DISCOVERY SERIES

K-2808 REGULATED POWER SUPPLY - 1.2V TO 37.5V / 1.5A max

ASSEMBLY MANUAL

This kit provides a general purpose regulated power supply module that attempts to fully exploit the versatility of the LM317T three terminal positive voltage regulator IC.

Regulators like this one are required for supplying equipment or devices that can be adversely effected by variations in their supply voltage, or where there is a possibility of line (e.g. 240v mains) variations or transients exceeding the absolute maximum limit of the equipment. The high stability of this circuit also makes it useful as a voltage or current reference for test purposes. Because of its low cost, it can simply be used as a substitute for batteries where the 240V mains or a car cigarette lighter supply is available.

The kit can be configured as any one of the following types of power supplies by inserting or deleting certain components as described in the instructions:

- *fixed or variable voltage regulator*
- *voltage regulator with programmable current limiting*
- *combined voltage/current limiting (e.g. for lead/acid battery charging)*
- *constant current source (e.g. for nicad battery charging)*

Specifications

Dimensions	51(L) x 53(W) x 41(H) mm (with optional lower voltage filter capacitors the height can be reduced to 24mm)
Output voltage limits	+1.2V to +37.5V (-1.2V to -37.5V with negative option)
Temperature Stability	1% typ for 0<Tj<125°C
Load Regulation	0.3% typ for 0<Iout<Imax (Iout taken from LM317T metal tab)
Line Regulation	0.02%/V typ for 3V<Vin-Vout<40V
Output current	1.5A max with heatsinking (see graph 1)

Input voltage limits
— AC supply (2 wire) 4 - 28Vac (recommend 25Vmax xfmr or 50V with C.T. xfmr)
— DC supply 5-40Vdc

Overload Protection (all configurations)
— current limit 1.5A min
— temp limit Tj = 125 deg C max

The LM317 has built-in current and power overload protection which makes it safe against those inevitable short circuits and overloads, even if the programmable current limiting is not used.

The circuit is built on a single 5x5cm (2"x2") PCB (printed circuit board) and includes rectifiers and filters, so that all that is required is an AC or DC source such as a power transformer or plugpack and, depending on specific requirements as explained in the instructions, a heatsink may be required (this may just involve mounting the board against the side of a metal box).

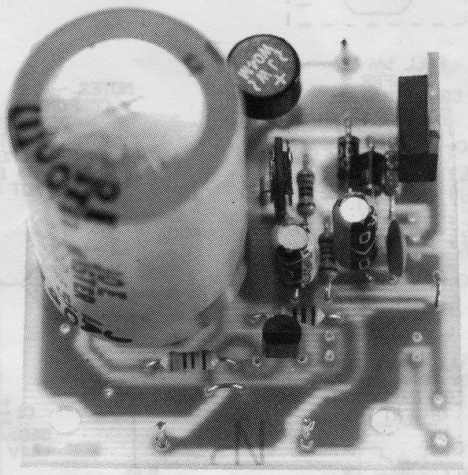
Please read Disclaimer & Guarantee carefully before commencing construction.

The guarantee on this kit is limited to the replacement of faulty parts only, as we cannot guarantee the labour you provide.

It is recommended that if a kit builder does not have enough knowledge to diagnose faults, that the project should not be started unless assistance can be obtained. (Unfortunately, one small faulty solder joint or wiring mistake can take many hours to locate and at normal service rates, the service charge could well be more than the total cost off the kit!).

If you believe that you will have difficulty in building this kit and you cannot get assistance from a friend, we suggest you return the kit to us in its original condition, accompanied by receipt of purchase, for a refund under our satisfaction guarantee.

Unfortunately, kits cannot be replaced under our satisfaction guarantee once construction has been commenced.



OPERATION

For the following description of the operation refer to the main circuit diagram and the application circuits. For the initial part of the description, we will assume that links J2 and J3 have been inserted to disable the current limiting and current source options.

