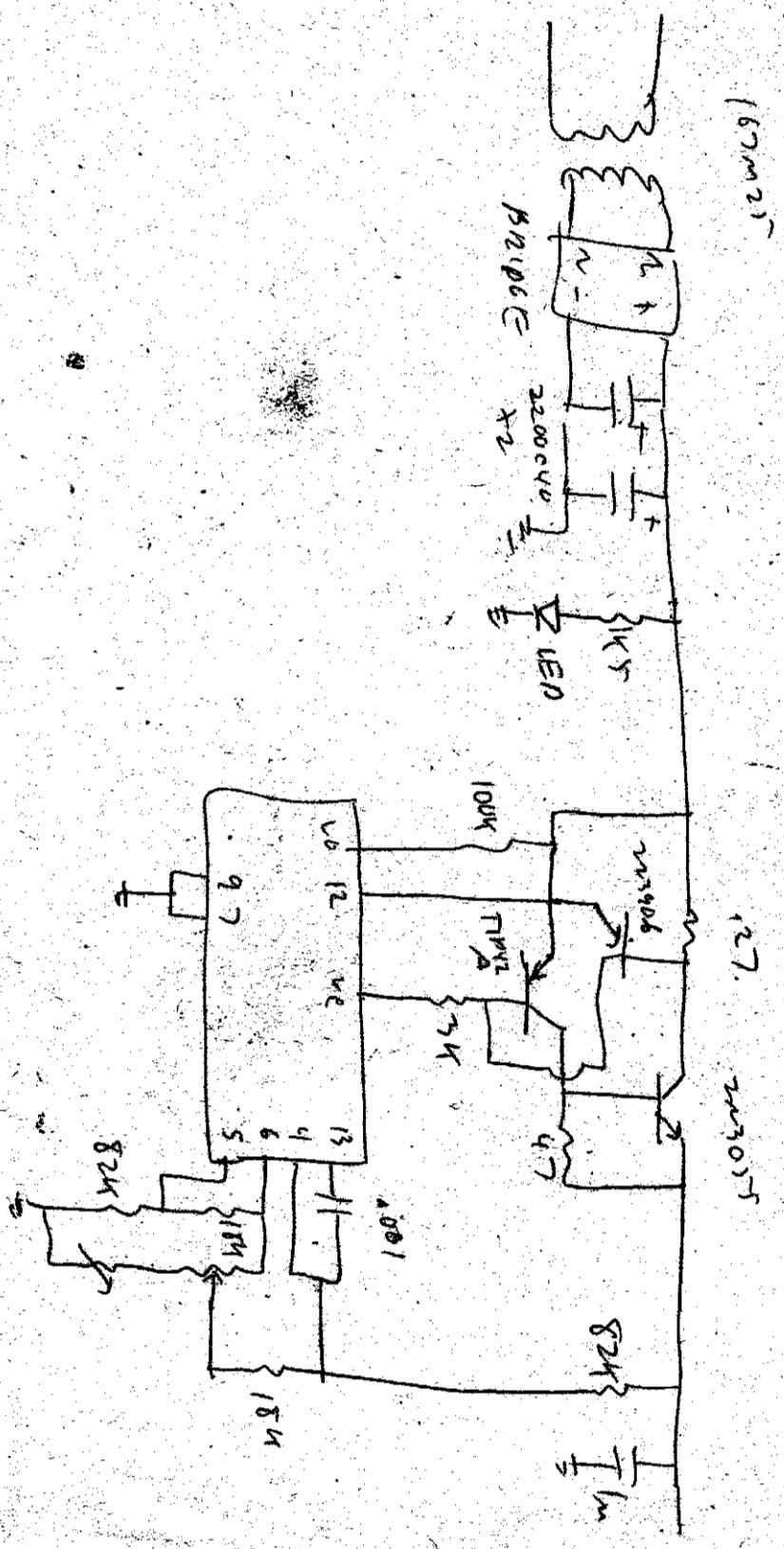


P.C.1 - 30V SUPPLY



WS TAKE
20 mA
screen.

Regulated power supply is adjustable from 0 to 38 V

by Frank P. Miles
Rochester, N.Y.

Through careful biasing of the error-sensing and the output driver for a 723C voltage regulator, a power supply that is variable from 0 to 38 volts can be designed. The stability of the circuit over both time and temperature is excellent, depending only on the internal reference of the chip and being essentially independent of output level. And finally, the circuit requires few com-

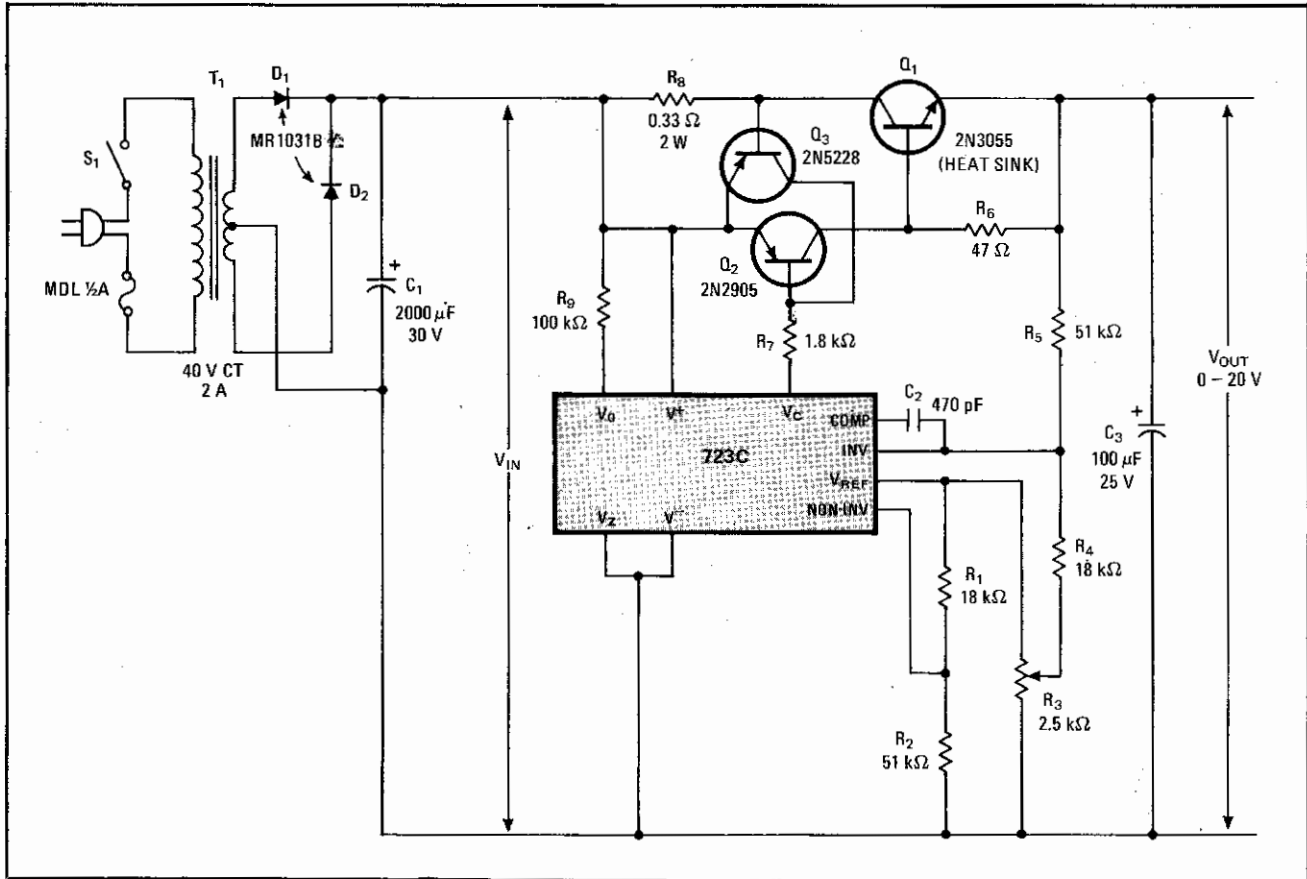
ponents; most notably, it requires no zener diodes external to the 723C.

The schematic shows how simple it is to custom-design the supply. R_3 is a 2.5-kilohm potentiometer, chosen to keep the reference current below 5 milliamperes. $R_1 = R_4$ and $R_2 = R_5$ for best bias stability and output-range swing. The leakage-limiting resistor R_6 has a value of 47 ohms; it increases the safe operating area of Q_1 .

