33120120-192
		Diodes	
26	D1	RGP10B	226-10400070-118
27	D2	RGP10J	226-10400060-118
28	D3	RGP10M	226-10400100-118
29	D4	RGP15B	226-10100040-118
30	D5	1N4606	212-10700210-158
31	D6	Heatsink Assembly	853-60200650-000
32	D7	Heatsink Assembly	853-60200650-000
33	D8	Heatsink Assembly	853-60200650-000
34	D9	RGP10B	226-10400070-118
35	D10	1N4606	212-10700210-158
36	D11	1N4606	212-10700210-158
37	D12	1N4001GP	226-10400080-118
38	Z1	Zener, 5.6V, +/-5% @ 40mA	222-56086002-148
39	DB1	Bridge Rectifier KBP10	226-30500010-118
		Fuse	
40	F1	Fuse 2.5A, 250V, 3AG	084-00200060-217



CIRCUIT TRACE #1700218, POWER SUPPLY ASSEMBLY #8790043

Parts List, Power Supply #8790043, (Astec AA12090)

Item	Sym	Description	Mfgr's Part No.
		Inductors	
41	L1	Toroid	024-00000110-484
42	L2	Toroid	124-00000110-484
43	L3	Base Choke 2.2 uH	328-00100030-124
44	L4	Choke 1.5 mH	328-00100010-124
45	L5	Choke Coil	852-20100180-264
46	L6	Choke Coil	852-20100180-264
47	L7	Filter Choke Coil	852-10100370-264
		Resistors	
48	R1	4 ohm, +/- 10%, Thermister	258-40970015-152
49	R2	4 ohm, +/- 10%, Thermister	258-40970015-152
50	R3	100K ohm, +/- 5%, 1W, Metal Film	247-10036054-156
51	R4	100K ohm, +/-5%, 1W, Metal Film	247-10036054-156
52	R5	33 ohm, +/-5%, 2W, Metal Oxide Film	248-33006063-189
53	R6	820 ohm, +/-5%, 1/4W, Carbon Film	240-82106022-152
54	R7	5.6 ohm, +/- 5%, 1/4W, Carbon Film	240-56906022-152
55	R8	47 ohm, +/- 5%, 1/4W, Carbon Film	240-47006022-152
56	R9	5.6 ohm, +/- 5%, 1/4W, Carbon Film	240-56906022-152
57	R10	10 ohm, +/- 5%, 1/4W, Carbon Film	240-10006022-152
58	R11	0.47 ohm, +/-5%, 1W, Metal Film	247-04786054-156
59	R12	5.6 ohm, +/- 5%, 1/4W, Carbon Film	240-56906022-152
60	R13	120 ohm, +/-5%, 1W, Metal Oxide Film	248-12106052-189
61	R14	1 ohm, +/- 5%, 1W, Metal Film	247-10086054-156
62	R15	39 ohm, +/-5%, 1/4W, Carbon Film	240-39006022-152
63	R16	270 ohm, +/-5%, 1/2W, Carbon Film	240-27106033-152
64	R17	270 ohm, +/-5%, 1/2W, Carbon Film	240-27106033-152
65	R18	8.2 ohm, +/-5%, 1/4W, Carbon Film	240-82906022-152
66	R19	330 ohm, +/-5%, 1/4W, Carbon Film	240-33106022-152
67	R20	56 ohm, +/-5%, 1/4W, Carbon Film	240-56006022-152
68	R21	56 ohm, +/-5%, 1/4W, Carbon Film	240-56006022-152
69	R22	12K ohm, +/-5%, 1/4W, Carbon Film	240-12306022-152
70	R23	470 ohm, +/-5%, 1/4W, Carbon Film	240-47106022-152
71	R24	4.7K ohm, +/-2%, 1/4W, Metal Film	247-47015022-189
72	R25	22K ohm, +/-2%, 1/4W, Metal Film	247-22025022-189
73	R26	2.7K ohm, +/-1%, 1/4W, Metal Film	247-27014022-189
74	R27	100K ohm, +/-5%, 1/4W, Carbon Film	240-10406022-152
75	R28	100K ohm, +/-5%, 1/4W, Carbon Film	240-10406022-152
76	R29	12 ohm, +/-5%, 1/4W, Carbon Film	240-12006022-152
		Transformers	
77	T1	Common Mode	852-20200120-264
78	T2	Power	852-10201340-000
79	T3	Control	852-10201510-000

Parts List, Power Supply #8790043, (Astec AA12090)

Item	Sym	Description	Mfgr's Part No.
		Transistors	
80	Q1	NPN, SD467	209-11700460-120
81	Q2	NPN, 2SC1358	209-30200020-143
82	Q3	PNP, SB561	210-11700350-120
83	Q4	Intergrated Circuit, TL431CLP	211-10800100-176

6.3 Power Supply #8790049, 65 Watt

6.3.1 System Description

Basic Principle

A switching power supply circuit employs a high-speed semiconductor switch to control the storage and release of electrical energy in an inductor and provide regulated DC output voltages with a minimum loss of energy in heat-dissipating elements. There are several schemes for achieving this result which differ primarily in the arrangement of the basic circuit elements. These elements include a switch, an inductor, a rectifier, a capacitor and a DC voltage source.

An arrangement well-suited for economical power supplies with rated power outputs under 100 watts is the FLYBACK CONVERTER shown in Figure 6-4. The waveforms in Figure 6-5 are used to describe the operation of the Flyback Converter circuit. For the purpose of this discussion we will assume that the duration of the "ON" time equals the duration of the "OFF" time.

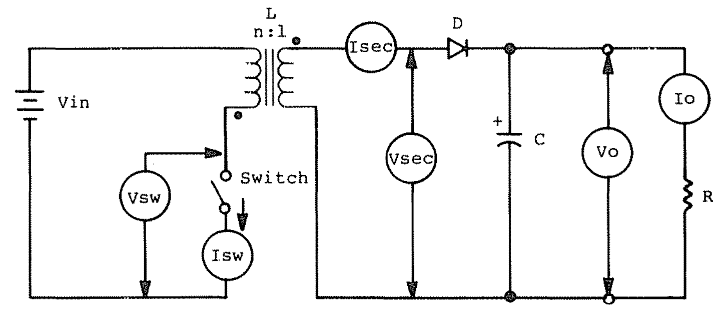


Figure 6-4. Basic Flyback Converter

When the switch is closed (ON) at time ta, Vin is impressed across the primary winding of inductor L and the current Isw increases linearly from zero until the switch opens (OFF) at time tb. Note that Isec is zero while the switch is closed. This is because Vsec is negative with respect to Vo thus reverse-biasing diode D. Note that Vsw is also zero while the switch is closed.

When the switch opens at time tb, the magnetic field of L instantly collapses and reverses polarity. At this moment, Vsw is equal to Vin plus the voltage across L just before the switch opened (also equal to Vin). Therefore, at the instant the magnetic field reverses polarity, Vsw = 2Vin.

During the interval when the switch is open (tb to tc), the secondary voltage, Vsec, is a replica of the primary voltage Vsw. Diode D is now forward biased due to the polarity of the inductor windings and because the turns ratio, n, is such that:

$$\text{Vsec} \times n > \text{Vo}$$

This biasing replenishes the charge in capacitor C that was delivered to the load R during the ta-tb interval. This is the "flyback" interval and is so named because the inductor releases the energy stored in its magnetic field while the switch is OFF.

Several other facts are illustrated by the waveforms of Figure 6-5. First, the voltage across the switch Vsw decays exponentially from 2Vin to Vin during the "OFF" interval. This is because the inductor and the switch timing are adjusted to transfer all of the energy that was stored in the inductor while the switch was ON, into the secondary while the switch is OFF. (Observe that Isec DECREASES linearly with time to zero at the end of the "OFF" time period.) This is known as resetting the core. Thus, at time tc when the switch is ready to turn on again, the DC input voltage Vin is again available to charge the inductor. Also at this time, all currents in the inductor are zero.

Second, since we have assumed that Isw increases linearly with time and that the ON and OFF time periods are equal (50% duty cycle), the average current in the primary, Isw (av), is 1/4 the peak current Isw. Also, the average current in the secondary, which is equal to the load current Io, is 1/4 the peak current in the secondary.

Third, the turns ratio is set by the ratio of the average primary voltage (Vsw) over a full cycle at its lowest value to the maximum permissible output voltage, Vo. The lowest Vsw value occurs at low AC line and maximum output load. In practice, the actual turns ratio, the ratio of peak-to-average voltages and currents, and the duty cycle may be adjusted to compensate for circuit losses.

Fourth, notice the ringing or oscillation that appears on the peak portion of Vsw and Vsec. This oscillation occurs at the resonant frequency of the leakage inductance of the inductor L and the parasitic capacitance of the circuit. The parasitic capacitance includes the interwinding capacitance of the inductor and stray capacitance of the switch. If this oscillation is not damped by a suitable means, the peak voltages may easily exceed the breakdown rating of the switch or the insulation in the inductor.

