BERNARDS

SOLID STATE POWER SUPPLY HANDBOOK

compiled by

M. H. BABANI B.Sc.(Eng.)

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DUAL 30V/2A VARIABLE POWER SUPPLY

Here is a dual variable power supply specially designed for those who experiment with solid state devices. Using relatively few components, it is easy to build and low in cost – yet will deliver up to 30V at 2 amps from each channel. Both channels are short-circuit protected, and feature regulation adequate for most purposes.

Original work was done on a design capable of 60 volts regulated at a maximum current of 2 amps. However the selection of suitable transistors and power dissipation was a problem when the supply was to be used at very low output voltages. Also a dual positive and negative supply facility was not provided for, and herein lay a clue as to how our new supply should be approached. Two 30 volt 2 amp supplies would avoid most if not all the obstacles.

By splitting the 60 volt supply into two 30 volt sections, the need for special high voltage transistors is avoided and readily available components may be used. When a low output voltage is required, the power dissipation in the 2N3055 transistor is reduced accordingly. When a balanced supply is required, the two units may be used to provide up to plus and minus 30 volts. There are applications where two different voltages are required separately and this need can also be met. Finally, the two units may be connected in series to give 60 volts at up to 2 amps.

Although the versatility of the power supply has been considerably extended by splitting, the cost has only been increased by a small margin, with the result that we have obtained many extra features for very little extra outlay.

We will assume that readers have already familiarised themselves with the principles involved, as referred to earlier, and we will take a look at the circuit diagram. There are two channels with a couple of differences between them, and these will be covered as we go along.

The power transformer has two secondary windings, each delivering 25 volts at 2 amps to its own channel.

The main filter in each case is a 4000uF 75VW electrolytic capacitor, following a bridge rectifier consisting of four OA626/50, or equivalent, silicon power diodes. We have used a LED as an indicator and this is connected in series with 10k ohms, directly across the 4000uF electrolytic on channel "A". The 10k resistor limits the current through the LED to a very low value but there is sufficient light output for indicator purposes. The resistor may be reduced in value to increase the light output, provided the LED ratings are not exceeded.

Reference voltage is stabilised at 30 volts with a type BZX70/C30 zener diode, fed via a 220 ohm resistor. In channel "A", this is a ½ watt resistor but in channel "B", a 5 watt resistor is used. This is necessary because of the different situation under short-circuit output conditions, where a high current is passed through the 220 ohm resistor. Additional filtering is achieved with a 1000 uF 35VW electrolytic across the zener diode.

A 5k 2W wire wound potentiometer is connected across the zener diode and the derived voltage is fed to the base of TR1, which sets the voltage at the output terminals. A 100 ohm 1W resistor is connected in series with the 5k potentiometer in each case. This is added to avoid excessive dissipation in the potentiometer for settings close to that end of its travel. The added resistor slightly restricts the available voltage to the base of TR1 but due to a small voltage rise across TR1, any loss is offset.

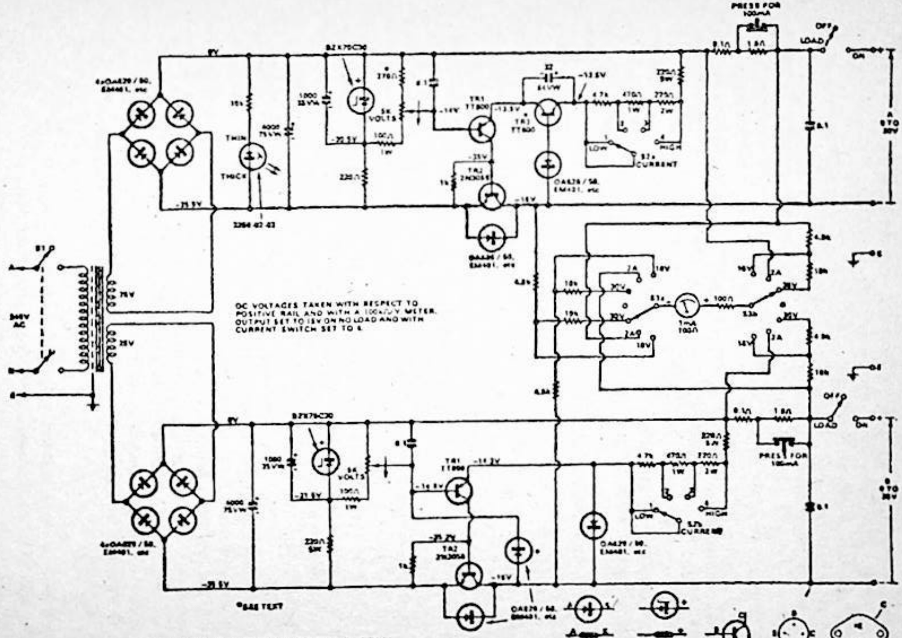
It may also be seen that there is a 270 ohm resistor at the other end of the potentiometer in channel "A". This is added to ensure reliable starting of this system at low voltage settings. It prevents the output voltage from being set to zero.

Transistor TR1 must be a PNP type, capable of withstanding 35 volts or so between collector and emitter, and it must also be capable of dissipating the power dictated by the settings of the voltage and current controls. A suitable transistor for this position is the TT800, or any similar type.

Transistor TR2 must be able to pass the maximum output current, it must also be able to dissipate the power resulting from the output current and the voltage drop between emitter and collector. In addition, it must also be able to withstand about 35 volts between collector and emitter. A logical choice here is the 2N3055, which is ideal. It may be seen that there is a silicon power diode between emitter and collector of TR2. This is added to protect TR2 from damage in the event of an external "same polarity" voltage being applied to the output terminals when the supply is switched off.

In channel "A", TR3 normally passes only a modest current, and as the transistor is saturated, the power dissipation is negligible. However, under short-circuit conditions, the full emitter voltage of TR1 will appear between collector and emitter of TR3. This can be anything up to about 30 volts, according to the setting of the voltage potentiometer. Again, a TT800 or similar is satisfactory.

The major difference between channels "A" and "B" is that TR3 and the 32 uF electrolytic capacitor are dropped from channel "B" and replaced with a silicon power diode between TR1 base and TR2 collector.



DUAL 30/2 VARIABLE POWER SUPPLY

The above circuit features an alternative method of overload protection for each channel.

This facility may be added to the circuit by the much simpler process of adding a diode between the zener point and the output. This normally has a small reverse voltage across it and does not affect the operation of the circuit until current limiting occurs and the load voltage starts to drop. It will then become conducting, diverting current from the zener diode, reducing the load voltage further. At low output current settings, the output is thus bootstrapped down until only the zener current flows through it. At high current settings, a current foldback action occurs, again reducing the output close to zero.

A 0.1 uF capacitor on the base of TR1 helps prevent oscillation. Both ideas have their merits. I have included both methods in the prototype so as to present both ideas to readers.

As I see it, builders may make up the unit just as shown in the circuit and after trying both protective systems make a decision and alter the other channel over to the system of their choice. On the other hand, you may even elect to leave both systems in, which is what I have done so far.

Current limiting is controlled in both cases by a switched series of resistors between the positive rail and TR3 and/or TR1. A constantly variable resistor in the form of a wirewound potentiometer would be preferable to switched resistors, but due to the high power dissipation for relatively low resistance values on one hand, and the need to run to a relatively large resistance on the other hand, an ordinary wirewound potentiometer is not suitable. The next best approach is to select discrete resistors, with adequate dissipation ratings where necessary. This works out quite well in practice.

With an understanding of the current limiting function of either circuit, it will be appreciated that the resistor values for any given current limiting will depend upon the gain of TR1 and TR2. With the inevitable spreads in these components, it becomes obvious that perhaps the best way of arriving at a resistor value for a particular current value is by experimental means. Indeed, to carry this theme to its logical conclusion, it would be necessary to select experimentally all of the eight resistors involved.

We selected the high and low values for one channel broadly along the above lines. The corresponding values for the other channel were simply duplicated. Even with a change in each case of TR2, we found that the results were consistent enough not to require any closer selection. The two intermediate values were selected more or less arbitrarily and the performance curves show that perhaps a little more care could be given to ensure a more even spread across the range. However, this can be dealt with on the merits of each individual case. Suffice to say that the values given on the circuit are a good place to start.

The subject of metering was one which presented us with a number of problems. Two meters, one for each channel, would be a convenient measure and make for easy switching. However, a considerable saving in cost results from the use of only one meter, although the switching is a little more involved. As may be seen, we settled for one meter and this has worked out quite well.

Having decided on one meter, the next question was just how best to make use of it. As the maximum voltage and current per channel would be 30 volts and 2 amps, it is obvious that these ratings should be provided for each channel. For convenient reading of lower voltages, we selected a 10 volt range as well. In addition, for low current readings, another range should also be added. This presented some rather complex switching problems and we finally added a 100 mA range, not as separate positions on the metering switch, but by the addition of two press buttons. With the 2 amp range selected and by pressing the appropriate push button, the meter reads 100 mA full scale.

Even after the general outline of metering had been decided, there were still problems to be solved. Due to the fact that readily available rotary switches are of the shorting type, measures had to be taken to avoid undesirable interaction between circuits during the actual process of switching. For the voltage ranges, it was necessary to split the multiplying resistors into two halves in each case, with a resistor on each side of the switch. Also, to avoid tying the two channels together momentarily when switching from one channel to the other, a blank position had to be provided on the switch. This necessitates a 7-position switch rather than one of 6-positions.

So much for the overall approach to metering. A few comments relating to the resistor requirements for metering may be of assistance. Once again, to keep costs down, we found that the ordinary 5 pc preferred range of resistors were quite good and accurate enough in most cases. The 100 ohm resistor in series with the meter is an ordinary 5 per cent type, as are the two 10k multipliers. The 4.9k multipliers were obtained by paralleling a 5.6k and a 39k. The 0.1 ohm shunt was obtained by paralleling two 0.22 and a one ohm together. The 1.9 ohm shunt was arrived at by paralleling 2.2 ohms with 15 ohms.

If you have no means of cross checking the meter readings given for each of the ranges, then those given with the resistors quoted should be fairly close in most cases. On the other hand, if you have access to a meter of known accuracy, you may check the readings given by the power supply meter and make any corrections where this may be found necessary or desirable.

The complete unit is built into a case whose measurements are 30.5 cm wide x 16.5 cm high x 11.5 cm deep. This accommodates the components without any crowding, or undue waste of available space.

Perhaps the best place to start with the construction is with the sub-assemblies.

The small components are mainly accommodated on two miniature tag strips, one for each channel. A complete wiring diagram is given for the channel "A" strip. The strip for channel "B" will be the same except that the 10k resistor for the LED will be eliminated. Also, TR3 and the 32uF electrolytic are deleted and the extra silicon diode is added. These changes can be made quite readily. When wiring these strips, leads of sufficient length should be added where indicated, for external connections.

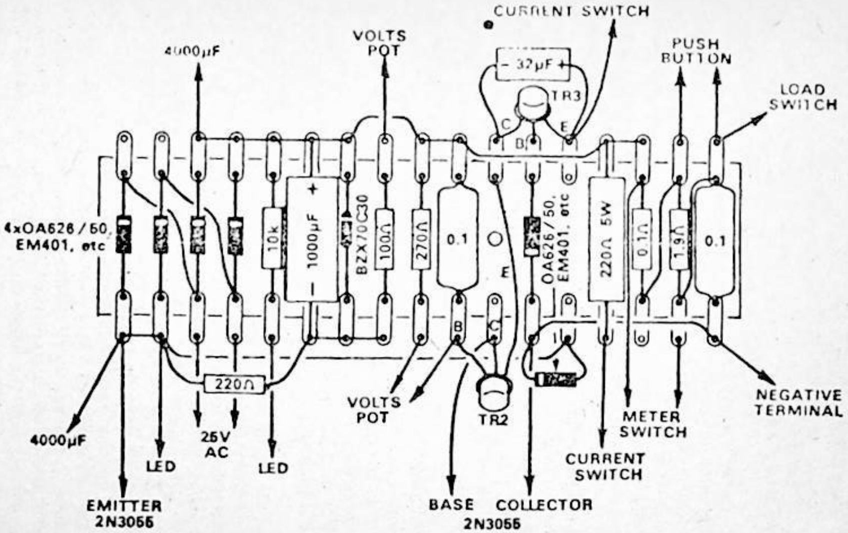
Each 2N3055 is mounted on a heat sink. Four holes must be drilled for each transistor and they must be accurately located. Great care must be taken to achieve this. The job is made easier if you have a drilling template in the form of the plate from a TO-3 dud transistor case. Four more holes must also be provided to mount each heat sink on the back of the cabinet.

Each transistor is mounted on its heat sink by means of the hardware provided, with a smear of silicone grease on each side of the mica insulator applied before assembly. A piece of spaghetti tubing should also be placed over each of the base and emitter leads, such that about 3mm are left bare for soldering. A solder lug should also be provided under one of the mounting screws for the collector connection. We mounted the 1k resistor directly across the base and emitter leads and then provided three leads of different colours, of sufficient length to reach the appropriate terminals inside the cabinet.

Before attempting assembly of the front panel, it makes the job easier if the current and metering switches are wired before they are mounted. This done, the components may now be mounted on the panel. There is quite a bit of wiring which can be done between the panel items.

Assembly and wiring of the cabinet will be made somewhat easier if it is approached in a sequence designed to avoid any backtracking. If you are going to fit a handle to the case, this may be done first. We used one which is designed for use with furniture, and any similar handle would be all right here. After the handle, the mains terminating strip is next, followed by the mains cord. This should be clamped just inside, after passing through a grommet. The mains leads are terminated on the strip.

The heat sinks, with their transistors and leads, should be fitted next, with the leads passed through a rubber grommet in each instance. The power transformer is next, followed by the two 4000uF electrolytics. The clamps on the electrolytics should be adjusted before they are finally screwed up. The two tagstrip assemblies are mounted with two 1/8in Whitworth screws, 1in long. Three nuts are used on each screw to make the screws function as stand-offs, so that the strips clear the bottom of the case by 5/8in or so.



Above is the wiring diagram for the channel "A" tag strip. Modifications to this strip for channel "B" are discussed in detail in the text.

At this stage, with one exception, all interconnecting wiring may be completed. The exception we suggest is the 25VAC leads from the transformer to channel "B" tag strip assembly. These leads should be insulated with tape for the time being and placed out of harm's way.

Before doing the interconnecting wiring between the front panel and the rest of the cabinet, to keep leads reasonably short and allow any servicing which may be necessary in the future, lay the front panel face down and with its bottom edge just touching the front face of the cabinet. After finishing this wiring, to make it a little tidier, we bound leads together at obvious points.

A few points which we observed during wiring are worthy of special mention. The electrostatic shield of the transformer is terminated on the earth screw of the mains terminating strip. A lead is also taken from this point, to a solder lug under the right front screw holding the transformer. From this lug, a lead is run to the two "earth" terminals on the front panel.

Resistors rated over 1 watt have been kept as clear as possible of adjacent components. The four leads terminated on the mains on/off switch have been covered with a short length of spaghetti and pushed over the soldered joint to ensure safety against accidental contact. The polarity of the LED must be observed and on the one we used, the thin lead is positive.

At this stage, the wiring is virtually complete and the next step is to make a thorough check of all wiring, making sure that switching is correct and all polarities have been correctly observed. Satisfied that all is well, channel "A" may be switched on and checked for correct operation.

Set the "volts adjust" potentiometer to maximum, the "current" switch to "low" (or 1) and the "metering" switch to 30V on "A". Switch on and the meter should indicate a little over 30 volts, Wind the volts adjust potentiometer up and down and the voltage should rise and fall accordingly. At the lowest current switch setting, very low voltages may be a little hard to get, with the supply tending to drop out, but this will disappear on higher current switch settings. Even on this setting, the supply can be easily reset by a rapid clockwise flick of the volts adjust pot.

Reset the volts adjust potentiometer to maximum and with the load switch on, short circuit the channel A output terminals. The voltmeter will indicate zero and will stay there after the short circuit has been removed. The output voltage can be restored by switching the mains off and leaving it for a minute or so and switching on again. A quicker way is to turn the load switch off and turn the volts adjust potentiometer down to half way or so, then quickly advance it again. At this stage, testing on channel A may be stopped and the 25VAC leads which were left unconnected, may be connected to channel B.

The procedure for channel A may now be repeated for channel B. However, there will be some differences. Initially the voltmeter should show a little over 30 volts with the volts adjust potentiometer fully advanced. Winding this control up and down will result also in the voltage rising and falling. Instead of the voltage only falling to a minimum of about two volts, it should go right to zero, with no signs of the erratic behaviour at low voltage settings, with the current switch still set to 1. Also, when channel B output terminals are short circuited, the voltage will fall to zero on the meter and immediately rise again when the short circuit is removed.

Tests thus far should indicate that both circuits are functioning normally and the only other detail to be determined is the current cut-off points for each of the current switch positions 1 to 4, for each channel. Reference to the curves will give a good idea what to expect.

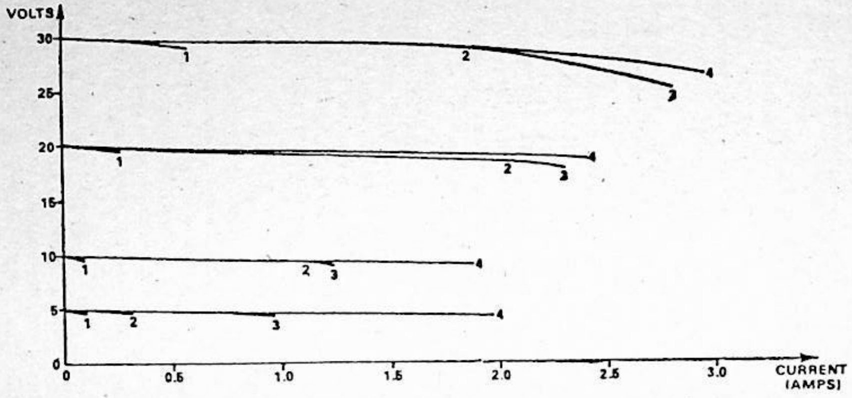
Unless you have a high power rated variable resistor, perhaps the best way to check the rest of the current ranges would be to have a handful of various resistors of suitable values and high enough power ratings, such that combinations of these resistors may be used to load the output and check the voltage roll-off points, prior to cutoff. This rather lengthy series of tests need not be undertaken unless you really wish to know just where cutoff occurs under any set of conditions. Your unit will probably behave in a manner similar to that shown by the curves, but the exact point of cutoff may differ somewhat, depending upon the respective transistor gains.

Even if you do not go through the complete test procedure, it would be wise to check progressively the current cutoff of each channel, by shorting out each in turn. In each case, the voltage will fall to zero; if all is well, channel "A" current will fall to zero and will remain in this condition after the short circuit is removed, while channel "B" current will fall to a low value and immediately the short circuit is removed, the voltage will return to normal.

A final test is a short circuit test with both channels connected in series. The negative terminal of one channel is connected to the positive terminal of the other channel. Although it is not essential, the voltages should be set so that they are equal. Shorting out the system should result in one of the channels opening up and becoming a high impedance, thereby protecting itself and the other channel as well.

With regard to the performance of our new supply system, the voltage regulation is not up to the standard of rather more sophisticated designs but for most purposes, the regulation should be adequate. Another point which should be brought out, is the condition where a high current is drawn at low voltage settings. About the worst case would be when the output voltage is set to 5 volts and the load draws 2 amps. This means

The curves below are a guide to the performance of the prototype.



that there will be approximately 35 – 5 volts across the 2N3055 and the power to be dissipated will be about 30 x 2, which is 60 watts. This is a lot of power and while the 2N3055 would stand up to it for a short time, damage may result from prolonged operation under these conditions. In short, it would be wise to watch this sort of situation closely.

From the above, it would seem that the supply has been under designed. On the other hand, when the output voltage is set to 30 volts, and 2 amps are drawn by the load, this means that the dissipation in the 2N3055 will be about 10 watts. Perhaps one could say that the unit is over designed for this condition. As is the case with many situations, a compromise must be struck and we feel that the compromise here is a reasonable one.

The uses to which the dual supply may be put are many and varied. There will be many cases where just one voltage is required. On the other hand, in cases such as modern solid state audio amplifiers, a low voltage will be needed for the low level stages and a higher voltage will be required for the power amplifier stage. There is the situation where an audio power amplifier stage will need a balanced power supply, say plus and minus 20 volts. Then there is the power amplifier which needs a 60 volt supply at a couple of amps.

Possibly there is no better way to get to understand the behaviour of each channel of the power supply than to experiment and "have a play". It seems to be virtually foolproof against overload and short circuit. Also, in the event of a charged capacitor being connected across either channel in the correct polarity and with the mains switch off, no damage will be done as the 2N3055 is protected against this treatment by a diode. We also charged a 2000uF capacitor to 30 volts and connected it in reverse polarity and with the mains switch off. This test was applied to each channel and again no ill effects were observed.

PARTS LIST

1 Case, approx. 30.5cm wide x 16.5cm high x 11.5cm deep
1 Front panel
1 Handle for case (optional)
4 Rubber feet
4 Knobs
3 Rubber grommets
2 heat sinks
1 Plastic terminal block, 5-way
1 Transformer, 240V primary, 2 x 25V 2A secondaries
1 Meter, 0-1mA, 100 ohms approx. 7.5cm x 6.5cm
2 Miniature tag strips, 17 prs tags
6 Terminals, 2-red, 4-black
2 Miniature toggle switches, DPDT
2 Miniature push-button switches, SPDT
1 Rotary swithh, 2-pole, 4-position
1 Rotary switch, 1-pole, 7-position, 2 wafers
13 Diodes, OA626/50, EM401, RS276-1136, BA219, IN4002
1 LED, McMurdo 3350-02-02, or similar
2 Zener diodes, BZX70/C30 or similar
2 Transistors, 2N3055, AM219, BD130, BDX10, BDY39, 2N3713, SK3027, CV8889
3 Transistors, TT800, AY9139
2 Heat sinks for TT800, AY9139

RESISTORS
(½W unless stated otherwise)
4 x 0.22 ohm, 2 x 1 ohm, 2 x 2.2 ohms, 2 x 15 ohms, 3 x 100 ohms 1W, 1 x 220 ohms, 2 x 220 ohms 2W (or 2 x 470 ohms 1W in parallel) 3 x 220 ohms 5W, 1 x 270 ohms, 2 x 470 ohms 1W, 2 x 1k, 2 x 4.7k, 2 x Potentiometers, 5k 2W, wire wound, 4 x 5.6k, 5 x 10k, 4 x 39k

CAPACITORS
4 0.1uF 160V polycarbonate
1 32uF 64VW electrolytic
2 1000uF 35VW electrolytics
2 4000uF 75VW electrolytics

MISCELLANEOUS
Hookup wire, solder, solder lugs, 3-core flex and plug, cable clamp, screws, nuts.
NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used, providing they are physically compatible. Components with lower ratings may also be used in some cases if available, providing ratings are not exceeded.

