Power Supplies

There are a number of ways to obtain the low voltages required to run small projects from the wall power outlet. The simplest way is to buy a factory-built molded supply which is designed to plug directly into the wall outlet. Some such supplies have an internal voltage regulator and need no additional parts, others provide an unregulated DC voltage and many are simply AC transformers in a box. The regulated types offer less power output for a given size with currents limited to a couple of hundred milliamps but the AC transformer types can provide several amps. The distinct advantage of the molded supply is that no line-voltage wiring is required and they are easy to find in local stores. Some deluxe models have a terminal for the earth ground which may be used to ground the chassis of your project. Such supplies should be grabbed up quickly when spotted at the flea market or in the surplus catalog! Inexpensive computer supplies offer high currents by using switching regulator technology but these supplies often require a fairly high minimum load current (usually on the 5 volt output), so use this type of supply with care.

The unregulated DC supply is a very common type and the simple regulator shown in fig. 1 may be added for projects that require a stable voltage.

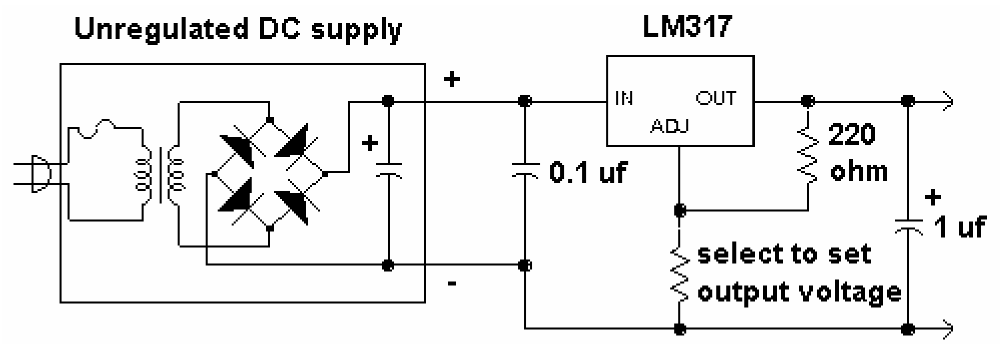
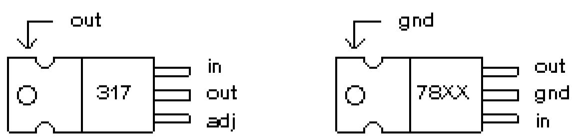


Figure 1: Voltage regulator for molded supplies.

Select a molded supply with an output voltage several volts above the desired regulated voltage but remember that the more voltage that the regulator drops, the hotter it will get. A heat sink may be added to the regulator but the regulator's metal tab is connected to the output voltage so insulation may be needed. The voltage set resistor is selected from the following chart.

Voltage	1.25	1.5	3	5	10	12	15	24
Resistance	0	47	300	680	1.5k	2k	2.5k	4k

A 5k potentiometer may be used to set the voltage or just to find the optimum value for a fixed resistor. The two most common packages for the LM317 are called TO-220 and TO-202 which have black plastic bodies with metal tab heatsinks. A hole is provided in the metal tab for mounting but this tab is electrically connected to the center pin which is the output pin. The input pin is on the right side and the adjust pin is to the left when the device is held so that the markings may be read (leads down, metal tab to the back):



Fixed regulators such as the LM7812 (12 volt) need no resistors and may be mechanically grounded without insulation since the tab is internally connected to ground. Either way, these three-terminal regulators perform well and offer built-in current limit and thermal overload circuitry. Make sure to include the input and output capacitors as shown and mount them fairly near the regulator IC.

To convert an AC molded transformer into an unregulated DC supply, simply add a full-wave bridge and large electrolytic capacitor as shown in fig. 1. The size of the capacitor will depend on the load current and the amount of allowable ripple voltage but a standard 1000uf capacitor with a voltage rating well above the output voltage is a good starting point. Measure the voltage across the capacitor with no load to make sure that its voltage rating is high enough. Here are some equations for selecting the transformer secondary voltage and the filter capacitor:

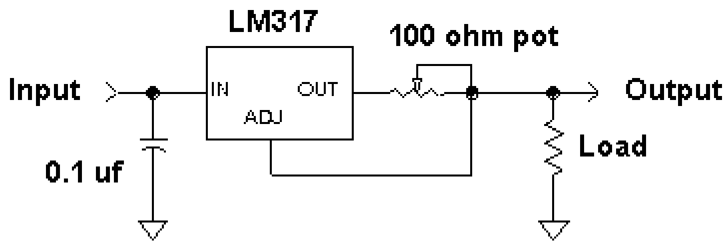
VRMS = 0.815 (VDC + 1.4) (assumes a full-wave bridge)

C = (DC current max.) /(60 x 2 x Vp-p) where Vp-p is the ripple voltage under full load.