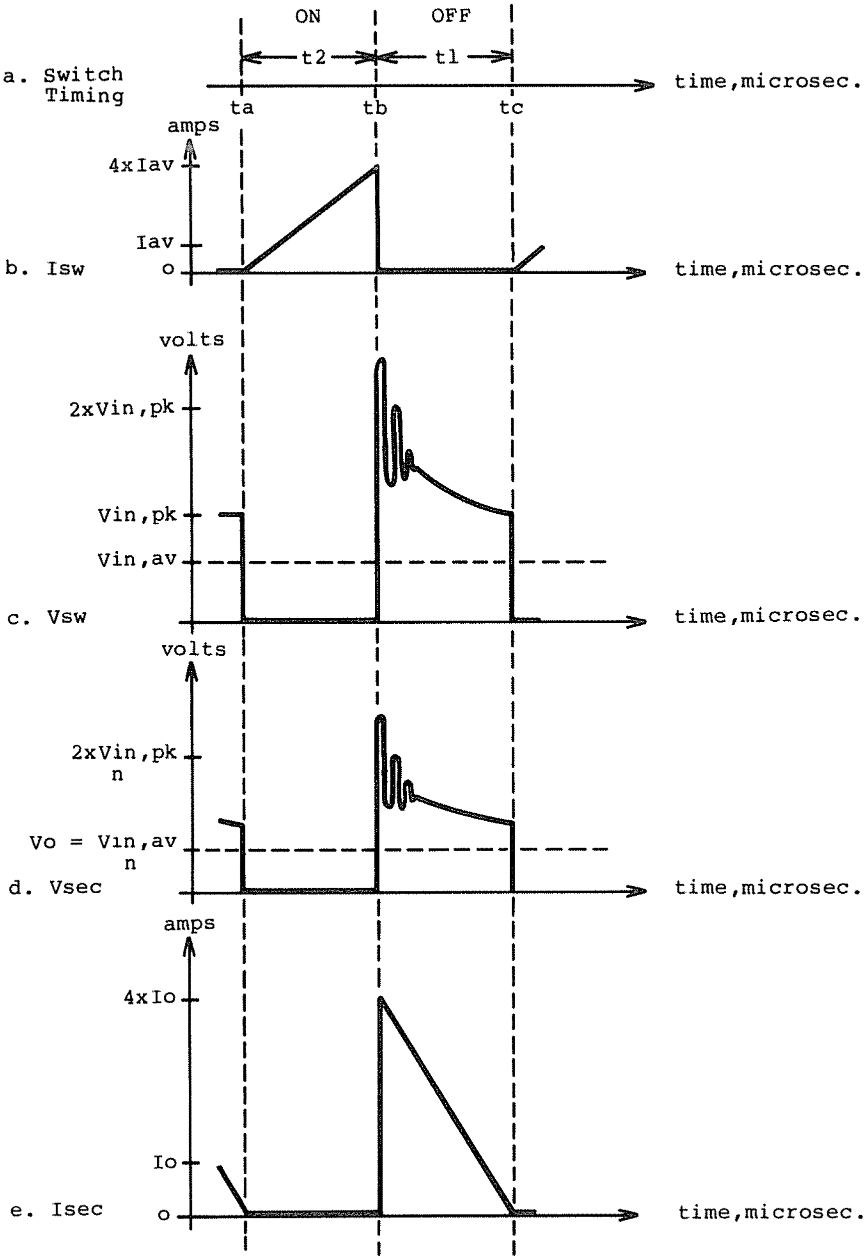


Figure 6-5. Waveforms for Figure 6-4.

Block Diagram

The basic circuit illustrated in Figure 6-4 can be divided into three functional blocks: Input DC supply, primary, and secondary. To make use of this model, we need to expand it to provide control for the switch timing and to include sufficient circuitry to satisfy performance and reliability specifications. The complete block diagram is shown in Figure 6-6.

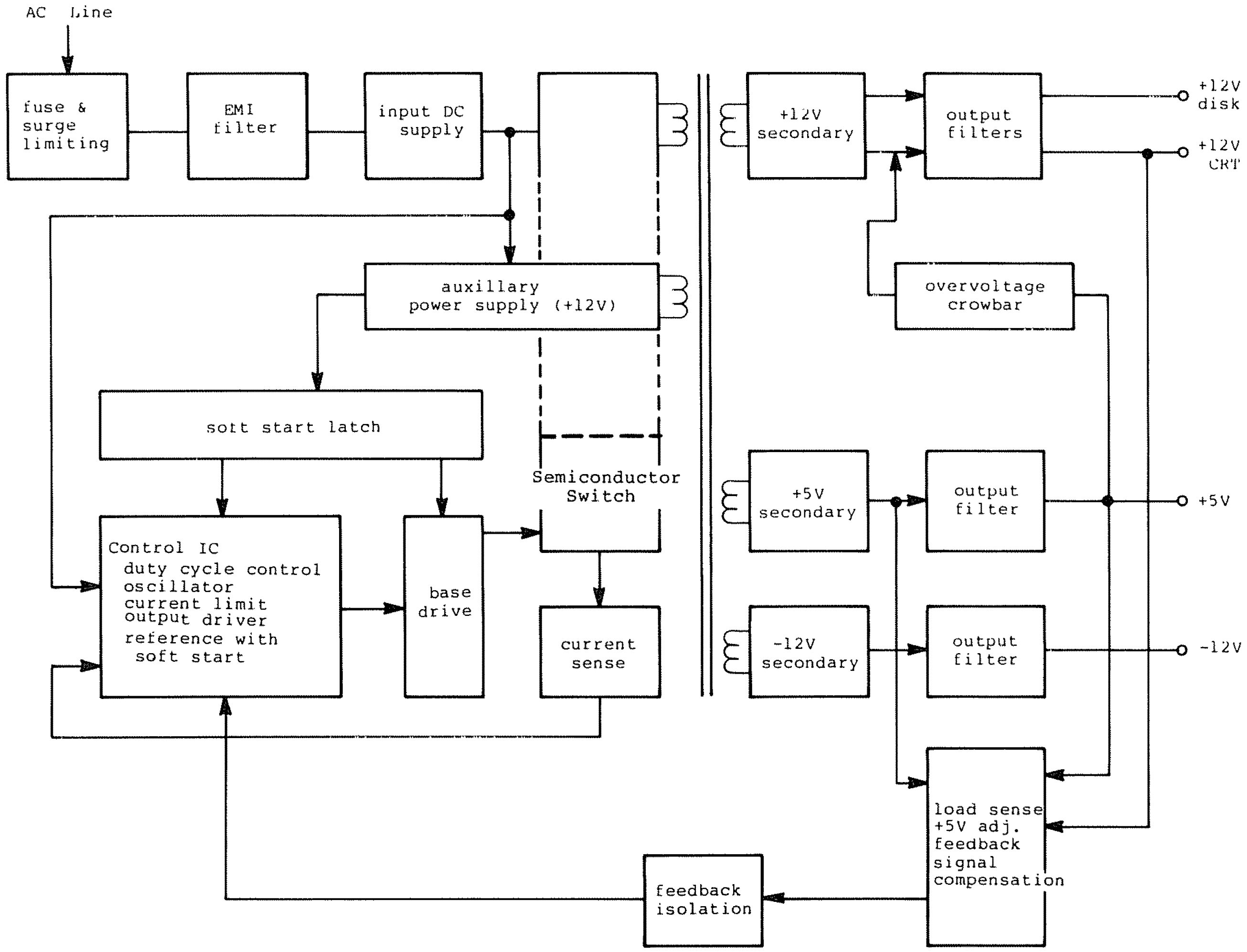


Figure 6-6. Block Diagram

The other blocks provide additional output voltages, add safety or protective features, reduce circuit noise, and develop signals for use by the control section. The control section continuously operates the bipolar transistor switch and varies the proportion of ON time to OFF time in response to changes in AC input line voltage or output load current. This is accomplished by feeding back a signal from the output terminals that instructs the control section to increase or decrease the ON time to compensate for a change in the output voltage.

The DC voltage supply to the control section is controlled by the latch circuit when AC power is first applied to the power supply. A built-in timing circuit allows the input DC supply filter capacitor to become fully charged before power is applied to the control section. After the control section circuit starts and secondary voltages reach their regulated output levels, the auxiliary power supply provides the required DC voltage to operate the control section. The latch is reset when the current limit or under-voltage sensors operate, thus removing DC voltage to the Control IC.

There are four secondary or output voltages in addition to the auxiliary supply: +5.05 volt, +12 volt CRT, +12 volt Disk, and −12 volt. The +5.05 and +12 DISK voltages are regulated by the control circuit response to the frequency compensated feedback control signal which comes from the load sense section. Since the load sensing occurs on the secondary side, an optional coupler circuit is necessary to provide safety isolation between the primary side common ground and the secondary side common ground.

All the secondary voltages, including the auxiliary +12 voltage, share the same magnetic flux linkage in the transformer core and are controlled by the flyback inductor. Any change in secondary load currents cause a change in the shared magnetic flux. This change in the flux of the inductor sets up an EMF (electromotive force) which causes a flux in opposition to the one which resulted from the change in load current. Thus, the original change tends to be counteracted and the current delivered to the load remains constant.

The output filters reduce the remaining ripple voltage components of the AC line and switching frequencies to levels low enough to prevent interference with the circuits operated by the supply. Switching frequency components that could be conducted out the AC input terminals are suppressed by the EMI filter to avoid interference with other equipment connected to the power line.

The overvoltage crowbar senses an abnormal rise in the +5.1 volt output and short-circuits the voltage line to the common secondary ground, thus tripping the current limiting circuit which finally shuts down the supply.

The surge limiter at the AC line input prevents the input filter capacitor in-rush current surge from exceeding component ratings or unnecessarily tripping external fuses.

6.3.2 Technical Specifications

Environment

Temperature; Operating		0° to 50° C (32° to 122° F)
	Storage	–40° to 85° C (–40° to 185° F)
Humidity; Operating		85% r.h. @ 35 C (95° F) max.
	Storage	95% r.h. @ 55 C (131° F) max.

Input Voltage:
90 to 135 VAC rms, 47 to 63 Hz

Input Surge Current:
48 amps max.

Efficiency:
70% min. at full load with 115 VAC rms input

Output Voltages:

V1, +5.05 VDC
V2, +12 VDC CRT
V3, +12 VDC DISK
V4, –12 VDC

Output Power:
continuous 65 watts max.

Output Current:

		Load	
	Output	Min.	Max.
Condition 1 (Model III use)	V1	1.35 A	4.0 A
	V2	0.60 A	1.5 A
	V3	0.40 A	2.1 A
	V4	0.005 A	0.10 A
Condition 2 (Hard Disk use)	V1	2.5 A	5.0 A
	V3	0.75 A	2.0 A*
	V4	0.005 A	0.10 A

*NOTE: V2 and V3 connect in parallel to provide the V3 output. The V3 output will support a 5.0 A peak load which decays to 1.0 A in approx. 8 seconds. V1 and V3 must be within specified regulation when this surge decays to 4.0 A.

Output Ripple Voltage:

V1	(5.05 VDC)	50mV p-p
V2	(+12 VDC)	150mV p-p
V3	(+12 VDC)	150mV p-p
V4	(–12 VDC)	150mV p-p

NOTE: Ripple is the composite 100/120 Hz ripple due to the line, plus the high frequency ripple due to the power oscillator. Common mode noise which may be observed due to oscilloscope connections should be ignored.