A POWER SUPPLY FOR SOLID-STATE RECEIVERS

This little power supply is capable of supplying a 3-watt class B audio amplifier from a 17.5-volt line, RF and IF amplifiers from a 12-volt regulated line and 9 volts regulated for all oscillators, for a full-size communications or short wave receiver.

During some recent work on the design of communications receivers, the need naturally arose for a power unit to meet specific power supply requirements. Although the design of the complete project is not past the drawing board in some areas, the power supply has been designed and built and has been found to meet the need satisfactorily and at moderate cost. At this stage, we thought that other readers may have need for a similar supply and we present it in the hope that it will meet some of those needs.

Firstly, 17 to 19 volts DC was needed to supply a class B audio amplifier system. This supply need not be regulated but, as the current demand would swing over very wide limits, from say 20 to 250 milliamps, the output voltage would vary accordingly.

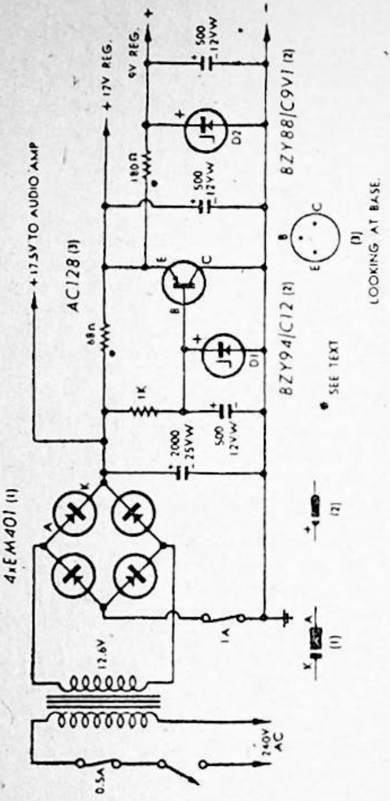
As a supply to the audio system, this arrangement would be entirely satisfactory. However, for the rest of a receiver the voltage would be somewhat higher than necessary, while a more stable voltage would be most desirable. And so the next requirement seemed to centre around a regulated supply of 12 volts and a current of 50 milliamps or so.

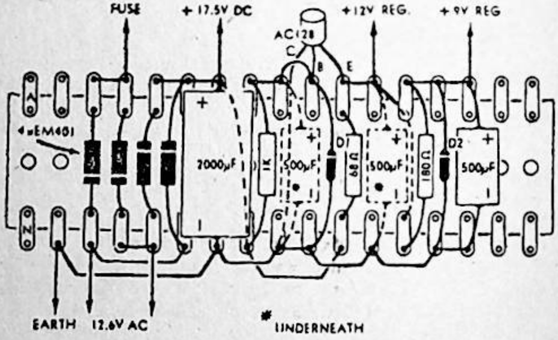
This would meet almost all the needs of a high grade receiver, except that it was felt that the regulation may be improved for a supply to the oscillators, in the interests of maximum frequency stability. By taking a line from the 12 volts regulated supply and further regulating it at 9 volts, an excellent source would then be available for the oscillators.

At first sight, this may seem to be rather involved but a very satisfactory design can be arrived at without difficulty. Let us take a look at the circuit of the finished article.

Starting with the transformer, there are several suitable types available. As examples, we can cite two types, one with two windings rated at 12.6 volts at 0.5 amp and the other with two windings rated at 6.3 volts at 1 amp. The former can have the two windings connected in parallel and the latter the windings connected in series. In each case, we end up with a supply of 12.6 volts at 1 amp. These are ideal for our purpose.

Rectification can be achieved efficiently, with four silicon diodes in a bridge arrangement. As the inverse voltage is quite low, diodes with a rating of as low as 50 volts or so can be used. We used diodes rated at 100 volts and they have a forward current rating of 1 amp.


+17.5V TO AUDIO AMP
AC128 (3)
+12V REG.
9V REG.
500 12VW
180Ω
68Ω
1K
2000 25VW
500 12VW
D1
D2
BZY88/C9V1 (2)
BZY94/C12 (2)
4xEM401 (1)
12.6V
240V AC
0.5A
1A
SEE TEXT
LOOKING AT BASE


FUSE
+17.5V DC
AC128
C
B
E
+12V REG.
+9V REG
4×EM401
2000µF
1K
500µF
D1
68Ω
500µF
180Ω
D2
500µF
EARTH
12.6V AC
UNDERNEATH

Filtering immediately after the rectifiers, is by one 2000uF 25VW electrolytic capacitor, the voltage at this point being about 17.5. This is sufficient filtering for this position, as it normally feeds a high level output stage, and earlier stages in the amplifier have extra filtering as required.

The next part of this exercise is to obtain 12 volts, regulated, and with a current capability of 50 milliamps or so. It may be possible to do this by simply using a suitable series dropping resistor and a 12 volt zener diode. This would mean that under conditions when the load is removed, the zener diode must be capable of passing the total load current, plus say a minimum of another 5 milliamps. This amounts to a dissipation of 12 x 55, which is equal to 660 milliwatts.

The regular type of zener diode which we are accustomed to using, has a maximum dissipation rating of, say, 340 milliwatts. This will not meet the situation and so we must use a larger zener diode, or resort to another method of regulation.

A satisfactory method is to use the zener diode as a reference for a power transistor, in either a series or shunt regulator arrangement. With the series arrangement, which is often used, the danger lies in overloading the output and a possibility of damaging the transistor, unless precautions are taken. On the other hand, if we use the shunt circuit there is no possibility of damaging the transistor. This is the method which we have adopted.

In designing such a regulator, the limiting factors are maximum emitter current of the transistor and its maximum power dissipation. We have decided on an AC128 transistor. It has a maximum permissible emitter current of 1000 milliamps and a maximum dissipation of 1.0 watt, with the proper heat sink fitted. Obviously, the emitter current rating is so far above that which we are likely to need, that we can concentrate on the dissipation rating only.

With 12 volts between collector and emitter and with a maximum collector dissipation of 1 watt, the maximum collector current would be 83 milliamps. Assuming also that there is no load on this part of the supply, then the lowest value of series resistor would be 66 ohms, say 68 ohms. This means that with a suitable heat sink for the transistor, the 12 volt line could be left unloaded. A maximum of about 70 milliamps or so could be taken from this point.

The manner in which regulation is achieved by the shunt transistor method is, briefly, as follows: The base voltage of the AC128 transistor is virtually pegged at 12 volts with the zener diode. Should the output voltage increase, the bias on the AC128 will also increase. This, in turn, causes an increase in emitter current and causes an increase in the voltage developed across the 68 ohms resistor, thereby tending to restore the output voltage to its original value. The opposite process would apply if the output voltage tended to drop, and so the output voltage is kept substantially constant.

This is true for load currents from zero up to almost the full value of the emitter current.

Moving along to the 9-volt zener regulated line, the series dropping resistor has to be calculated. Disregarding other factors for the moment, the maximum dissipation permissible for the zener diode is 340 milliwatts. At nine volts, this means that the maximum permissible current is 37 milliamps. To drop the voltage from 12 volts to 9 volts, the series resistor will be 81, say 82 ohms. Under these conditions, the 9-volt regulated output can just safely be left unloaded. Up to about 30 milliamps could be taken from this point.

In an attempt to simplify the calculation of the value of each of the two series dropping resistors, we have left out some factors which need to be taken into consideration. The logical place to start is with the 9-volt regulated output. First of all, we must determine the load current. Let us suppose that this amounts to 10 milliamps. Added to this is the current through the zener diode. We can allow 5 milliamps for this. The total current flowing through the dropping resistor will therefore be 15 milliamps. With the voltage to be dropped from 12 volts, the resistor will be 3/.015, which gives a value of 200 ohms. This could safely be made 180 ohms.

Now in order to calculate the value of the dropping resistor for the transistor regulator, we must take into consideration three current components. Firstly, there is the 15 milliamps for the 9-volt supply. Secondly, we must determine the external load current and we will assume that this is 50 milliamps. Thirdly, we must allow a residual of collector current of say, 20 milliamps. This totals 85 milliamps. To drop the 17.5 volts nominal, to 12 volts, the resistor will be 5.5/.085, which gives us 65 ohms. We can make this one 68 ohms.

The above figures are given as an illustration and, if your needs are somewhat different from those quoted, it is an easy matter to make the calculations and change the resistors accordingly. Make sure, however, that dissipation ratings of the transistor, zener diode and resistors are not exceeded.

Apart from the power transformer, we built the unit on a piece of tag board, with a total of 17 pairs, some of which were not used. The layout of the components is shown in the diagram. Apart from the usual need to take care with soldering, making good joints and not overheating components in the process, there is not much more need be said along these lines.

Note that the 9-volt zener diode is clamped with a heat sink. This is one of the old type of the OAZ series and we found this a convenient way to mount this item. The AC128 transistor is also mounted in the same way. The complete assembly is provided with two ¾in long spacers, to allow its being mounted to a chassis. The two heat sinks are thereby clamped to the chassis, affording ample metal for dissipation.

So there is our power supply which could have many applications and we hope that it will do the job which you have for such a device.

EQUIVALENT SEMICONDUCTORS

EM401 = BA219, BY126/100, EM501, OA626/100, IN4002, RS276-1136.
AC128 = AC117R-153VI-180, NKT302, SFT232, 2N659-1373-1384-1926-2001-2431-4106, 2SB370, SK3004, RS276-2001
BZY94/C12 = CV7146, KS180B, IN759
BZY88/C9VI = DZ10A, RS276-623

A SIMPLE, LOW-COST TRANSISTOR POWER SUPPLY

Here's a small variable power supply for the many jobs which don't really need the performance of a costly regulated unit. Simple and inexpensive, but at the same time burnout-proof, it should be ideal for servicemen, students, amateurs and experimenters.

There are many occasions in electronics when the job at hand calls for one or more sources of adjustable low-voltage DC. Such occasions arise frequently in circuit development and equipment servicing, in teaching institutions and in amateur experimental work.

It is, of course, possible in such situations to derive the required voltages and currents from fully regulated supplies. However, supplies of this type tend to be rather too expensive to permit the convenient acquisition of even a moderate number. Furthermore, in many cases the high regulation and filtering performance provided by such supplies is not really required.

Accordingly, there are many potential applications for rather simpler and less costly types of power supply unit, capable of little more than the supply of an adjustable low voltage under modest loading conditions. A desirable but perhaps not essential feature of such supplies would be inbuilt overload protection, if this could be provided at low cost.

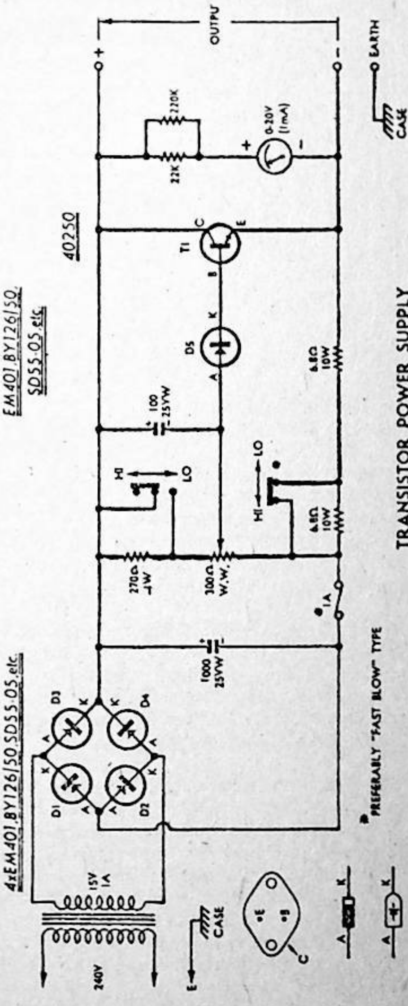
The small power supply described in this chapter has been designed expressly for this type of application. It is a simple, low cost unit based around easily obtainable components, and would be suitable not only for "one-off" construction and use by the individual serviceman or experimenter, but also for multiple construction and use by development labs and teaching institutions.

Despite its simplicity and economy, the unit offers a performance specification adequate for most not-so-critical jobs. Output voltage is adjustable from around 1.5V to above 20V; available load current at 1.5V is close to 1A, dropping to around 200mA at 20V. Output is not regulated, but effective supply resistance is low – from 1 to 5 ohms, approximately, depending upon load voltage and current. Output ripple and noise is less than 300mV peak-to-peak before current limiting. And, in addition to these features, we have been able to provide the unit with inbuilt protection against overload damage.

The circuit diagram of the new supply shows that it uses a minimum of components. At the heart of the design is a simple "active" voltage divider circuit, using a NPN silicon power transistor as the shunt element, and fed from a conventional bridge rectifier circuit using a small 15V/1A stepdown transformer and four 1A silicon rectifier diodes.

The transistor, a type 40250, is effectively connected as an "upside-down" emitter-follower across the rectifier output. The power resistor(s) in series with the negative line from its emitter load, while its base is connected to a potentiometer which is also wired across the rectifier output. The output terminals are connected across the transistor itself, positive to collector and negative to emitter.

Below is the circuit, which may be used in conjunction with the wiring diagram



TRANSISTOR POWER SUPPLY

Because of the emitter-follower configuration, the transistor acts to duplicate approximately at its emitter the voltage level at its base. Hence when the base is carried by the potentiometer to the positive rectifier output, the voltage drop of the transistor – which is the output voltage – drops to near-zero. Conversely, if the base potentiometer is turned to the opposite extreme, the output voltage will tend to rise and approach the full rectifier output. Intermediate positions of the potentiometer will tend to give appropriate fractional output voltages.

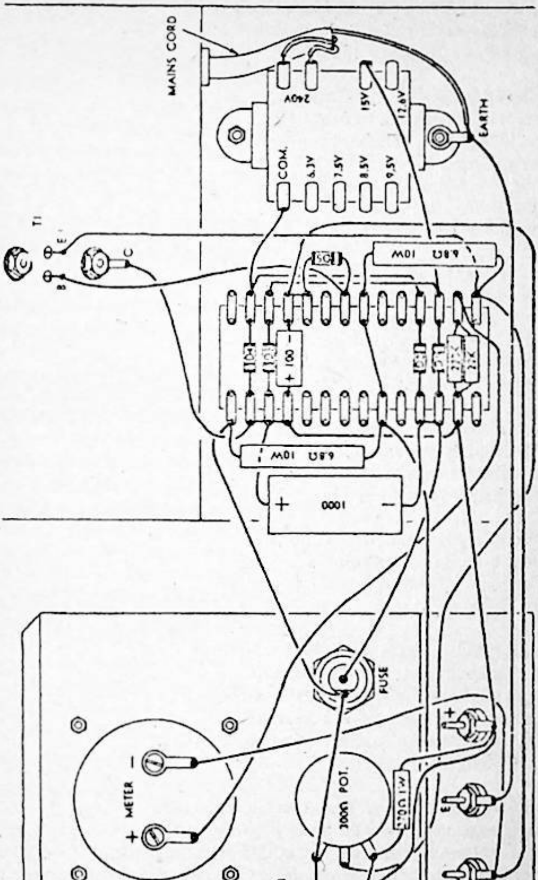
The use of a transistor as an emitter-follower is quite common in power supplies, and has the advantage of giving the supply an intrinsic output resistance considerably lower than would be obtained with a simple "passive" voltage divider system. However by using the transistor as the shunt divider element, in contrast with the more usual practice of using it as the series element, the present design gains simply and at virtually no additional cost an important advantage: inherent protection against output shortcircuits.

Because the output terminals are connected directly across the transistor, any load connected to the terminals is effectively connected in parallel with the transistor. The current drawn by a load therefore subtracts from that which must otherwise be drawn by the transistor in order to maintain a given output voltage, and thus the transistor dissipation actually falls with supply loading. If the output terminals are short-circuited, the transistor is simply cut off; the rectifier circuit is presented with the significant but not unduly embarassing load provided by the series divider resistors.

It should be appreciated that the foregoing state of affairs is somewhat in contrast with that of the more usual circuit, in which the transistor is connected as the series divider element. In such circuits the transistor dissipation rises with load current, and special precautions must be taken if the transistor is not to be ruined by the excessive current which tends to flow on short-circuit.

Although the transistor is thus protected by the basic circuit configuration against collector over-dissipation, it is also necessary that it be protected against base-emitter reverse bias break-down in the event of a short-circuit applied when the base potentiometer is turned for near-maximum output. This is in fact the purpose of the diode in series with the base, which prevents base current flow in the reverse direction.

The value of the voltage divider series element necessary to prevent excessive "internal" supply dissipation in the minimum output condition is approximately 14 ohms, being here provided by two 6.8 ohm 10 watt power resistors. However, because this value tends to limit somewhat unduly the current available from the supply at higher voltages, provision has been made for halving this element in value when required by means of a slide switch which shorts out one resistor. At the same time the switch is arranged to insert a fixed resistor in series with the "low" end of the base potentiometer, ensuring that the "internal" dissipation of the supply is limited.



Above is the complete wiring diagram of the new suppiy, Externally the effect of the switch is to provide a second, "HI" range in which additional current is available, but only for a range of output voltages limited from about 11-20V.

As with the normal or "LO" range, an output short-circuit on the HI range merely causes the transistor to switch off. However, because the current load on the rectifier circuit in this case becomes excessive, a protective fuse has been provided. The fuse should be rated at either 1A or preferably 800mA if this value is available, and should ideally be of the "fast-blow" variety to prevent excessive overheating of the transformer and rectifier diodes.

An output voltmeter is provided, to permit convenient adjustment and monitoring of supply output during operation. The meter used in the prototype is an economy 3-inch rectangular type of Japanese manufacture, and having a standard 0-1mA/100 ohms characteristic. We removed the original 0-1 scale markings with a typewriter eraser and replaced them with an appropriate 0-20V numbering.

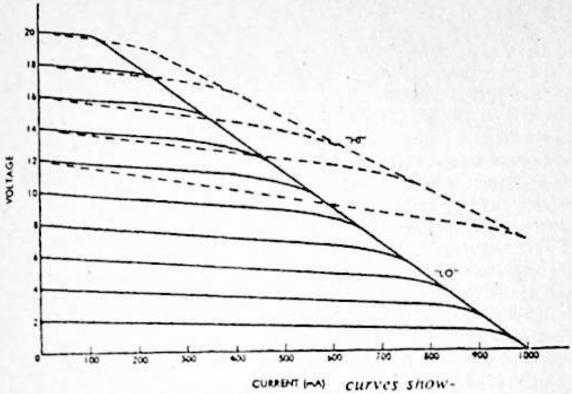
Neither side of the basic supply is internally connected to the case and mains earth, but rather a third "earth" output terminal is provided to permit either output polarity to be tied to earth if and when required. This approach offers complete flexibility, at no sacrifice in performance.

The supply is constructed in a compact sloping-front case which makes it very suitable for convenient bench-top operation. The case is a standard type measuring 5in x 5in x 5in, and having a wrap-over front panel.

The output voltmeter is mounted at the top of the sloping case panel, with the output potentiometer beneath it and the fuse and range switch mounted to the left and right of the latter, respectively. The three output terminals are mounted at the lower front of the case, with the earth terminal in the centre to allow convenient linking of either output terminal when required.

The power transistor is mounted on the outside of the upper rear of the case. Although the transistor body is connected internally to the collector and must therefore be isolated electrically from the earthed case, for efficient cooling of the device the two must be closely coupled thermally so that the case can act as a heatsink.

Although the case of the supply is quite small, the interior is not unduly crowded as a result of the few components used. The power transformer occupies the lower right-hand area, with most of the minor components supported alongside by a 14-tag length of miniature resistor panel.



curves showing the typical performance under loading.

The position of all components is shown in the wiring diagram and constructors should as a result have little difficulty in duplicating the unit if they so desire. However the wiring is not critical, and providing care is taken to provide the components with suitable mounting support and adequate ventilation, all should be well.

In the interests of safety the mains cord is clamped to the bottom of the case immediately upon entry via a grommeted hole at the rear, the clamp being between the transformer and the right-hand side of the case. The transformer is mounted with the primary winding lugs nearest to the cord entry, so that the mains wiring is kept as far as possible from the low-voltage circuitry. The mains earth connects to the case via a solder lug under one of the transformer mounting screws, and thence to the front panel terminal.

When the supply is completed and put into operation; it will be found that the transistor body and the adjacent case surface become quite warm, even hot if the unit is set at the "minimum" position of the "HI" range with no external load connected (the latter condition is that corresponding to maximum transistor dissipation). Do not be alarmed at this, as it is quite normal and has been allowed for in the design of the unit.

PARTS LIST

1 Sloping front case, 5in x 5in x 5in.
1 Stepdown transformer, 15V–1A.
5 Silicon diodes, type EM401, BY126-50, or similar
1 Transistor, type 40250, BD131, BPX24, or similar, with mica insulating washer.
1 3in rectangular meter, 0-1mA/100 ohms.
2 6.8 ohms 10 watt resistors.
1 270 ohms 1 watt resistor.
1 300 ohms wire-wound pot.
1 22K ½ watt resistor.
1 220K ½ watt resistor.
1 1,000uF 25VW electrolytic.
1 100uF 25VW electrolytic capacitor.
1 DPDT slider switch.
1 1A or 800mA cartridge fuse and holder.
1 Mains cord and plug. Also grommet and clamp.
3 Screw terminals – red, green, black.
1 14-lug section of miniature resistor panel.
Nuts, bolts, washers, connecting wire, solder, handle and rubber feet for case.

SIMPLE POWER SUPPLIES FOR DIGITAL LOGIC CIRCUITS

Here are two designs for rugged low-voltage DC supplies suitable for powering logic circuits using digital ICs. One is a simple fixed voltage 5V/1A unit using a new regulator IC, while the other offers adjustable voltage and higher current capability.

A low voltage DC supply is virtually essential when you are experimenting with digital ICs or developing IC logic circuits. And the supply needs to be electrically rugged – tolerant of overload – in order to cope with the accidental short circuits that are almost inevitable in any experimental situation. Ideally, it should also be well regulated, to obviate the need for continual adjustment to maintain the supply voltage within the specified limits despite loading changes.

A fixed 5V supply is generally quite adequate for many applications, because this is the nominal supply voltage used for the popular "workhorse" TTL and DTL families of devices (low, normal, high and superhigh speed TTL all work from 5V). This voltage is also used for ECL devices.