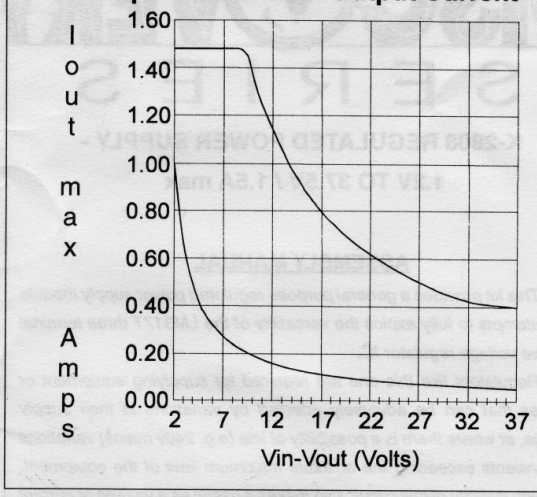
This power supply is based on the LM317T three terminal series voltage regulator (IC1). It is basically a 1.25V regulator which is programmed by two external resistors to get an output range of 1.25V to 37.5V. The LM317 maintains a very stable 1.25V reference (which will be referred to in the text as Vref) between the OUT and ADJ terminals of the regulator. Vref can actually be anywhere between 1.20V and 1.30V, a 4% range due to manufacturing tolerances, but for any particular device it has a value within this range which varies no more than typically 0.3% with an output current variation of 10mA to 1.5A, and by 1% with an internal temperature variation of 0 to 125 deg C.

The voltage at the DC OUT terminals is determined by the values of resistors R1, R2 and VR2 and is given by the formula:

Vo = Vref * (1 + R / R1) where R = R2 + VR2..... (1)

The current that flows from the ADJ terminal through R2 to ground is typically 50uA which is a negligible fraction of the total current through R2 (10mA) and so is not included in formula (1). Table 1 gives sample values for R2, VR2 and Vo as calculated from formula (1). The minimum output voltage obtainable from the supply is equal to Vref and is achieved by replacing R2 and