Output Voltage Regulation:
After initially setting V1, output voltage tolerances under all conditions of rated line, load, and temperature should remain within the following limits:

V1	(+5.05 VDC)	+/– 3%
V2	(+12 VDC)	see *NOTE
V3	(+12 VDC)	+/– 5%
V4	(–12 VDC)	+25%, –8.3%

*NOTE: a) The initial value of V2 must not change by more than +/– 100mV under the following load conditions of V3:
- A step increase in output current from 0.6 A (initial condition) to 2.4 A, decaying within 60 msec to 2.1 A.
- A step decrease in output current from 2.1 A (initial condition) to 0.6 A.

b) V2 output voltage may vary +/– 5% under all other conditions of rated line, load, and temperature as defined in the specification.

Over-Current Protection:
Power supply will shut down before total power exceeds the point where damage would result. No damage will result when any output is short circuited continuously with 100 milliohms or less.

Over-Voltage Protection:
The +5.05 VDC circuit is protected with a "crowbar" circuit with a trip range of 5.8 to 6.8 VDC.

Hold-Up Time at Continuous Max Load:

Nominal Line	16 mSec minimum
Low Line	10 mSec minimum

6.3.3 Theory of Operation

The basic operating principles of a flyback converter and the necessary functional blocks to form a complete power supply were reviewed in the System Description section. In this part, the operation of each section of the circuit will be analyzed and later these sections will be connected to illustrate the signal flow in the power supply.

AC INPUT

A conventional bridge rectifier and a filter capacitor are connected directly across the AC line to provide the DC input voltage to the power supply.

An EMI filter consisting of capacitors C30-C33 and choke T2 are inserted at the input to the rectifier. This filter circuit keeps the high frequency signals generated in the power supply from being conducted into the AC power line. C30 and C31 provide a low impedance to the earth ground terminal for signals common to both hot and neutral sides of the AC line. C32 provides a low impedance dissipative path for the RF signal energy which appears across the line. T2 blocks RF signals common to both sides of the line and reflects them back toward the lower impedance elements near the rectifier. T2 also helps block differential (across-the-line) signals by using the EMF set up by the signal current on one side of the line to oppose the signal current flowing in the other side. C33 serves as a transient bypass capacitor to protect the power supply from large transient voltages that appear on the AC power line. C33 also improves the efficiency of the RFI filter choke T2 by terminating the line in a low impedance to absorb and dissipate any remaining differential RF energy.

R38 is a negative-temperature-coefficient-themistor which limits the turn-on surge current of the power supply filter capacitor C29. The resistance of this thermistor when "cold" is approximately 10 ohms. As the filter capacitor charges toward the peak value of the AC input voltage, it draws less current from the line. At the same time, the heating effect of the current flowing in the thermistor causes its resistance to decrease until it reaches its rated "hot" resistance of less than 1 ohm. As you can see, the thermistor dissipates very little power when the power supply is in operation. The thermistor is designed to cool rapidly enough, during power loss or turn-off, to limit the turn-on surge after only a few seconds cool-down.

The fuse, a fast acting 3.0 amp unit, is selected to ignore the short term turn-on surges, but open quickly in the event of an abnormally high current that would result from a component failure in the DC input supply or current limiting circuits.

Auxiliary Power Supply

The auxiliary power supply is operational when the main supply is on and not in a shut-down condition. This power supply consists of winding 2-3 on T1, half-wave rectifier CR4, and filter capacitor C14. The voltage output is approximately +15 volts under normal conditions but momentarily reaches about +31 volts during start-up.

Kick Start Latch

Start up of the circuit is initiated by the kick start latch. This latch is shown in simplified form in Figure 5a along with the accompanying waveforms in Figure 5b. When power is applied, C14 charges toward Vin = +160 volts through R26 with a time constant of approximately RC or 37.5 seconds. However, as we'll see, the kick start latch turns on in 2 or 3 seconds, the time required for the voltage across C14 to reach 30 + Vbe4 = 30.7 volts. At this point Q4 turns on and develops a bias across R21 which turns on Q5.

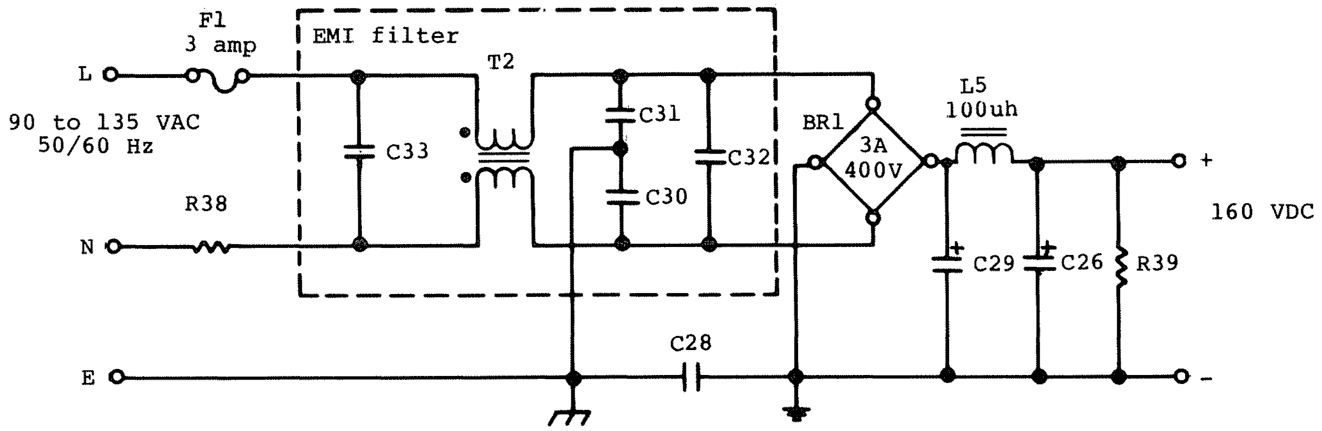
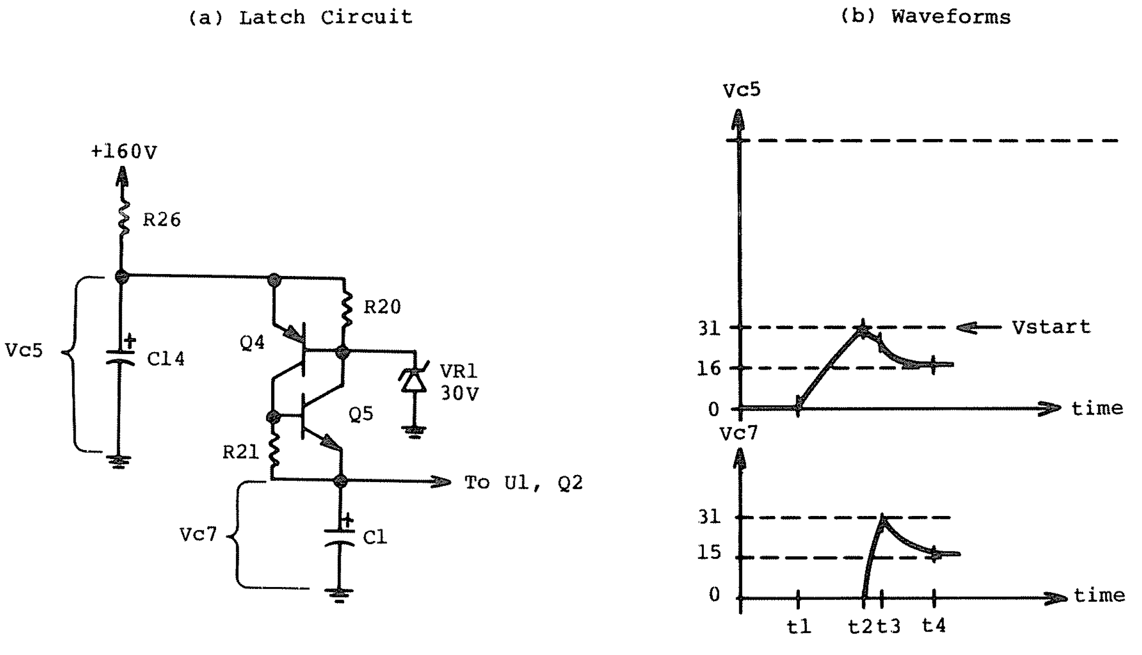


Figure 6-7. Input AC Supply



t1: Power applied
t2: Latch turns ON
t3: C1 peak charge
t4: C1 voltage at loaded value
Vin = 160 volts

Figure 6-8. Kick-Start Latch

Referring to Figure 6-8b, as C14 dumps its charge into C1 beginning at time t2, the voltage across C14 starts to decrease toward a level that will be determined by the load composed of U1 and the base drive circuit. Notice that the voltage across C1 momentarily approaches the full 31 volts at time t3 before it drops down under load to about +15 volts at time t4.

With C1 charging rapidly through the low resistance of a saturated Q4 via Vbe5, the reference supply inside U1 develops its 5.0 volt output when the voltage across C1 exceeds about 8 volts. At this point, the supply has not quite yet started, but U1 has a DC supply at pin 10. All that remains is to start up the pulse generator so that the supply operates and replenishes the charge in C14 on each cycle, thus maintaining a DC source for U1 of about +15 volts. Completion of the start-up sequence occurs when the soft start circuit, described in the next section, has started the pulse generator.

Control Section

The control section consists of the control IC, the primary half of the feedback optocoupler U2, and the base drive circuit for the switching transistor. The control circuit IC has three major parts: an internal regulator, a pulse generator, and an error amplifier section.

The internal reference is a regulated +5.0 DC voltage. This voltage provides the reference voltages for the comparators used in the pulse generator as well as the DC supply voltage for the feedback optical coupler and the internal circuits of U1 except for its output transistors.

The pulse generator section of the control IC has four major parts: (a) sawtooth oscillator; (b) wave-shaping and output circuit; (c) regulating comparator; (d) dead-time comparator. Figure 6 illustrates the sawtooth oscillator and output circuit waveforms and the approximate levels of the DC control voltages applied by the comparators to the wave-shaping logic. The oscillator frequency is set by the values of R3 and C7 shown in Figure 7.

The amplitude of the sawtooth is set at 3.0 volts (approximately 60% of the 5.0 volt reference voltage). Whenever the sawtooth voltage, Vosc, exceeds both of the DC control voltages, Vreg and Vdt, the output circuit will be in the ON condition.

The DC control voltage, Vreg, set at a quiescent value by R6 and R9, varies in response to changes in the supply's DC output voltages as sensed by U3 and coupled through U2. Notice that these voltages will vary because of changes in output loading, AC input voltage, and also because of the residual 120 Hz ripple component from the main DC supply.