This equation is for 60 Hz and other frequencies may be accommodated by changing the 60 in the denominator.

The three-terminal regulators can also be used to drop and regulate a battery voltage but remember that the regulators usually need at least a 2 volt drop to regulate properly. (Low drop-out versions needing less than 1 volt drop are available.)

The LM317 can also be used as a current limiter which is handy when experimenting with new circuitry since a simple mistake can lead to disaster if unlimited power is available from the power source. Fig. 2 shows a simple current limiter for the test bench which simply connects in series with the bench power source or battery.



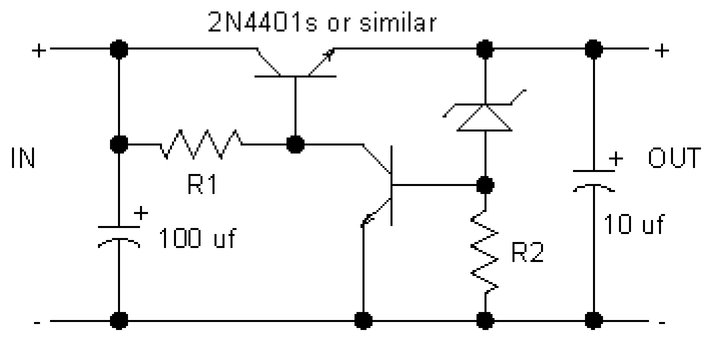
Place the current limiter ahead of the voltage regulator so that the limiter doesn't drop the regulated voltage presented to the load. The 100 ohm pot may be replaced with a fixed value if the adjustment is not needed. The value is selected by:

R = 1.2 / I

With the 100 ohm pot shown, the lowest current setting will be about 12ma. Lower currents will require additional circuitry since the LM317 must supply a minimum amount of load current for proper operation. A voltage regulator may be added after this current limiter to make a current-limiter, variable voltage bench supply.

This current limiter may be made without a heatsink to add a slow foldback feature. When the current limits, the LM317 will become hot and its internal thermal limit circuitry will reduce the current below the set point. The device must cool down before full current will be available again.

Misc. Regulator Circuits



This simple regulator provides excellent performance when the input voltage is several volts above the output voltage. The output voltage is set by the zener and is approximately 0.6 volts above the zener's rating. Select R2 to set the zener current from the following equation:

R2 = 0.6 / Iz

A 600 ohm resistor will give about 1 mA of zener current.

Select R1 for sufficient base current for the pass transistor. A good first cut is found from:

R1 = (Vin - Vout - 0.7)/(0.1 Iout)

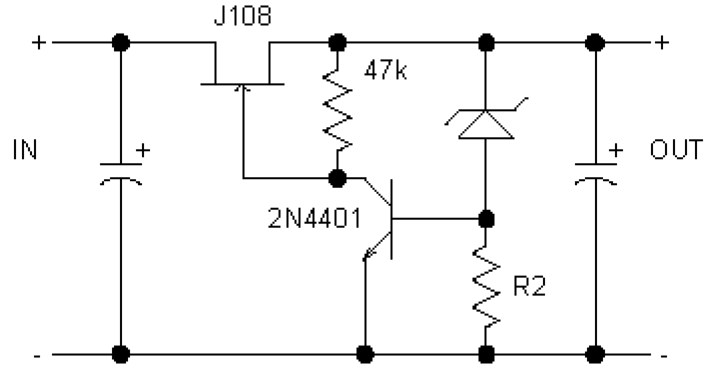
A 15 volt regulator powered from 24 volts and supplying 30 mA max. should use:

R1 = (24 - 15 - 0.7)/(0.1 x 0.03)