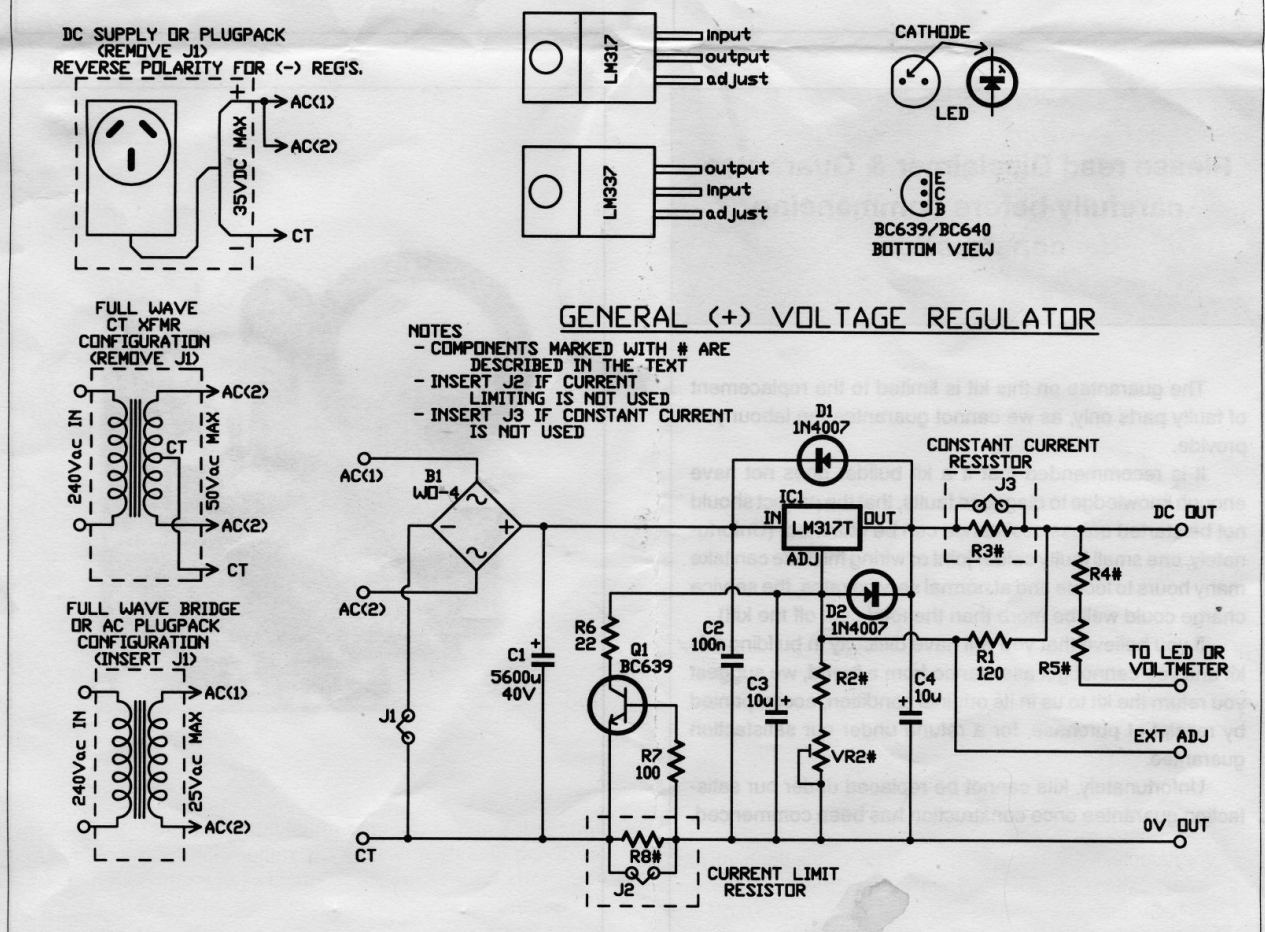
Graph 1: Maximum Output Current



NOTES:

- This graph applies to an ambient temperature of 25deg C
- The lower curve is for the LM317 not attached to a heatsink, the upper curve is for a heatsink with a thermal resistance of 2°C/W.
- Vin-Vout is the voltage between the IN and OUT terminals of the LM317.

Circuit Diagram



PARTS LIST

Resistors

(0.25W 1% metal film unless otherwise stated)

R0	0 Ω	jumper wire
R1	120Ω	
R2	values from table 1 supplied;	
	24Ω, 150Ω, 430Ω, 680Ω, 1k, 1.2k, 2k	
R3	optional, not supplied - see text	
R4,5	optional, not supplied - see text	
R6	22Ω	
R7	100Ω	
R8	1Ω 1W carbon film - see text	
VR2	200 ohm vert trimpot - see text	

Capacitors

C1	5600µF 40VW RB electrolytic
C2	100nF/0.1µF/104 ceramic
C3,4	10µF 63VW RB electrolytic

Semiconductors

IC1	LM317 adjustable regulator
Q1	BC639 NPN transistor
D1,2	1N4007 silicon rectifier diode
B1	WO-4 bridge rectifier

Miscellaneous

PCB 53 x 51mm, coded ZA-1208; PCB pins; solder.

Resistor Colour Codes

	4 Band 1%	5 Band 1%
22Ω	red red blk brn	brn red blk gld brn
100Ω	brn blk brn brn	brn blk blk blk brn
120Ω	brn red brn brn	brn red blk blk brn
24Ω	red yel blk brn	red yel blk gld brn
150Ω	brn grn brn brn	brn grn blk blk brn
430Ω	yel org brn brn	yel org blk blk brn
680Ω	blu wht brn brn	blu wht blk blk brn
1k	brn blk red brn	brn blk blk brn brn
1.2k	brn red red brn	brn red blk brn brn
2k	red blk red brn	red blk blk brn brn
0Ω	blk (single band)	-
1Ω 1 watt 5%	brn blk gld	-

VR2 with zero ohm resistors or wire links.

One requirement for proper operation of the LM317 is that the current from its OUT terminal must be at least 10mA. This is achieved by making R1 equal to 120 ohms so that the current through R1, R2 and VR2 is always 10mA independent of the value of R2 and VR2. This way the voltage regulation is maintained even without an external load.

Although R1, R2 and VR2 determine the ultimate output voltage of the regulator, it is necessary to add some capacitance, as with most regulators, to stabilize the circuit against rapid changes in load or line conditions. The 10uF capacitor C3 connected between the adjust terminal and ground is used to reduce the amount of AC ripple that is fed through from the unregulated input to the output, and the 10uF capacitor C4 is used to swamp any ringing that may otherwise appear at the output under various load conditions. The 0.1uF ceramic capacitor C2 is necessary to bypass high frequencies that appear at the input to the LM317, because large capacitors like C1 are

Component Overlay

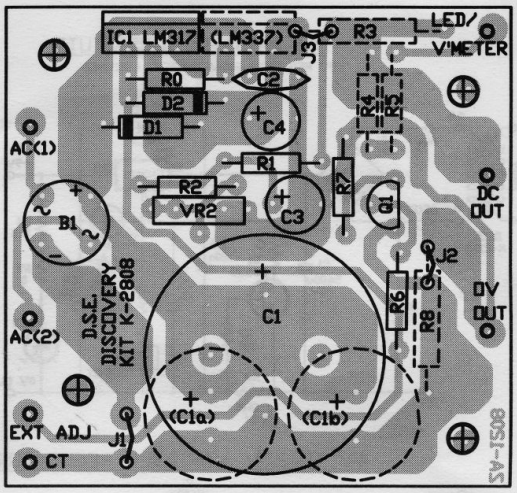


TABLE 1 - TYPICAL VALUES OF R2, VR2
(set value, not total resistance) and Vo

Vo	R2	VR2
1.25	0	0
1.5	24	0
3.0	150	18
6.0	430	27
9.0	680	62
12.0	1k	33
15.0	1k2	120
24.0	2k	180