The maximum output voltage is given by

$$V_{OUT(max)} = (R_2/R_1)V_{REF}$$

where the reference voltage V_{REF} , a characteristic of the 723C, is typically 7.15 V. Resistor R_1 is picked to be high enough to minimize loading of R_3 , but small enough to avoid bias-current problems at the error-am-



Regulated power supply. Setting of R_3 gives output voltage as low as 0 V, or as high as V_{IN} minus small drop across Q_1 . Value of V_{IN} must not exceed 40-V limit of the 723C. Components shown here are for 0-20-V, 2-A supply.

plier inputs. Resistor R_2 is then calculated from

$$R_2 = (V_{OUT(max)}/V_{REF})R_4$$

The other resistors are calculated from straightforward circuit considerations. Resistor R_7 limits the output drive of the 723C to about 10 mA because the internal zener diode is used. Its value, in kilohms, is

$$R_7 \approx 0.1 V_{IN} - 0.62$$

where V_{IN} is the unregulated voltage out of the rectifier. (The value of V_{IN} must not exceed the 40-v limit of the 723C.) R_8 , calculated in ohms, provides the proper current-limit point:

$$R_8 \approx 0.65/I_{LIMIT}$$

where I_{LIMIT} is the maximum output current (in amperes). The pass transistor characteristics and heat sink are also determined by the value of I_{LIMIT} . Resistor R_9 , calculated in kilohms, maintains zener regulation for low output currents:

$$R_9 \approx 5V_{IN} - 31$$

The output voltage from this supply can be as low as 0 V, or as high as V_{IN} minus a small drop across the pass transistor. The component values shown in the circuit diagram are chosen for a 0-20-v, 2-A supply. □

Dc-dc power supply regulates down to 0 volt

by P.R.K. Chetty and A. Barnaba
ISSP, Bangalore, India, and CNES, Toulouse, France

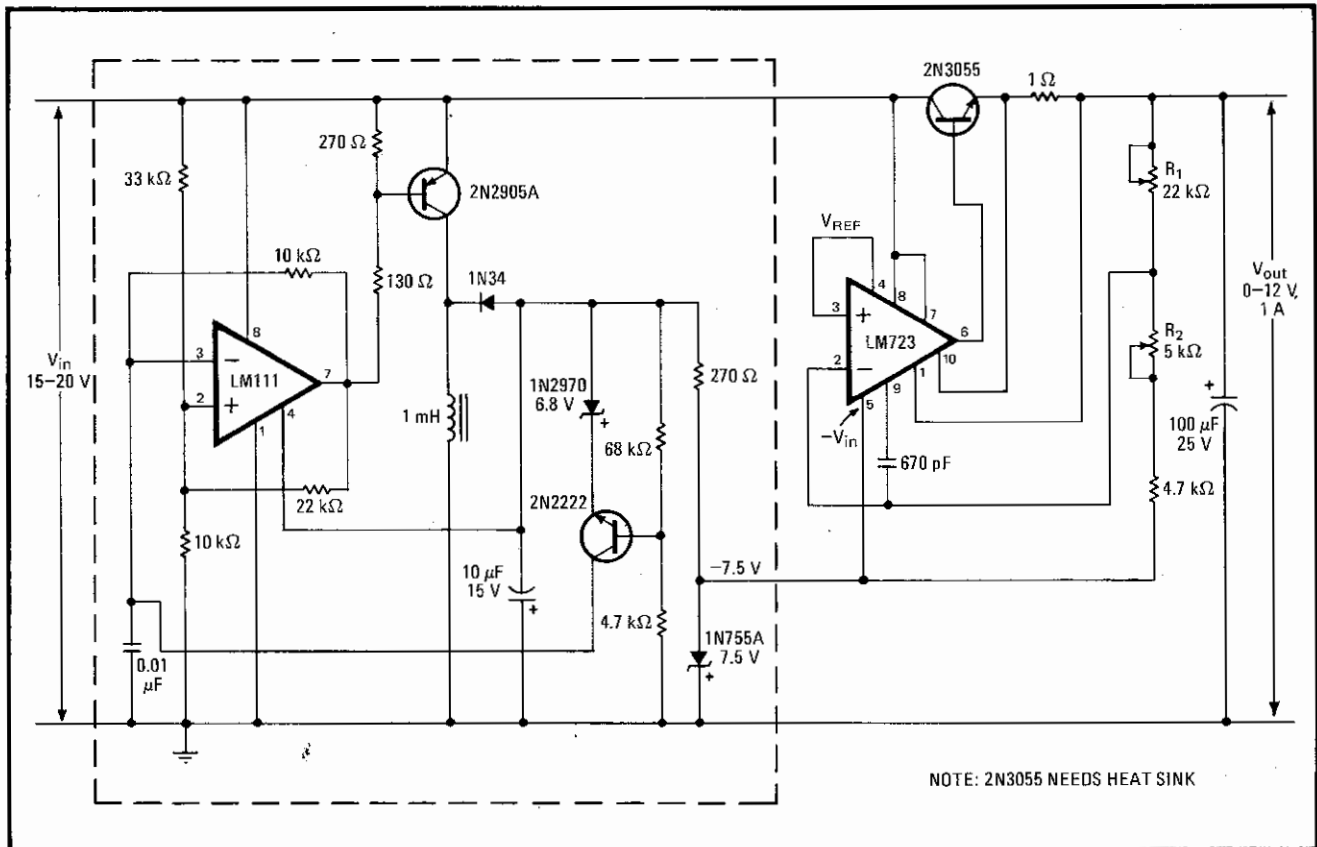
In most dc-input, regulated power supplies, regulation is poor when the desired output voltage is less than the source's internal reference voltage. In addition, circuit considerations usually limit the minimum reference voltage attainable and consequently the minimum regulated output voltage possible. This circuit, however, with a configuration that can bring the reference voltage to virtually zero, overcomes both problems.

The LM723 voltage regulator shown, which provides 12 volts at 1 ampere, must be biased with a negative supply voltage at its $-V_{in}$ port (pin 5) for proper operation. This voltage is provided by the switching inverter shown within the dotted lines.

The LM111 voltage comparator is configured as an astable multivibrator that oscillates at a frequency of about 10 kilohertz. With the aid of the 1-millihenry inductor, which generates the counterelectromotive force required to produce a negative potential from a switched-source voltage, the inverter delivers a well-regulated -7.5 v to the $-V_{in}$ port of the 723.

The magnitude of this voltage is essentially equal to that of the regulator's internal reference voltage, V_{REF} , appearing at pin 4, and properly biases its voltage-reference amplifier. This condition in turn precipitates a condition in the amplifier whereby V_{REF} clamps to ground potential. Thus the output voltage may be adjusted throughout its maximum possible range by potentiometers R_1 and R_2 . Although the potential of V_{REF} as measured with respect to ground has been changed, the circuit will retain the regulating properties of the 723. Both the line and the load regulation of the supply are 0.4%. □

Designer's casebook is a regular feature in *Electronics*. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay \$50 for each item published.



Full-range regulation. Dc-input supply is regulated all the way down to 0 V. LM111 and associated circuitry provide negative bias required for LM723 regulator. Regulator's internal-reference voltage, V_{REF} , is clamped to ground; output voltage is thus adjustable from 0 to 12 V.

Dual Tracking Power Supply

A lab-quality power supply with one output voltage tracking the other; it features 0-50 volts and 2.5 amperes per output.

By David Bedrosian



A POWER supply is required in almost every electronic circuit, whether it is a small LED flasher or a high powered amplifier; this makes a power supply one of the most useful pieces of test equipment. To be able to fully test a circuit, the supply must put out enough voltage and current to properly run the circuit under test; as well, the supply must remain stable for all possible load conditions. To protect the circuitry under test, the supply must have a continuously variable output voltage down to zero volts, and must provide some form of current limiting. An added requirement when testing amplifiers which require dual polarity supplies (both positive and negative voltages with respect to ground) is that the supply must be capable of generating a negative voltage which tracks the positive voltage. If, for example, the output voltage is varied upward from 0 to plus 20 volts the negative supply must vary downward from 0 to minus 20 volts.

The power supply described in this article is a dual tracking supply capable of producing up to plus and minus 50 volts at an output current of up to 2.5A. The maximum current before limiting is adjustable between approximately 50mA and 2.5A for both the positive and negative outputs, using the two knobs on the front panel. The positive voltage is varied using a ten-turn potentiometer, and the negative voltage tracks the positive output with a ratio adjustable between 0 and 100 percent. Two LEDs on the front panel indicate when the supply is operating in the constant current mode, and two meters accurately monitor the output voltages and currents.