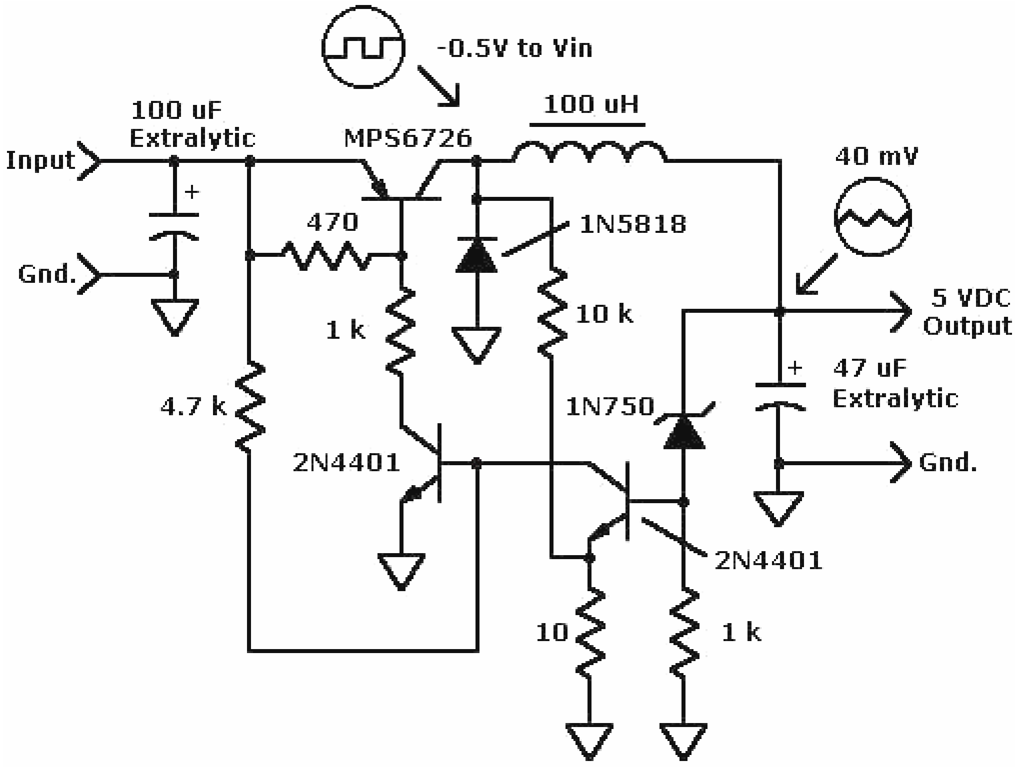
R1 = 2.8 k

A higher value may be used since this equation assumes a low gain pass transistor. The designer may multiply the value by 3 for most transistors.

This version uses an N-channel JFET as the pass element to achieve excellent line noise rejection and a bit of short circuit current protection but it is only suitable for light loads. Choose a JFET with sufficiently high Idss to power the load and select R2 as before. The output voltage must be above the pinchoff voltage of the JFET but most JFETs will work if the regulated voltage is above 5 volts.



When batteries are used to power lower voltage circuits, a switching regulator is desirable to conserve battery life. There are excellent ICs that can do the job with great efficiency and small size. An example is the Maxim (www.maximic.com) MAX639 which converts inputs from 5.5 to 11.5 volts to 5 volts at up to 225mA. The only additional parts are an inductor, schottky rectifier and a couple of capacitors. The following circuit is a discrete switcher similar in power handling capability to the MAX639. The performance is somewhat inferior to the IC switchers but suitable components can be found in most junk boxes.

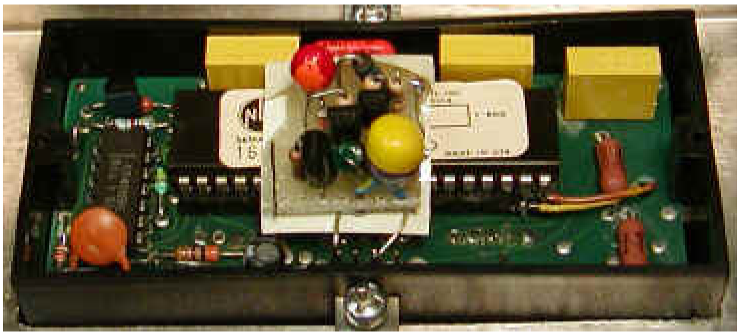


There are a few component selection considerations:

- The input and output capacitors should have a low ESR. Tantalums or special electrolytics intended for switching supplies are recommended. (Extralytic is a trade name for a low ESR aluminum electrolytic.)
- The pass transistor should have good gain at the maximum load current. The MPS6726 works well at 200mA and a 2N4403 works well up to about 150mA. The first symptom of trouble is that the top of the squarewave at the collector starts to roll off.
- The 100uH choke can be an ordinary molded type with a DC resistance not more than a couple of ohms. The circuit works with a fairly wide range of values.
- The 1N5818 may be just about any schottky rectifier since both the voltage and current are low.

The efficiency is about 80% at 200mA and drops to about 75% at 100mA due to the quiescent circuit current. The effect on battery life can be significant since small batteries are more efficient at lower discharge rates.

An example of an application is a homemade medical thermometer that uses a 3 1/2 digit LED panel meter as the readout. The meter draws about 120mA most of the time and the switcher lowers this current drain to about 80mA from a 9 volt battery. Current drain would be less for a higher voltage battery. The circuit was built on a small piece of perf board with many of the parts standing up for maximum density:



The top of the molded choke can be seen between the large yellow capacitor and the black transistor.