NOTE: These values assume Vref = 1.25V

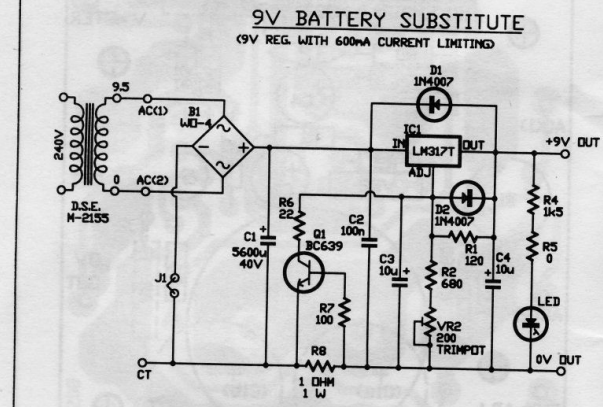
not very effective at high frequencies, and the isolation between C1 and the IN terminal due to the inductance of the connecting track also reduces its effectiveness at high frequencies.

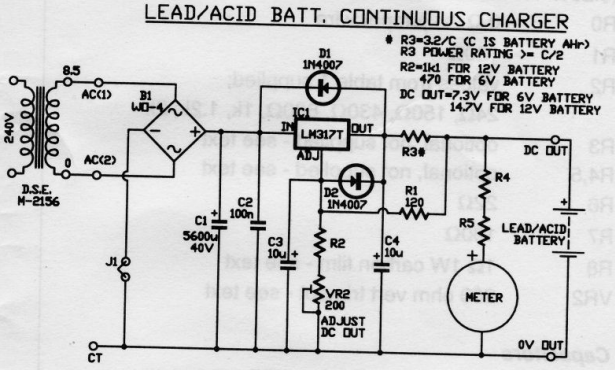
If the input to the regulator is switched off, it is possible for the voltage on the OUT terminal to be higher than the voltage on the IN terminal due to the charge stored in C4, or due to having a battery under charge connected to the output. To prevent this reverse voltage from damaging the LM317, diode D1 is added to bypass this voltage around it. In a similar way, the LM317 can be damaged by the charge on C3 causing the ADJ and OUT terminals to be reverse biased when the output is shorted to ground. This is prevented by D2 which bypasses the reverse voltage.

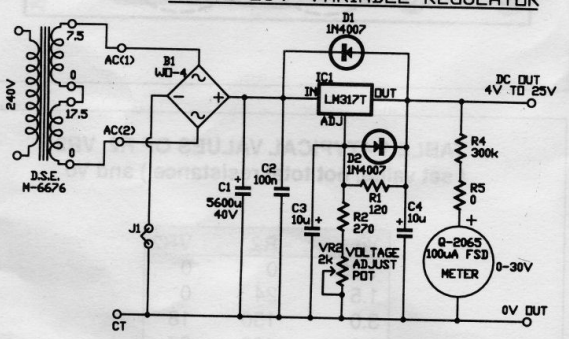
When the kit is used as a fixed voltage regulator, VR2 can be either a 1/4W metal film resistor or a 5mm vertical mount trimpot (there are suitable pads on the PCB for mounting either one). It is better to use a resistor than a trimpot because trimpots can later change their value due to vibration, dirt or maladjustment. If the kit is used as a variable voltage regulator then VR2 can be replaced by two PCB pins to make connection to a an externally mounted potentiometer used as the variable voltage control.