The dead-time control voltage, Vdt, is set at a constant value by R4 and R5 and ensures that the pulse generator "OFF" time will be at least 50% of the sawtooth period. This allows adequate time for the complete transfer of stored energy from the primary to the secondary of transformer T1 as discussed in the section on basic principles.

A concept known as duty cycle was introduced in earlier paragraphs. Duty cycle is defined as the ratio of the "ON" time of the sawtooth cycle to the total length of the sawtooth period. Since the sawtooth has a linear ramp characteristic, the duty cycle is also equal to:

$$\text{duty cycle d} = \frac{\text{Vosc, pk} - \text{Vreg}}{\text{Vosc, pk}} = \frac{\text{ton}}{\text{T period}}$$

There are three possible conditions of the duty cycle:

$d = 0$	which occurs when either control voltage Vreg or Vdt exceeds the peak value of the sawtooth waveform Vosc
$d = 50\%$	which occurs when Vreg is less than Vdt. This happens when the loading on the output of the supply is heaviest and the AC input voltage is at its lowest permitted level (see specifications)
$0 < d < 50\%$	which occurs during normal operation.

The dead-time control voltage is used in one other important way. Notice the 4.7 μfd capacitor, C2, connected across R4 in Figure 6-10. When power is first applied to the supply, the voltage across the capacitor is zero. Therefore, Vdt = Vref = 5.0 volts and no pulses appear at the output because Vdt is greater than Vosc,pk. As C2 charges, Vdt decreases toward 1/2 (Vosc,pk) in a time determined by R5 and C2 as t = 5x15k ohm X 4.7 μfd = 1/3 second. As Vdt decreases past Vosc, pk, very narrow pulses begin appearing at pin 8 of U1. The pulses become successively wider until Vdt is less than Vreg. C2 continues charging until Vdt reaches the final correct value of about 1.5 volts. This action provides the soft start feature of the power supply and allows sufficient time for the DC input supply and latch to reach normal operating conditions before the supply is started. In effect, the load is connected to the supply gradually by the soft start circuit.

Frequency stability of the sawtooth oscillator is provided by the 2% tolerance and polyester construction of the timing capacitor, C7, and the 100 parts-per-million temperature stability and 1% tolerance of R3. Voltage stability of the DC control voltages is provided by the +/– 2 1/2 percent stability of the 5.0 volt reference.

The control section consists of two error amplifiers in U1, the primary half of U2, and associated circuitry shown in Figure 6-10. One of the error amplifiers serves as a regulator or pulse-width modulator which derives the DC control voltage, Vreg, from the signal voltage developed across R7 by the current in U2.

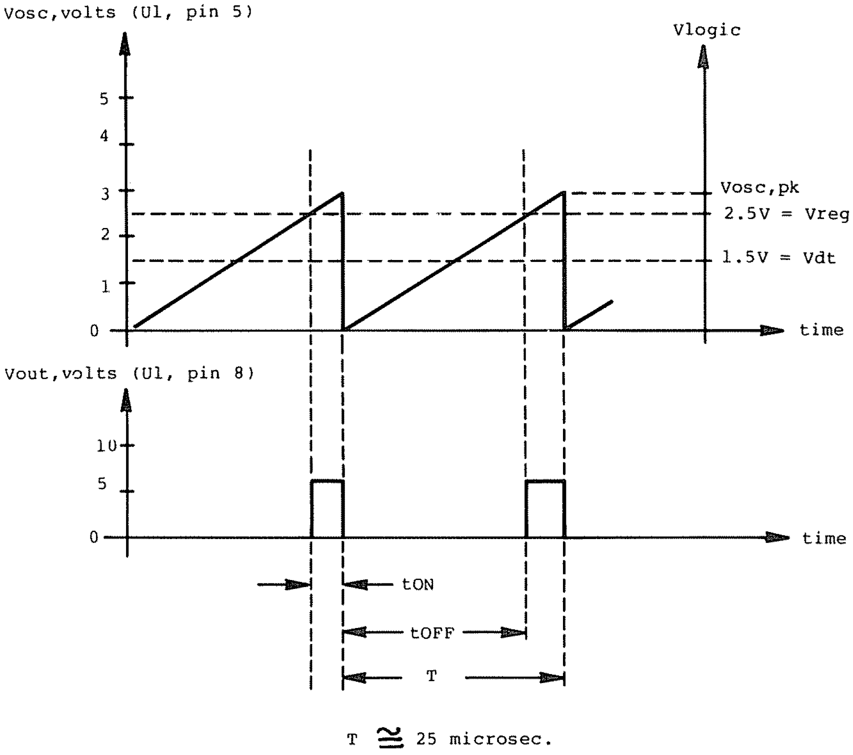


Figure 6-9. Oscillator, Pulse Generator Waveforms

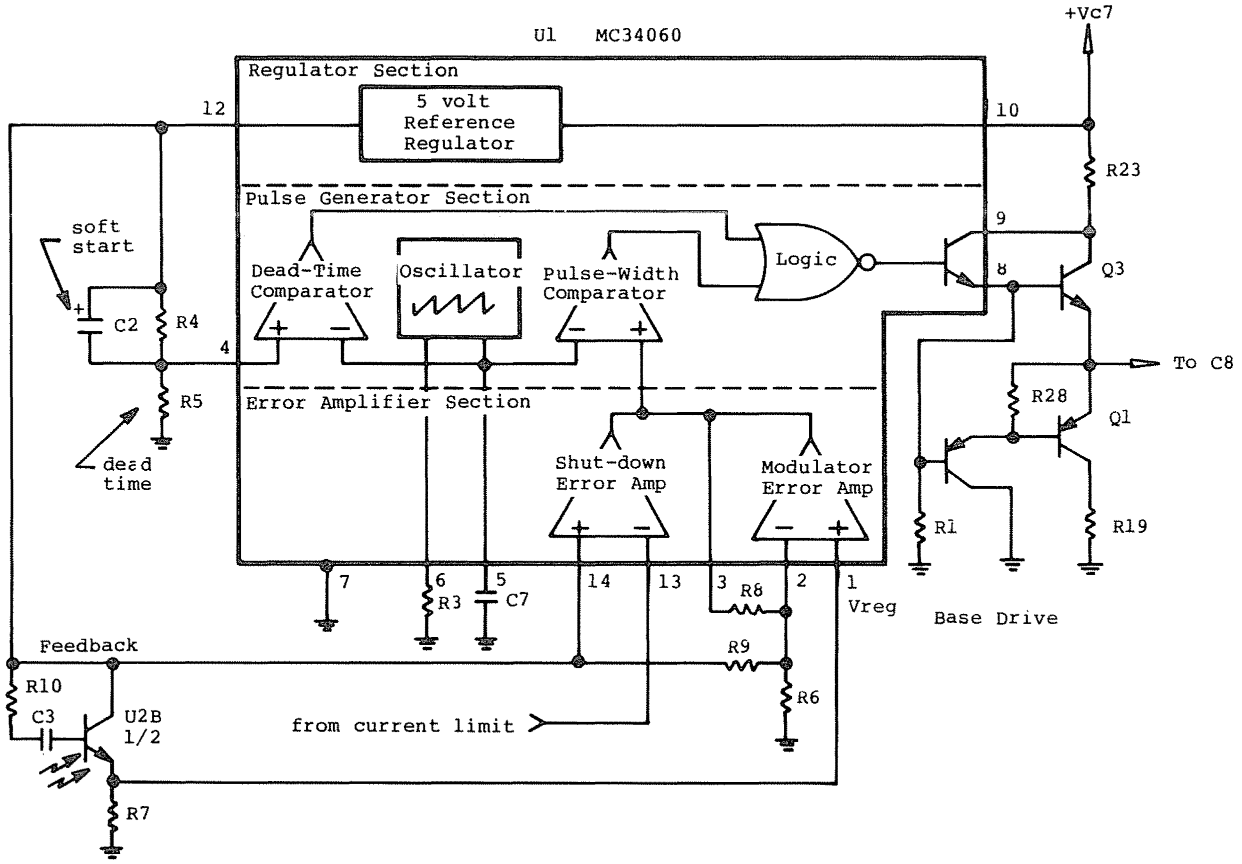


Figure 6-10. Control Section

This current is a replica of the current developed by U3 in response to the condition of the output voltage at the +5.1v and +12v outputs. This amplifier has a gain of about 10 determined by:

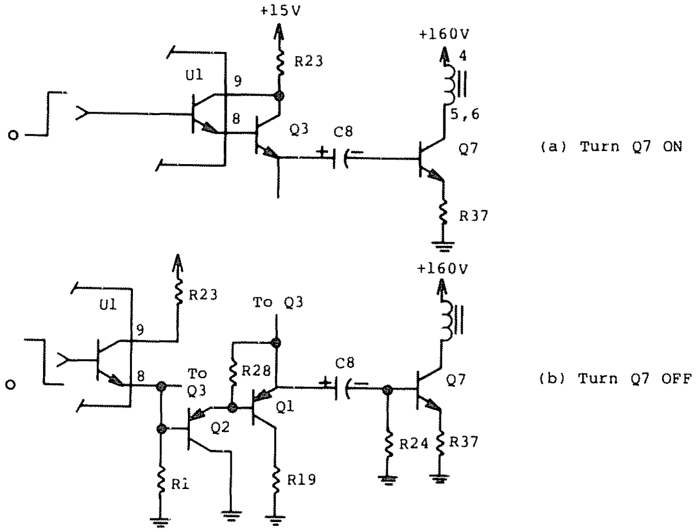
$$A = \frac{R8}{R9 \parallel R6} = \frac{22k\ \text{ohm}}{2.35k\ \text{ohm}} = 10$$

The other error amplifier in U1 serves as a shut-down comparator. The positive terminal, pin 14, is set at the +5.0 volt reference and pin 13, the negative terminal or shut-down pin, is tied to the current limit latch. The output of this error amplifier (equal to Vreg since both error amplifier outputs are tied to the wave-shaping logic) will rapidly increase toward the +5.0 volt reference when pin 13 drops below 5.0 volts. Recall that if Vreg exceeds the peak sawtooth voltage, pulses are inhibited and the power supply shuts-down.

Base Drive

Figure 6-11 illustrates the BASE DRIVE circuitry which turns switching transistor Q7 on and off in response to the output of the pulse generator portion of U1. The "ON" circuit is shown in Figure 6-11a and the "OFF" circuit is shown in Figure 6-11b. Waveforms for these circuits appear in Figure 6-12.