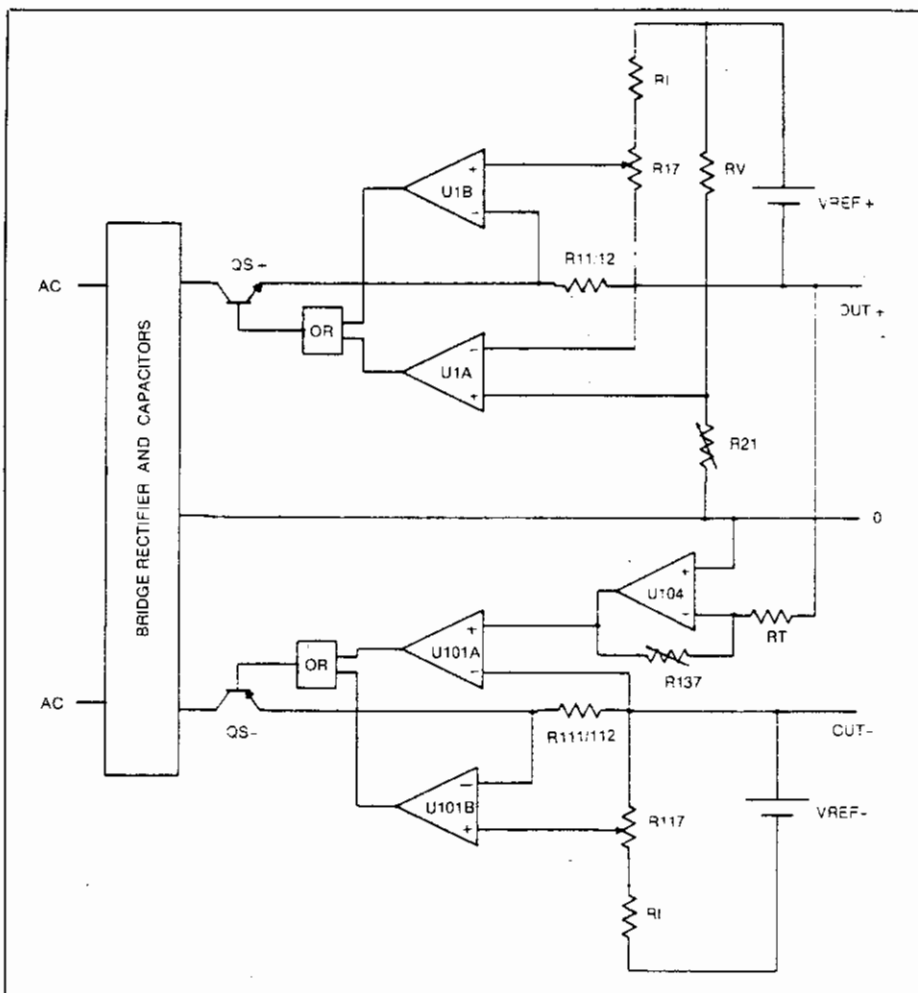


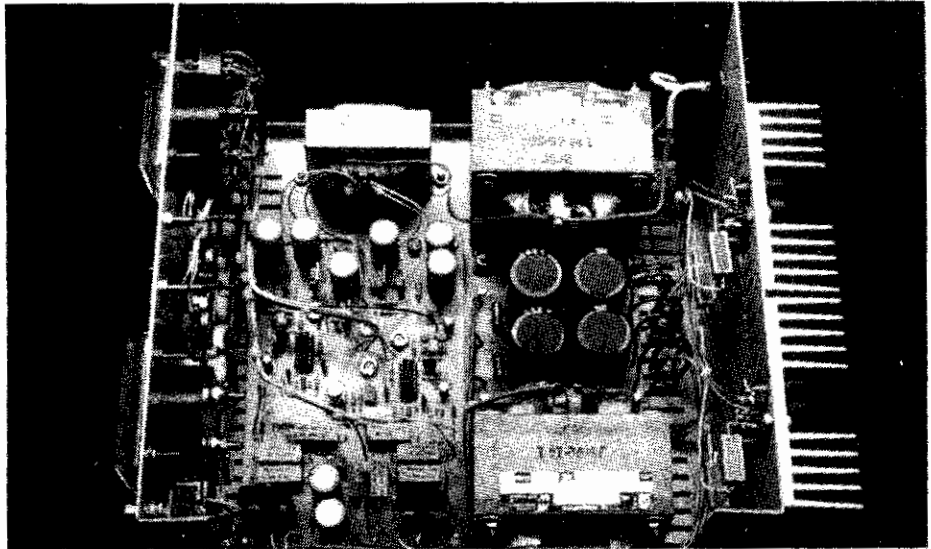
Fig. 1 The block diagram of the power supply.

The project also contains the necessary information to modify the existing circuit depending on the availability of parts and the requirements of the builder. The maximum output voltage and current values can be changed according to the transformers, transistors and heatsinks available; the negative supply can be made totally independent of the positive supply, or it can be omitted altogether.

Construction

The resistor values given in the Parts List are appropriate if the power supply is going to have the same output voltage and current as shown in this project, and if XFRMR1 and XFRMR2 put out between 50 and 60VAC under no-load conditions, and if the meters used to indicate voltage and current both require 100uA for full scale deflection. If the supply is going to be modified, refer to Parts Selection and Modification to determine the appropriate part values before beginning construction.

The circuit board designs shown are recommended to speed construction and minimize wiring errors. It is also recommended that resistors, diodes and transistors be tested before being soldered into place; this may seem time-consuming, but



The interior of the power supply unit.

can actually save a considerable amount of time later if troubleshooting is required. Diodes will have a very high resistance in one direction and low in the other; transistors should have a high resistance between both the base and emitter leads and the base and collector leads in one direction, and a low resistance in the other. The resistance between collec-

tor and emitter will be high in both directions.

Construction begins with the main circuit board. First solder in the three jumpers and the IC sockets; the long jumper should be insulated. Next install all of the quarter and half watt resistors. The capacitors and power resistors can now be soldered in place; be sure to check

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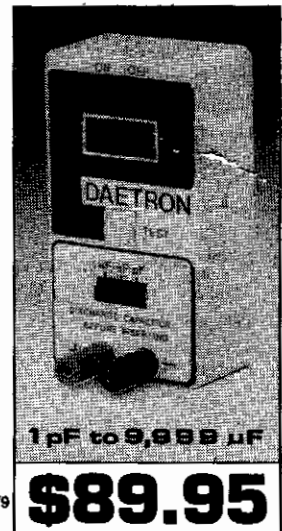
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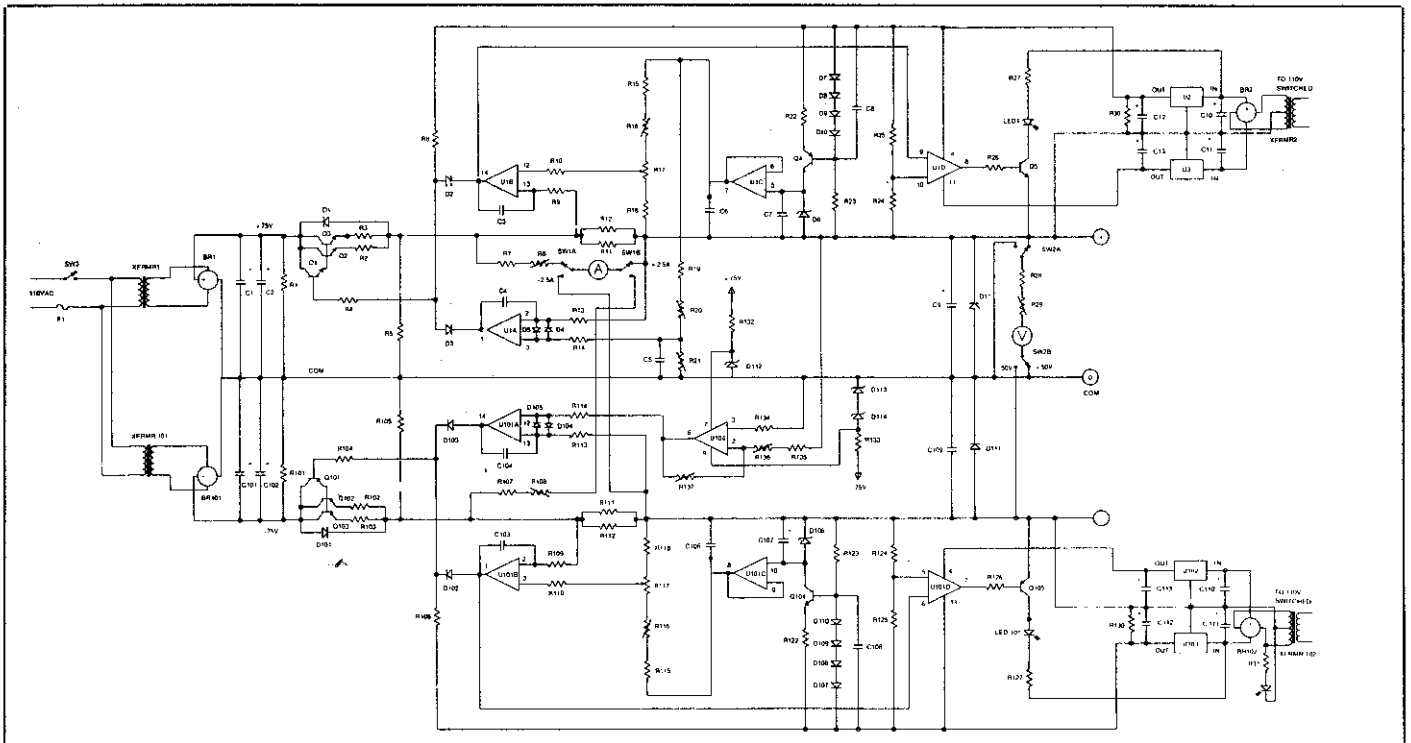


Fig. 2 The schematic of the power supply

the orientation of the electrolytic capacitors, as a reversal can cause serious circuit damage when power is applied. The 5W resistors should not have to dissipate more than one or two watts, and can therefore be mounted directly on the PCB. The seven trim pots are next soldered onto the board; provision has been made for both the upright and the flat types. If 25-turn upright trim pots are available (Bourns series 3299W) they can be used to allow for finer adjustment. The bridge rectifiers, diodes, and transistors can now be soldered into place. Note that the two bridges are oriented differently; look for the plus signs on the circuit board

overlay to ensure correct insertion. Be sure to differentiate between zener diodes and the rectifiers. Before soldering in Q1 and Q101, attach a small heatsink to each device; silicone grease is not necessary and the heatsinks need not be insulated from the collectors as long as they don't touch any other metallic object (each heatsink is at the full input voltage of 75V, so beware). The op amps (U1, U101, and U104) should not be inserted yet; however, the voltage regulators (U2, U102, U3, and U103) can be soldered in place without heatsinks. This completes the assembly of the main circuit board.