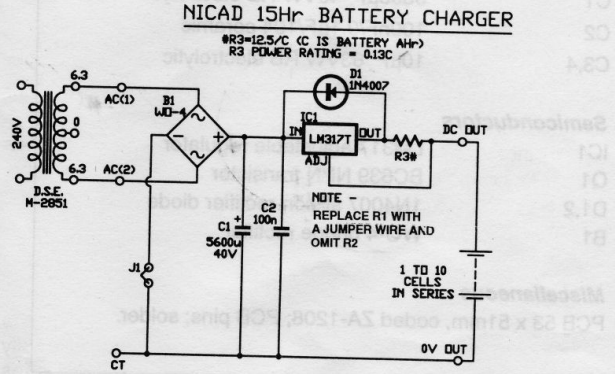
There is a minimum voltage that must be maintained between the IN and OUT terminals of the LM317 for proper regulation. This value (Vin-Vout) is called the dropout voltage. The dropout voltage varies with temperature and load current, but for this device it does not exceed 2.5V under normal operating conditions.

Typical Applications









The kit has been fitted with a rectifier bridge B1 and a 5600uF filter capacitor C1 so that the supply to the regulator can be either AC or DC. The circuit diagram shows how to connect the various sources to the input. Filter capacitor C1 ensures that the ripple voltage appearing at the input to the LM317, when using 50Hz ac supplies, does not exceed 2Vp-p under any load conditions. The capacitor supplied for C1 has a working voltage rating of 40V to match the 40V absolute maximum input voltage of the LM317, but provision has been made on the PCB for using two smaller 2200uF/25VW capacitors in parallel if the voltage is not going to exceed 25V.

If the source is a dc supply, the positive terminal of the supply is connected to both AC(1) and AC(2) and the negative terminal to CT. Wire link J1 must be left out or else the bridge will be damaged if the polarity is reversed. With this connection method, the input current effectively flows through two parallel diodes in B1 which offer reverse polarity protection and result in a voltage at the IN terminal of less than 1V below source voltage.

The most common ac source is the two wire mains transformer output. This is connected between AC(1) and AC(2) with link J1 inserted. To work out what voltage is going to appear at the IN terminal in this case, let us connect a transformer with a 25V/60VA secondary winding to it. Firstly, we have to allow for the possibility of the 240V mains reaching about 254V which will increase the secondary voltage to 26.5V. Secondly, if the transformer regulation is about 6%, which is a typical value for this size transformer then, without a load connected to the regulator output, the transformer secondary voltage will be about 28.0V. The instantaneous peak value of this voltage is 39.7V and so the value of Vin will be 39.7V, minus two diode voltage drops through bridge B1, which makes Vin about 38.5V. The overvoltage conditions just mentioned are the reason why the recommended maximum transformer secondary voltage applied to this circuit is 25V.

Current Limiting

The current limiting built into the LM317 is designed to limit its power dissipation to 25W. This is the maximum power that the LM317 can dissipate when the room (ambient) temperature is 25°C, even if it is attached to an infinite heatsink, before its internal (junction) temperature exceeds 125°C. So without the optional external current limiting, the maximum available current from this regulator can be calculated from the following formula:

Imax = 25 / (Vin - Vout)..... (2)
or Imax = 1.5A
(whichever is smaller)

If the maximum current you want from the regulator is significantly less than the current calculated from formula (2), then it is a good idea to limit the current further, and so protect the load from damaging excess currents. To this end, components Q1, R6, R7 and R8 have been added. The effect of this circuit is to pull the ADJ terminal voltage, and hence the output voltage, down until the current is no more than the limit value determined by the value of R8. The way it works is that the load current causes a voltage drop across R8 which is fed between the base and emitter of Q1 via R7. This voltage has no effect until it reaches about 0.6V at which point transistor Q1 gets enough

base current to start to conduct from collector to emitter. The value of this current limit is given by the following formula:

Imax = 0.6 / R8..... (3)

There are a couple of restrictions on the effectiveness of this current limiting. Firstly, the current limit is not a sharp cut-off, it starts to limit when the Vbe of Q1 is just below about 0.6V and increases rapidly above that. Secondly, even when the ADJ terminal voltage has been pulled down to 0V the output voltage is still 1.25V, and if this voltage is not low enough to reduce the current then the limit reverts to the LM317 internal limiting. Resistor R8 must be rated to withstand a 2A constant current.

Constant Current Source

The LM317 can be configured as a constant current source as shown in the Nicad charger application circuit.

The value of the output current is determined by the value of resistor R3 according to the following formula:

Iout = Vref / R3..... (4)

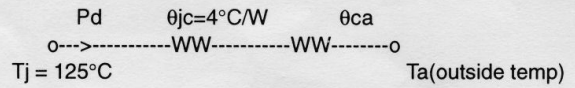
The value of this current cannot exceed the LM317 limit as given by formula (2), and the link J2 should be inserted to disable the optional current limit circuit. This form of current control can be combined with voltage regulation to provide a circuit that is especially suitable for charging lead/acid batteries (refer to the circuit application), with current limiting when the batteries are flat, and voltage limiting when they are fully charged.