The output transistor of U1 combined with Q3 forms a Darlington pair. This circuit provides the relatively large current necessary (through coupling capacitor C8) to turn on Q7. R23 limits this base current to a value large enough to turn on Q7 quickly, but not so large that it will exceed the ratings of Q3, C8, or the base emitter junction of Q7, or so large that the turn-off time of Q7 is excessive.



(a) Turn Q7 ON

(b) Turn Q7 OFF

Figure 6-11. Base Drive Circuit

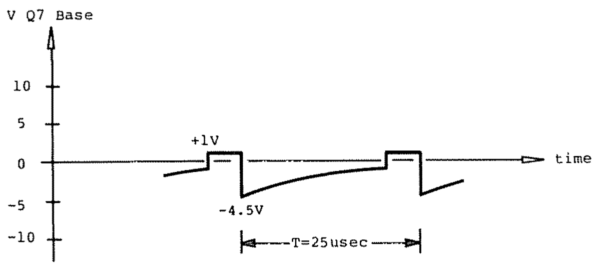


Figure 6-12. Q7 Base Voltage Waveform

As Q3 turns on, C8 charges to approximately +5 volts and Q7 is driven into saturation. Energy is stored in the primary winding of T1 as the collector current of Q7 increases or "ramps up" at a rate determined by the inductance of the transformer primary winding.

When the output transistor of U1 turns off, the emitters of Q1 and Q2 are initially at the +6 volt level determined by the charge on C8, the Vbe drop of Q7, and the drop across R37. Both base-emitter junctions of the Q1-Q2 Darlington pair are biased ON and the positive terminal of C8 is clamped to near-ground by the saturating Q1. At this point, C8 still has most of its charge and the base voltage of Q7 is approximately –4.5 volts with respect to ground.

With the strong reverse polarity provided by C8 across the base emitter junction of Q7, the "forward" charge stored in the junction capacitance is quickly swept out and Q7 is turned off. C8 continues to discharge through R24 to prepare for the next "ON" cycle. R19 limits the initial discharge of C8 while Q7 is turning off.

Notice the symmetry in the base drive circuit and the key role played by C8 in both the turn-on and turn-off sequences. Because of this crucial role in the circuit, this capacitor is specified as a high temperature, low-equivalent-series-resistance component.

Primary Circuit and Current Limit Shutdown

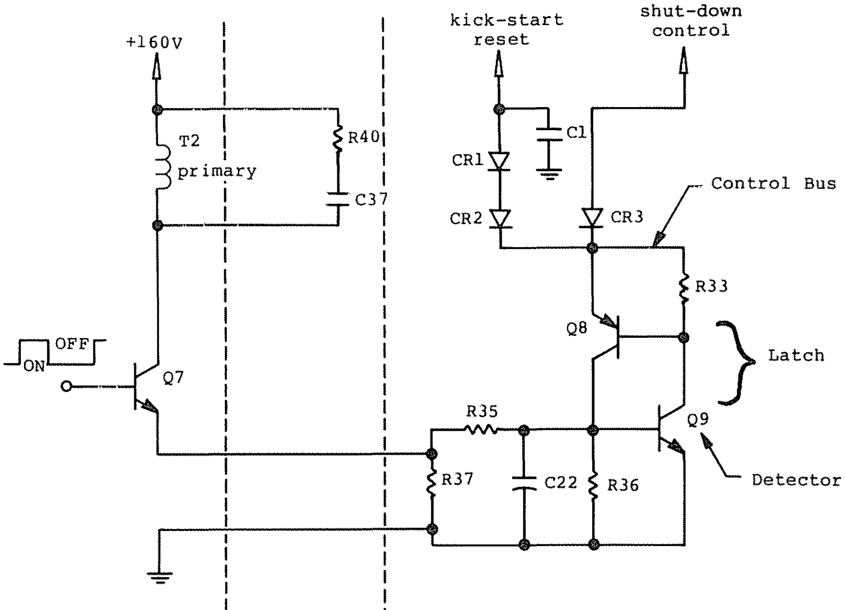
The Primary Circuit

The Primary circuit, shown in Figure 6-13a functions exactly as described earlier in the "Basic Principle" section. That is, the switch (Q7) is controlled by the base drive waveform developed by the control section.

The Snubber Circuit

Practical transformers cannot couple 100% of the stored energy from the primary to the secondary since all of the flux from the primary fails to link all the secondary turns. A circuit using this practical transformer behaves as though a small fraction of the primary inductance was not wound on the core of the transformer, but instead placed apart from the primary and in series with it. This small, separately-acting inductance does not participate in the transformer action and is called the leakage inductance.

If the resonant circuit, consisting of this leakage inductance and the stray capacitance in the adjacent circuit, has sufficient Q (relatively low resistance losses), a damped oscillation will occur in this resonant circuit when the transistor switch opens. The peak value of this oscillation will add to the Vce = 2 x Vin which appears across the transistor switch just after turn-off.



(a) Primary (b) Snubber (c) Current Limit Sense

Figure 6-13. Primary Side Protection

The combined peak Vce may exceed the transistor breakdown rating if not damped out by the action of a snubber circuit.

When Q7 turns off, the energy stored in the leakage inductance is transferred to the electric field of the total capacitance of C37 plus stray capacitance. (Since C37 capacitance is much larger than the strays, it dominates in this action and tends to limit the peak value of the Q7 turn-off voltage.) If there were no resistance in this series connection of C37-plus-parasitics and leakage inductance, they would exchange this energy back and forth indefinitely. R40 is used to damp this oscillation without excessively slowing the turn-off of Q7, thus effectively snubbing the turn-off voltage spike at the collector of Q7.

Current Limit Circuit and the Shut-Down Sequence

The current limit circuit forces the voltage level at a control pin of U1 to change to a near-zero value very quickly when the current in the transistor switch exceeds a predetermined point. It also removes the supply voltage from the control circuit and resets the kick start latch and soft-start circuits.

The current limit circuit shown in Figure 6-13c has three parts: a control bus, a detector, and a latch. The control bus supplies the operating DC voltage to the current limit circuit. It also conducts the current limit signal to control pin 13 and to the reset-point in the kick start latch circuit. Diodes CR2 and CR3 steer this signal.

The normal maximum peak current in switching transistor Q7 is 3 amps. The detector transistor Q8 is biased to turn on by the divider action of R35 and R36 whenever the Q7 peak current through R37 exceeds 4 amps. A low-pass filter, formed by R35 and C22, prevents false detections on transient signals that don't represent an over-current condition.

As soon as Q9 turns on, its collector current develops the turn-on bias for Q8 across R33, and the Q8-Q9 pair "latches" in the "ON" state until the DC source for the latch is removed. Removal of this DC source occurs when C1 discharges through CR1, thus removing DC voltage from the control IC. Notice also that the kick start latch, Q4 and Q5, is still in the "ON" state and thus provides a discharge path for C14. When the decreasing voltage across C14 is less than approximately one volt, the Q4-Q5 latch also switches off.

At this point in time, all circuits are in an OFF condition except the input DC supply. C14 now begins to re-charge toward the input DC supply to restart the power supply. If a fault remains, the kick start and current limit circuits will continue to shut-down and re-start the power supply several times per second until the fault is removed or AC power to the supply is turned-off.

Under-Voltage Lockout

The Under-Voltage Lockout, UVL, shuts down the supply whenever the AC input voltage drops below about 90 volts. This occurs when the voltage at pin 13, set by the divider action of R27 and R25, diminishes to a level below the internal reference supply of the control IC. Pulses are inhibited immediately and because the DC supply to the Control IC is no longer replenished by the auxiliary supply, it discharges toward zero.

Why is it important to shut down the supply if the input AC line drops below 90 volts? The answer will become clear when an inherent characteristic of the circuit is discussed, namely, its negative input resistance.

Imagine the situation where the supply is delivering full power to its load and the AC input voltage drops five or ten volts. The supply control circuit responds by increasing the "ON" time of the switching transistor thus increasing the average current in the primary winding. The only way the DC supply can deliver more current is to draw it from the AC line. So the negative change in AC input voltage was accompanied by a positive change in AC input current.

Another way to describe this characteristic is that the supply is a constant power device, that is:

Pin = Vin x Iin = constant.

Thus if V decreases, I will increase, and vice versa. The supply will thus draw more and more current from the AC line if the AC voltage continues to decrease. In order to limit the average current to a safe value, the control circuit senses the input voltage and shuts down the supply before the AC voltage level becomes too low or the AC current input becomes too high.

Secondary Outputs

Each of the secondary windings consist of a half-wave rectifier followed by a pi filter. The input capacitor of the filter stores the charge delivered to it when the rectifier is biased ON by the polarity of the transformer winding. The inductor and the output capacitor form a low-pass filter which removes the switching frequency ripple component.

The current output of the −12 volt supply is much smaller than that of the positive voltage outputs. Because of this, the current limit circuit response is not sufficiently effective to prevent damage to the −12 volt circuit. Therefore, a three terminal regulator with its own current limiting circuit is used to protect the −12 volt output.

All of the 12 volt rectifiers are fast recovery types and the +5 volt rectifier is a Schottky type. These diodes feature high switching speeds during turn-off. Their low forward voltage drop minimizes dissipation resulting in maximum efficiency. Each of the positive outputs has a bleeder resistor.

The combined peak Vce may exceed the transistor breakdown rating if not damped out by the action of a snubber circuit.

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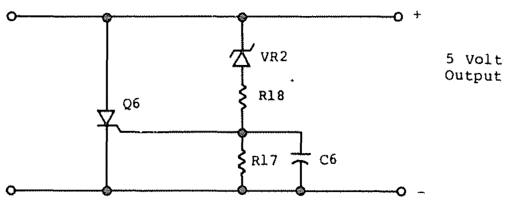


Figure 6-15 Overvoltage Crowbar

transformer turns ratio. Notice that the turns ratio determines the ratio of collector voltage to secondary voltage, both of which are alternating voltages. The ratio of input-to-output DC voltage is determined by the duty cycle and the turns ratio together.