The small circuit board should be

completed next. This board may need to be modified if different sized capacitors are used for C1, C2, C101 and C102; otherwise assembly should be straightforward. After completing both boards, they should be thoroughly inspected for poor solder joints or bridges.

Construction now begins on the cabinet; the following description assumes the recommended Hammond cabinet is being used. Start with the back panel; drill holes for the fuseholder, the power cord (or connector), and the heatsinks. Temporarily mount the heatsinks and mark on the back panel where the power transistors will come through. The four power

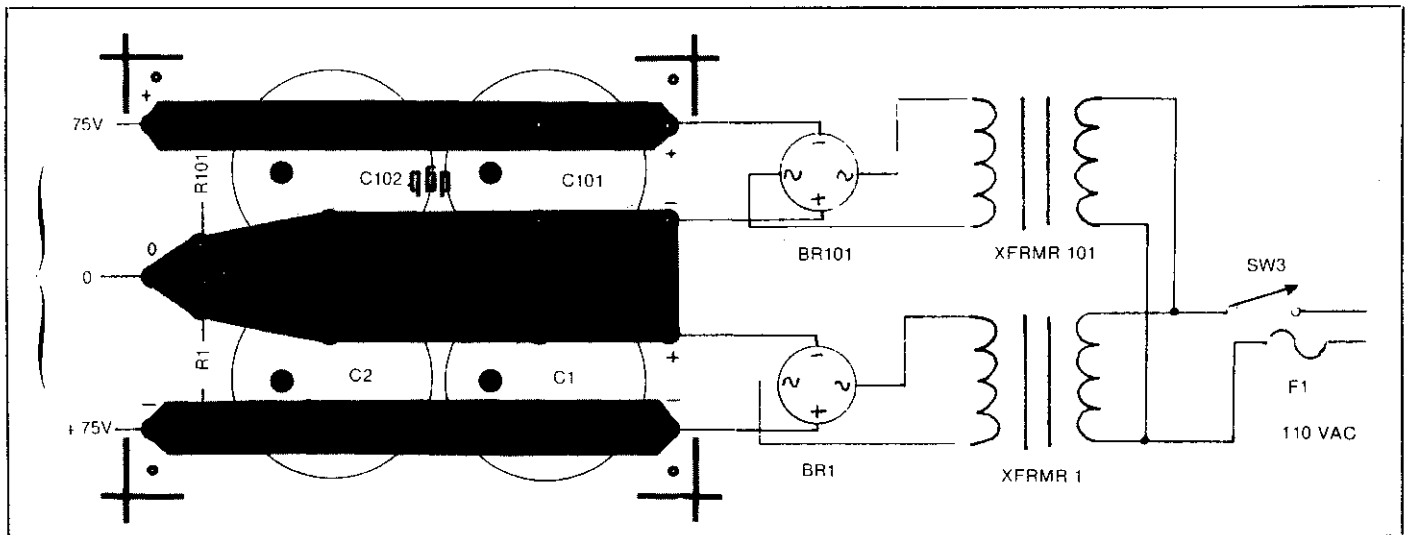
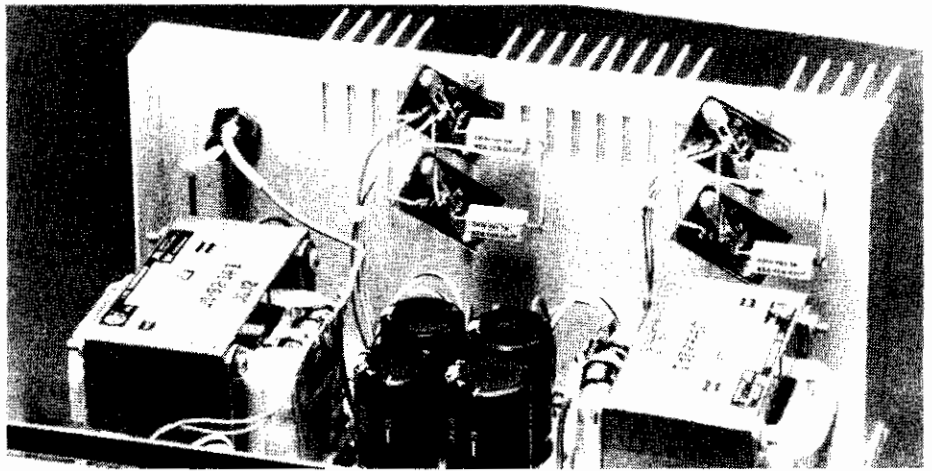


Fig. 3 Component location for the small printed circuit.

transistors should then be mounted; each transistor should then be isolated from the heatsink using a mica insulator with silicone grease on both sides. If transistor sockets are not used, the bolts holding the transistor must be insulated with a plastic sleeve and shoulder washer. The heatsinks can now be permanently fastened to the case, and the power transistors should be tested with an ohmmeter for possible shorts to the heatsink or cabinet.

The main power transformers, the large bridge rectifiers, and the small circuit board should be bolted to the bottom of the cabinet and wired with at least 18 gauge wire. The power cord ground lead should be attached directly to the cabinet with a ground lug between a bolt and the cabinet. The bridge rectifiers should be mounted directly on the cabinet, which will act as a heatsink; silicone grease is not required. Do not wire in the power switch yet; instead run two wires to the front cabinet of sufficient length to reach the power switch. The three wires to the main circuit board should not be soldered in place yet. The wiring in this section is critical, so be sure that all wires are mechanically sturdy and connected to the proper location.

The front panel can now be drilled and all parts should be mounted. Only the power switch should be wired at this time to allow for testing of the main power supply. With a 3A slo-blo fuse installed, apply power to the supply and measure the voltage at the output of the small circuit board (the voltmeter leads can be clipped across R1 and R101). If no voltage is present or it is very low, measure the AC voltage to the input of each bridge; they



The rear panel, showing the transistor and emitter resistor mounting.

should have about 55VAC each to their inputs, depending on which transformer is used. If there's a problem, check the wiring and fuse.

With approximately plus and minus 75VDC at the output of the small board, the power supplies on the main board can be tested. Mount XFRMR2 and XFRMR102 in the cabinet and wire their primary windings to the switched 115VAC connected to XFRMR1 and XFRMR 101. Temporarily connect the secondary windings to the main circuit board and run three wires from the small circuit board to the main board for 0, plus 75, and minus 75V. Apply power to the circuit and measure the voltages at U1, U101, and U104. The voltage at pin 4 of U1 with respect to the positive output (clip onto the outside end of R11 or R12) should read 12V plus or minus 0.5V, the voltage

at pin 11 should read -12V plus or minus 0.5V, and the voltage at pin 5 should be 6.2V. The voltage at pin 4 of U101 with respect to the negative output should be (clip onto the outside end of R111 or R112) should read 12V, the voltage at pin 11 should be -12V, and the voltage at pin 10 should be -6.2V. Pin 7 of U104 should be at about 4V with respect to ground (clip onto the inside lead of R1 or R101) and pin 4 should be at -55V, again with respect to ground.