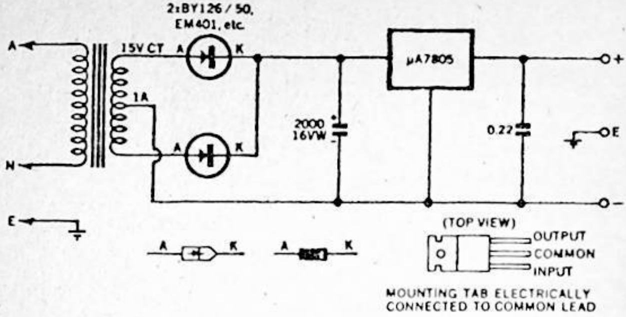
To be really practical, however, a simple supply of this type should deliver at least 500mA. This will allow it to drive a reasonable number of small-scale (SSI) and medium-scale integration (MSI) devices, or alternatively at least a few large-scale or LSI devices.

The simpler of the two supplies to be described here delivers 5V at currents to more than 1A, and is completely protected against overload and short circuits. It is therefore suitable for general experimenting and experimental work involving either TTL, DTL or ECL devices.

The second supply is a more elaborate unit which provides an adjustable output voltage and an output current of more than 3.5A. The output voltage is adjustable from below 3V to above 6V, making the supply suitable for work with RTL and low-speed discrete 6V logic circuits as well as those operating from 5V. The adjustable output voltage also makes it possible to check circuit operation at the extremes of the specified supply voltage range for each type of device, a very worthwhile feature for development work where devices are being pushed to performance limits.

In this supply, a meter is also provided to allow convenient monitoring of both voltage and current.

The simple supply has been built up and tested, but to conserve space only the circuit will be given here. It is a very straight-forward unit, and could be built up in a variety of physical forms as desired.



SIMPLE 5V/1A LOGIC SUPPLY

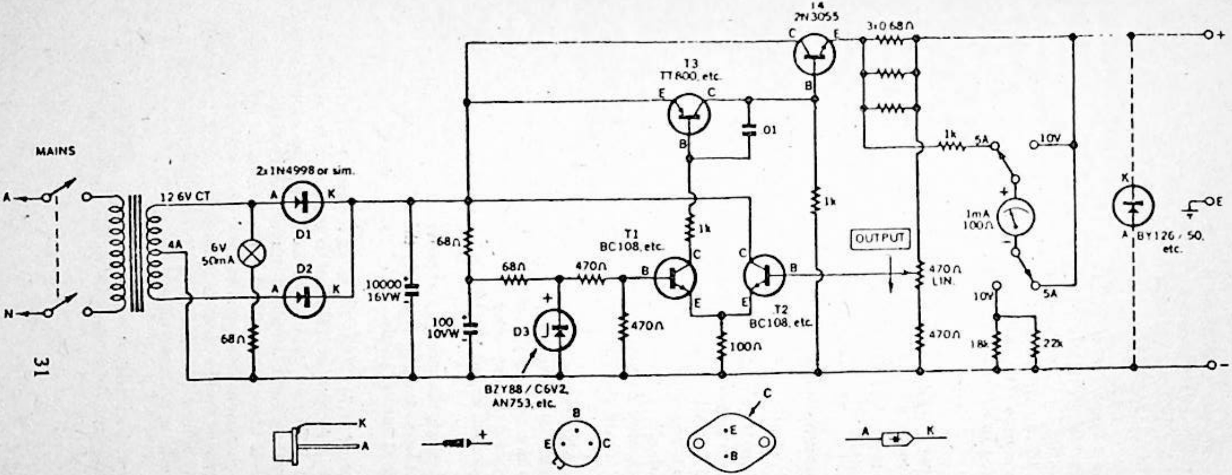
As may be seen from the circuit, it uses only six main parts: a power transformer, two silicon diodes, two capacitors and a new Fairchild regulator IC, the uA7805. Apart from these, all you will need is a case to support and protect them together with such incidentals as a power cord and plug, a few tagstrips, and three output terminals.

The 7805 is one of a series of three-terminal voltage regulator ICs recently released by Fairchild. Apart from the 7805 there are six other devices in the 7800 series, designed for nominal output voltages from 6V to 24V. All devices are designed to deliver current in excess of 1A, with virtually no external components required for fixed voltage output. The devices incorporate internal thermal shutdown, short circuit current limiting, and safe-area compensation to make them essentially blowout-proof. All this in a device which looks exactly the same as a plastic package power transistor!

Thanks to the 7805, all that is basically needed to produce the 5V/1A supply is a transformer with a 15V CT x 1A winding, together with a full-wave rectifier using two 1A silicon diodes such as the BY126/50 or EM401. The 2000uF electrolytic capacitor forms the reservoir capacitor for the rectifier, while the remaining component is a 0.22uF mylar capacitor connected across the 7805 output to assist it in coping with current transients.

Virtually the only point to bear in mind, when building up this simple supply, is that the 7805 must be provided with a suitable heatsink.

The supply may be built in a small aluminium utility box measuring 5¼ x 3 x 2-1/8in. The transformer and rectifier components were mounted in the "base" of the box, with the power cord entering at one end and the output terminals mounted at the other. The 7805 was bolted centrally inside the top of the box, using a small mica insulating washer of the type supplied with plastic power transistors. This ensures that when theebox is assembled, the complete box acts as the 7805 heatsink.



LOGIC POWER SUPPLY (3-6V/3.5A)

The circuit of the more elaborate supply, which uses discrete components. Its usefulness is extended considerably by the output meter.

Note that the use of three output terminals allows the supply to be connected with either output polarity earthed. This gives greater flexibility when working with circuits using combinations of different types of logic – ie, TTL and ECL.

The more elaborate supply shown in the pictures uses discrete circuitry, as may be seen from its circuit. It would be entirely possible to build up a similar unit using an IC as the basic control element in conjunction with a power transistor, but I elected to follow the discrete approach on the grounds of economy. The regulation is perhaps not quite as good as one could get using an IC feedback amplifier, but it is still quite adequate.

A full-wave rectifier is used as before, only this time the transformer is a 12.6V CT unit rated at 4A and the diodes are high-current automotive types. I used the type 1N4998 diodes made by STC, but any similar type would be suitable.

The main reservoir capacitor is a high capacity type: 10mF (10,000uF) rated at 16VW.

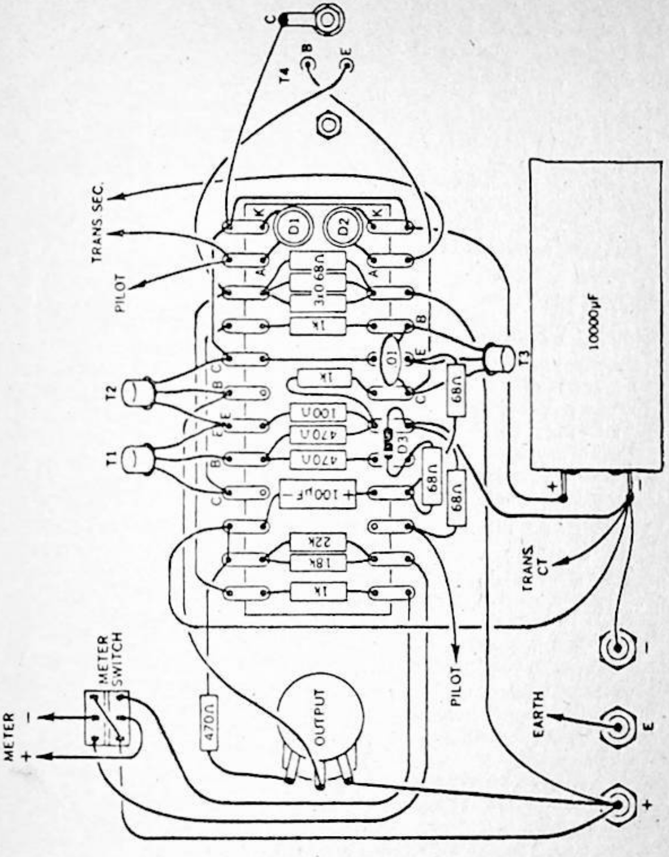
The regulator circuit itself is quite conventional. A pair of general-purpose NPN silicon transistors (BC108 or similar) are used as the error amplifier (T1 and T2), which compares a feedback signal taken from a divider across the supply output with a reference signal produced by means of a zener diode. The amplified error signal produced by the amplifier is used to drive an NPN series pass transistor (T4), via a driver stage using a PNP transistor (T3).

The series pass transistor should preferably be of the epitaxial-base type to ensure high tolerance to overload. I used one of the Fairchild "bi-mesar" devices, which are of this type, but similar devices are available from other manufacturers. Use either the 2N3055 or similar house-designation devices such as the AY8150, AY8149, or MJE 3055.

The PNP driver transistor is necessary to provide sufficient power gain within the control loop, and also to supply the drive current required by T4 at high output current levels.

The dissipation rating of 115W for T4, when it is provided with an adequate heatsink, is more than sufficient to cope with the static short-circuit dissipation. If an epitaxial-base device is used, the supply should therefore be undamaged for all overload situations except those of esoteric nature. Note that because a PNP driver is used for the series pass transistor, even reasonably large reverse-polarity voltages applied to the output terminals should cause no damage. However, for some applications it may still be desirable to fit a reverse-polarity shunt diode across the output, as shown dashed.

The output meter uses a standard 0-1mA movement. This is arranged to read 0-5A for current and 0-10V for voltage, using a simple shunt and multiplier setup.



interior view of the larger supply, together with a wiring diagram.

Note that the value of the resistor in series with the lower end of the output voltage control pot determines the maximum output voltage of the supply, while the zener diode and the resistive divider across it determine the minimum voltage. The values of these components have been selected with some care, and should be optimum. However, it is best that you know where to modify a value if adjustment may be required.

The construction of the higher power supply is also quite straightforward. The case is a small utility type measuring 8in x 6in x 3in.

The series pass transistor T4 is mounted close to the centre of the rear of the case, so that the assembled case again forms the heatsink. Most of the supply wiring and minor components are supported by a 12-lug section of miniature resistor panel, and to assist readers in duplicating the wiring we show this in an accompanying diagram. But note that the wiring is not at all critical, and could be built up in a variety of possible alternative forms if desired.

A final word on safety: with both supplies, make sure that the mains power cord enters the case through a carefully deburred hole fitted with a grommet. It should be firmly clamped after entry to prevent strain on the connections, and the earth wire connected reliably to the case.

PARTS LISTS

Simple 5V Supply

1 Case, as required, (see text)
1 Power transformer, 240V to 15V CT at 1A
2 Silicon diodes, BY126/50, EM401 or similar
1 Power supply IC, Fairchild uA7805
1 2000uF 16VW electrolytic capacitor
1 0.22uF 160V mylar capacitor
3 x Output terminals, mains cord and plug, etc.

Variable 3.5A Supply

1 Case, as required (see text)
1 Power transformer, 240V to 12.6V CT at 4A
1 2-in meter, 0-1mA, type VT3 or similar
2 DPDT miniature toggle switch
1 6V/50mA miniature pilot assembly
3 Output terminals, red/green/black

SEMICONDUCTORS
2 1N4998 or similar automotive silicon diode
1 BZY88/C6V2, AN753 or similar 6V zener
2 BC108, 2N3565 or similar NPN silicon
1 TT800 or similar PNP silicon
1 2N3055 or similar NPN silicon

RESISTORS
3 x 0.68 ohm ½ watt, 3 x 68 ohm ½ watt, 1 x 100 ohm ½ watt, 3 x 470 ohm ½ watt, 3 x 1k ½ watt, 1 x 18k ½ watt, 1 x 22k ½ watt, 1 x 470 ohm linear pot

CAPACITORS
1 01uF ceramic
1 100uF 10VW electrolytic
1 10mF 16VW electrolytic (10,000uF)

MISCELLANEOUS
Mains cord and plug, clamp for cord, grommet, 3-lug section of "B-B" terminal strip for mains terminations, 12-lug section of miniature resistor panel, scrap of brass sheet for clamping the reservoir electro, knob for voltage control, connecting wire, solder, etc.

P.A. AMPLIFIER POWER SUPPLY

Here is a useful 12 volt regulated power supply, suitable for use with battery operated amplifiers and portable equipment. With extremely low ripple output the unit is eminently suitable as a low voltage, high current bench supply.

We want to stress, at the outset, that the supply is being presented as a general purpose 12 volt unit suitable for many applications.

Readers may ask what point there is in making an amplifier specifically for battery operation and then running it from the mains. Well it's not quite such a paradox as might first be thought.

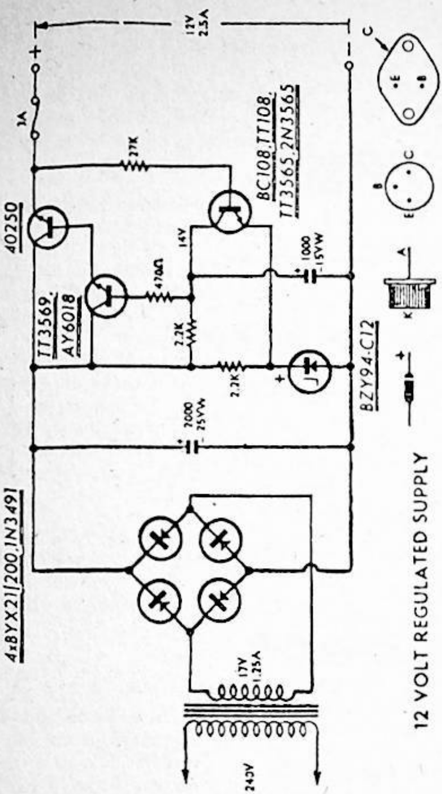
For a public address amplifier to have complete utility it must be capable of operating in all situations. Unavoidably there will be situations when it will be just as difficult to operate the amplifier, indoors, from a battery, as it would be outdoors from a mains supply. Anybody who has carried a 12 volt accumulator, of the type used in cars and boats, would not relish the thought of having to carry such a battery to supply an amplifier when a mains source was available.

The 12 volt power supply presently described will add greatly to the usefulness of any battery operated amplifier. Also, it would be perfectly satisfactory as a 12 volt bench supply having excellent regulation and only a few millivolts of ripple output. A typical use would be as a bench power supply for testing transistor type car radios.

Necessarily, certain limitations of price and complexity had to be set in order that the supply would be economically practicable. Usually the most expensive items in any low voltage high current mains operated supply are the power transformer, series regulating transistor and the filtering electrolytics. In addition there are the rectifying diodes, the exact number depending upon the configuration used. The rectifying configuration, in turn, is dependent upon the transformer which is selected.

Any advantage obtained by the use of only two diodes with a centre-tapped transformer in a full wave configuration might be outweighed by the necessarily more expensive transformer. However, this is not entirely the reason for having selected the particular transformer which we used.

The problem was largely the non-existence of an ex-stock transformer, centre tapped or not, suitable for a 12 volt regulated supply of modest current capacity. Transformers delivering the required volume had either inadequate current ratings or else, having more than necessary current ratings, were far too expensive.



The circuit diagram of the power supply. Note that the specified output current rating is only an intermittant rating, as the transformer is rated at 1.25A. Details of the supply rating are given in text.

The transformer which we decided on delivers 17 volts and is rated 1.25 amps. It has a single untapped secondary winding which necessitates the use of a full-wave bridge rectifier.

The diodes we selected are automotive types, used as rectifiers for the output of automotive alternators. They have a maximum voltage rating of 100, and are capable of about 20 amps continuous current. Although these specifications might seem extravagant in this application, these diodes are really about the most economical devices currently available.

It should be noted that these diodes are available in a reversed polarity version, which are designated with an "R" in the type number. If such diodes are used, it is only necessary to reverse the connection as given in the base diagrams on the circuit diagram. The case becomes the anode and the pigtail becomes the cathode connection. Two polarity versions are necessary because of the two polarity conventions in automotive electrical systems.

The current rating on the transformer will limit the continuous RMS current capability of the supply output to around 1 amp. However, for a short duration the transformer will sustain a much heavier load, consistent with the required regulation. If the overload is excessive, the voltage delivered to the series transistor regulator will fall below 12 volts, well outside the control range of the regulator.

After rectification and filtering, the unloaded voltage available to the input of the regulator is around 25 volts. At the maximum continuous rating of 1.25 amps the voltage will fall to about 18 volts, while, for the maximum peak amplifier load of about 4 amps, this voltage will be 12 volts.

Thus, under maximum amplifier load conditions, the power supply will no longer be transistor regulated, but will exhibit the approximate regulation of the basic DC source. However, this limitation does not mean that a 30-watt amplifier will not deliver rated power.

Provided that the amplifier has sufficient capacitance across the voltage terminals, it will deliver the rated "music" or dynamic power.

What is music power?

Quite often commercial amplifiers are given a music power rating which, in effect, is a measure of the power supply regulation of the particular amplifier. A quantitative definition of the dynamic power rating has been formulated. This states, according to the NAB standard, that the dynamic power is that which can be delivered continuously for a period of 10mS.

For our measurement of the dynamic power, delivered by the 30-watt amplifier when used with the mains supply, we used a tone burst gate. For the specified 10mS burst, we fed an 800Hz sine wave to the tone burst gate and set it to deliver 8 cycles.

Under these conditions we found that, in addition to the 2000uF electrolytic in the amplifier, we needed a 1000uF capacitor across the 2N3565 voltage amplifier in the power supply. With the addition, the power supply allows our 30W amplifier to deliver a dynamic power of 30 watts.

The circuitry of the mains supply is straight forward, and typical of most simple regulated power supplies. For the series regulating transistor, the heart of all such supplies, we have selected an economical silicon power transistor, with a collector current rating of 4 amps, capable of dissipating 29 watts at 25 deg. C, case temperature.

The ratings of the 40250 regulating transistor may suit those readers who might desire to equip the supply with a more robust power transformer for use with heavier loads. If such an application is envisaged, say for bench use, a more efficient heat sink will almost certainly be required.

A second transistor is used as a current amplifier, in a Darlington configuration, for the base current of the series regulator. The two transistors in such a configuration may be regarded as a single, composite, transistor having a current gain (beta) equal to the product of the two individual gains. Hence, a smaller load is placed on the voltage amplifier making for improved output voltage regulation.

A zener diode in the emitter of the voltage amplifier transistor forms the basis of the voltage reference circuitry, together with the BC108 voltage amplifier. The supply output voltage is compared directly with the zener reference voltage plus the forward biased diode voltage drop between base and emitter of the amplifying transistor.

Changes of output voltage, due to loading, produce a corresponding change of base current in the voltage amplifier. This error signal is then amplified and transmitted to the Darlington coupled current amplifier which, through the series regulator, adjusts the output voltage to almost its original value.

Some control of the actual output voltage can be exercised with this particular configuration. A change in the value of the 27K resistor from the output to the base of the voltage amplifier will produce a corresponding change in the output voltage.

The actual voltage supplied to the amplifier proper will usually be something like 11.25 volts, depending upon the current through the diode.

The ripple voltage, at the output of the supply, is very small even by "hi-fi" standards, being only 5mV at 2 amps. Significant dynamic filtering is afforded by the series regulating pair effectively multiplying the value of the 1000uF capacitor by a factor approximately equal to their composite current gain. So far as ripple is concerned, the effective capacitance at the output would be 1 farad!

Our prototype supply was housed in a small mild steel box. It was necessary to construct the supply on a small sub-chassis made from 16-gauge aluminium, and bent up to form an "L" shaped bracket.

The box had a small flange around the open side so that a flat lid could be screwed down. This flange necessarily reduced the size of the opening such that the power transformer could not be inserted, due to the width of the mounting feet, without tilting it to one side.

However, with the transformer attached to a chassis of the same width, and of sufficient length, it was impossible to insert the whole assembly. As a solution, we found that the "L" shaped chassis had to be reduced in width over its entire length, except for a small area at one end where the transformer was mounted. So that in plan, before bending up, the bracket is actually T-shaped.

The series regulator transistor is mounted on the vertical end of the chassis, which forms the heatsink. A small "flag" type heat sink was attached to the TT3569 also. We made this from a small piece of light guage brass, 2in long and 1in wide. A cut was made to halfway along the length of the rectangle, making a strip about 1in long and 3-8in wide which was rolled into a circular clamp, to fit tightly over the transistor's metal case.

The flag heat sink was soldered to the miniature resistor panel which is used to mount the smaller components. The miniature resistor panel was then screwed to the vertical section of the chassis-cum-heatsink.

The four automotive diodes in the bridge rectifier are wired between two six-lug tag strips. Because the diodes are made with only one pigtail for mounting in a socketed heatsink, we had to solder an additional lead directly to the case.

With the chassis assembly complete and inserted in the box, the fuse-holder, mains terminal block, and output terminals may be fitted. The chassis is held in place by the two transformer mounting screws. Four self-tapping screws, retaining the lid, complete the unit.

PARTS LIST

1 Metal box with lid, 7in x 4in x 4in
1 Transformer, 240 volts to 17 volts at 1.25 amps.
2 Terminals, one red, one black.

DIODES
4 BYX21/200, IN3491, RS276-1041, or similar.
1 BZY94-C12 or similar.

TRANSISTORS
1 40250, BD131, BDX24.
1 TT3569 or AY6018.
1 TT108, BC108, TT3565, 2N3565, RS276-2009 or similar.

RESISTORS
(½-watt 5 per cent.)
1 x 27K, 2 x 2.2K, 1 x 470.

CAPACITORS
1 2000uF 25VW electrolytic.
1 1000uF 15VW electrolytic.

MISCELLANEOUS
Miniature resistor panel, two six-lug tag strips, plastic terminal block, mains cord and plug, 3 amp fuse and holder, grommet for mains cord, scrap brass, nuts, bolts and self-tapping screws, connecting wire, solder, etc.

POWER SUPPLIES FOR TRANSISTORS AND PORTABLES

Described here are four voltage-regulated power supplies which connect to the AC mains and deliver smooth low voltage DC for the operation of transistorised equipment, relays, models, etc. All four supplies employ a simple but highly effective overload protection system, which makes them ideally suited for test-bench and experimental use. Details are also given for a dual power supply of the type required to operate 1.4-volt battery valve receivers from the mains.

Transistors are essentially low-voltage devices, and a great deal of transistorised equipment operates from 6 or 9 volts. This is very convenient where battery operation is required, as dry cells and accumulators alike are essentially low-voltage sources.

Where transistorised equipment must be powered from the AC power mains, however, the procedures which must be adopted are somewhat different from those used in AC operated thermionic valve equipment. A simple rectifier-and-passive filter combination is rarely adequate for transistor power supplies, and virtually useless for high current applications.