For example, lets look at the +5 volt output of Figure 6-16 at normal loading and approximately 120 VAC input. Under these conditions, the DC input voltage is 168 VDC and the duty cycle is approximately 40%. Thus, our average DC voltage at the switching transistor collector (or across the primary) is 40% of 168 or 67.5 volts. Dividing this average DC voltage by the turns ratio for the 5 volt secondary (54 : 4 = 13.5) gives us 5.0 volts.

$$\frac{67.5V}{13.5} = 5V$$

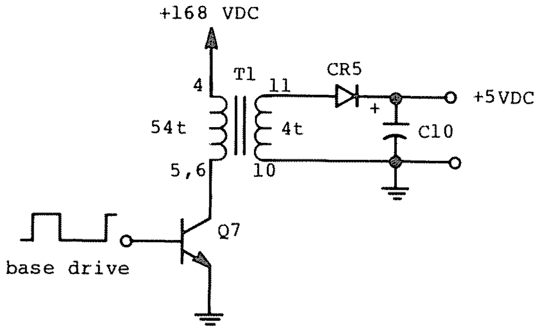


Figure 6-16. Power Chain

Control Chain

Imagine the load end of the feedback path disconnected from the +5.1 volt output terminal and unfolded so that the load sense network is now at the "input". The secondary rectifier (CR5) and filter (C10/C11, L1, C12) remain as the output. The circuit as it now appears, redrawn in simplified form in Figure 6-17 is known as the control chain. To see how the regulation action occurs, assume a small negative voltage change at the "input" of the feedback network and follow it through the control chain.

This negative voltage change, which would correspond to a slightly heavier load current, appears at pin 1 of U3 as a decreasing voltage. The error amplifier in U3 inverts and amplifies this signal. The positive-going output voltage of U3 at pin 3 causes less current to flow in the internal LED of U2A. A replica of this smaller current, optically coupled and induced in the phototransistor of U2B, develops a reduced voltage across R7 at the non-inverting input of the regulator error amplifier in U1.

The regulator error amplifier in U1 does not invert the signal, but further amplifies it, improving the sensitivity of the control chain to small changes at the power supply output. The regulator error amplifier output is Vreg. Since we established earlier that a negative-going Vreg increases the length of the base drive pulse, Q7 is turned on a little sooner so that it can store more energy from the AC line in the primary inductance. Finally, this increased energy is stored in the filter capacitor C10/C11 during the flyback interval and supplies the increased demand for current that resulted in the original reduction in the output voltage.

More simply stated, the control chain uses an amplified version of the output voltage CHANGE to adjust the width of the base drive pulse through the action of a control voltage at a comparator input.

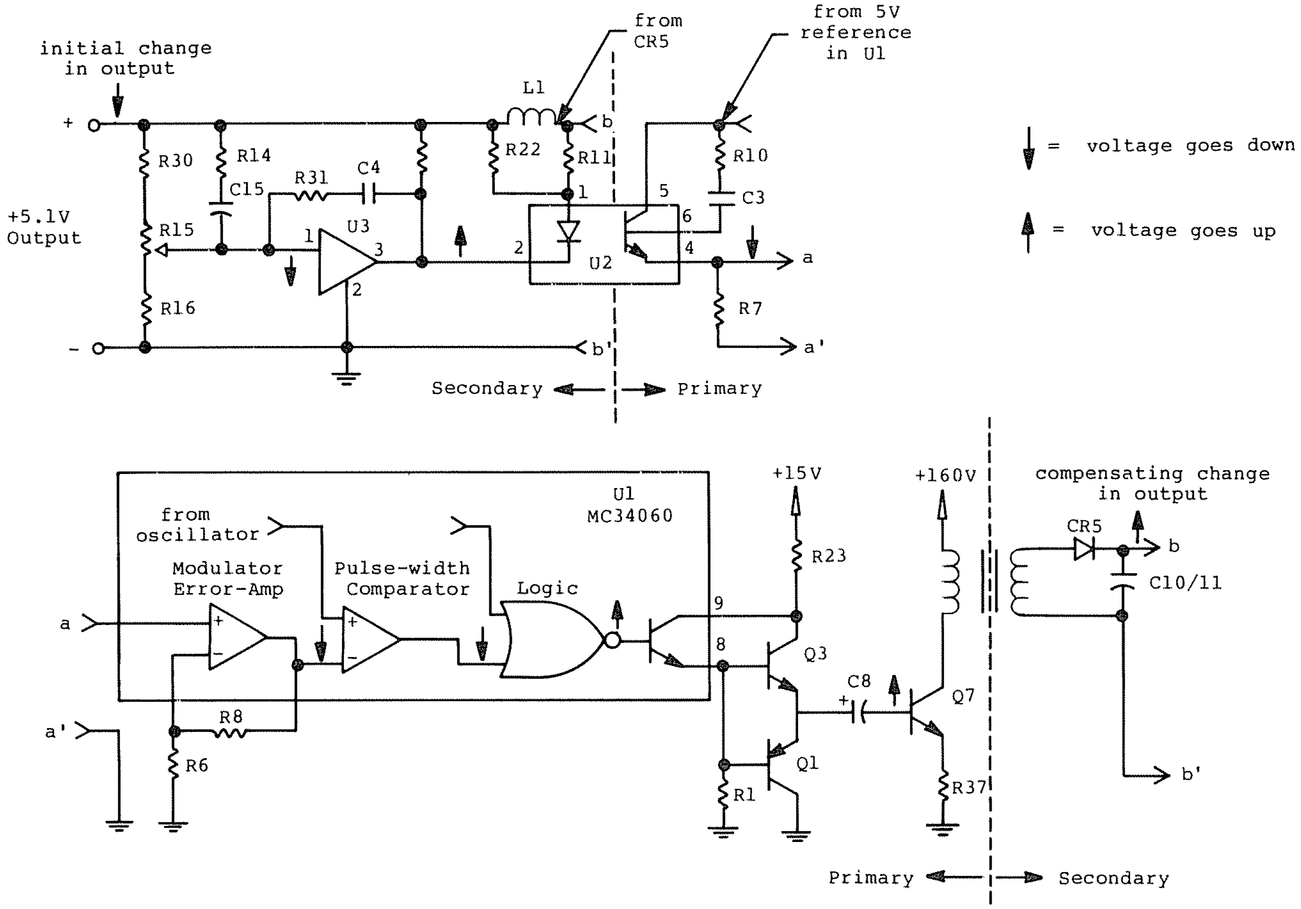


Figure 6-17. Control Chain Simplified Schematic

6.3.4 Troubleshooting Chart for Power Supply #8790049, 65 Watt

Trouble	Cause	Remedy
open fuse	shorted line input filter capacitor	check and/or replace C33, C32, C31, C30
	shorted bridge	check BR1
	shorted filter capacitor	check C29, C26, R39
	shorted switching transistor	check Q7, C37, R40, C26, T1 pri., Q3, Q1, R37
Current limit cycle	single rectifier open in bridge	check and/or replace BR1
	open filter capacitor	check C29
	shorted snubber capacitor or resistor	check C37, R40
	open opto-coupler	check U2
	shorted supply output	check computer for short on +5V, +12V CRT, +12V DISK, –12V outputs and clear shorted condition
	shorted output rectifier	check CR5, CR6, CR7, CR8
	open or shorted output filter capacitor	check C16, C18, C25, C23, C10, C11, C12, C19, C20
	defective crowbar	check Q6

no pulses at pin 8 of U1, (i.e., supply shut down)	no aux. DC supply	check and/or replace CR4, C14, T1 aux.
	no "kick start"	check R26, Q4, Q5, VR1, CR1, C1
	no base drive	check U1, Q3, R23, C8, R24
	dead-time control divider malfunction	check C2, R4, R5, U1 (for V ref.)
	under-voltage protect divider malfunction	check R27, R25, C9, Q9
	PWM feedback malfunction	check and/or replace U1, U2, C3

6.3.5 Testing and Adjustments

The following tests should be performed to guarantee correct operation of the power supply after repairs have been made. The first test checks the primary circuits and is to be made without AC power applied. The second test is a complete operational test with AC power applied.

Primary, Checks T2, U1

NO AC POWER APPLIED

1. Apply +35 volts DC via 3900 ohm resistor from Q5 emitter to primary side ground. Observe the voltage across C5 as it charges. As it reaches a value near +31 volts (about 2 seconds), it should drop to near +15 volts as Q5 turns on.

2. Check U1 pin 8 and/or Q8 base for a base drive pulse: a 40 kHz square wave of 8 volts/4 volts amplitude respectively.

3. Apply +35 volts DC through a 120K ohm resistor and a normally closed SPST switch to U1 pin 13. Operate the switch and observe Q8 base (TP1) for loss of base drive pulses.

Operational, Checks T2, U1, U2

APPLY AC POWER

1. Apply rated maximum loading for condition 1 (Model III use) or condition 2 (5 1/4" Hard Disk use).

2. Apply 120 VAC input voltage and observe Q7 current (via loop on PCB) and voltage (at TP2). Supply should start in two to four seconds.

3. Observe the +5.05 volt output and adjust R15 until the output is exactly +5.05 volts DC.

4. Measure +12V and –12V outputs.

5. Check all outputs at Vin = 90 VAC and 135 VAC at:
   (a) minimum and maximum loads
   (b) check +12V CRT when +12V DISK varies in transient test.