Heatsinking

For optimum regulation and maximum output current the LM317 should be attached to a heatsink. Although it is internally protected to prevent its semiconductor junction temperatures exceeding 125°C, its life can be shortened if this limit is reached too many times. The junction temperature depends on the total power dissipation of the device and on the thermal resistance between the junctions and the outside. For the LM317T the thermal resistance between the semiconductor junctions and the metal tab (θjc) is 4°C per watt i.e. for every watt of power it dissipates, the temperature difference between the junctions and the case increases by 4°C. Between the junctions and the air (θja), without a heatsink, it is 50°C per Watt. Thermal resistance (θ), temperature (T) and power (P) are analogous to electrical resistance, voltage and current respectively, and are related by the following formula:

T = θ* P (analogous to Ohms law V = R * I)..... (5)

Using this formula the junction temperature of the IC can be calculated using heatsinks of known thermal resistance (θca). If you are familiar with ohms law then the following diagram can be used to calculate the maximum allowed power dissipation, and hence the maximum output current. The thermal resistance of D.S.E. heatsinks are shown in the D.S.E. catalogue.



The maximum current that the LM317 can supply is given by the following formula:

Imax = Pmax / (Vin - Vout)
= (Tj - Ta) / (θjc + θca) / (Vin - Vout)
= (125 - Ta) / (4 + θca) / (Vin - Vout).....(6)

For example, if the air temperature is 25°C, the heatsink has a thermal resistance of 2°C/W and the voltage across the LM317 is 20V, then (allowing for a thermal resistance of 0.8°C/W for the joint between the heatsink and the case of the LM317):

Imax = (125 - 25) / (4 + 2 + 0.8) / 20
= 0.74A

Graph (1) shows this example for the whole voltage range.

External Voltage Control

If there is a need to remotely set the regulator voltage, then R2 and VR2 can be replaced by resistance connected between the EXT ADJ terminal and the 0V terminal (not the CT terminal). The voltage could then be controlled by a computer program using the Discovery Series Computer Interface Kit K-2805, with each of its digital outputs switching a different resistor to the EXT ADJ terminal (the computer and K-2805 earths have to be connected to the 0V terminal of this kit.

Negative Regulator

If you want to provide a regulated negative supply then all that is required is to use an LM337T instead of the LM317T (the overlay diagram shows where it is mounted), replace the BC639 with a BC640 and reverse all polarized components including diodes, electrolytic capacitors and rectifier bridge B1. And of course, if the source is a dc supply its polarity will also have to be reversed. All of the circuit operation applies equally to the negative regulator.

CONSTRUCTION

To mount the components on the PCB, start with the low profile components first and then work your way up to the larger components. If any of the parts are missing or the wrong type then use the enclosed quality control card to order replacements.

To place the components, look at the overlay diagram which shows how the components and wire links actually appear on the PCB. Read the label of the component, e.g. C2, from the overlay and then look up the description next to that label in the parts list. For example, C2 is a ceramic type capacitor and it has the value 100nF and may be marked either 100n, 0.1 or 104.

Begin construction by installing the links and resistors. The resistors have their values marked on them as a colour code, which is given in the parts list. The last band of the colour code gives the tolerance value and is the one that is farthest from the others. Resistors can be mounted in either direction, but it is good practice to mount them with their colour codes all in the same direction for ease of reading the values. One of the resistors supplied with the kit, R0, is actually a wire link. It has the appearance of a 1/4W 5% carbon resistor but has a nominal 0 ohm resistance, and on the overlay it is shown as a resistor.

When mounting the rectifier bridge B1, leave about 1cm of lead length above the PCB so that it can conduct heat away more effectively. The LM317 should also be left with as much lead length as possible so that it can be attached to a heatsink if necessary.

All of the capacitors except for C2 are polarized types which will have a negative (-) or (+) sign printed on them (normally the (-) lead is marked). These must be mounted in the direction shown on the overlay.

When the assembly of the board is complete, carefully check all the soldering. Look especially for dry solder joints, and solder bridges shorting tracks together.

Note on connecting the regulator output

If the constant current resistor R3 is not used then it is better to take the output from the metal tab of the LM317T, either by soldering directly or with a lug, rather than from the DC OUT terminal because it results in better voltage regulation. If resistor R3 is used, then connection has to be made via the DC OUT terminal.