It becomes necessary to employ "active" regulation and filtering circuitry in the power supply, to supply the equipment with voltage which remains ripple-free and constant over the range of currents involved. "Active" here implies regulation and filtering circuitry using amplifying or control devices, such as transistors, silicon controlled rectifiers and zener diodes.

The regulation and filtering system used in the first four power supplies described in this chapter uses a single transistor and zener diode combination. The zener diode is used as a source of reference voltage, used to control the conduction of the transistor. The latter is connected in series with the load circuit and is effectively connected as an emitter-follower DC amplifier.

Figure 1 shows the circuit of the first supply to be described, a unit which has an output of 9 volts and will deliver up to 85 milliamps (approx.) before it ceases to deliver regulated and filtered voltage.

The level of AC ripple superimposed upon the DC output is very low. The prototype supply has less than 0.3mV ripple output over the regulation range. The rectifier circuit uses two low-voltage silicon power diodes in a voltage-doubling circuit. The zener diode is fed with well-filtered current from the rectifier output, and thus develops a constant and ripple-free reference voltage at the transistor base. The transistor acts to produce a close replica of this voltage across the output terminals and any load which is connected between them.

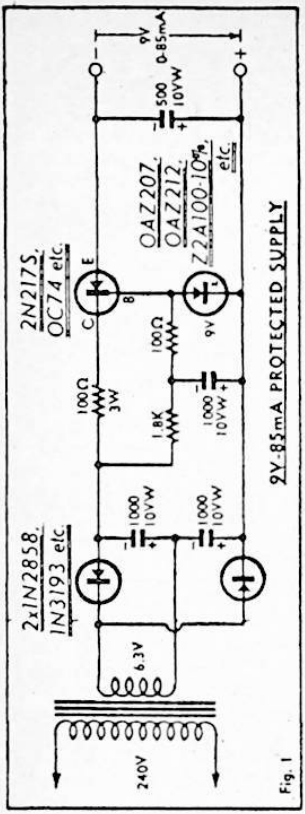


Fig. 1

9V-85mA PROTECTED SUPPLY

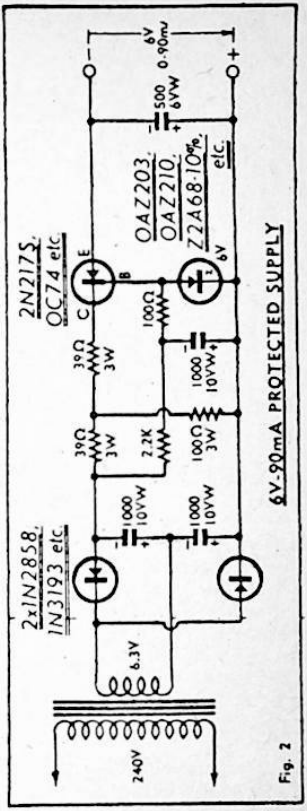


Fig. 2

6V-90mA PROTECTED SUPPLY

The 100ohm 3W resistor connected in series with the transistor collector protects it from damage due to overload. When the current rises the voltage drop of the resistor increases, so that the transistor is always kept well within its dissipation rating.

So effective is this overload protection that neither momentary nor prolonged short-circuiting of the output will cause the power supply any embarrassment. After an initial current surge due to the 500uF output capacitor discharging, the supply will simply deliver a steady current of about 150mA into the short-circuit.

The supply of figure 2 is very similar to the first, but is arranged to deliver 6 volts – the output voltage is regulated up to approximately 90mA. As with the first supply the output ripple is very low, being less than 0.5mV over the regulation range.

Apart from the use of a different zener diode and diode supply resistor, the second supply differs from the first only in the exact method of protecting the transistor. In addition to the series resistor there is a divider circuit to reduce the voltage fed to the transistor at low and medium current levels. This maintains the transistor dissipation to approximately the same level as that of the transistor in the first circuit.

Figures 3 and 4 give the circuits of the other two transistor supplies. These are more suited to high-power equipment than the first two designs, being able to deliver up to 1 amp continuously at 9V or 6V respectively. Ripple output of both designs is less than 10mV for 1A output current, falling rapidly as the current falls. The regulation is quite good, in both cases the effective DC resistance over the regulation range being approximately 0.4 ohms. The AC impedance is effectively that of the 500-uF capacitor, and surge currents of many amps may be drawn from these supplies.

The regulation circuitry of the two higher-powered supplies is very similar to that of the first two. The transistor used is a higher power type than before and the zener diode is run at a higher current level to maintain regulation for the higher base currents involved, but otherwise the circuit is the same.

Protection is provided in these designs not by series resistors or dividers but by a second transistor arranged as a current limiter. Forward bias is applied to this transistor at its base by the resistor connecting to the negative output terminal, being fixed in level and temperature stabilised by the forward-biased diode. For normal load currents this bias keeps the limiting transistor saturated or "bottomed" at a very low resistance.

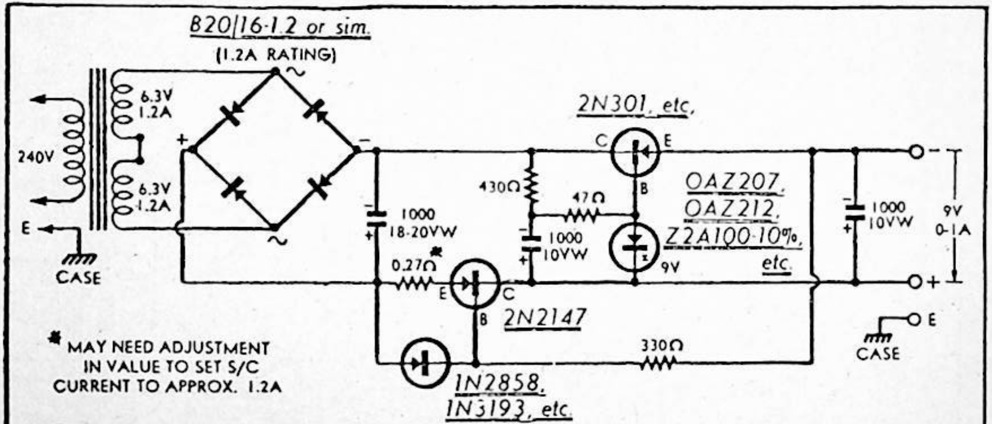
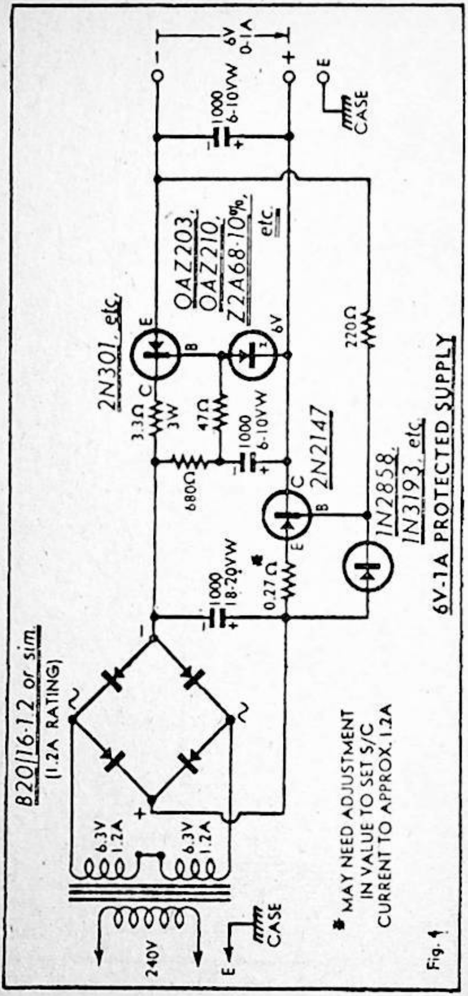


Fig. 3 9V-1A PROTECTED SUPPLY



6V-1A PROTECTED SUPPLY

Fig. 4

A small resistor connected in series with the emitter develops a voltage drop due to load current which opposes the forward bias at the base. When the load current rises sufficiently, the bias is cancelled and the transistor ceases to conduct. Like a switch, it "opens up" and prevents further current from flowing.

The action of this protection circuit is most effective. The limiting transistor has no effect for currents below about 1.1 amp, acting like a very small series resistor in series with the rectifier (before the regulator – it doesn't effect regulation), but above this current level it rapidly increases in resistance. With a short-circuit applied to the output it limits the current to approximately 1.2 amps.

The exact turnoff current depends upon the forward-bias diode, the base and emitter resistors, and the transistor parameters. In practice the easiest way to adjust the circuit to "turn off" at the correct current level is to alter the value of the emitter resistor.

This resistor, which is marked with an asterisk in both circuits, will typically be about 0.27 ohms. If the short-circuit current is greater than 1.25-1.3 amps, increase the value of the resistor, while if the short-circuit is less than 1.15 amps the resistor should be reduced.

It is unlikely that constructors will be able to purchase a variable resistor of this low value, and most will have to use the method of adjustment which we ourselves used. To make small reductions in the size of the resistor, shunt it with progressively smaller resistors (starting at say 33 ohms) until the correct value is reached. On the other hand, if 0.27 ohms proves too small (high turnoff current) replace it with a 0.47 ohm unit and shunt this down with parallel resistors as before.

As may be seen, the higher-power supplies use a full-wave selenium bridge unit as the rectifier. The rectifier specified on the circuits is a small 1.2 amp unit which is very well suited to the demands of this type of supply.

The 6V and 9V versions of the higher-power design are very similar, and apart from zener diode and resistor value differences, the only difference is that the 6V unit has an additional resistor to keep the regulator transistor dissipation low at medium current levels.

The circuit shown in figure 5 is that of a dual power supply suitable for the operation of old-type portable radios and other equipment using 1.4 volt battery valves. The reason for its inclusion in this chapter is that the basic regulation and filter circuit used in the transistor supplies has been adapted to supply the filtered 1.4 volts required by the filaments of such battery valves.

To develop a reference voltage close to 1.4 volts we have used three forward-biased silicon rectifier diodes, as zener diodes with this breakdown voltage are not commonly available. The silicon diodes are quite satisfactory in this mode of operation, the only catch being that the actual voltage developed by three in series will depend upon the particular diodes.

Because of this, and because battery valves are rather critical with regard to their filament voltage, we have used an additional transistor as an emitter follower. A 100 ohm slider potentiometer in its emitter circuit allows the exact output voltage of the supply to be set to 1.4 volts under load.

The emitter follower stage has been used to act as a buffer between the diodes and the varying load presented by the base of the regulator transistor. This provides quite good output regulation for relatively modest diode and emitter follower currents.

An AC128 or AS128 transistor is used as the actual regulator transistor, as these types have an emitter current rating of 1A despite their small size and modest cost. Note that small class-B output transistors of the OC74 variety are not suitable in this position, although they are quite suitable for the reference emitter follower.

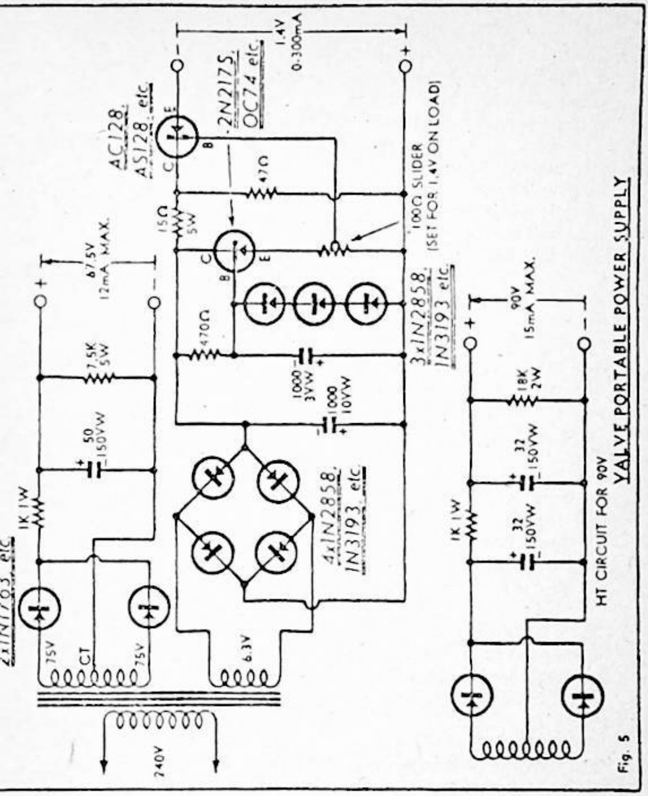
The HT supply circuit is quite conventional, using two 400-volt (P.I.V.) silicon diodes in a full-wave circuit. We have shown alternative circuits, one to deliver approximately 90V and the other to deliver approximately 67V. The version of the circuit to be used will depend upon the particular battery set concerned. The available current should be adequate for all 4-valve and 5-valve portables, and similar equipment.

Before we pass to a brief description of the mechanical construction of the five supplies it should be noted that forward-biased low-voltage silicon diodes (as used in the last circuit) may be used to "pad up" the voltage of zener diodes which are at the low end of the tolerance range.

Thus there is a simple and cheap way of increasing the output voltage of any of the first four supplies described, if the output voltage proves to be lower than expected due to a "low" zener diode. Simply add a forward-biased silicon diode (type 1N2858, 1N3193, etc) in series with the zener diode, and the output will rise by about 0.5V.

This technique may be used in just about all zener diode applications, not just in the power supplies described in this chapter. It can save you quite a bit, as most zener diodes are considerably more expensive than low-voltage silicon diodes. Figure 6 should make the idea quite clear.

Now for a few words on the construction of the supplies. All five supplies are built into the small "biscuit-tin lid" case which measures 6½in by 4½in by 2in.



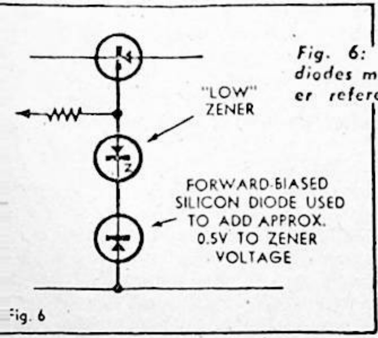


Fig. 6: Showing how "low" zener diodes may be used to provide a higher reference voltage with a silicon diode.

CHASSIS

The lid of the case forms the "chassis" in all the supplies. In the two low-power supplies, four miniature 7-lug tagstrips support the minor components. The transistor is fitted into a small heat sink clip which is clamped under one of the power transformer mounting screws. The actual wiring is not critical.

The two 1-amp supplies are laid out somewhat differently. A small bracket bent up from 16G aluminium supports the two power transistors and the bridge rectifier, and together with the rest of the case acts as a heat sink for the transistors. The main surface of the bracket measures 3¼in by 1¾in, with the mounting and rectifier support flanges ¾in wide.

Two miniature 5-lug tagstrips support the minor components, and the wiring is no more crowded nor critical than that of the lower-power supplies. The power transistors must be insulated from the mounting bracket by mica washers, and the insulation should be checked with an ohm-meter before they are wired into circuit. Note that the 9-volt unit shown had a forward-biased silicon diode fitted in series with the zener, to bring the output voltage to just over 9 volts (this zener was low).

In all four transistor supplies we have kept both sides of the output floating with respect to earth, so that they will be suitable for use with all types of equipment. With the 1A supplies we have also provided an earthed output terminal, to allow convenient earthing of either polarity (or an artificial "centre-tap") if this is desired.

There is no reason why the third terminal could not be added to the lower-power supplies, if it is thought desirable. Make sure that the terminals used are insulated types, incidentally, or you might find that one (or both!) sides of the supply are earthed whether you like it or not.

The valve portable power supply unit is very similar in construction to the lower-power transistor supplies. The 75 0-75V midget power transformer is virtually identical in size to the twin 6.3V filament transformer used in the other supplies and apart from a few more minor components the wiring is no more crowded.

As with the lower-power transistor supplies the minor parts are supported by four miniature 7-lug tagstrips. The two transistors are mounted in heat sink clips which are clamped under two of the tag-strip mounting screws.

All five supplies should operate correctly from the moment of switching on, and should give many years of trouble-free service. The only initial adjustments which may be required are adjustment of the slider pot in the last circuit to give the correct 1.4V, adjustment of the current limiting transistor's emitter resistor in the 1A supplies to give approximately 1.2A short-circuit current, or the possible addition of a forward-biased silicon diode to any of the transistor supplies should they give a low ou

EQUIVALENT SEMICONDUCTORS USED IN THIS CHAPTER

IN2858 = IN3193, BX127, IN4003, IS101
2N2175 = OC74; RS276-2005, MPS3639, 2N2944-2945, RS276-2005
OAZ207 = OAZ212, Z2A100
OAZ203 = OAZ210, Z2A68
2N301 = RS276-2006; AD131-138/50, 2N2836-2869-3611
2N2147 = RS276-2006, AD149-167, 2N1907-2832
IN1763 = BY114-126-127, IN4004
AC128 = AS128; AC117R-153VI-180, NKT302, SFT232, 2N659-1373-1384-2430, 2SD96, SK3010, RS276-2005

PARTS LIST FOR LOW-POWER UNITS
(9V unit wiring at right)

1 Small "biscuit-tin-lid" case, 6½in x 4½in x 2in.
1 Filament transformer, 240V to 6.3V at 0.5A.
2 Silicon diodes, type 1N2858, 1N3193 or similar.
1 Medium power transistor, type 2N217S, OC74 or similar.
1 Zener diode. For 9V supply, type OAZ207, OAZ212, Z2A100-10% or similar; for 6V supply, type OAZ203, OAZ210, Z2A68-10% or similar.
3 1000uF 10VW electrolytic capacitors.
1 500uF 10VW (9V) or 6VW (6V) electrolytic.
1 100-ohm ¼ watt resistor.
1 100-ohm 3 watt resistor.
1 1800-ohm ½ watt resistor (9V only).
1 2200 ohm ½ watt resistor (6V only).
2 39-ohm 3-watt resistors (6V only).
2 Terminals, one red and one black; four 7-lug miniature tagstrips; mains cord and plug; screws, nuts and star washers; grommet for mains cord; connecting wire, solder, self-tapping screws for case, heat sink clip for transistor, etc.

PARTS LIST FOR HIGH-POWER UNITS

1 Small "biscuit-tin-lid" case, 6½in x 4½in x 2in.
1 Filament transformer, 240V to 6.3V-plus-6.3V at 1.2A.
1 Selenium Bridge rectifier, type B20/16-1.2 or similar.
1 Power transistor, type 2N301 or similar.
1 High-gain power transistor, type 2N2147 or similar.
1 Low-voltage silicon diode, type 1N2858, 1N3193 or similar.
1 Zener diode. For 9V supply, type QAZ207, OAZ212, Z2A100-10% or similar; for 6V supply, type OAZ203, OAZ210, Z2A68-10% or similar.
1 1000uF 18-20VW electrolytic capacitor.
2 1000uF 10VW (9V) or 6-10VW (6V) electrolytics.
1 47-ohm ½ watt resistor.
1 0.27-ohm ½ watt resistor.
1 430-ohm ½ watt resistor (9V only).
1 680-ohm ½ watt resistor (6V only).
1 330-ohm ½ watt resistor (9V only).
1 220-ohm ½ watt resistor (6V only).
1 3.3-ohm 3 watt resistor (6V only).
3 terminals, one red and two black; two 5-lug miniature tagstrips; small piece of 16G aluminium sheet to make transistor and rectifier bracket (see text); mica washers for power transistors; small 2-connector section of "B-B" connector strip for mains termination; mains cord and plug; grommet for mains cord; heat sink clip for zener diode; connecting wire, solder, self-tapping screws for case, etc.

PARTS LIST FOR THE DUAL SUPPLY
For valve portables

1 Small "biscuit-tin-lid" case, 6½in x 4½in x 2in.
1 Small power transformer, 240V to 150V-CT at 20-30mA with 6.3V at 1A.
2 Silicon diodes, type 1N1763 or similar.
7 Low-voltage silicon diodes, type 1N2858, 1N3193 or similar.
1 Medium-power transistor, type 2N2175, OC74 or similar.
1 Medium-power transistor with high emitter current rating, type AC128 or AS128.
1 50uF 150VW electrolytic capacitor (67V version), or
2 32uF 150VW electrolytics (90V version).
1 1000uF 10VW electrolytic.
1 1000uF 3VW electrolytic.
1 100-ohm slider pot.
1 15-ohm 5 watt resistor.
1 47-ohm ½ watt resistor.
1 470-ohm ½ watt resistor.
1 1000-ohm 1 watt resistor.
1 7.5K 5 watt resistor (67V).
1 18K 2 watt resistor (90V).
4 terminals, two red and two black; four 7-lug miniature tagstrips; small 2-connector of "B-B" connector strip for mains termination; mains cord and plug; grommet for mains cord; heat sink clips for two transistors; connecting wire, solder, self-tapping screws for case, etc.

SIMPLE DUAL POWER SUPPLY FOR OP AMPS

Thinking of experimenting with some of the low cost op amps that are now readily available? If so you can probably use this simple dual-polarity power supply, designed especially for the job. It uses very few parts, and can be built at low cost.

Now that linear circuitry such as audio amplifiers, modulators, active filters, comparators and many others is tending increasingly towards the use of integrated-circuit units rather than individual transistors and discrete components, the experimenter and circuit applications engineer begins to have a real need for a simple power supply unit which is specifically designed to feed such ICs, as a stable replacement for batteries. The rapdily-increasing use of the so-called Operational Amplifier or "Op Amp" in particular calls for specific voltage, current, regulation and hum requirements which, while they fall ideally within the province of battery supply, can nevertheless be met by a mains-operated unit with the added advantages of low running cost, stability and reliability.

The circuit described here has been designed to power up to six or seven operational amplifiers simultaneously, and is believed to meet these requirements. Additionally, it can easily be adapted to supply much higher currents at a higher voltage – sufficient to supply, for example, Class B amplifier output stages of ten to fifteen watts whose earlier stages can also be supplied from the unit, whether or not they use operational amplifiers. It can thus be regarded as a fairly flexible arrangement, despite its simplicity.

The typical operational amplifier now freely and cheaply available, such as the uA709 and uA741, normally requires both positive and negative power supplies. The usual voltage for each supply is 15 volts, though lower voltages can often be used for certain applications. However, lower voltages in general only restrict performance so there is little point in providing for them. Therefore, in this design no provision has been made to continuously vary the output voltages.

Some linear integrated circuits may be met for which unequal positive and negative supplies are specified, eg. plus 15V and minus 6V. A simple addition can be made to cater for this, as will be described.

Close regulation of the output voltage against changing load or varying mains voltage is regarded as essential for this work and has the added important property of keeping down the effective impedance of the supply unit as seen by the circuits being supplied. The present design has load regulation so good that it is almost impossible to measure with normal volt-meters. The change of output voltage from zero load to full load is no more than the thickness of the meter's pointer.