6. Measure ripple. See Measurement Techniques below.

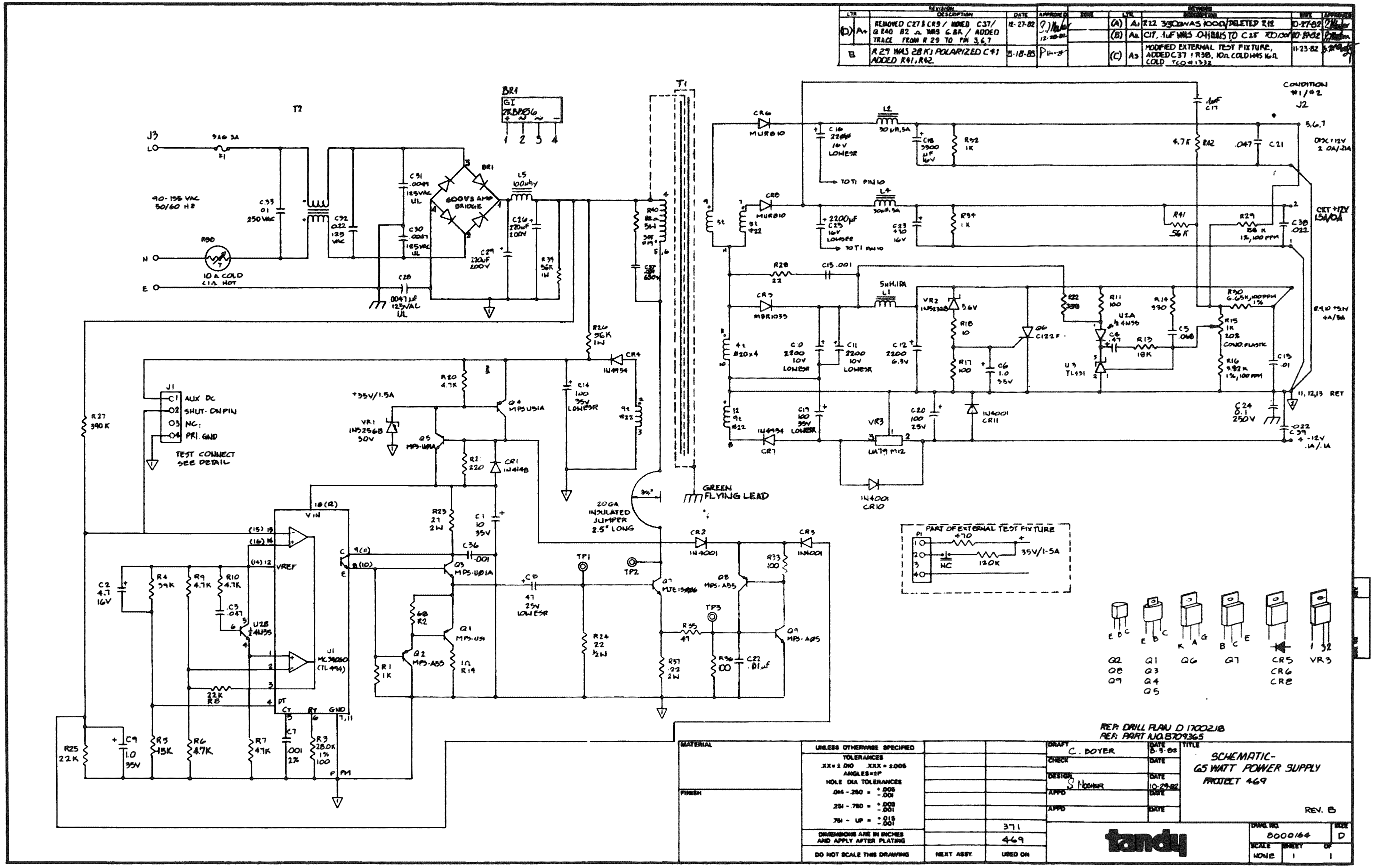
7. Measure efficiency. See Measurement Techniques below.

8. Test operation of current limit and over-voltage protection circuits by applying +7.0 volts to the +5 volt output.

Measurement Techniques

1. Ripple – Unit connected to full load at low line. One end of 50 ohm coaxial cable connected to output terminals. Other end of cable (terminated with 0.01uF ceramic cap in series with 51 ohm resistor) connected to scope using BNC T-fitting. Two components at 120 Hz and 40 kHz.

2. Efficiency – Use Diego Systems Series 200 power monitor. Efficiency = $\frac{\text{Power Out}}{\text{Power In}}$



LTR		DESCRIPTION	DATE	APPROVED
(D)	A4	REMOVED C27 & CR9 / MOVED C37/ @ R40 82 Ω WAS 6.8K / ADDED TRACE FROM R 29 TO PIN 3,6,7	12-27-82	S.J. Mosher 12-28-82
B		R 29 WAS 28 K; POLARIZED C 43 ADDED R41, R42	5-18-83	

ZONE	LTR		DESCRIPTION	DATE	APPROVED
	(A)	A1	R22 330Ω WAS 100Ω / DELETED R12	10-27-82	
	(B)	A2	C17, .1uF WAS .01; BIAS TO C25 TO 130	10-29-82	
	(C)	A3	MODIFIED EXTERNAL TEST FIXTURE, ADDED C37 & R38, 10Ω COLD WAS 16Ω COLD TCO #1332	11-23-82	

REF: DRILL PLAN D 1700218
REF: PART NO. 8709365

MATERIAL

FINISH

UNLESS OTHERWISE SPECIFIED
TOLERANCES
.XX = ±.010 .XXX = ±.005
ANGLES = ±1°
HOLE DIA TOLERANCES
.014 - .250 = +.005 -.001
.251 - .750 = +.008 -.001
.751 - UP = +.015 -.001
DIMENSIONS ARE IN INCHES AND APPLY AFTER PLATING
DO NOT SCALE THIS DRAWING

NEXT ASSY.	USED ON
	371
	469

DRAFT C. BOYER DATE 8-3-82
CHECK DATE
DESIGN S Mosher DATE 10-29-82
APPD DATE
APPD DATE

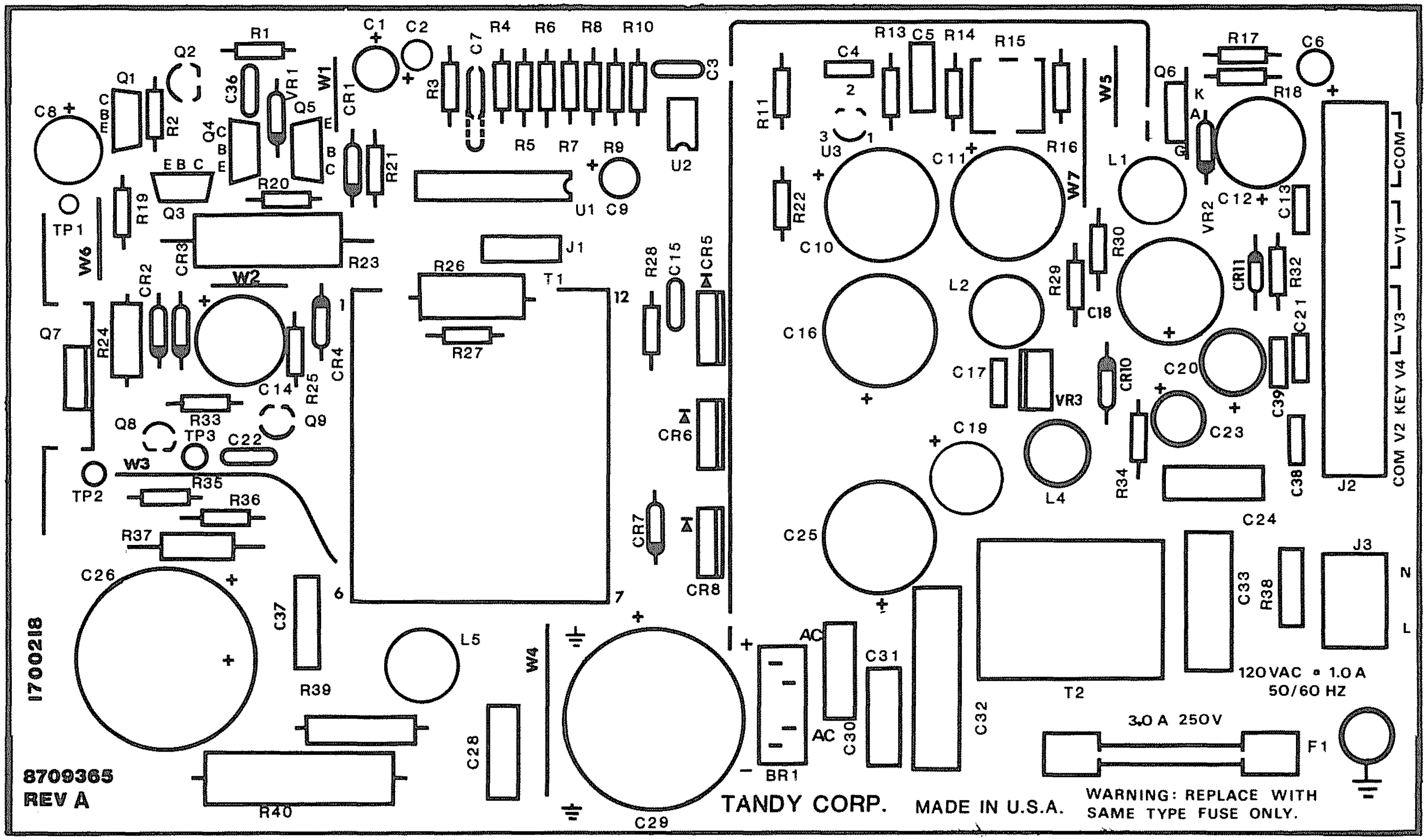
TITLE
SCHEMATIC-
65 WATT POWER SUPPLY
PROJECT 469