The main board should be removed from the cabinet and the ICs inserted. Suitable length wires should be soldered to the main circuit board for connection later to all of the front panel parts, the power transistors, the small circuit board, and the low voltage transformers. The wires to the power transistors, the small circuit board, and the output binding

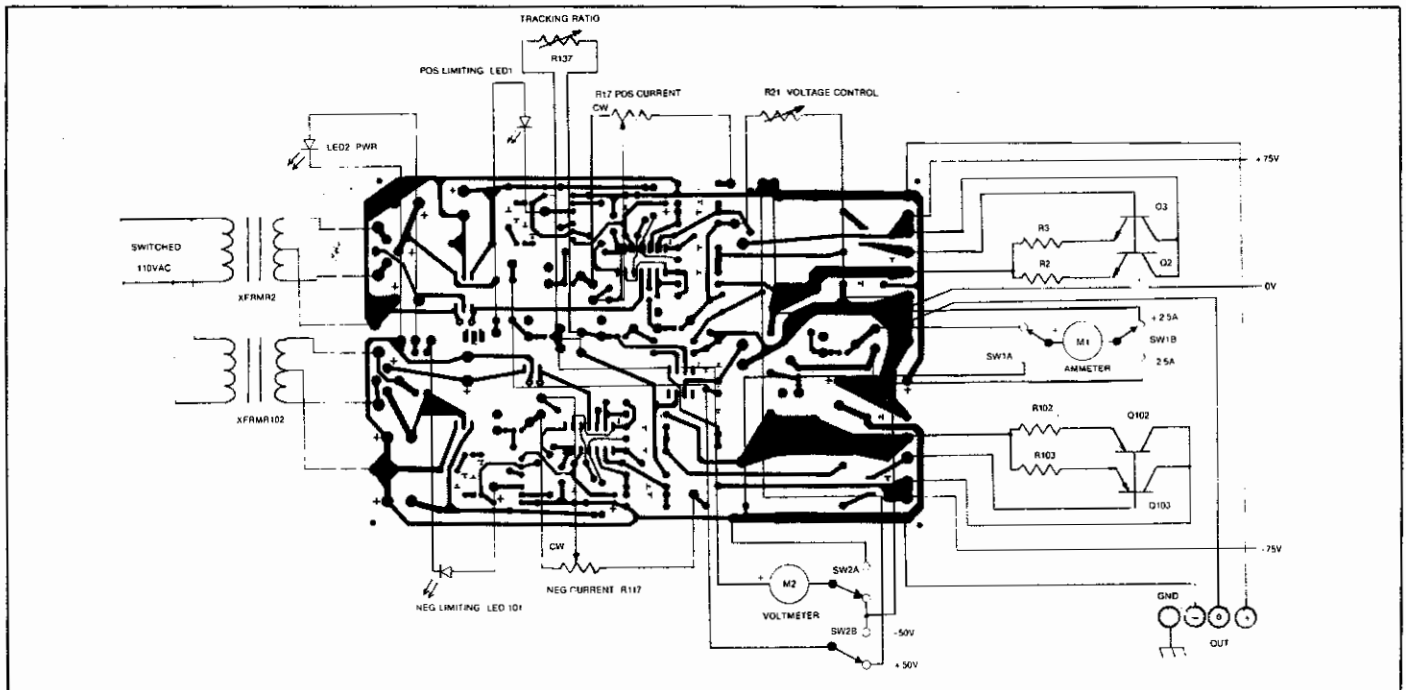


Fig. 4 The wiring points for the main printed circuit.

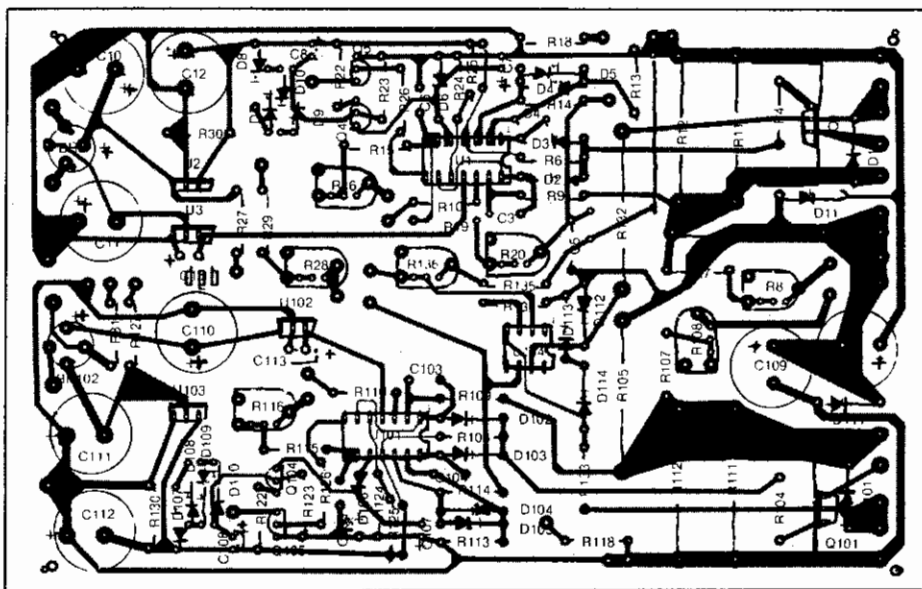


Fig. 5 The component location for the large printed circuit.

posts should be 18 gauge or larger; all other wires can be a lighter gauge. The main circuit board can now be fastened to the cabinet and the wiring can be completed. The chassis ground binding post is wired directly to the cabinet using a ground lug. The 0R2 5W resistors (R2, R3, R102, and R103) can be attached directly to the emitter terminals of Q2, Q3, Q102, and Q103. The voltage control pot, R21, and the tracking ratio pot, R137, should both be wired so that clockwise rotation gives maximum resistance.

The final step in constructing the power supply is to replace the voltmeter and ammeter scales with the ones shown; these scales should work well for most 2.5" meters.

Testing and Adjustments

Before turning the supply on, check that both M1 and M2 are zeroed, and then connect an external voltmeter between the positive and the ground binding posts. Switch on the power supply and turn the voltage control pot clockwise; the output voltage should increase. Set the output voltage to exactly 25V and adjust R29 until M2 reads 25V; be sure SW2 is in the +50V position when making this adjustment. Turn the output voltage up to 50V and see that M2 also shows 50V. If the output voltage will not go up to 50V, adjust R20 until it does; this trimpot should be set to give an output voltage about 1 or 2 volts above 50V with the voltage control pot fully clockwise. Turn the voltage back down to 25V and connect the external voltmeter to display the negative output voltage; also switch SW2 to the -50V position. Turn the tracking pot clockwise; the output voltage should become more negative. With the tracking pot set fully

clockwise, adjust R136 until the output voltage is exactly 25 percent (100 per cent tracking). Turn the positive output up to 50V and check that the negative voltage goes down to -50V; if the output will not go this low, the negative supply to U104 is not negative enough and D114 must be changed; refer to the Part Selection section. The tracking ratios can be adjusted to 25, 50, 75, and 100 percent and appropriate markings added to the front panel.

To set the current limiting, adjust the positive output to about 2V and connect an ammeter between the positive output binding post and the ground binding post; be sure the ammeter is set to a current range greater than 2.5A. The positive output current limiting LED should be on. Turn the positive current limiting pot clockwise; the current should increase; set the pot at 1/2 rotation and adjust R16 until the output current is approximately 1.3A. Also adjust R8 until M1 reads the same value as the ammeter (SW1 must be in the +50V position). Turn the current limiting pot fully clockwise and adjust R16 for a current output of 2.5A. The same procedure should be followed for the negative supply, adjusting R116 for a maximum output current of -2.5A and adjusting R108 so that M1 displays the correct current. Lines can be added to the front panel for both current control pots to indicate plus and minus 1, 2, and 2.5 amperes. This completes the testing and adjustment of the power supply.

Troubleshooting

If the op amp supply voltages or the reference voltages are not present, refer to Table 1 for assistance in locating the problem. If all of the required voltages are present but the supply does not function

properly, use the schematic and carefully measure the voltages around the circuit. The voltage between the inverting and non-inverting terminals of each op amp should be 0V within a few millivolts unless the output of the amp is saturated to +12 or -12V. The output voltages of U1C and U101C should be equal to the collector voltages of Q4 and Q104 respectively. The output voltages of U1A and U101A should be within 1 or 2 volts of the positive and negative outputs respectively when the supply is operating in the constant voltage mode. The outputs of U1B and U101B should be approximately equal to the respective output voltages when operating in the constant current mode. The voltage across R21 should be the same as the positive output voltage, and the output of U104 should be the negative of this voltage. The base voltages of Q2 and Q102 should be within 1 volt of the respective output voltages.

Part Selection and Modification

If some of the recommended parts are not available, or if the supply does not fulfill the requirements of the builder, the existing circuit can be modified quite easily.

The most expensive components are the transformers and are the most likely to be substituted; the transformers selected, however, will greatly affect the available output voltage and current. Choose a transformer that has an AC output current approximately 1.5 times the required DC output current, and an AC voltage several volts above the required DC output voltage. Operating a transformer above its maximum rating for long periods of time will cause the transformer to overheat, and is not recommended.

The selection of the power transistors and the heatsinks should be based on the output rating of the supply. The MJ15003 and MJ15004 transistors used will work well for most configurations with currents up to 10A and voltages up to 100V; however, as the current and voltage ratings are increased, the size of the heatsinks must be increased. The maximum power dissipated by each pair of transistors is equal to the product of the maximum output current and the collector voltage. For this supply, the maximum power dissipation is about 200W (75V x 2.5A) for each pair of power transistors. If the temperature rise is to be kept to 100 degrees C, the heatsinks must have an efficiency of 0.5W/deg C in free air convection; alternatively, smaller heatsinks could be used with a cooling fan. Instead of the MJ15000 series transistors, a pair of 2N3055s and a pair of MJ2955s can be used for Q2, Q3, Q102, and Q103 respectively if the input voltage to these transistors is kept below 50V.