The total drain at either positive or negative terminal of an operational amplifier will not normally exceed 5 milliamps, and may be much less. Therefore the present design, which can supply up to 35 milliamps on each side, should take care of circuits using up to six or seven op-amps simultaneously without exceeding the safe load limits of the transistors employed and without need for heat-sinks.

The residual hum level which can be tolerated depends upon the type of circuit being supplied and upon its effective gain and bandwidth. The intrinsic gain of an op-amp is very high indeed and in practical circuits is always heavily reduced by negative feedback. Even so, gains of as much as 1000 times can easily be obtained from a single uA709 and can sometimes be usefully employed; in such a case low hum from the power supply is essential. Experiment suggests that a residual hum of one millivolt is satisfactory in most cases and the present design as it stands meets this requirement. If lower hum is desired it can easily be obtained at little extra cost, as later described.

To meet the requirements, therefore, the needed specification is:

Input: 230/240 volts, 1 Amp. (see text)
Outputs: Plus and minus 15 volts at 35 milliamps max.
Hum: Less than 1 millivolt RMS at full load; (proportionally less on lighter loads).
Regulation, no load to full load: Better than 0.1 pc
The design meets these demands.

As may be seen from the diagram, the two sides of the circuit are identical except for the transistors. The centre-tapped power transformer secondary winding supplies 15 + 15 volts to two full-wave rectifier circuits for the positive and negative supplies, using silicon rectifiers D1, 2, 3 and 4. These were type 1N4002 in the prototype but any 1 amp rectifier of peak inverse voltage 100 or more can be used. C1 and C2 provide sufficient smoothing, but can be increased in capacity if thought necessary, as discussed later.

The transistors used are inexpensive complementary types, with a safe dissipation of 0:5 Watt in free air at 25C ambient temperature. As the normal full-load dissipation in this circuit does not exceed 0.25 Watt there is a good safety margin. Type AY6108 is an NPN type and AY6109 a PNP; their characteristics are otherwise similar and both are of silicon planar construction with correspondingly good temperature leakage and drift characteristics. If desired, AY6108 can be replaced by the 2N2219, and AY6109 by the 2N2905. These all have very similar characteristics.

Looking at the positive side of the circuit, Tr1 is a series-type regulator through which the whole of the regulated output current flows. This current flow is controlled by the voltage applied to Tr1 base, and this in turn is controlled by Tr2 through the voltage-drop across R1. Tr2 base is biased by the voltage drop across R5, due to the current through the 15-volt reference zener diode D5. If this diode current varies due to a change in load at the 15 volt output terminal, the voltage across R5 also varies and this change is amplified by Tr2. Its collector current therefore changes and alters the voltage drop across R1 in such a sense as to bias Tr1 in the proper direction to increase or decrease its emitter current as required by the changed output load. The output voltage, being determined by the zener diode, meanwhile remains almost unchanged. The negative side of the circuit behaves similarly but the positive and negative supplies react independently to load changes. C7 and C8 are ceramic discs serving as RF bypasses for stability.

The unit could, of course, be used as a single-sided supply of 30 volts of either polarity by disregarding the zero terminal and making the appropriate 15-volt terminal "earthy", but the need for this may seldom arise. The most likely case is where an op-amp is being used as an AC-coupled amplifier. It is possible in this case to work with a positive supply only, the negative supply terminal of the op-amp being grounded, but this requires extra components in the op-amp circuit. It seems simpler and more reliable, in both AC and DC-coupled circuits, to use the op-amp with the standard arrangement of both positive and negative supply lines.

If a lower voltage on either side is needed for a particular op-amp, it can easily be provided by adding a further zener diode of the required voltage, in series with a suitable ½ watt resistor, across the appropriate 15 volt output, as shown dotted. Such an extra output should be limited to a drain of, say, 4 milliamps, which is sufficient for any likely single integrated circuit.

At the collectors of Tr1 and Tr3 there are available positive and negative supplies of approximately 20 volts, fairly well smoothed but not regulated. These can often be used successfully for the Class B output stages of, for example, a pair of stereo amplifiers with outputs of up to 15 watts or so per channel. The permissible average current drain will be controlled mainly by the rectifier diodes and power transformer used; with the suggested transformer a limit of around 1 ampere should be safe. However, in such a case it would be wise to increase C1 and C2 tenfold to around 5000uF, 25VW, and to substitute larger rectifier diodes such as the BY118 or BYZ13 to take care of the heavier surge and ripple currents of these capacitors.

No attempt has been made to incorporate overload current limiting in this design, as this would require more components and much larger transistors with heat sinks for Tr1 and Tr3. However, breakdowns causing serious overloads seem to be extremely rare in integrated circuits. Of course accidental short-circuits of the power supply should be guarded against – transistors are unforgiving creatures!

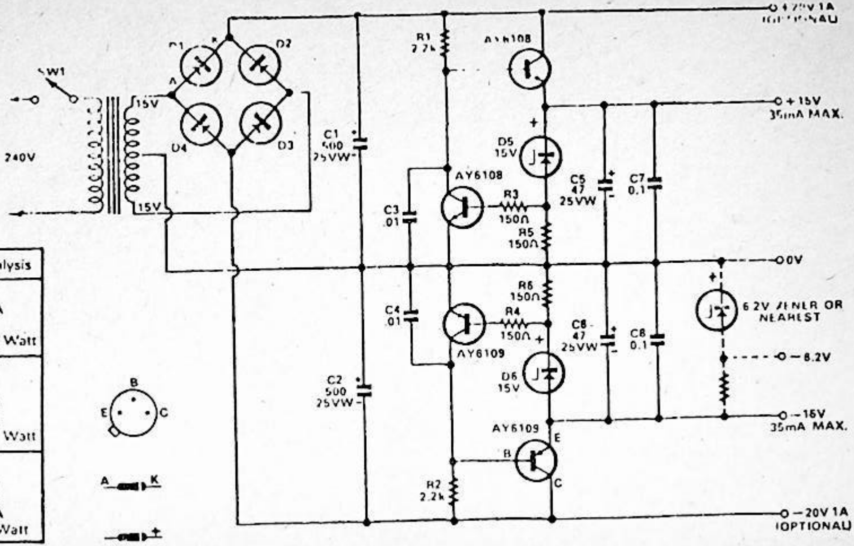


TABLE 1 Voltage and current analysis	
Zener diode	
Current	4.2mA
Voltage	15V
Dissipation	0.063 Watt
Tr1 / Tr3	
Voltage, collector to emitter,	7V
Voltage base to emitter,	0.55V
Collector current	32mA
Dissipation	0.214 Watt
Tr2 / Tr4	
Voltage, collector to emitter,	16.5V
do base to emitter,	0.62V
Collector current	2.5mA
Dissipation	0.04 Watt

NOVEL REGULATOR CONFIGURATION is used in both sides of the supply, to give very stable output despite the few components used. The power transformer may be a low current type if the 1A outputs are not required.

A filament transformer was used in the prototype and this has a 30 volt secondary with several tappings, including one at 15 volts which becomes the centre-tap in the present design, the rest being unused. The current rating is 1 ampere, making it much larger than is needed if the unit is to be used only for IC's, but it becomes quite suitable if the 20 volt 1 amp outputs are to be used. The excess size has no electrical drawback and can only improve the regulation.

There is nothing critical about the construction, and a fairly small piece of Veroboard of 0.15 inch matrix will accommodate everything except the transformer. It is quite practicable to mount the circuit board onto the transformer itself, without using a case, but keeping the transistors at a reasonable distance from the heat of the transformer. A tag-strip with screw terminals, or a strip carrying sockets for banana-plugs, is convenient for the output connections. A metal case, earthed through a 3-core flex, is neater and would allow the fitting of the ON-OFF switch Sw1, which otherwise is inconvenient.

Table 1 gives a voltage and current analysis to assist in trouble-shooting. This applies to the Fairchild transistors but should be reasonably accurate for the Motorola types also.

A final caution – DO remember to switch off the power supply unit before doing any work on the circuit which it is supplying!

PARTS LIST

RESISTORS
½ watt, 5 pc
R1/2 2.2k
R3, R4, R5, R6, 150 ohms

CAPACITORS
C1/C2 500 uF 25VW electrolytic
C3/C4 .047 uF Mylar or paper, 100VW or higher
C5/C6 47 uF, 25VW electrolytic
C7/C8 0.1uF ceramic disc, 20VW or higher

SEMICONDUCTORS
Tr1/Tr2 AY6108 or 2N2219, BCW78/16, BSW52, BSY34, 2N697-698
Tr3/Tr4 AY6109 or 2N2905, BCW80/16, SK3025, RS276-2021
D1, D2, D3, D4 1N4002, BY127, EM502, RS276-1102, 1136, IS100 or larger (see text)
D5, D6 zener diodes, 15 volts, 400 mW

MISCELLANEOUS
Transformer, 230/240 Primary, 15-0-15V Secondary, Sw1, single or double-pole ON-OFF switch, Veroboard or tag-strips, wire, machine-screws and nuts, case if used, plugs and sockets if used.

6V to 12V CONVERTER

Here is an ingenious DC-DC converter circuit which doubles its battery input voltage and does not require any diodes to rectify its output. It can be used to power 12V car radios and stereo cartridge players from a 6V battery.

While the number of cars with 6V batteries is now a minority and confined to Volkswagens five years old or more, we still have readers who write for just such an inverter circuit. And we felt the circuit was unusual enough to be of general interest. Readers will undoubtedly find other applications for the idea.

We can't claim that the novel circuit used is original, it is of Japanese origin.

Refer now to the simplified circuit in Fig 1. It shows the converter as consisting basically of two power transistors and a transformer with two centre-tapped windings.

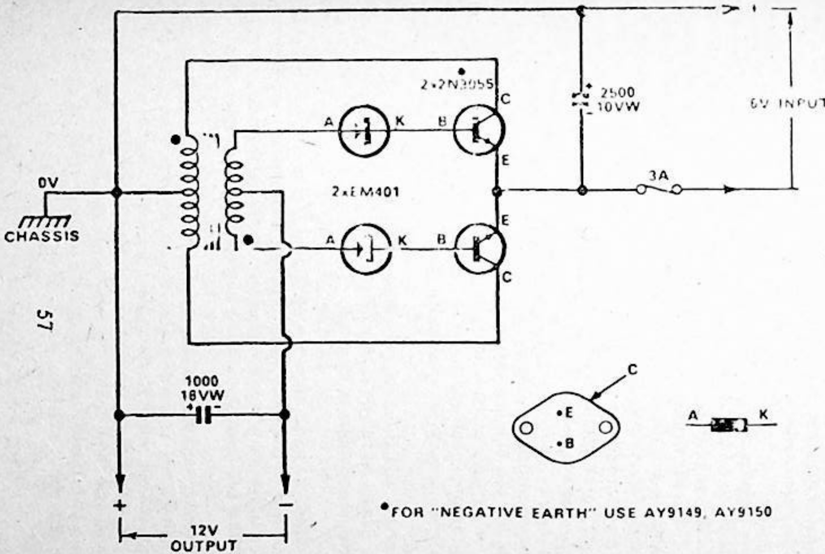
One of the transformer windings has each "leg" connected to a transistor collector while the other winding has each "leg" connected to a transistor base. The transistor emitters are connected together and thence to the minus 6V supply rail from the battery. The centre-tap of the collector winding connects to the positive rail (OV) from the battery while the centre-tap of the base winding becomes the negative output lead (minus 12V). Thus the 12V output is taken from between the two centre-tap connections of the transformer windings.

The mode of operation is as follows: Consider that Tr1 and Tr2 are functioning as a typical transformer coupled multivibrator with both transistors switching alternately between "cut-off" and "saturation". Now consider Tr1 "on" and Tr2 "off". This place minus 6V directly across the Tr1 collector's half winding, so that plus 6V appears across the other half, by transformer action. In total, 12V or double the battery voltage appears across the whole collector winding.

For the purpose of our explanation, we have neglected the small "saturation" voltage from collector to emitter of Tr1 and we will also neglect the base-emitter forward-bias voltages of the transistors.

Now, at the same time as the conduction of Tr1 places 12V across the collector winding, transformer action causes slightly more than 12V to appear across the base winding in the opposite direction, so that the base of Tr2 is minus 12V (approx) with respect to the minus 6V established at the other end by the base of Tr1 (conducting). This means that the centre tap of the base winding is now minus 12V with respect to the 0V line.

6-12V DC CONVERTER



•FOR "NEGATIVE EARTH" USE AY9149, AY9150

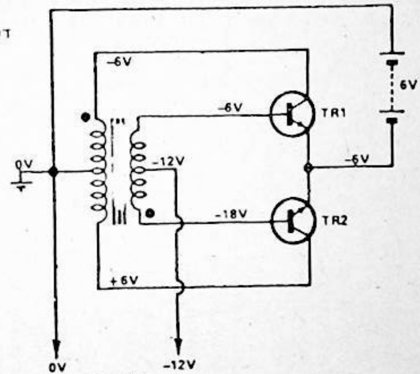


FIG. 1

A simplified circuit of the converter.

When the transistors switch over so that Tr2 conducts, the same process occurs so that the base of Tr1 becomes minus 18V with respect to 0V and again the centre-tap is minus 12V with respect to 0V. This means that while ever the transistors are switching, the centre tap of the base winding is maintained at minus 12V with respect to the positive battery line (0V).

Thus, the transformer's output does not require any rectification. The base current is supplied via the load connected between the two centre-tap connections. Indeed, under normal conditions, the inverter will not function without a load. The transformer's slight "step-up" from collector winding to base winding is to compensate for losses in the transformer and in the transistors.

Referring now to the complete circuit diagram, readers will note that it contains additional components: two silicon diodes and two large electrolytic capacitors. The transistors are the easily available silicon NPN power type 2N3055. The purpose of the capacitors is to provide filtering of the input and output lines so that "switching hash" is heavily attenuated.

Two important functions are served by the diodes connected in series with each transistor base. First, they prevent damage to the transistors which is possible because of the reverse voltage applied to the transistor base (when the transistor is "cut-off") with respect to its emitter. Second, the diodes prevent spurious operation of the converter which is possible when no load is connected – the unit may then run without any apparent base current supply. What apparently happens is that leakage via the reverse-biased transistor is sufficient to enable the other transistor to conduct.

As the circuit stands, with diodes incorporated, it needs a load before it will operate. This is a desirable feature as it means no power is drawn from the battery unless it needs to be. It also means that the unit can be wired into circuit and does not require a power switch – the power switch on the car radio or cartridge player it powers is sufficient.

Minimum load current for reliable operation of the circuit is of the order of 100 milliamps. It may be used at lower currents with somewhat less reliable starting and running.

The prototype transformer has a 6V input, and maximum output current at 12V is about 750mA. At this load, input current is about 1.8A. Heavier loads can be connected but the output voltage drops somewhat and losses in the small transformer core become excessive.

We have incorporated a fuse in the circuit to limit the input current to less than 3 amps. This is to protect the diodes, which are rated at 1 amp each but will in fact withstand more than this for a short period. The fuse also protects the base-emitter junctions of the transistors which are rated at 4 amps. In fact, the ratings off all components in the circuit will not be exceeded provided that the load current does not exceed more than about 800mA.

Note that one side of the output is connected to chassis (of the motor car). As shown, the circuit is suitable for use with cars having a "positive earth" electrical system. At the same time, it must be used with car radios or stereo tape players which also have a "positive earth" chassis.

If the unit is required to operate in a vehicle with a "negative earth" electrical system, the battery polarity is reversed so that the negative electrode connects to chassis. At the same time, several circuit changes must be made. First, the polarity of the diodes and electrolytic capacitors is reversed. Second, PNP transistors are substituted. Suitable PNP silicon power transistors which are reasonably priced are AY9149 or AY9150. These are very robust transistors which have similar ratings to the NPN 2N3055.

Now a few words on the construction. We housed our unit in a diecast case measuring 120 x 95 x 55mm which are available at quite an attractive price. There is no reason, however, why it cannot be housed in smaller case, provided all components fit. Heatsink requirements of the transistors are very modest and the diecast case is more than adequate for the purpose. The main source of heat in the circuit is the transformer, and this does not become overly warm at the maximum recommended load current.

Use mica washers and plastic bushes to mount the transistors so that they are insulated from the case. Since the transistors each dissipate relatively small amounts of power, it is really not necessary to use silicone jelly to improve heat transfer.

Wiring layout is not at all critical and provided solder joints are made properly, the circuit should work without any trouble. Remember that a load must be connected otherwise it will not operate. If it does not operate at first try, swap over the orange leads to the collectors of the transistors.

We found that when the unit is used to power a typical dash-mounting car radio, hash generated by the inverter was not a problem – there was only a very slight buzz from the speaker even when the volume control was at maximum setting. However, if it is used to power a radio or stereo tape player with inadequate internal interference suppression components, audible hash and whine could be a problem.

In this situation, a worthwhile reduction in "hash" and whine can be obtained by connecting an LC network to filter the output of the converter. It consists of an inductor in series with the "hot" output lead and then a shunt capacitor across the output leads of about 500uF, rated at 16V or more.

A suitable inductor can be made as follows: Start by winding a layer or two of plastic insulation tape on a 50mm length of 10mm (approx) ferrite rod. If a full length rod has been purchased it can be cut by filing a groove around the circumference of the rod and then snapping it as if it were glass.

Close wind a layer of SWG 23 enamelled copper wire over the insulation tape, and finally wind insulation tape tightly over the wire to anchor it all. Then tin the ends of the wire prior to soldering.

We used an in-line type of fuseholder but there is no reason why a panel-mounting type cannot be used.

While the primary use of the circuit is to obtain 12V from a 6V battery to run a car radio or tape player, we have no doubt that readers will come up with other applications. It can be used at input voltages of 12V, but losses are higher and heat-sinking of the transistors becomes more stringent.

PARTS LIST

1 diecast box, 120 x 95 x 55mm.
1 inverter transformer, see text.
2 silicon NPN power transistors, 2N3055, AM291, BD130, BDX10, 2N3713 (for "positive earth" version).
2 silicon PNP power transistors, AY9149 or AY9150 (for "negative earth" version).
2 silicon power diodes, EM401,,BA219, BY126/100, EM501, OA626/100, IN4002, or equivalent.
1 1000uF/10VW electrolytic.
1 2500uF/16VW electrolytic.
1 in-line fuseholder.
1 3A fuse.
1 2-pin polarised socket and plug.
2 7-way tagstrips.

MISCELLANEOUS
Mica washers and plastic bushes to mount transistors, solder lugs, hook-up wire, screws, nuts, lockwashers, solder.
NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases, providing the ratings are not exceeded.

MAINS SUPPLY FOR CAR CASSETTE PLAYERS

If you have a cassette or cartridge tape player installed in your car and it is fitted in a cradle for easy removal, then you have no doubt been wanting to use it elsewhere, powered from the normal 240V mains supply. Using this simple supply you can do so, even if your player uses a power consuming solenoid operated mechanism.

Our new power supply has a nominal 12V rating, and can supply a 2A current continually. Up to 5A can be supplied intermittently. The regulation is only modest, but is quite adequate as tape players are designed to operate from a supply which varies from about 11V to 15V.

It is built in a small steel box which acts as a heatsink for the series pass transistor, and also provides some shielding from the magnetic field of the transformer.

As shown in the diagram, we have opted for a very simple circuit. The transformer is rated at 60VA, and has two 15V secondaries, each with a tap at 12V, and rated at 2A each. We have connected them in series and used two diodes to form a fullwave rectifier, using the centre tap. We have opted for this configuration rather than a standard bridge, as it gives only one diode in series with the load, instead of two.

The diodes specified are type 1N5408. These are rated at 1,000V at 3A. However, any silicon diodes with a current rating of 3A or more and a PIV rating of more than 45V would be suitable.

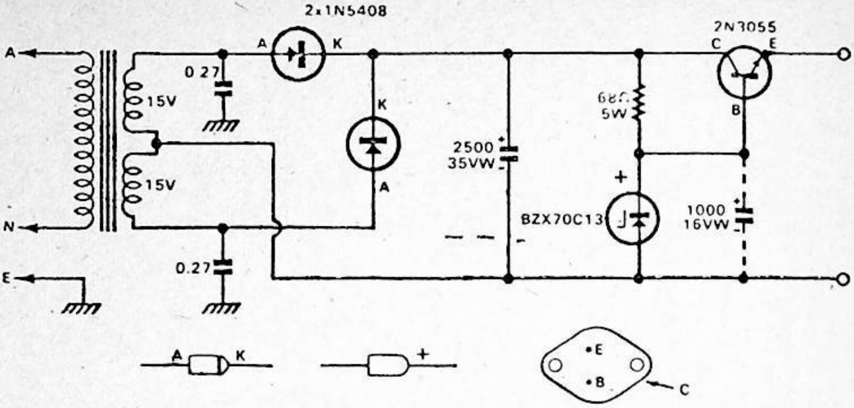
Base current for the 2N3055 series pass transistor is supplied via the 68 ohm 5W resistor. The voltage at the base is regulated by the zener diode, for all values of load current up to 2A. At values of load current above this, the regulation falls off fairly rapidly. Maximum power dissipated in the 2N3055 is of the order of 24W, so fairly good heat-sinking is required. Maximum dissipation occurs at full load and when the supply voltage is at a maximum.

In the interests of simplicity and economy, we have not provided any protection facilities. Sufficient protection for the player unit should be provided by the in-line fuse with which these are usually fitted. If your unit does not have such a fuse, then it would be wise to fit one.

RFI suppression of hash entering from the mains is provided by the 0.47uF ceramic capacitors bypassing the ends of the transformer secondary.

The component shown dotted is a 1000uF electrolytic capacitor. If this is fitted across the zener diode as shown, then the ripple performance of the supply is improved.

Alternatively, it may be fitted across the output terminals. This will improve the short term load regulation of the supply, so that it can withstand short overloads better. This type of overload will occur when some player solenoids operate. However unless your player has an exceptionally heavy current drain, this component should not be necessary.



PLAYER POWER SUPPLY

The circuit for the new supply, which is basically a conventional full-wave rectifier followed by a simple series-pass regulator.

With the 1000uF capacitor fitted across the zener diode, we measured the load regulation as 4% for currents up to 1A and 6% for currents up to 2A. The line regulation was 1%, for variations in the supply voltage of + and -10%. The peak-to-peak ripple at the output was 0.02% at no load, 0.16% at 1A, and 0.32% at 2A. These figures appear more than adequate for most players, and those we have tried with the supply performed in a completely satisfactory manner.