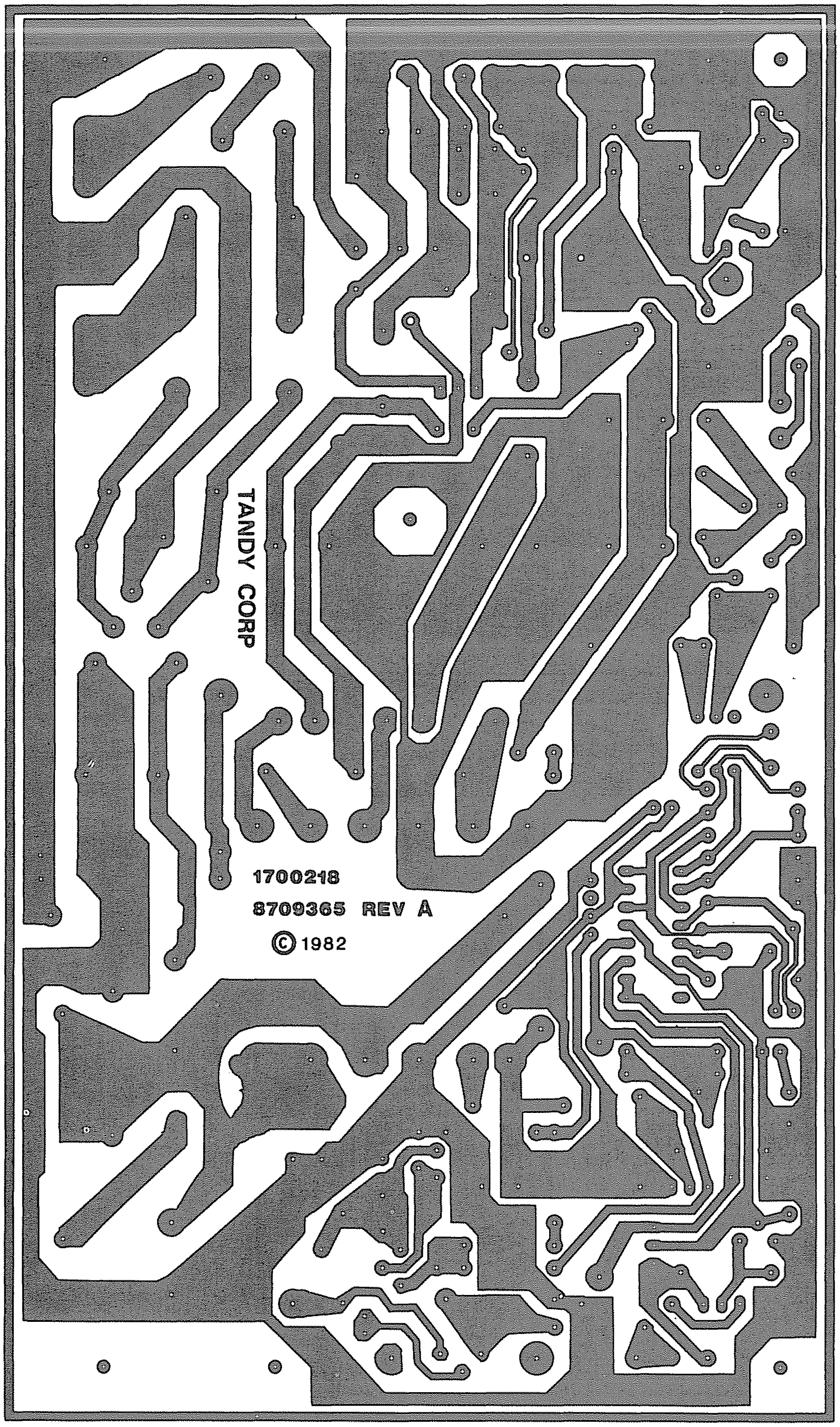
REV. B

tandy

DWG. NO. 8000164
SIZE D
SCALE NONE
SHEET 1 OF 1

COMPONENT LOCATION, POWER SUPPLY PCB #8790049 65W (TANDY)





CIRCUIT TRACE, POWER SUPPLY PCB #8790049, SOLDER SIDE 65W (TANDY)

Parts List, Power Supply #8790049 (Tandy 65W)

Item	Sym	Description	Mfgr's Part No.
1	C1	Capacitor, 10 ufd, 35V Elect Radial	8326103
2	C2	Capacitor, 4.7 ufd, 25V Elect Radial	8325470
3	C3	Capacitor, 0.047 ufd, 50/63V	8393474
4	C4	Capacitor, 0.47 ufd, 50/63V	8394474
5	C5	Capacitor, 0.068 ufd, 50/63V	8393684
6	C6	Capacitor, 1 ufd, 50V, Elect Radial	8325014
7	C7	Capacitor, 0.001 ufd, 63V	8392104
8	C8	Capacitor, 47 ufd, 25V, Elect Radial	8326472
9	C9	Capacitor, 1 ufd, 50V, Elect Radial	8325014
10	C10	Capacitor, 2200 ufd, 10V, Elect Radial	
11	C11	Capacitor, 2200 ufd, 10V, Elect Radial	
12	C12	Capacitor, 2200 ufd, 6.3V, Elect Radial	8328220
13	C13	Capacitor, 0.01 ufd, 50/63V	8393104
14	C14	Capacitor, 100 ufd, 35V, Elect Radial	8327103
15	C15	Capacitor, 1000 pfd, 100V, Ceramic Disk	8302106
16	C16	Capacitor, 2200 ufd, 16V, Elect Radial	8328221
17	C17	Capacitor, 0.1 ufd, 50/63V	8304104
18	C18	Capacitor, 3300 ufd, 16V, Elect Radial	8328331
19	C19	Capacitor, 100 ufd, 25V, Elect Radial	8327102
20	C20	Capacitor, 100 ufd, 25V, Elect Radial	8327102
21	C21	Capacitor, 0.01 ufd, 50/63V	8393104
22	C22	Capacitor, 0.01 ufd, 50/63V	8393104
23	C23	Capacitor, 470 ufd, 16V, Elect Radial	8327461
24	C24	Capacitor, 0.1 ufd, 250V	
25	C25	Capacitor, 2200 ufd, 16V, Elect Radial	8328221
26	C26	Capacitor, 220 ufd, 200V, Elect Radial	8327226
27	C27	Not Used	
28	C28	Capacitor, 0.01 ufd, 250 VAC	8393106
29	C29	Capacitor, 220 ufd, 200V, Elect Radial	8327226
30	C30	Capacitor, 4700 pfd, 125VAC, Ceramic Disk	8303475
31	C31	Capacitor, 4700 pfd, 125VAC, Ceramic Disk	8303475
32	C32	Capacitor, 0.1 ufd, 250VAC	8394106
33	CR1	Diode, 1N4148, Switching	8150148
34	CR2	Diode, 1N4001, 1A/50PIV	8150001
35	CR3	Diode, 1N4001, 1A/50PIC	8150001
36	CR4	Diode, 1N4939, 1A/100PIC	8150934
37	CR5	Diode, MBR1035, 8/10A, 35V, TO-220	8150035
38	CR6	Diode, MUR810, 8A/100PIV, TO-220	8150810
39	CR7	Diode, 1N4934, 1A/100PIV	8150934
40	CR8	Diode, MUR810, 8A/100PIV, TO-220	8150810
41	BR1	Dioide Bridge, 2A,600PIV	8160402
42	VR1	Zener Diode, 1N5232B, 5.6V	8150232
43	VR2	Zener Diode, 1N5256B, 30V	8150256
44	VR3	Diode, A79M12	

Parts List, Power Supply #8790049 (Tandy 65W)

Item	Sym	Description	Mfgr's Part No.
45	F1	Fuse, 3A, AGC	8479104
46	L1	Inductor, 5.0h,m 10A	8419006
47	L2	Inductor, 30h, 5A	8419008
48	L3	Not Used	
49	L4	Inductor, 30h, 5A	8419008
50	L5	Inductor, 100h, 2A	8419009
51	U1	IC, MC34060, Switching Regulator	8060060
52		uA/TL494 Switching Regulator	8060494
53	U2	IC, 4N35, Opto-Isolator	8170428
54	R1	Resistor, 1 kohm, 1/4W 5%	8207210
55	R2	Resistor, 68 ohm, 1/4W 5%	8207068
56	R3	Resistor, 28 kohm, 1/4W 1%	8200328
57	R4	Resistor, 39 kohm, 1/4W 5%	8207339
58	R5	Resistor, 15 kohm, 1/4W 5%	8207315
59	R6	Resistor, 4.7 kohm, 1/4W 5%	8207247
60	R7	Resistor, 4.7 kohm, 1/4W 5%	8207247
61	R8	Resistor, 22 kohm, 1/4W 5%	8207322
62	R9	Resistor, 4.7 kohm, 1/4W 5%	8207247
63	R10	Resistor, 4.7 kohm, 1/4W 5%	8207247
64	R11	Resistor, 100 ohm, 1/4W 5%	8207110
65	R12	Resistor, 620 ohm, 1/4W 5%	
66	R13	Resistor, 18 kohm, 1/4Q 5%	8207318
67	R14	Resistor, 330 ohm, 1/4W 5%	8207133
68	R15	Potentiometer, 1 kohm, 20%, Linear	8275211
69	R16	Resistor, 3.31 kohm, 1/4W 1%	8200232
70	R17	Resistor, 100 ohm, 1/4W 5%	8207110
71	R18	Resistor, 10 ohm, 1/4W 5%	8207010
72	R19	Resistor, 1 ohm, 1/4W 5%	8207001
73	R20	Resistor, 4.7 kohm, 1/4W 5%	8207247
74	R21	Resistor, 220 ohm, 1/4W 5%	8207122
75	R22	Resistor, 330 ohm, 1/4W 5%	8207133
76	R23	Resistor, 27 ohm, 2W 10%	8248127
77	R24	Resistor, 22 ohm, 1/2W 5%	8217022
78	R25	Resistor, 22 kohm, 1/4W 5%	8207322
79	R26	Resistor, 75 kohm, 1W 10%	8248127
80	R27	Resistor, 430 kohm, 1/4W 5%	8207443
81	R28	Resistor, 22 ohm, 1/4W 5%	8207022
82	R29	Resistor, 28 kohm, 1/4W 1%	8200328
83	R30	Resistor, 6.65 kohm, 1/4W 1%	8200266
84	R31	Resistor, 1 kohm, 1/4W 5%	8207210
85	R32	Resistor, 1 kohm, 1/4W 5%	8207210
86	R33	Resistor, 470 ohm, 1/4W 5%	8207470
87	R34	Resistor, 1 kohm, 1/4W 5%	8207210
88	R35	Resistor, 470 ohm, 1/4W 5%	8207470

Parts List, Power Supply #8790049 (Tandy 65W)

Item	Sym	Description	Mfgr's Part No.
89	R36	Resistor, 1 kohm, 1/4W 5%	8207210
90	R37	Resistor, 0.22 ohm, 2W 10%	8248022
91	R38	Thermistor	8298016
92	R39	Resistor, 75 kohm, 1W 10%	8248375
93	R40	Resistor, 82 kohm, 5W 10%	8248268
94	Q1	Transistor, MPSU51A, PNP, TO-202	8100051
95	Q2	Transistor, MPSA55, PNP, TO-92	8100055
96	Q3	Transistor, MPSU01A, NPN, TO-202	8111001
97	Q4	Transistor, MPSU51A,PNP, TO-202	8100051
98	Q5	Transistor, MPSU01A, NPN, TO-202	8111001
99	Q6	SCR, 8A/50PIV, TO-220	8140122
100	Q7	Transistor, MJE13006, NPN, 8A, 400V	8110006
101	Q8	Transistor, MPSA55, PNP, TO-92	8100055
102	Q9	Transistor, MPSA05, NPN, TO-92	8110005
103	T1	Transformer, Power, Ferrite Core	8790046
104	T2	Transformer, Line Choke, 5.5 mH/side, 2A	8790045