If the power supply's voltage or current ratings are changed, the formulas

HOW IT WORKS

It's best to refer to the block diagram. The AC input is converted to plus and minus 75V by the bridge rectifiers and the filter capacitors, and applied to the collectors of Q_{s+} and Q_{s-} . Ignoring the negative supply, the base of Q_{s+} is driven by U1a if the supply is operating in the constant voltage mode, or U1b if it is in the constant current mode. V_{ref} sets up a constant current through R1 and R17 and through RV and R21; the current through R21 produces a voltage directly proportional to the resistance of R21. U1a attempts to keep this voltage and V_{ref} equal by generating an error signal proportional to the difference between the voltages. If the load resistance decreases and the output voltage drops, U1a increases the conductance of Q_{s+} , causing the output voltage to return to its previous level. Similarly, an increase in output voltage causes U1a to reduce the drive to the base of Q_{s+} . The output regulation is very good because the high gain of U1a produces a large error signal for even very small input voltage differences.

Op amp U1b compares the voltage at the wiper of R17 to the voltage across R17/R12, the latter voltage being proportional to the output current. If the output current increases past a certain point, the output of U1b goes negative and reduces the drive to Q_{s+} , reducing the output current. The OR circuit selects the lower of the two output voltages from U1a and U1b to drive the base of Q_{s+} . This causes the supply to operate in the constant voltage mode until the output current exceeds the value set by R17, at which time U1b will take over and switch the supply to constant current.

To provide the negative supply with tracking, the positive supply voltage is inverted by U104 and applied to U101a. The gain of U104 can be varied between 0 and -1 by adjusting R137, thus giving a tracking range of 0 to 100 percent. The output of U101a is an error signal which tries to maintain a constant voltage. The current limiting operates in the same way as the positive supply, except that the OR circuit now selects the higher of the output voltages from U101a and U101b.

The operation of the negative half is much the same as the positive. Referring to the schematic, Q2 and Q3 are the pass transistors and Q1 is the driver; resistors R2 and R3 help compensate for differences between transistors. The base current for Q1 comes from the OR circuit, D2, D3, and R6; this circuit selects either U1a or U1b as controller, depending on which has the lower output voltage. The high gain of the op amps ensures a sudden transition; the drive current actually comes from R6.

The reference voltage is provided by D6 and constant current source Q4, which is biased by D7-D10 and R22. C8 provides a soft start when the supply is switched on. The reference voltage is buffered by U1c.

The reference voltage generates a constant current through R21; the developed voltage is compared to the output and any difference controls U1a. R20 allows adjustment of the current through R21 and C5

stabilizes the voltage; C4 provides extra compensation against oscillation.

The voltage at the non-inverting input of U1b is taken from the wiper of R17; when the voltage across resistors R11/R12 exceeds the voltage set by R17, the output of U1b will drop from 12V to a voltage which will maintain the current at the limiting value.

The plus and minus 12V for the bias circuitry is provided by XFRMR2, U2 and U3. This voltage is referenced to the positive output because the outputs from the op amps must swing around the power supply output voltage. C13 prevents oscilla-

tion, and C12 and R30 are included to prevent the supply from putting out its full voltage when first switched on. The negative supply requires that the positive 12V come on first, so C112 and R130 are added to the negative regulator.

C9 and C109 improve the overall stability of the power supply. D11 and D111 protect the supply from an accidental connection of another power supply with the opposite polarity. D1 and D101 protect the supply if it is turned off with another power supply of the same polarity still connected.

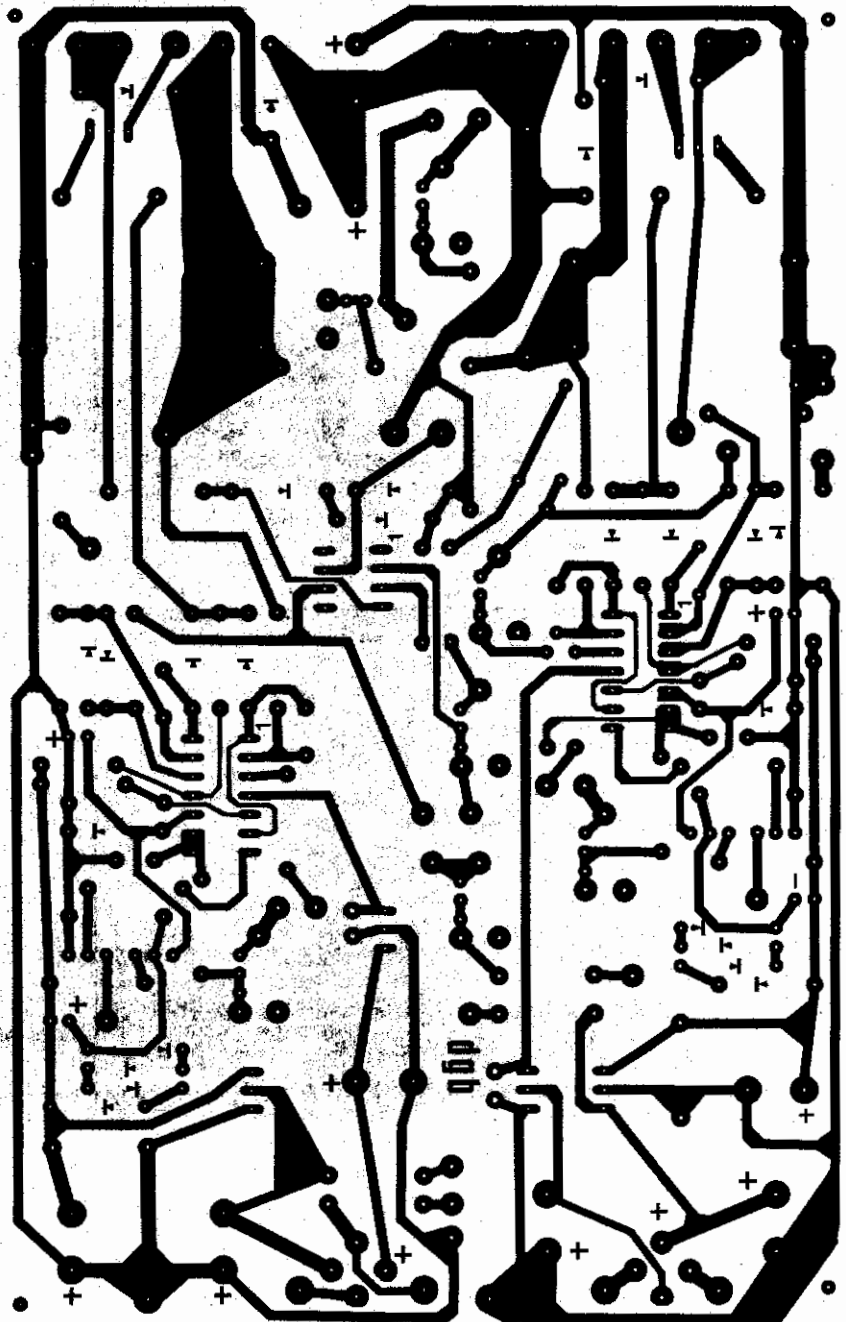
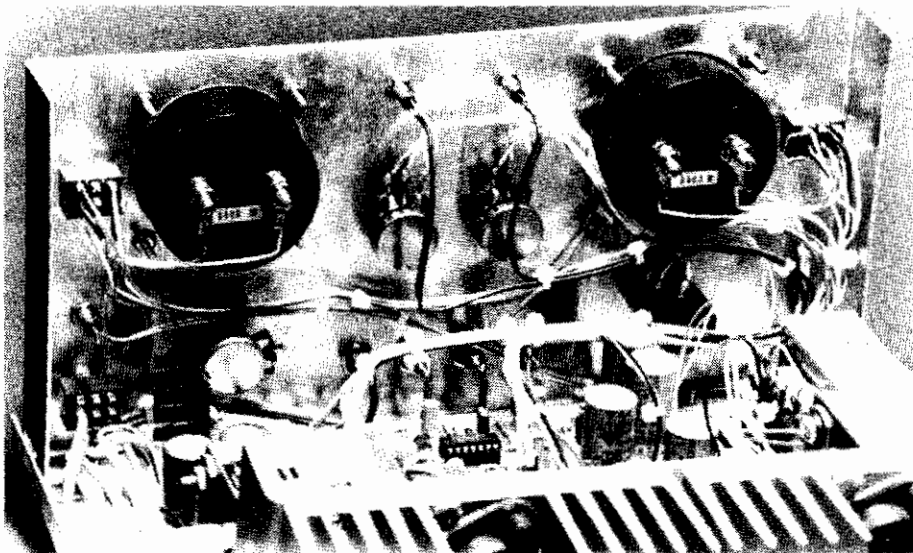


Fig. 6 The main printed circuit.



The front panel, showing the meter and control wiring.

given in Table 2 can be used to calculate the new resistor values. This table also includes the formula to calculate new series resistors for the meters if the recommended ones are not used. In the table, V_{max} and I_{max} are the maximum output voltage and current of the supply, respectively. I_{meter} is the current required for the full-scale-deflection of the appropriate meter.