We fitted our supply into a standard steel box, measuring 153 x 86 x 71 mm; As output terminals, we fitted a pair of combination banana plug and screw terminals, one red and one black. If required, a suitable polarised plug and socket could be fitted instead.

The power transistor is mounted on one end of the case, using a plastic mounting socket. It is electrically insulated from the case by a mica washer, but thermally connected using a silicon grease. All other components are mounted on a small section of tag-strip.

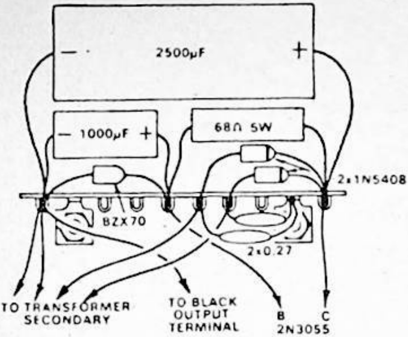
Construction of the supply should not present any difficulties. The mains cord enters through a grommeted hole, and is then clamped to the case. The active and neutral leads terminate at the terminal block, while the earth lead is wrapped and soldered to a lug which is then connected to the case. The most convenient spot is at the cord clamp.

Mount all the small components onto the tag-strip, as well as the required connecting wires, using the diagram as a guide. Ensure that when the tag-strip is fitted into the case, there are no short circuits, particularly to the case. Then fit and mount the socket for the power transistor, as well as the two output terminals.

Pop rivets make an easy and convenient way of fastening the various components to the case. As there is not a great deal of room to spare, it is wise to check first that all components will fit in their correct places, before actually riveting any in place.

The transformer is mounted centrally in the box, leaving sufficient room for the push-on connectors supplied with it. When all components have been fitted, the lid may be attached using self tapping screws. This completes the Player Power Supply, which can now be tested by actually using it.

When in use, remember that the case may become quite warm, particularly when currents approaching 2A are being drawn. So do not place the unit near any heat sensitive objects.



The diagram above is to guide you in wiring the 10-lug tagstrip used to support the basic rectifier components and those associated with the zener diode. Note the polarity of all three diodes, and of the electrolytics.

PARTS LIST

1 steel case, 153 x 86 x 71 mm
1 mains transformer, 30V @ 2A, centre tapped
1 2N3055, AM291, BD130, BDX10, BDY39, 2N3713, SK3027 power transistor, with mounting kit to suit
1 BZX70/C13 Zener diode (13V at 2.5W)
2 1N5408 silicon diodes (3A rating)
1 2500uF 35VW electrolytic capacitor
1 1000uF 16VW electrolytic capacitor
2 0.27uF ceramic capacitors, 25VW
1 68 ohm 5W resistor
1 mains plus, mains cord, grommet and mains cord clamp
1 2-way terminal block
4 rubber feet
2 screw terminals, one red, one black
1 10-lug tag strip, with 2 mounting lugs
Pop rivets, washers, hook-up wire, solder, machine screws and nuts, self tapping screws.
NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with high ratings may generally be used provided they are physically compatible.

POWERPAC – A LOW COST GENERAL-PURPOSE BATTERY ELIMINATOR

Anyone who had a battery-operated record player or cassette recorder knows that battery replacement can become monotonously frequent and downright expensive if the machine is used often. Ideally, the machine should be powered from the AC mains where possible. Here is a low cost mains adaptor which we have called the "powerpac"; it uses only two economy silicon transistors.

Powerpac is a compact, regulated power supply whose output can be set by screwdriver to any voltage between 3 and 12VDC. Maximum current is about 500mA at 12V, with higher currents available at lower settings. Hum and noise output is very low and the unit is protected against accidental short circuits.

Most cassette recorders require a DC supply of between 6V and 9V at up to several hundred milliamps. Normally, this is supplied from the requisite number of "C" size carbon-zinc cells. At the level of current required, the batteries do not last very long at all, especially if the machine is used for long listening or recording sessions.

It was mainly to satisfy the power requirements of these machines that the Powerpac was designed. However it is also suitable for powering transistor radios with DC rails of 3 to 12V, portable (battery operated) record players and automotive cartridge players – although some cartridge players may require heavier current than the Powerpac can supply.

As well as powering the above audio appliances, Powerpac can also be used to provide a 5V rail for digital logic circuitry. The circuit could also be used as the basis for a simple variable power supply with optional metering circuitry added.

As the accompanying regulation curves show, the performance of the prototype Powerpac is quite good considering the circuit simplicity. At 12V, the supply delivers 500mA before coming out of regulation. At the point where regulation stops, the ripple (100Hz) superimposed on the DC increases very rapidly. Voltage change, from no load to full load at 500mA, is 0.35V.

At the 9V setting, the performance improves; regulation ceases at 600mA for a load voltage drop of less than 0.25V. At this current, the 100Hz ripple is only 10mV peak-to-peak, as shown by the curves. More current again can be delivered at the lower voltage settings.

A simple method has been devised to protect the Powerpac from short circuits, by limiting the current into a short circuit to 1.2A. This means that the maximum surge current supplied to a load when first switching on is also 1.2A. While the Powerpac is thus protected against inadvertent short circuits, a short circuit should not be maintained for more than about five minutes, otherwise the Powerpac will become very hot and damage could possibly result.

Since the concept of the Powerpac was to provide a convenient and economical supplement to battery power, we have tried to keep the cost as low as possible while maintaining reliability and good performance. A first step towards this was to select a low cost transformer. It has two 15V windings and a nominal maximum rating of 20VA.

Refer now to the circuit diagram. The two windings of the power transformer are connected in series and two diodes in a full-wave rectifier supply DC to the 2200uF 25VW filter capacitor. With a 240V input to the transformer, the voltage across the filter capacitor at no load is about 23V DC. We could have connected the two windings in parallel and used a bridge rectifier to get much the same result, but we felt the cost of the extra diodes was not justified for the small likely improvement in performance.

Regulation in the Powerpac is obtained by the following mechanism: The 2N3055 silicon power transistor functions as a "voltage-follower", reproducing the voltage at its base (minus 0.7V) at its emitter – which is connected to the output terminal. The base voltage of the 2N3055 is controlled by the BC108, which functions as an "error amplifier"; it compares a portion of the output voltage at its base with the voltage drop across a silicon power diode connected in series with its emitter.

Bias current for the 2N3055 is provided by an RC filter network consisting of a 220uF/25VW capacitor plus a 390 ohm and a 100 ohm resistor. These provide base current filtering and limiting in the case of a short circuit.

If the imput voltage to the regulator rises and/or the load current drops the load voltage will tend to rise. The "error amplifier" transistor senses this rise and begins conducting more heavily thus robbing the 2N3055 of base current and causing it to move towards cut-off until the load voltage is back to the required setting.

Similarly if the load voltage tends to drop, the error amplifier conducts less heavily so that the 2N3055 has more base current and can turn on harder to restore the load voltage to the required value. These fluctuating adjustments will be continuous so that, in practice, the load voltage variations over the operating current range will be small.

Maximum current handled by the error amplifier transistor is of the order of 40mA, at the 3V output setting. This means that a small signal transistor such as a BC108 can be used. However, the maximum power dissipation, which occurs if the output is set to about 11.5V, is about 250mW which means that flag heatsink is required for the BC108. Plastic encapsulated transistors such as the BC148 or BC208 cannot be used as they have a lower dissipation rating than the TO-18 metal encapsulated devices.

Several advantages result from using an ordinary silicon power diode instead of a zener diode to provide the reference voltage for the error amplifier transistor. The first is lower cost; the second is a lower available voltage from the Powerpac. If we used a 3.3V zener diode (the lowest voltage rating currently available), the minimum voltage that we could set the Powerpac to and obtain good regulation would be about 4.5V. With the ordinary diode, on the other hand, we can set the minimum output voltage to below 3V.

Readers will be aware that a varying current will be drawn by the error amplifier, and therefore the reference diode current varies. This means that the reference voltage must vary also and ideally this variation should be minimised by using a reference diode (or zener) with a very sharp "knee" characteristic. This is another way of saying the voltage should not change for varying current. Here again, the advantage tends to lie with the silicon power diode when compared with a zener diode of less than 5 volts.

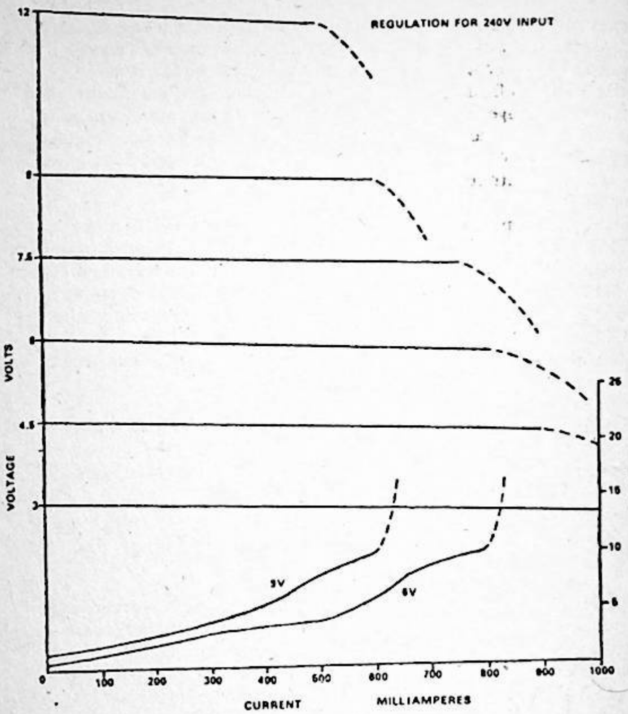
Short-circuit protection is provided by the 12 ohm 10 watt resistor connected in series with the collector of the 2N3055. This is simple and economical and has the advantage that it needs no adjustment.

The resistors in series with the output voltage adjustment potentiometer are selected to give an approximate overall adjstment range of 2.6 to 13V.

Some further points concerning the voltage regulation curves can now be explained. Readers will notice that the voltage current curves are straight and unbroken for the most part and this represents the region in which the supply does regulate the output voltage and ripple is maintained at a low value. Where the curve becomes dotted the regulation ceases and ripple voltage suddenly increases. Note also that the supply regulates up to 500mA at 12V but up to 1 amp at 3V.

This does not mean that a continuous current of 1 amp should be drawn for long periods from the Powerpac, because the transformer is only rated to deliver 700mA continuously. What it does mean is that, at voltages below 7.5V, the Powerpac will deliver a constant voltage for peak currents in excess of 700mA but the average current should not be more than 700mA.

If a more generously rated power transformer was on hand it could be used to increase the ratings of the supply. But in this case the circuit should ideally be redesigned to give optimum performance with a different transformer.



CONSTRUCTION: The Powerpac is conveniently installed in a box measuring 165 x 115 x 51mm (6½ x 4½ x 2 inches) which may be a diecast case or a sheet steel box with "biscuit tin" lid. Whatever box is used, make sure the transformer fits before purchase.

Mount the transformer at one end of the case. Then mount the power transistor on its heatsink. This is made from a piece of 16 SWG aluminium measuring 90 x 66mm bent so that it has a 66 x 38mm mounting flange. It is secured to the case with one screw and nut, plus a lockwasher. All screws should have lockwashers otherwise they become loose before very long.

Use a mica washer and plastic bushes to insulate the transistor from the heatsink. Both the mounting face of the transistor and the appropriate area of the heatsink should be lightly coated with silicone compound. The rest of the hardware may now be installed.

A defined procedure must be used for installing the power cord. It passes through a grommetted hole in the side of the chassis and is secured with a cord clamp. The earth wire is terminated to a solder lug screwed to the case, while the active and neutral wires are connected to an insulated terminal block. The transformer primary wires also connect to this terminal block. All the transformer leads have push-on connectors. Make sure you obtain a set of leads with the transformer.

Of the four secondary wires, the two outside wires connect to the diodes while the centre pair connect to the negative electrode of the 2200uF capacitor. Note that the 12 ohm 10 watt resistor should not connect directly to the 2200uF capacitor but via a hook-up wire link as in the wiring diagram. This is to stop heat generated by the resistor being conducted directly into the capacitor. Note that the rectifier diodes and the 1k, 390 and 100 ohm resistors should have their leads sleeved with varnished cambric (spaghetti) to prevent the possibility of short circuits.

If the constructor wants to make the Powerpac tamperproof he can mount the preset tab potentiometer inside the case so that the lid has to be removed to adjust it. Alternatively, it can be replaced by selecting two fixed resistors to give the required output voltage. For a high voltage the base of the error amplifier transistor must be taken down the divider, and vice versa.

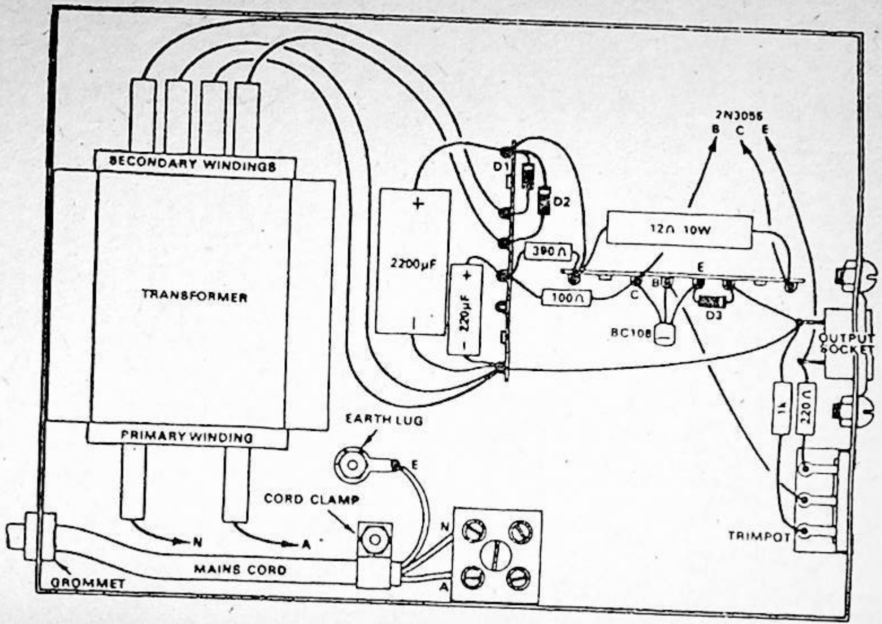
Do not forget to place the flag heatsink on the error amplifier transistor. If you cannot obtain one from your parts supplier, it is easy to fashion one from a piece of tinplate, brass or copper.

When assembly is complete, carefully check the Powerpac against the circuit and wiring diagrams. Note that no part of the low voltage circuit is connected to chassis.

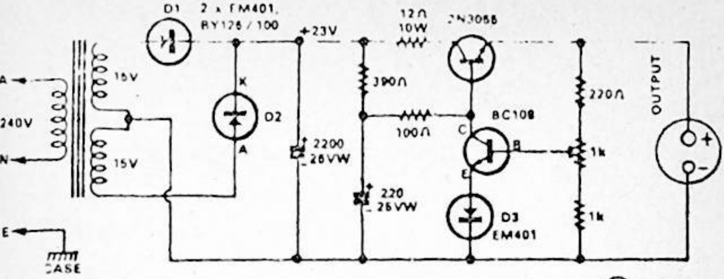
When power is applied the output voltage may be set, without a load connected, using a multimeter. Under conditions of light load, all the circuit components should remain cool, or at most, warm to the touch.

No doubt there will be some readers who will find that their Powerpac does not work after they have carefully assembled, checked and switched on. For the benefit of these we provide the following short troubleshooting procedure. You will need a multimeter to follow it.

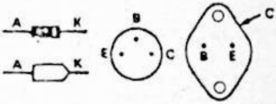
If you cannot obtain any output voltage and the base voltage of the 2N3055 is at approximately 0.7V with respect to negative, then the BC108 is probably short circuit. If the voltage at the output is above 20V and not adjustable by means of the potentiometer, then there are several possible causes: the BC108 is open circuit: the reference diode is open circuit or reverse connected: the 2N3055 is short circuit or finally, the potentiometer wiper is not contacting the element.



Use the circuit in conjunction with the wiring diagram to ensure straightforward assembly.



POWERPAC



POWERPAC PARTS LIST

1 Diecast or steel case, 165 x 115 x 51mm
1 Transformer, 2 x 15V at 20VA
1 16 SWG aluminium heatsink (see text)
1 2-pin polarised socket
2 8-lug tagstrips
1 2N3055, AM291, BD130, BOX10, BDY39, 2N3713 silicon power transistor
1 BC108, BC107, RS276-2009, AM252, TT108 silicon transistor with flag heatsink
3 EM401, BY126/100, BA219, EM501, OA626/100, 1N4002 silicon diodes
1 2200uF/25VW electrolytic capacitor
1 220uF/25VW electrolytic capacitor

RESISTORS
(½ watt unless specified)
1 x 1k, 1 x 390 ohms, 1 x 220 ohms, 1 x 100 ohms, 1 x 12 ohns/ 10 watts

SUNDRIES
4 rubber feet, 2 solder lugs, mains cord and plug, cord clamp, insulated terminal block, TO-3 transistor hardware, grommet, varnished cambric sleeving, hook-up wire, screws, nuts, lock-washers, solder.

REGULATED 30V/1A SUPPLY IS SHORT-CIRCUIT PROOF

A simple unit, fully solid state and easy to build, and its cost may be kept low by the use of components from the "junk-box". Output is adjustable from zero to 30V, with regulation to 1 amp and full short-circuit protection.

Anyone who does much experimental work with semiconductors must sooner or later lose patience with the high cost, unreliable output and rising internal resistance with age of batteries as a power source, and must long for a precisely-adjustable DC supply powered from the mains. Such a supply is always at peak performance and involves negligible running cost. This becomes the more desirable year by year as the required collector voltage of transistors rises steadily from the 3 to 6 volts of earlier days towards figures previously associated with valves, coupled with average currents which, in the case of power amplifiers, may run to several amperes.

The design to be described aims to meet this need, with due regard to economy, simplicity and above all, reliability and with safeguards against error or failure in the apparatus to which it is connected. It is bad enough if such a fault causes destruction in that apparatus, but if it also takes the power unit with it in a general holocaust, the economics of the set-up become questionable, to put it mildly. And simple fuses are not always fast enough to save the day.

The design is based upon known and tried principles and no claim is made for originality, but the practical details have been the subject of considerable study and testing. The writer's specification for the unit follows, and it is hoped that it will be found adequate by most potential constructors for a general-purpose bench supply.

OUTPUT VOLTAGE: Continuously variable from 0 to 30 volts, with self-contained voltmeter.
OUTPUT CURRENT: Up to 1 ampere at 24 volts, or up to 500 milliamps at 30 volts, with self-contained ammeter.
EFFECTIVE OUTPUT RESISTANCE: Less than 0.25 ohm.
REGULATION: No load to 1 ampere at 24 volts = –3.5pc. No load to 0.5 ampere at 24 volts = –1.25pc. No load to 100mA at 30 volts = –0.3pc.
MAINS FLUCTUATION: At output – 24 volts 0.5 ampere, mains drop from 240 volts to 216 volts drops DC output by 0.5 volt.
RESIDUAL HUM: 2.5 millivolts maximum at any setting.
OUTPUT POLARITY: Both output terminals to be floating; ie, no part of the circuit to be grounded.

The output can be taken with either terminal earthy and is sufficient to take care of most requirements irrespective of the polarity required, including Class B amplifiers up to around 10 watts output.

As it was intended that the unit should be able to supply more than one device at a time, two polarised two-pin output sockets are used in parallel with the main output terminals and more could be added if desired. However no attempt has been made to supply more than one voltage at these outlets, as it is a simple matter to reduce the voltage to whatever a particular auxiliary device or instrument may need by providing it with its own zener diode regulator circuit.

The circuit is shown complete in Fig. 1, and the following explanation may help an intending constructor.

It was desired to maintain good regulation down to at least 4 to 5 volts and this makes it desirable, in this type of regulator circuit, to have available a fairly stable negative supply rail of about the same voltage as the main filtered but unregulated positive supply. Additionally, it was hoped to avoid the need for centre-tapped transformers of relatively high voltage, which tend to be expensive and rather scarce.

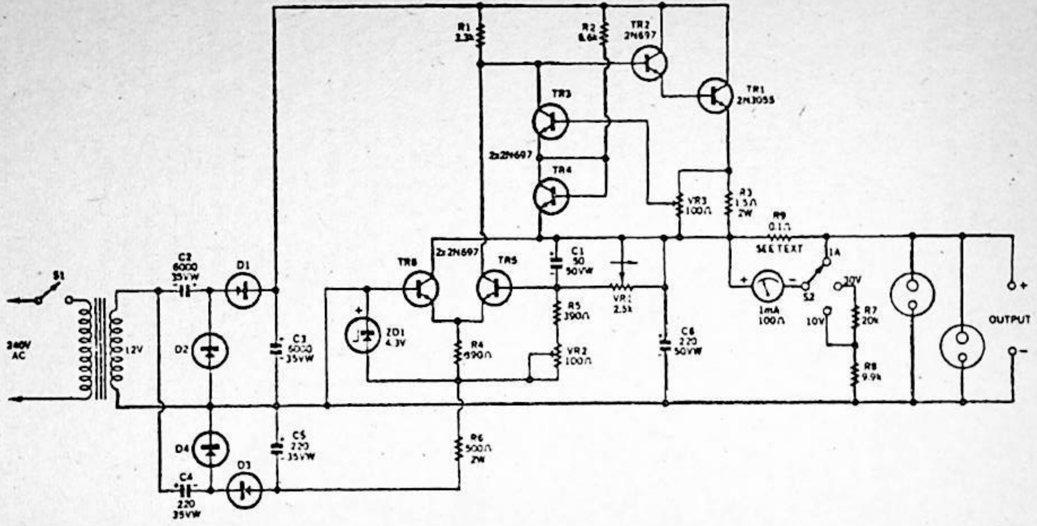
Accordingly, a voltage-doubler circuit was adopted to permit use of small battery-charger or bell transformers of low voltage and without tappings; these, being simple and serving a relatively large market, are usually inexpensive. A 12 volt secondary winding rated at 2 to 3 amps is needed and suitable types are mentioned in the parts list. However, a disused power transformer taken from a typical 5 or 6-valve broadcast receiver of earlier days can probably be used with every satisfaction if the original receiver used a 5Y3G or similar rectifier valve.

Such a transformer will then probably have two heater windings, one rated at 5 volts 2 amps and another at 6.3 volts 1.5 amps or so. These two windings, if connected in series and aiding (an AC voltmeter will soon show if they are aiding or opposing) will provide an almost ideal AC source for the present job, the high-tension secondary being left disconnected. The writer's unit uses such a transformer, which gives 12.25 volts AC on no load, falling to 11.6 volts when the DC output is 1 amp at 24 volts.