A change in the output voltage also requires a change in the zener diodes D113 and D114. Choose two 1W zeners that sum to approximately 5V more than the maximum output voltage. Note that the MC1436 has a maximum supply voltage of 60V. R133 must also be changed in order that each zener diode dissipates about 200mW.

$R133 = 4 \times V_z \times (V_{supply} - V_z)$
 where V_{supply} is the magnitude of the negative input voltage from C101 and C102, and V_z is the sum of the zener diode voltages of D113 and D114.

The voltage reference diodes D6 and D106 are temperature compensated zener diodes; however, ordinary 6.2V (1N4735) zener diodes can be used with some loss of temperature stability. The current through these diodes should be increased by decreasing R22 and R122 to 75R.

If the negative supply is to be fully independent of the positive supply, U104 and its associated circuitry can be replaced with a duplicate of R19, R20, R21 and C5 off pin 8 of U101. If the negative supply is not required, all the 100-series parts can be deleted.

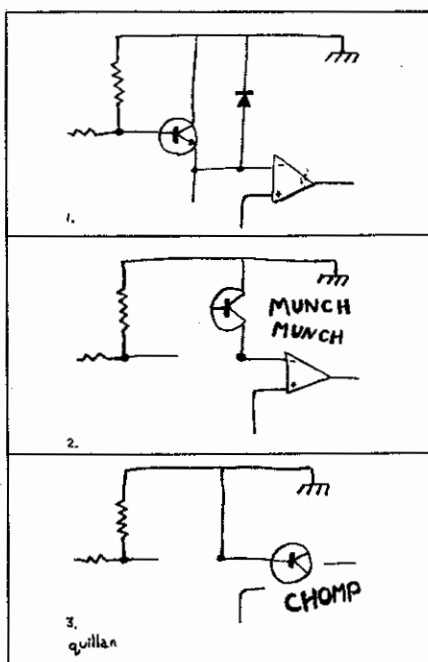
The 10-turn potentiometer (R21) can be replaced with one or two single-turn pots; if two pots are used, one should have a value of 50k for coarse voltage adjustment, and the other in series should be 1k for fine adjustment.

There are many other options available to the user, such as providing terminals for remote sensing when long leads are used, or replacing XFRMR1 and XFRMR101 with one larger transformer; however, these are left to the ambitious builder.

Use

Using the power supply is very easy; the maximum output currents are set on the current limiting pots (this can be done by shorting the output of the supply and adjusting the current limiting pot until the desired current is reached). If there is a problem with either load, assuming both positive and negative supplies are being used, the current limiting circuit will override the voltage control pot and keep the current constant. As the output voltage is increased, the output current also increases until the limiting current is reached. At this point the output voltage will not go any higher because the current would not remain constant. If the resistance of the load decreases, the output voltage will also decrease to keep the output current constant. With a short circuit, the output voltage is zero.

When the positive supply is current limiting, the negative supply will be limited to the output voltage of the positive supply regardless of the operating mode of the negative supply (the negative supply voltage can go below this voltage, of course). In other words, the magnitude of the negative supply can never exceed the magnitude of the positive supply.



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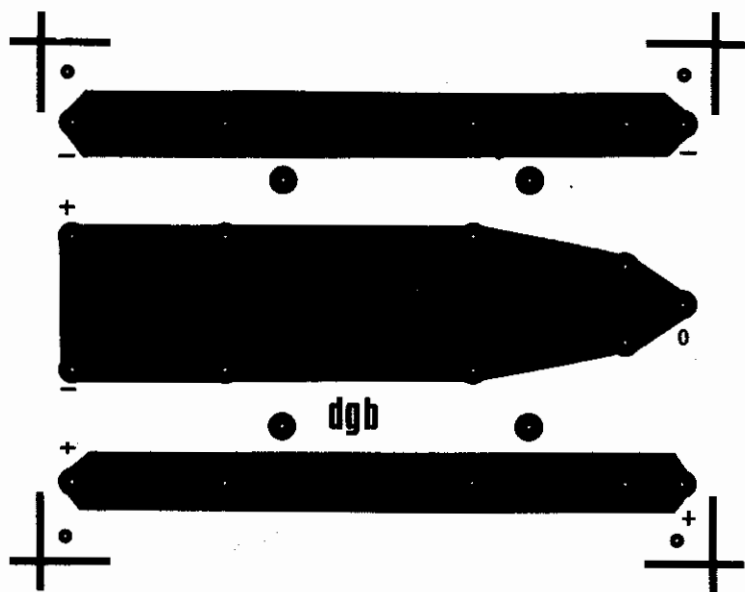


Fig. 7 The small printed circuit for the capacitors.

PARTS LIST

Resistors (All resistors 1/4W unless otherwise noted)

R1, R101	10K 1W
R2, R102, R3, R103, R11, R111,	
R12, R112	.0R2.5W
R4, R104	.47R
R5, R105	.2K7.5W
R6, R106	.2K7
R7, R107	.680R
R8, R108	.5K trimpot
R9, R109, R13, R113, R134	1K
R10, R110, R14, R114, R26	
R126, R135	10K
R15, R115	10K
R16, R116	.50K trimpot
R17, R117	1K pot
R18, R118	10R
R19	.4K7
R20	.5k trimpot
R21	.50K ten turn pot Bourns # 3540S-1-503
R22, R122	.270R
R23, R123	.2K2
R24, R124, R25, R125	.47K
R27, R127	.470R 0.5W
R28	.270K
R29	.500K trimpot
R30, R130	1K 0.5W
R31	.200R 0.5W
R132	.3K3 5W
R133	.4K3 0.5W

R136	.50K trimpot
R137	.50K pot

Capacitors

C1, C101, C2, C102	.2200u 100V
C3, C103, C4, C104	.470p
C5	.470n
C6, C106	.100n
C7, C107	.1u 25V
C8, C108	.47u 25V
C9, C109	100u 100V
C10, C110, C11, C111,	
C12, C112	100u 25V
C13, C113	.4u7 tant.

Transistors

Q1	TIP31C
Q101	TIP32C
Q2, Q3	MJ15003
Q102, Q103	MJ15004
Q4, Q105	2N3906
Q5, Q104	2N3904

Diodes

D1, D101, D11, D111	1N4004
D2 - D5, D102 - D105,	
D7 - D10, D107 - D110	1N914
D6, D106	1N821A
D112	1N4731 (4.3V 1W)
D113	1N4757 (51V 1W)
D114	1N4731 (4.3V 1W)

Integrated Circuits

U1, U101	LM324
U2, U102	LM7812
U3, U103	LM7912
U104	MC1436

Miscellaneous

BR1, BR101	KBPC602 (6A 200V)
BR2, BR102	WO2M (1A 200V)
XFMR1, XFMR101	50V @ 3-4A Hammond # 167-P50
XFMR2, XFMR102	20VCT @ 0.3A Hammond # 166-F20
LED1, LED101	green panel mount LED
LED2	red panel mount LED
M1, M2	100uA 2.5" panel meter
SW1, SW2	DPDT switch
SW3	SPST switch
Cabinet	Hammond # 1426Q
4 binding posts	
4 knobs	
2 small TO-220 heatsinks	
2 large TO-3 heatsinks	
2 14 pin IC sockets	
1 8 pin IC socket	
4 TO-3 transistor sockets	
1 panel mount fuse holder	
1 5A slo-blow fuse	

continued from page 17

For Your Information

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FBAB 8D FF 9F 178 STA OUTPORT
FBAB C9 FF 179 CMP #FF ;QUIT IF BYTE IS #FF
FBAD 08 F3 180 BNE OPTST
FBAF 48 181 RTS
FB88 182 ;XXXX COMMAND TABLE 'CTABLE'
FB88 183 ;
FB88 184 ;SUBROUTINE INDICATED WILL BE EXECUTED WHEN CORRESPONDING
FB88 185 ;COMMAND BYTE IS RECEIVED:
FB88 186 ;(NOTE: ALL COMMAND BYTES MUST BE EVEN)
FB88 187 ;
FB88 FF E2 188 CTABLE DBY EXEC-1 ;#00
FB82 F8 69 189 DBY RRAM-1 ;#02
FB84 F8 8F 190 DBY SRIOT-1 ;#04
FB84 F8 A1 191 DBY OPTST-1 ;#06
FB88 192 ;
FB88 193 ;
FB88 194 ;XXXX SUBROUTINE 'EXEC'
FB88 195 ;
FB88 196 ;MAPS RAM ADDRESS SPACE TO #FB00-#FFFF AND PERFORMS
FB88 197 ;INDIRECT JUMP TO (#FFFC) I.E. HARDWARE RESET VECTOR
FB88 198 ;LOCS. #DFF7-9 OVERRITTEN IN RAM
FB88 199 ;
FFE3 200 ORG #FFE3
FFE3 201 OBJ #9FE3
FFE3 A9 6C 202 EXEC LDA #96C ;OF-CODE FOR 'JMP (#FFFC)'
FFE3 8D F7 DF 203 STA #DFF7 ;TO END OF RAM AT #DFF7
FFE8 A9 FC 204 LDA #9FC
FFE8 8D F8 DF 205 STA #DFF8
FFED A9 FF 206 LDA #9FF
FFED 8D F9 DF 207 STA #DFF9
FFF2 A9 98 208 LDA #998 ;CLEAR MODE BIT THEREBY
FFF4 8D FF BF 209 STA TXPORT ;MAPPING 2K RAM
FFF7 210 ;INTO #FB00-#FFFF, AND DISABLING ROM
FFF7 211 ;AT THIS POINT ROM IS DISABLED AND INDIRECT JUMP IN RAM
FFF7 212 ;WILL BE EXECUTED
FFFA 213 ORG #FFFA
FFFA 214 OBJ #9FFA
FFFA 88 F8 88 215 ;SET NMI, RESET & IRQ VECTORS TO 'RESTART'
FFFD F8 88 F8 216 ADR RESTART, RESTART, RESTART
9000 217 END
    