It is not always realised that by suitable choice of circuits an untapped transformer can be made to supply both positive and negative rectified and smoothed outputs simultaneously from a single winding and this has been done in the present design. The main (positive) supply requires two silicon rectifiers rated at 1 amp and with any peak inverse rating above 100 volts; the prototype used a pair of RAS508AF avalanche rectifiers (STC) which were on hand, but there are plenty of alternatives.

For good overall regulation it is well to use plenty of filter capacitance in this part of the circuit. A pair of 6000 uF 35WV capacitors are used in the prototype. A minimum 35 volt working rating is sufficient.

The negative side of the supply can use smaller components, since it handles only the regulator section comprising Tr5 and Tr6 and related circuitry. Silicon rectifiers rated for 100PIV and 100 milliamps load are adequate, with filter capacitors of 220 uF 35WV or more.



The circuit for the supply, which as may be seen uses a relatively small number of discrete transistors. Note the negative emitter supply used for the comparator transistors TR5 and TR6, to allow the output to be reduced to zero.

Tr1 is a normal series regulator, controlled by Tr2 and with it forming a Darlington pair whose current gains multiply together to give a high overall sensitivity. The base current of Tr2 is subject to further amplified control by the collector current drain of Tr5, whose base receives from the positive output rail the error voltage which is to be corrected. Tr5 and Tr6 form a differential amplifier of the so-called "long-tailed pair" type.

Any error voltage occurring at the positive output rail is fed through variable resistor VR1 to the base of Tr5, where it is compared against the fixed voltage of Tr6 base and thereby amplified in the collector circuit of Tr5 in the proper sense to change the voltage drop across R1. This consequently changes the base current of Tr2 and emitter current of Tr1 to the extent needed to correct the output voltage error. The voltage between Tr6 base and the emitter supply rail for Tr5 and Tr6 is held constant at 4.3 volts by ZD1, which also ensures that the base-to-emitter voltage rating of these transistors is not exceeded.

VR1 controls the regulated output from zero to maximum voltage, minimum resistance giving minimum output, and it should be wired to give clockwise increase of resistance. VR2 serves to adjust the maximum output voltage, and once set correctly is not disturbed again. Capacitor C1 ensures smooth control of output and also feeds back residual hum voltage in the output to the base of Tr5, giving a very useful degree of cancellation.

Looking now at Tr3 and Tr4, these provide the overload protection in conjunction with R3 and VR3 Tr4, whose base is connected to its collector, is used as a diode with a very low slope resistance and its characteristic base-emitter voltage drop of 0.6 volt, together with the similar drop in Tr3, provides a base bias sufficient to keep Tr3 normally cut off. However it will be seen that the total output current flows through R3, setting up a proportional positive voltage at its upper end, amounting to 1.5 volts for an output of 1 amp.

A portion of this voltage is tapped off by VR3 and applied to the base of Tr3, and when it exceeds about 1.2 volts Tr3's collector circuit begins to draw current, thus increasing the voltage drop across R1 and robbing Tr2's base of current, thereby increasing the voltage drop through Tr1 and limiting any further rise in output current. This control is quite effective; when supplying a load drawing the rated maximum of 1 amp, a dead short-circuit across the load will not increase the current beyond 1.15 amp, and this current can be supplied continuously without damage.

Switch S2 permits meter M to serve either as a voltmeter reading 0-10 or 0-30 volts full scale, or as an ammeter reading 1 amp full scale. The meter is a standard 15/8 inch square voltmeter, scaled 0-10 volts and drawing one milliamp for full-scale deflection, the resistance of the moving coil is 100 ohms.

The internal series resistor of 9.9k was removed from the meter case and installed externally at switch S2, with another 2pc resistor of 20k, giving alternative voltage readings of 10 or 30 volts maximum. Additionally, a shunt resistor of 0.1 ohm was made and connected as shown to provide a 1 amp full-scale reading. This facility is very useful when working with heavy loads and during the setting-up of the overload protection control VR3.

Additional shunts to cover lower current drains could have been provided using more switch positions, but were not thought worth while as the normal volt-ohm-milliammeter found on most benches takes care of such cases.

The above-mentioned shunt consists of 3.1 inches of 22 swg Eureka wire, coiled and soldered between tags on a tag-strip mounted near switch and meter, it will be noted that it is connected permanently in circuit, so that switch contact resistance cannot seriously affect the calibration or if a resistor of the required value rated for one ampere can be bought it can of course be used.

The choice of transistors is somewhat restricted by considerations of cost, dissipation limits and collector voltage rating. It is believed that the types specified will give the most economical and reliable combination. Somewhat closer regulation might be had by substituting, say, BC107's for Tr5 and Tr6, but some work would be needed to re-balance the circuit and under no-load conditions (maximum output voltage and zero current) the collector dissipation in Tr6 would be close to the 300 mW limit for this type; this was thought too risky. The 2N697 is rated for 600 mW without heat sink, giving a safe margin.

The maximum load on the series regulator 2N3055 occurs under short-circuit conditions, and is 1.15 amps at 26 volts, or 30 watts roughly. This is well within the capability of this transistor when used on an adequate heat sink.

There is nothing at all critical about construction or layout, so details are not given and a constructor is free to use his own ideas and available parts where suitable. The only exception is the above-mentioned heat sink. It is presumed that a metal cabinet will be used to house the unit, and any such cabinet which is big enough to contain all the components, including the power transformer, will form an adequate heat sink if the 2N3055 is bolted externally to its flat surface using the necessary mica insulator and bushes.

If such a case is not used, a standard finned heat sink should be fitted. It is as well to fit a standard finned T05 heat sink to Tr2 also, for an extra safety margin.

Other components can be assembled on Veroboard, on tag strips or by any other method, though the trouble and expense of a special printed wiring board never seems worth while to the writer for these "one-off" jobs – it is essentially a mass-production technique. Rather than assemble and wire everything on one board, however, it may be wise to make a separate unit of the power supply and rectifier components, so that the operation can be checked separately for proper voltages and polarities, before connection to the rest of the circuit with almost certainly disastrous results if an error has occurred. And double-check the correctness of the anode and cathode connections of the silicon rectifiers being used.

The prototype used a case having a base chassis 2½ inches deep and a cover 6 inches high above the chassis. All of the present circuitry, except the power transformer, was mounted under the chassis and on one face, leaving the upper space empty except for the transformer. This is because it is hoped later on to add a variable high-voltage regulated supply, probably using valves to give around 500 volts at 100 milliamps, and an AC heater source. The idea is to make a sort of universal "experimenter's powerhouse" in a single unit.

Table 1 gives a general voltage analysis which may be helpful in preliminary testing or fault-finding.

TABLE 1: VOLTAGE ANALYSIS

NOTE: The negative output terminal is treated as the neutral point for this analysis. Output control set to 30 volts. No load. Measured with 50k ohms / volt meter.

Neutral to regulated negative rail	−4.9V
Neutral to Tr5 and Tr6 emitters	−0.6V
Neutral to unregulated negative supply	−29.5V
Neutral to Tr5 base	0V
Neutral to unregulated positive supply	+35.5V
Neutral to Tr3 emitter	+30.5V
Neutral to Tr3 and Tr5 collectors	+31V
Positive unregulated supply rail to Tr2 base	+4.0V
Positive unregulated supply rail to Tr2 emitter	+4.6V
Positive unregulated supply rail to Tr1 emitter	+5.2V

Before first switching on the unit, it is recommended that one end of resistor R4 should be disconnected and a milliammeter inserted temporarily in this circuit, With the output control set to zero, the milliammeter should show 11 to 12 milliamps, if not, reduce or increase R4 until this current is obtained. For good regulation it should not be allowed to fall below 10 milliamps. Any change in R4 will not be large unless a fault exists.

Next, adjust the maximum output voltage. Set switch S2 to the 30 volt position 2, turn the output control to maximum, and adjust VR2 until the meter reads full scale.

Finally, set the overload limit. Connect a 25-ohm 20 watt resistor to the output terminals, set S2 to position 3 to read current, and with the output control at maximum adjust VR3 until full scale reading (1 ampere) can just be obtained before limiting commences. The onset of limiting can be observed very clearly as VR3 is turned slightly to and fro around the desired position.

This completes the setting-up. The output control VR1 should now give smooth variation of voltage when unloaded from zero up to 30 volts and up to 24 volts on a 1 amp load. The unit will be found very simple and easy to use, and the prototype has proved perfectly reliable.

Editor's Note: It would appear to be possible to improve the regulation of this unit slightly, by incorporating the current shunt R9 into the regulator feedback loop. This could be done by connecting the rotor and "top" end of VR1 to the output end of R9, rather than to the junction of R3 and R9 as at present.

PARTS LIST FOR POWER SUPPLY

1 Power Transformer, (see text).
1 Toggle switch, SPDT.
1 Rotary switch, 1-pole 3-position, shorting or non-shorting contacts.
2 Terminals, 1 red, 1 black.
2 Two-pin polarised sockets.
1 Heat sink, finned, T05 type.
1 Heat sink (may not be needed; see text).
1 Metal case to suit.
M Voltmeter, 0-10 Volts DC, 15/8" square face, meter resistance 100 ohms;

SEMICONDUCTORS
Tr1 2N3055, AM291, BD130, BPX10, 2N378 or equivalent.
Tr2-6 2N697, BSX45-45/10, BSY44-51, 2N2218, RS276-2009 or equivalent.
ZD1 Zener Diode, 4.3 Volts, 300 mW.
D1-D2 Silicon rectifier, 1 Amp 100 PIV or larger.
D3-D4 Silicon rectifier, 100 mA, 100 PIV or larger.

RESISTORS
R1 3.3k, ½W, 10pc.
R2 5.6k, ½W, 10pc.
R3 1.5 ohms, 2W, 10pc.
R4, R5 390 ohms, ½W, 5pc.
R6,500 ohms, 2W, 10pc.
R7 20k, ½W, 2pc.
R8 9.9k (see text).
R9 0.1 ohm (see text).
VR1 2.5k, wire wound.
VR2, VR3 100 ohms pre-set trim-pots.

CAPACITORS
C1 50 uF, 50 VW electrolytic.
C2, C3 6,000 uF, 35 VW electrolytic, (see text).
C4, C5 220 uF, 50 VW electrolytic.
C6 220 uF, 50 VW electrolytic.

MISCELLANEOUS
Two knobs for controls, mica washer for TR1, mains cord and plug, etc.

NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for the prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases, providing the ratings are not exceeded.

SIMPLE POWER SUPPLY – REGULATED AND VARIABLE

A variable regulated power supply, capable of supplying up to 12 volts at 500mA. Cost has been kept to a minimum by keeping the design very simple, and at least some of the parts may be obtained from oddment sources.

Basically the circuit involves a centre-tapped transformer, followed by a bridge rectifier and a 2-transistor regulator using a zener diode as a reference.

Voltage adjustment is made by a potentiometer on the front panel but, because of component tolerances, we have not provided for a graduated voltage scale. We suggest you calibrate it, after completion, with the aid of a multimeter.

The neatest way to mark these is to use "Letraset" rub-on lettering, but ordinary ink letters may have to suffice.

As well as variable DC, AC is also brought out to the front panel. Since it involves mainly the price of three extra terminals, we thought it worthwhile.

We must make a point, however, about simultaneous use of the AC and DC outlets. While this is possible, there are limits to the amount of current which can be taken from the transformer. If you find the regulation of the DC supply is poor, too much current is probably being taken from the AC terminals. Note also that there must be no common paths between the devices connected to the AC and DC outlets, because such a path could short out the internal circuitry.

We mentioned that the supply is both regulated and variable. Let us see what this entails:

There are a number of ways by which a power supply can be made variable. Perhaps the simplest is to use a high power rheostat or potentiometer in series with the load circuit, so that the voltage is divided between the load and the rheostat element.

In cases where cost or simplicity are important, (such as mass-produced model train controls) this system is used extensively. However, the voltage at the end of the resistor, being proportional to current, changes with changing load and regulation is therefore poor. Obviously, a better approach is required for our present purpose.

If we now place a voltage divider across the zener diode, and transfer the base of the power transistor to the variable arm, the emitter of the power transistor will tend to follow the voltage at its base. In other words, we have made the supply variable. (See Fig 1.)

The behaviour of the circuit will, however, depend heavily on the base current of the transistor. If it varies in proportion to the emitter load current and becomes large enough to affect significantly the voltage at the potentiometer tapping, then the regulation of the supply will be poor.

We tried out the idea using a single 2N3055 power transistor but it became obvious that the current drawn by the base circuit would, indeed, be too high with a heavy output current being drawn from the emitter.

We had set an arbitrary figure of 500mA on the maximum current to be drawn from the supply, and to obtain this current under worst-case transistor parameters (the lowest gain of a 2N3055 is 20) we would need about 500/20 or 25mA base current. We could not expect to draw anything like this amount of current from the potentiometer without upsetting regulation.

So we thought of another idea – the "Darlington pair" circuit. To make a Darlington pair, we connect two transistors together as shown in Fig2 and treat them as one. The gain of the pair is equal to the product of both the transistor gains and, as the TT801 transistor we chose to connect to the 2N3055 has a gain of 40 (minimum) the pair have a gain of at least 800!

The pair thus require a base current ranging up to less than 1mA for 500mA out, and we can afford to take this order of current from across the zener and potentiometer with very little effect on the base voltage, as set.

Now let's turn to the main circuit diagram of Fig3 and see how the Darlington pair has been incorporated – with refinements.

To minimise the amount of AC ripple across the zener diode, we have added a 100uF capacitor in parallel. Fairly obviously, any ripple in the zener "reference" voltage would be transferred very faithfully into the output voltage!

To the base circuit we have added a silicon diode – we used an EM401 – which prevents damage to the transistor base-emitter junctions by breakdown.

The diode affords protection because its breakdown voltage is very much higher than that of the transistors.

Because there are now three P-N junctions involved, (two transistors and a diode) the difference in voltage between that at the potentiometer wiper and the emitter of the 2N3055 will not be 0.6V, but about 1.8V. For this reason we have specified two 6.8V zener diodes in series – we want to be as close as possible to 1.8V above 12V, in order to obtain an effective 12V supply. If we used a 12V zener, the maximum output voltage would be limited to about 10.2V.

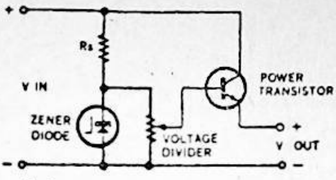


Fig. 1

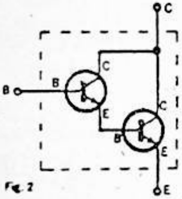


Fig. 2

Fig. 1: The basic "emitter follower" circuit described last month, with added zener voltage divider to make the supply variable.
Fig. 2: The "Darlington pair" configuration used to keep base current to a minimum.

Now the disadvantage of the series regulator is its liability to damage with a short circuit. However here the 1.5 ohm resistor and fuse should provide the necessary protection. The resistor will limit the short circuit current to less than 9 amps, whereas the transistor is capable of passing 15A without damage. If the short is maintained for more than an instant the fuse will blow, thus preventing damage to the rectifier diodes or transformer.

In other words, a momentary short – such as often happens on the workbench – will not worry the supply at all. A sustained short will simply blow the fuse.

Two other components are worthy of comment: a 1000uF capacitor and a 1k resistor across the output circuit. The capacitor contributes to filtering and also helps meet peak current demands by (for example) a class B audio amplifier.

The 1k resistor across the output is to provide a small load on the supply. This assists the emitter follower section by providing a return path at all times – not just when a load is connected.

Let us now look at the construction of the circuit from the power point to the transformer.

We start with a standard 3-pin plug and a 3-wire mains flex, which is brought into the case at the bottom of the rear panel. The hole through which it comes must be grommeted and, immediately after entry the cord must be clamped. It must then be separated into its 3 leads: active, neutral and earth. The active and neutral leads must screw into a terminal block while the earth lead must make reliable mechanical contact with the case of the supply, usually per medium of a solder lug fastened by a brass nut and bolt.

The particular transformer we used in the prototype has two 7.5V windings, which we connect in series to give us 15V AC for the rectifier, and 15V centre tapped for the AC output terminals.

Coming now to the actual assembly of the supply, most of the components are mounted on an 18 lug section of tagboard.

Follow our board wiring diagram and you should have no trouble. Some of the components, notably the two large electrolytics and the 10W resistor are soldered between the outside pairs of holes, as they are too large to fit between the inner holes.

The two zener diodes can be soldered together before they are placed in position on the board. Be careful, when soldering the semiconductors, not to apply too much heat for too long. Use just enough heat from a suitably hot iron to flow the solder, then take the iron away. Note that other wires share the same holes as the collector and emitter leads of the TT801. These should be inserted and soldered same time as the leads from the TT801.

It may appear from the drawing that some of the tags on the tagboard are wasted. This is not really the case, because some of the components are too big to accommodate another component immediately alongside. Also, if a component is likely to dissipate significant heat (such as the 10W resistor) it is unwise to place other components in contact with it.

Note that some of the components are underneath the tagboard: the 470-ohm resistor and two of the rectifier diodes. Treat these in exactly the same manner as the components on top. All of the links between the tags are also soldered underneath. Where links cross the board, and there is a danger that they might short onto something else, cover them with a length of spaghetti or nylex sleeving (or the plastic covering from some insulated hookup wire).

Trailing hookup wire should be left until last, as they get in the way while soldering other components. Where two or more wires go to the same place, twist them together for the sake of neatness.

Once the tagboard is wired, we can concentrate on the case and panels. We used a small instrument case, measuring 7in x 5in x 4in and covered in black vinyl.

If you do use another case, or change our layout, make sure that the mains and low tension wiring is well separated. This is important for your safety.

Because we are using the rear panel as a heatsink for the 2N3055, it must have good heat conduction properties.

When drilling holes, always punch an indent first. Then drill a small (1/16in) pilot hole, working up to a hole of the wanted size. This will ensure the final hole is where you want it – not 1/32nd or more away!

Using the same techniques, drill the required holes in the case. You can de-burr all holes by rotating a much larger drill in the hole by hand.

With the holes in the panels de-burred, fix the components on them in their correct places. On the front panels, the DC terminals can logically be coloured red, green and black, for positive, earth and negative respectively. The AC terminals can be blue, yellow and blue for 7.5, 0, 7.5 volts respectively.

On the rear panel, the transistor is located exactly in the centre, with the fuse holder above it. The mains input lead is below and to the right. The transistor requires special attention when fixing.

When you buy your 2N3055, you should get with it a mounting kit. If you don't, ask for it. It consists of a mica washer the shape of (but slightly larger than) the transistor, and two plastic bushes. There may also be two nuts and bolts, a number of washers, and a solder lug, depending on where you buy your transistor.

This transistor should be screwed to the panel as shown in Fig. 5. This prevents the case of the transistor (which is internally connected to the collector) from shorting to the panel. Note there will only be one solder lug. Its place at the other end should be taken by a washer.

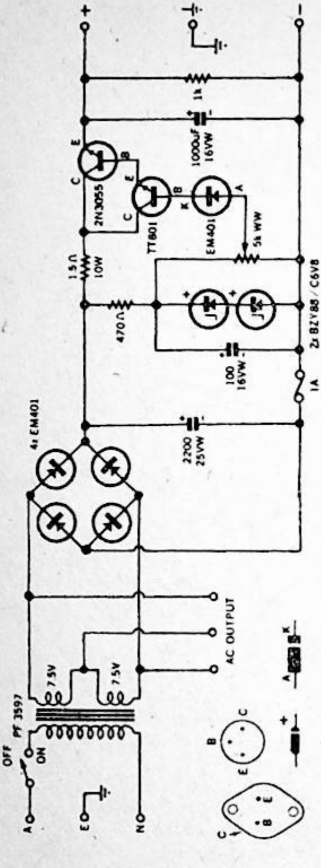
It is wise to put a small dab of silicone grease (or heat conductive compound) between the transistor and mica washer and between the mica washer and case. Small tubes of silicone grease are available from most parts suppliers. Only a small dab is necessary – as the transistor is tightened down it spreads the grease.

Connection of the fuseholder is straightforward, but it must be tightened well to prevent it from turning when a fuse is replaced. The mains cord entry hole must be grommeted as mentioned earlier. If you have difficulty in passing the mains cord through the grommet when it is in place, try dipping the cord in baby powder.

Once these points are taken care of, the transformer can be installed. Washers should be used between the transformer legs and the nuts. Next, screw the tagboard into place on the other side wall of the case. It is mounted on 2½in brass spacers. If you countersink the holes on the side of the case, and use countersunk head screws, the heads will hardly be noticeable.

Once the tagboard is in position, the leads can be placed in their correct positions and trimmed as required. The transistor and fuse leads can be soldered to their correct points at this stage. The mains input can be treated next.

Push the mains cord through the grommet until approximately six inches is protruding. Trim back two inches of plastic covering, leaving the red, green and black wires. Cut the red and black wires down to approximately one and a half inches, and strip the insulation from ¼in of each of these wires. These can be twisted, tinned and locked into the terminal block before it is screwed into the case.


2N3055
TT801
EM401
1k
1000uF 16VW
1.5Ω 10W
470Ω
5k WW
2x BZY88 / C6V8
100 16VW
1A
4x EM401
2200 25VW
PF 3597
7.5V
7.5V
AC OUTPUT
OFF
ON
A
E
N

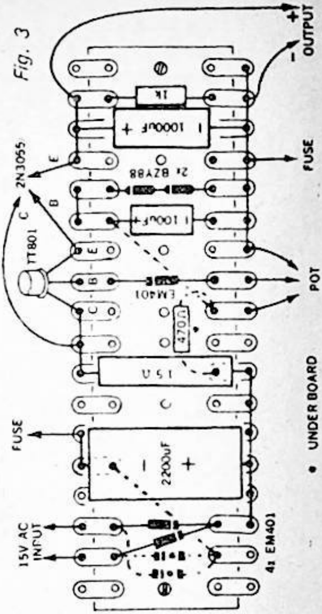

OUTPUT
FUSE
POT
2N3055
TT801
EM401
2x BZY88
1000uF
100uF
1k
470Ω
1.5Ω
2200uF
FUSE
15V AC INPUT
4x EM401
UNDER BOARD

Fig. 3

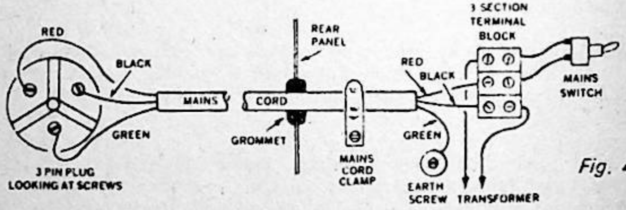

RED
BLACK
GREEN
3 PIN PLUG LOOKING AT SCREWS
MAINS
CORD
REAR PANEL
GROMMET
MAINS CORD CLAMP
RED
BLACK
GREEN
EARTH SCREW
TRANSFORMER
3 SECTION TERMINAL BLOCK
MAINS SWITCH

Fig. 4

The lead to the mains switch goes from the same terminal as the active "in", while the lead from the switch goes to the terminal adjoining it. One lead to the transformer goes from this terminal, and one from the terminal to which the mains neutral is connected. These leads may now be attached to the transformer, and the back of the case screwed on.

The terminal block can be screwed into position in the case. Next, the mains cord can be pulled back through the grommet, until the end of the plastic insulation is just past the terminal block. The mains cord clamp is fitted at this point, being locked down hard onto the outer insulation of the mains cord.

The earth lead must make mechanical contact with the chassis – not a soldered connection. It should be stripped for approximately one inch, then wound around a screw located near the terminal block. A washer, then a nut is placed on this screw and tightened.

The only wires which should now need connecting are those to the front panel, including the potentiometer, mains switch and AC output leads. Connect the AC output leads first.

Note that there are six leads supplied with the transformer – each with its own connector. Two of these are for the mains input; the other four are for the secondary output. We presume the transformer will have connection data, but if this is mislaid, the secondaries must be connected together so that 15 volts (approx) appears across the windings. If 7.5V or 0V is measured, the connection is wrong.

The pairs of secondary output leads can be cut to the correct length, then soldered to the AC output terminals, with two leads being soldered to the 0V terminal. The twisted pair of wires which go to the rectifier on the tagboard can also be soldered to the terminals, one going to each of the 7.5V outputs.

Each of the terminals is equipped with a fibre washer. In the case of the DC earth terminal (NOT the AC 0V terminal) the fibre washer can be discarded and replaced by a brass type to ensure a good connection to the front panel (and therefore earth). A solder lug should be placed between each fibre washer and nut. On these are connected the various leads.

Each of the pot leads can be attached, as can the mains switch. Be sure that when the panel is placed in position, the mains switch does not foul any other parts.

That should complete the interior wiring of the supply. After checking your wiring, you can close the front panel. All that remains is to connect a power plug.

The plug MUST be connected as shown in the wiring diagram.

Set your multimeter to 20V DC or higher, and connect it across the DC terminals. Turn the voltage control fully clockwise and switch on the power. The supply should give approximately 12 volts. Turning the pot down should decrease the voltage to zero. If the reverse happens, turn it off, un-plug the lead and swap the two outside connections to the pot (not the wiper).

If there is no voltage, check with your multimeter on 20V AC across the AC terminals to see if the transformer is putting out any voltage. If it is, you have made a mistake in your wiring (or have a faulty component) after the transformer. If no voltage, your mistake is in the mains wiring.

And that is just about all there is to our power supply. Should you wish to fit output voltage or current meters, there is plenty of space on the front panel. The current meter should be connected in series with the positive output lead, while the voltage meter should be connected in parallel with the output. Take care with the polarity.

A 0-20V meter would be quite suitable (or if you know how to work out shunts and multipliers, any meter may be used). For the current meter, 0-500mA would be the logical choice.

We hope you have enjoyed building this supply, and find it useful.

Equivalent Semiconductors used in this chapter

EM401 = RS276-1136, BA219, BY126/100, EM501, OA626/100, IN4002 or equivalent.
2N3055 = AM291, BD130, BDX10, BDY39, 2N3713, SK3027 or equivalent.
BZY88 C6V8 = IN3411, IN4628 or equivalent.

POWER SUPPLIES FOR TRANSISTORS IN VALVE EQUIPMENT

When transistor circuitry is to be incorporated into equipment originally or predominantly using valves, provision must usually be made for a suitable low-voltage power supply. Described in this brief article are some of the many possible approaches.

Possibly the simplest means of obtaining a suitably low supply voltage is a resistive voltage divider connected to the HT line, as shown in figure 1(a). However, in general this approach can only be used where the current drain of the transistor circuitry is quite modest, where the HT power supply circuit of the valve equipment is capable of supplying the additional current involved.

With this circuit the values of the two divider resistors R1 and R2 are determined both by the voltage and current requirements of the transistor circuit, and by any further requirements regarding loading regulation, ripple filtering or signal decoupling (note that the line voltage regulation remains fixed and equal to that of the HT voltage supply).

Broadly speaking the ratio of the two resistors determines the output voltage, while their absolute values both directly determine the ripple filtering and decoupling, and inversely determine the loading regulation. Low values give good regulation but poor filtering and decoupling, and vice-versa. It should also be borne in mind that low resistor values give increased loading of the HT line.

From theory the effective output circuit of a simple resistive divider may be represented by a battery whose voltage is a fraction of the HT voltage given by R2/(R1 + R2), in series with an AC generator whose output is a similar fraction of any signal or ripple on the HT line, together with a series resistance equal to the value of R1.R2/(R1 + R2). The latter component will determine the load regulation of the divider, and also in conjunction with capacitor C the ripple filtering and decoupling.

For typical applications in which the load current is modest and ripple of minor concern, a convenient rule of thumb is to allow resistor R2 to draw a current equal to that of the transistor circuit load. This permits simple calculation of R2, whose value will be given by the load voltage V divided by the load current. Similarly R1 may be found by dividing the difference between the HT and transistor load voltages (HT-V) by twice the load current.

Capacitor C may be an electrolytic type with a value as large as necessary to satisfy filtering and decoupling requirements, and with a working voltage rating equal to or exceeding V. The resistors should have dissipation ratings adequate for the job, of course; the dissipation of R1 will be given by (HT-V).2I, where I is the load current.

In cases where the loading regulation, line voltage regulation or filtering performance of a simple resistive voltage divider is inadequate it may be found necessary to employ a zener diode divider circuit as shown in figure 1(b). Here the lower divider resistor is effectively replaced by a zener or "breakdown" regulator diode Z, whose terminal voltage remains substantially constant for a range of current values. As the diode is connected directly across the transistor circuit load, the load voltage may therefore be stabilised.

Naturally enough the zener diode Z is chosen to have a nominal "regulation plateau" voltage equal to the required transistor circuit supply voltage V. The value of resistor R is then determined, using one of two approaches depending upon the circuit parameters of major interest.

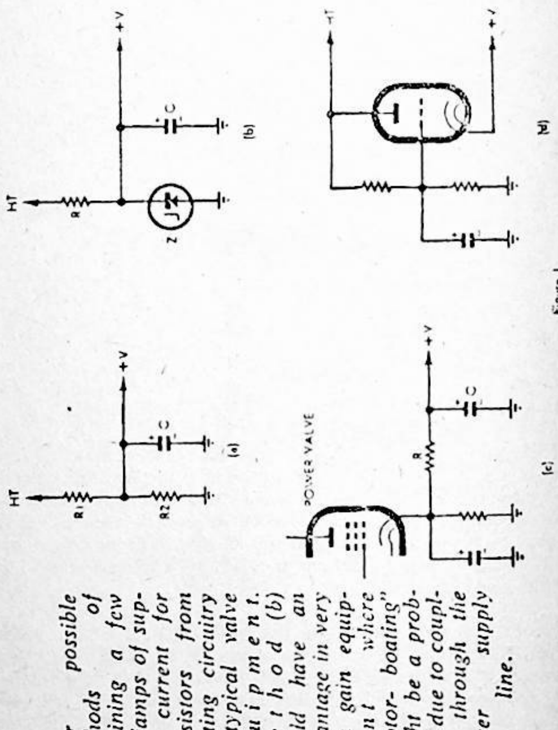


Figure 1

Four possible methods of obtaining a few milliamps of supply current for transistors from existing circuitry in typical valve equipment. Method (b) would have an advantage in very high gain equipment where "motor-boating" might be a problem due to coupling through the supply power line.

If the current drain of the transistor circuit load is substantially constant, and the main concern is to stabilise its supply voltage despite variations in the main HT voltage, then R should have a value such that Z still remains in the breakdown state when the HT voltage is at its minimum value. Typically this will mean that R will have a value equal to (HTmin – V) divided by a current of about 3 or 4 milliamps larger than the load current. Naturally Z will have to be a device capable of dissipating the appropriate maximum power when the HT is at its maximum value.

On the other hand if the HT supply is substantially constant while the load current is subject to variations, then R should have a value such that Z still remains in the breakdown state when the load current is a maximum. In the typical case this will give a value for R of (HT–V)/I, where I is a current about 3 or 4 milliamps larger than the maximum load current. As before, the zener will have to have a dissipation rating adequate for the maximum dissipation condition, which will in this case be when the load current is a minimum.

The loading regulation of a zener diode divider will tend to be significantly better than that of a simple resistive divider, due to the stabilising action of the zener diode. The latter also gives a significant measure of line voltage regulation, together with intrinsic ripple filtering and signal decoupling.

As a result of the ripple filtering and decoupling action of the zener diode itself, capacitor C may not be required in less critical applications; however, when used it will give improved performance. Note that in contrast with similar regulator circuits employing gaseous discharge tubes, there is in general no tendency for a circuit of this type to produce relaxation oscillations.

In some types of valve equipment, provision of simple or zener HT voltage dividers may be rendered unnecessary as a result of the availability of low voltages at power valve cathodes. Where only moderate currents are required, such points can provide a convenient and quite satisfactory source of low voltage supply, as illustrated in figure 1(c). In most cases the voltage available at a power valve cathode is well regulated and filtered, due both to the low impedance of the cathode components and to the high effective impedance of the valve itself.

When the current required by the transistor circuit load is slight compared with the power valve cathode current, this type of supply need typically consist of nothing more than a simple R-C filtering and decoupling circuit, as shown. The value of the resistor R will be dictated largely by the allowable voltage drop, which will depend in turn upon the available cathode voltage and the required transistor supply voltage. Once the value of R has been fixed, the value of capacitor C may then be determined on the basis of adequate decoupling and ripple filtering.

If the current drain of the transistor circuit load will represent a significant proportion of the existing cathode current, it will generally be necessary to replace the existing cathode resistor with one of higher value, to maintain the same effective resistance between cathode and earth. If this were not done, the valve operating point would tend to change, possibly upsetting its operation.

The value of the new cathode resistor can easily be found using Ohm's law, as the new value will simply be that which develops the original cathode voltage when the available current is diminished by an amount equal to the transistor circuit load current.

In the limiting case, where the transistor circuit current is sufficient to equal the original cathode current, the cathode resistor will no longer be required; however, it should be realised that the latter situation may involve problems if the drain of the transistor circuitry tends to vary appreciably. In such cases it may be necessary to employ a zener diode in place of the cathode resistor, to maintain a constant cathode voltage.

Equipment in which no suitable power valve stages are available for the foregoing approach may alternatively permit the addition of a simple valve "series regulator" circuit of the type shown in figure 1(d). Here the valve is effectively operated as a cathode-follower stage, a resistive voltage divider pegging the grid at a potential greater than the required transistor supply voltage by an amount which will provide the appropriate valve bias for the current required. A bypass capacitor at the grid also provides a significant measure of ripple filtering and signal decoupling, as a result of the familiar cathode-follower action.

Naturally enough the valve selected for use in such a circuit will need to be capable of tolerating the power dissipation involved, which will be equal to (HT-V). I where I is the load current. Apart from this requirement, the valve should also have a fairly high transconductance and low plate resistance if the transistor supply is to be well regulated and filtered.

Any of the four power supply approaches thus far described will in general only be suitable where the HT supply of the existing equipment has sufficient capacity to supply additional current. In equipment where this is not the case, it may be necessary to derive the supply for the transistor circuitry from the AC heater line, using a circuit perhaps similar to those illustrated in the remaining diagrams.

In figure 2 (a) and (b) are shown rectifier circuits suitable for equipment having a 6.3V heater line in which one side of the line is earthed. The circuit of (a) is for a simple half-wave supply, while that of (b) is for a half-wave voltage doubler supply. Although both are shown as arranged for earthing of the output negative polarity, either may be adapted to produce an output of opposite polarity simply by reversing the connections of the diodes and electrolytic capacitors.

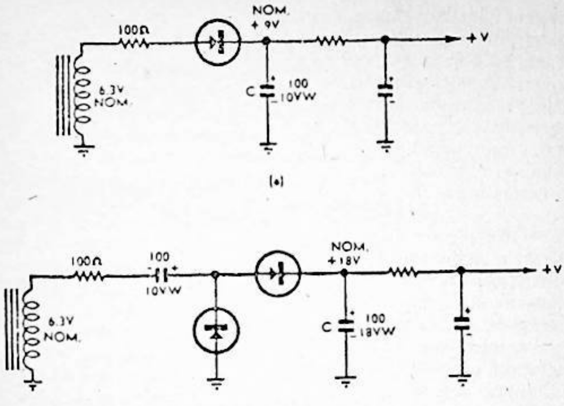


Figure 2 (b)

Simple half-wave circuits for heater wiring which is earthed by one side. Output can be positive or negative as desired.

The simple half-wave circuit of figure 2(a) tends to have high 50Hz ripple, together with rather poor regulation. This makes it suitable mainly for very low current applications, or where ripple and poor regulation are of little consequence. The peak DC output voltage developed across the reservoir capacitor C is approximately 9V, so that any R-C filtering used will provide a load voltage of less than this figure.

The addition of a further diode and "bootstrap" reservoir capacitor to the simple half-wave circuit produces the half-wave doubler circuit of figure 2(b). Here the peak output voltage generated across the output reservoir capacitor is approximately double the previous value, or roughly 18V. Hence although the regulation and ripple characteristics of this circuit tend to be rather similar to the previous circuit, the higher initial output voltage typically allows the use of more extensive R-C filtering.

It may be noted that the circuits of figure 2(a) and (b) both incorporate a fixed resistor in series with the connection to the heater winding. The purpose of this resistor is to limit the amplitude of the switch-on current surge through the diode(s), which surge occurs when power is first applied to the uncharged reservoir capacitors.

Calculation of the resistor value is based upon knowledge of the surge current rating of the diode(s) in use. As the effective AC supply resistance of the transformer heater winding will in general be negligibly low, a convenient assumption is that upon switch-on, the reservoir capacitor(s) are an effective short-circuit, with the only circuit resistance provided by the surge limiting resistor. The value of this resistor should thus be equal to or greater than the value 9/I, where 9 represents the approximate peak value of the 6.3V transformer secondary voltage, and I is the surge current rating of the diode(s) employed.

The value of 100 ohms shown in the diagrams may thus be seen to be appropriate for diodes having a surge current rating of approximately 90mA,which figure is typical for many of the small glass-package germanium and silicon devices which lend themselves for use in low-current supplies. Naturally if diodes of higher rating were used, the resistor value could be reduced proportionally; for silicon metal – or epoxy-encapsulated devices having an average current rating of 500mA-1A and a typical surge rating of 5A, a value of 2.2 ohms would be in order.

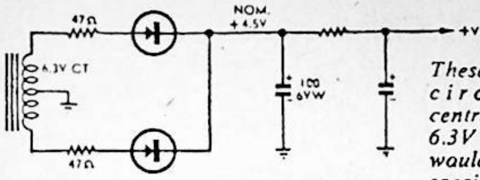
Although there may be a natural temptation to give the surge limiting resistor a value larger than that sufficient to limit the surge current within the diode ratings, this is not necessary. In fact it will generally be undesirable, because increasing the resistor will degrade the potential loading regulation of the supply.

Fairly obviously the circuits shown in figure 2(a) and (b) will be of limited use in equipment where the 6.3V heater line has an earthed centre-tap, because in this case they will provide peak output voltages of only 4.5V and 9V respectively. In such equipment it will therefore generally be necessary to employ other rectifier circuits, possibly those illustrated in figure 3.

In figure 3(a) is shown a full-wave circuit. While this will only provide a peak voltage output of 4.5V across the reservoir capacitor, the full-wave action results in somewhat improved regulation and reduced ripple amplitude (also twice the frequency, at 100Hz) compared with the half-wave circuit. Hence it is often quite feasible to employ such a circuit to deliver well-filtered 3V DC to a pre-amp or similar circuit, whereas this is usually not possible with the half-wave circuit.

Although the circuit configuration shown produces a DC output having the negative polarity at earth potential, the alternative positive-earth arrangement can be provided as before simply by reversing the polarity of the diodes and capacitor(s).

In fact there is no reason why positive-earth and negative-earth full-wave circuits cannot be connected to the same heater winding, and this is shown in figure 3(b). From the diagram it may be seen that the circuit then becomes virtually a "full-wave bridge", in which the DC output is inherently centre-tapped with respect to earth. The resultant +4.5V and –4.5V supplies may typically be used for pre-amplifiers, logic gates and other control circuitry.



(a)

These full-wave circuits for centre - tapped 6.3V windings would have a special appeal if used in conjunction with a small, centre - tapped 12V transformer.

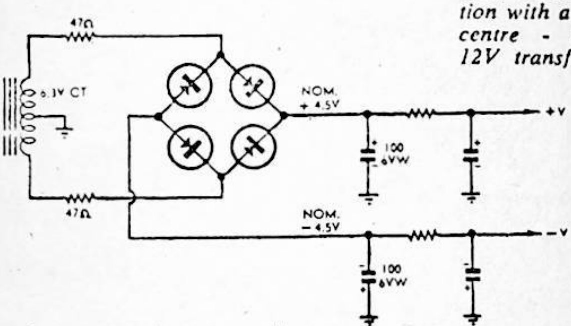


Figure 3 (b)

As before the circuits are fitted with surge limiting resistors, in this case having a value of 47 ohms to permit a maximum diode surge current of 90mA. Lower values may of course be used with diodes having higher surge ratings.

There will no doubt be cases where higher DC supply voltages than are provided by the circuits of figure 3(a) and (b) must be derived from a centre-tapped 6.3V heater line. In such cases the circuits shown in figure 4 may prove useful, particularly where only moderate current drains are involved.

The basic circuit shown in figure 4(a) may be regarded as a half-wave "voltage one-and-a-halfer", for it combines some of the features of both the simple and voltage-doubling half-wave circuits. During one AC half-cycle it charges up reservoir capacitor C1 via diode D1 to the peak value of the full 6.3V secondary voltage – i.e., to approximately 9V. Then during the next half-cycle the capacitor voltage is effectively added to the voltage produced by half the heater winding, and fed via diode D2 to charge up reservoir capacitor C2 to a peak value of some 13.5V.

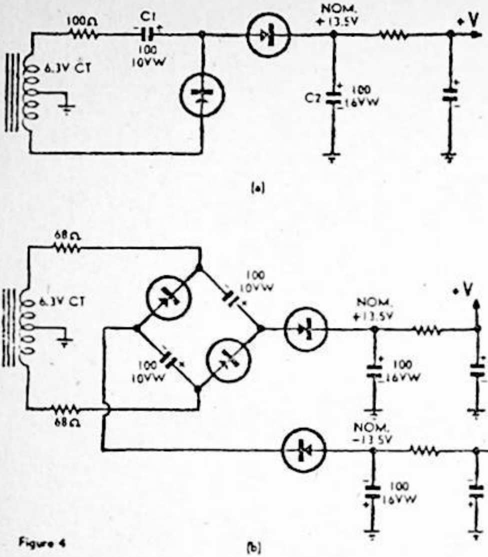


Figure 4

Novel arrangements which give a peak or unloaded DC output approximately equal to 1.5 times the peak value of the AC supply circuit. They would be suitable for situations where voltage and hum level were not critical factors.

Although shown in the form which delivers output having earthing of the negative polarity, this circuit as with the others described may easily be arranged to produce positive-earthed output simply by reversing the polarity of the diodes and the electrolytic capacitors. And as with the circuit of figure 3(a), there is no reason why the two versions of the circuit cannot be connected to a single heater winding, as shown in figure 4(b). As may be seen this arrangement provides a simple and convenient method of providing both +13.5V and −13.5V for differential amplifiers and similar circuitry.

In closing it should be noted that the output voltages shown for each of the circuits given in figures 2, 3 and 4 are the "peak" values, which correspond to the situation where the circuits concerned are lightly loaded. With increasing loading, the voltages will generally gall fairly rapidly to approximately 0.6 of the values shown, thereafter falling less rapidly.

The actual current levels at which each voltage will have fallen by a particular proportion will depend largely upon the size of the reservoir capacitors, and also to a lesser extent upon the value of the surge limiting resistor(s) and the regulation of the transformer heater winding. Hence to obtain as close to the peak output as possible from each circuit, it will be necessary to use the largest feasible values for the reservoir capacitor(s), and to use no larger value for the surge limiting resistor(s) than is strictly necessary.

EQUIVALENT SEMICONDUCTORS

AC128	AS126, AC117-124-153, CV9779, NKT281-302, OC74-318, GET110, SK3004, RS276-2001, SFT232, 2SB222-415, 2N467-659-1373-1384-1926-2001-2431-4106.
AY6108	2N2219, BCW78/16, BSW52, BSY34, 2N697-698.
AY6109	2N2905, BCW80/16, SK3025, RS276-2021.
AY9149	AY9150
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BYX21/200	1N3491, DD6123, 1N2156-3493, 2SB20T, 26MB2, H7682
BZY88/C6V8	1N3411, 1N4628.
BZY88/C6V2	AN753.
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EM401	OA626/50, BY126/50, SD55-05, RS276-1139-1101-1105, BY127, 1N4002-4007, BY127, BAY219.
OAZ203	OAZ210, Z2A68 - 10%
OAZ207	OAZ212, Z2A100 - 10%
TT800	AY9139, BFR80.
TT801	BFR40, RS276-2018, 2N4921, BD131, T1P29, 2SC496
TT3569	AY6018
2N301	RS276-2006, AD131-138/50, 2N2869-3611, OC16, 2N257.
2N697	BSX45-45/10, BSY44-51, 2N2218, RS276-2009, 2N697.
2N2147	RS276-2006, AD149-167, 2N1907.
2N2175	OC74, RS276-2005, 2N2944/5.
2N3055	BD130, BDX10, BDY20-39, 2N3713, RS276-2020, AM219, SK3027, CV8889.
1N1763	BY114-126-127, 1N4004.
1N2858	1N3193, 1N4001.
1N4002	BY127, EM502, RS276-1102, IS100.
40250	RS276-2019, BD131, BDX24, BD130, 2N3055.

N. B. Although equivalent semiconductors may have similar electrical properties, physical dimensions may be different and this must be born in mind if space is tight and for mounting detail.
Remember polarities when replacing PNP with NPN and vice versa.
If in doubt always be advised by your local dealer for suitable equivalent semiconductors.

NOTES

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