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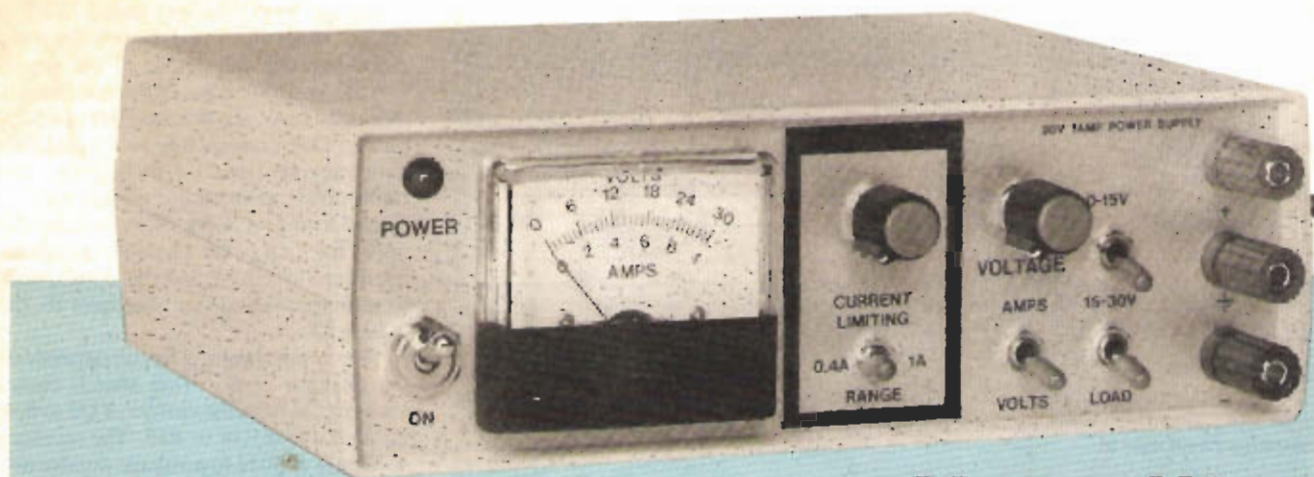
DARK ROOM TIMER ROM

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0000: 3E CF D3 03 3E 80 D3 03 3E CF D3 02 3E OF D3 02
0010: 0E 30 79 E6 OF 59 57 CB 3A CB 3A CB 3A CB 3A 06
0020: 3C 3E 00 D3 00 DD 21 21 00 DB 00 E6 OF FE OF 20
0030: 03 C3 FA 00 DD 21 7A 00 3E 60 D3 00 DB 00 E6 OF
0040: FE OF 28 08 FE 07 CA D0 00 F6 60 08 C3 FA 00 3E
0050: 50 D3 00 DB 00 E6 OF FE OF 28 06 F6 50 08 C3 FA
0060: 00 3E 30 D3 00 DB 00 E6 OF FE OF 28 06 F6 30 08
0070: C3 FA 00 DD 21 21 00 C3 FA 00 08 D9 4F D3 00 E6
0080: OF 47 DB 00 E6 OF B8 28 08 DD 21 21 00 D9 C3 FA
0090: 00 06 00 21 C5 00 7E FE FF 28 07 B9 28 0C 23 04
00A0: 18 F4 DD 21 21 00 D9 C3 FA 00 78 D9 CB 21 CB 21
00B0: CB 21 CB 21 B1 4F 3E 00 D3 00 DB 00 E6 OF FE OF
00C0: 20 F8 C3 12 00 57 6E 5E 3E 6D 5D 3D 6B 5B 3B FF
00D0: 3E B0 D3 00 AF B9 20 02 16 0A 05 20 OF 06 3C 1D
00E0: 7B B2 CA 12 00 FE FF 20 03 1E 09 15 DD 21 DA 00
00F0: DB 00 E6 08 CA 21 00 C3 FA 00 21 1A 01 7A 85 6F
0100: 7E D3 01 DB 01 E6 80 28 FA 21 1A 01 7B 85 6F 7E
0110: D3 01 DB 01 E6 80 20 FA DD E9 3F 06 5B 4F 66 6D
0120: 7D 07 7F 6F 3F 29
    
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Probotics, Toronto's personal robot user's association, will hold its first robot contest in the afternoon of Saturday, October 26, 1985. The contest will be open to robots which will have been designed and built by members of the club, and prizes will be awarded in each of two categories. The first category is for robots that can learn their way through a maze; the robot making a second pass in the shortest time wins. The second is for speech-recognition systems. Robots are required to be able to

tell left from right when one of the words is spoken, which is more than some people can do. Robots must be home-built; anyone who feels that their robot has too little design and too many commercial parts should contact Probotics prior to the contest. A third category, that of robots which must negotiate the Don Valley Parkway at rush hour, has been eliminated. Write to Probotics, 38 Arlene Crescent, Scarborough, Ontario M1P 3L9.



Versatile Bench Top Power Supply

Here's a high-performance power supply to help get your designs off of the drawing board and on to a PC board!

GREG SWAIN AND FRANCO UBAUDI*

EVERYONE WHO WORKS WITH ELECTRONICS needs a power supply, but a commercially-produced variable-voltage current-limited power supply can take quite a chunk out of your pocketbook. So we decided to find a better way. Our power supply provides any voltage between 3 and 30 volts, at any maximum current you desire less than 1000 mA. In addition, our supply provides short-circuit protection, load switching, and switchable voltage/current metering. Further, all parts are readily obtainable and inexpensive, and the supply is easy to build and calibrate.

One feature that really sets our design apart is that it's capable of providing a full amp of power over most of its range of output voltage. Many comparable power supplies can provide one amp of current, but only over a restricted range of output voltage.

Output voltage is selected by means of a range switch with two positions: 3-15 and 15-30 volts. A potentiometer varies voltage continuously throughout the selected range. Similarly, current limiting is selected by a switch providing ranges of 150-400 and 400-1000 ma, and by a potentiometer that allows current to be varied continuously over the selected range. Actually, both current and voltage ranges overlap slightly to ensure that there are no gaps in output.

*Adapted with permission of *Electronics Australia*

The graph in Fig. 1 illustrates the high performance you can obtain from our power supply. As you can see, maximum load current (one amp) is maintained up to 27 volts, after which the load curve falls away due to transformer losses. Other specifications include load regulation that is better than 0.2% from zero to full load, and output ripple that is less than 2-mv rms.

Design considerations

Initially we considered using an LM317 three-terminal variable-voltage regulator as the basis for our supply, but we soon ran into difficulties. Despite various ap-

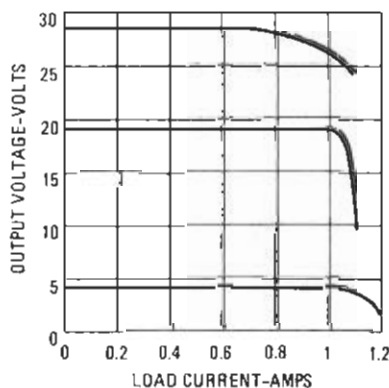


FIG. 1—POWER SUPPLY CAN SUPPLY ONE amp of current all the way to 27 volts, where output drops to about 0.75 amp.

proaches, we were unable to come up with a cost-effective circuit that would deliver one amp over the entire voltage range. The problem was thermal limiting in the LM317 with a high input voltage and a low output voltage. Another drawback was that an additional op amp was required to provide current sensing for the current-limiting circuitry, and that would have increased both cost and complexity of the circuit.

So we rejected the LM317 and adopted the LM723. It requires a current-boosting transistor, but it has built-in current limiting. The guts of the 723 are shown in Fig. 2. It consists of a series-pass transistor, an error amplifier and a voltage reference. The error amplifier compares a portion of the output voltage with the internal reference voltage and continually regulates the base current that is applied to the series-pass transistor. That's what provides regulated output.

The 723's built-in series-pass transistor can deliver a maximum of 150 mA of current, so, in order to obtain more current, an external power transistor is required.

One particularly useful characteristic of the 723 is its built-in current-limiting circuitry. When output current reaches a preset value, the current-limit transistor turns on and that reduces the base drive to the series-pass transistor. The output voltage is thereby reduced.

