A Stable, Adjustable Voltage Source to Replace Mercury Batteries in EMs and Other Instruments

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From time to time, a stable but adjustable voltage source can be quite handy. This article was prompted by a request for a replacement for mercury battery voltage references which are not only difficult to find, but are not environmentally friendly. Another application could be powering a 3 to 9 volt diskman (or whatever) from a nominal 12 volt source such as an automobile. In fact, the circuit can be set to supply any voltage from 3 to 38 volts.

The DC input voltage must be a minimum of 2 volts higher than the desired output voltage and absolutely no higher than 40 volts. The LM317 regulator integrated circuit (for less than $2) is rated for up to 1.5 amperes output under optimum conditions (for the TO-220 package, shown in the following figure). Power dissipation in the form of heat can limit the output current to a lower value. The power dissipated can be calculated by subtracting the output voltage from the input voltage then multiplying the difference by the output current in amperes. The maximum allowable dissipation at room temperature (< 30° C) is about 1.5 watts (I recommend somewhat less, or the use of a heat sink). For example, an input of 24 VDC and output of 9 volts yields a difference of 15 volts. If the current requirement is 0.1 amperes, then the power dissipated is 15 X 0.1, or 1.5 watts. In this case, a small heat sink would be a good idea.

If a suitable heat sink is used to keep the tab below 60° C, the device can dissipate nearly 20 watts. If a heat sink is used, be sure to electrically isolate the tab (or heat sink) from ground or other circuitry. It is good practice to use a bit of heat sink compound between the back of the LM-317 and the heat sink surface.

Referring to the figure:

For proper operation the sum of R1 and R3 should be a value which draws about 8 ma (0.008 amps) at the desired output voltage (V_o).

$$R1 + R3 = V_o/0.008$$

The trim potentiometer value (R2) will depend on the adjustment range desired. For most applications, a potentiometer value of 10% of the sum of R1 and R2 is a good starting point. Because this article is somewhat generalized, a little experimenting with resistor values may prove necessary.

The output voltage (V_o) is a function of the ratio of resistors R1 and R3. A variable resistor, R2, is used to trim (adjust) the output to the exact voltage desired. To calculate the approximate values of R1 and R3, use the following formula:

$$V_o = 1.25\,(1 + R1/R3)$$

Standard value resistors are available only in certain fixed value steps. The closest values to those calculated should be chosen. R2 is then adjusted to obtain the exact ratio (*i.e.*, output voltage) required. Be sure to use stable resistors, either wirewound or metal film.

Parts layout is not critical, but for good temperature stability the proper resistor type should be used. Also, keep them as far away as practical from heat sources. Overall stability of the voltage will depend on a number of variables, but should typically be better than 0.25% after warm-up, and better, if the supply to the circuit is regulated and the load is constant.

The diode (D1) and capacitor (C2) are optional. The diode protects the LM317 from reverse voltages which may arise in certain applications. The capacitor (C2) will ever so slightly slow the regulator transient response, but can help reduce the possibility of introduced noise when the regulator is used in a location subject to strong interfering fields. For the most simple circuit, R2 may be eliminated, connecting R1 directly to R3 and then connecting that junction to the "adjust" lead of the LM317. Available standard resistor values will limit the output voltage values.

The LM317 is limited to a maximum of 1.5 amps. Higher current devices are available which work in a similar manner. The chip package is typically different in order to handle the higher current. The LM350 can supply 3 amps and the LM338 is rated to 5 amps. Data on these devices, as well as the LM317 can be found at the following National Semiconductor www site:

http://www.national.com/catalog/AnalogRegulators_LinearRegulatorsStandardNPN_PositiveVoltageAdjustable.html

PARTS LIST

Catalog numbers referenced here are from Digi-Key: (800)344-4539 or http://www.digikey.com. I have no vested interest in this supplier, but have been satisfied with their performance over several years and they carry all the needed parts.

LM317: (LM317AT-ND), Adjustable positive voltage regulator (see figure for pin-out). PT# 92448-ND

D1: 1N4002, 1 Amp, 200 volt (observe polarity when installing). PT# 1N4002GICT-ND

R1, R3: Exact values dependent on calculations. For best stability, precision wire wound resistors are specified. Other types may be substituted if precision stability is not a concern. PT# SC1A(value)-ND or SC3D(value)-ND

R2: Trimmer potentiometer, Bourns series 3059P, Value dependent on desired adjustment range and V_o (see calculations). PT# 3059P(value)-ND

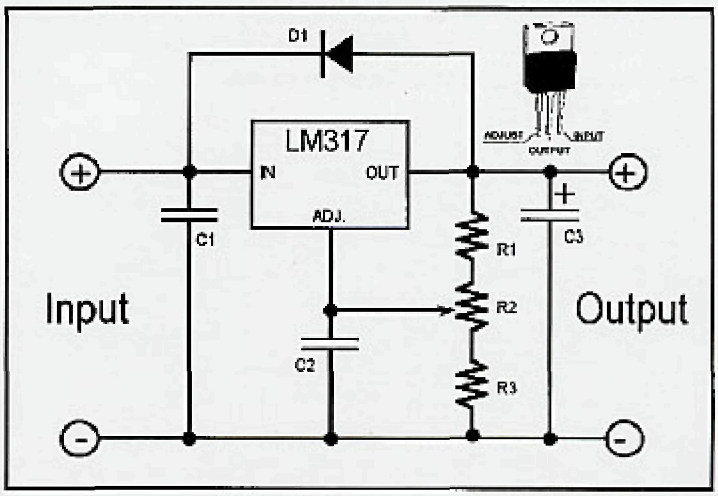
C1: 0.1 μF, 50 volt minimum, monolithic ceramic. PT# P4887-ND

C2: 220 pF, 50 volt minimum, monolithic ceramic. PT# P4804-ND

C3: 2.2 μF, 50 volt electrolytic (observe polarity when installing). PT# P6790-ND

Perfboard: Epoxy-Glass or phenolic board with pre-punched hole arrays. Available from Digi-Key, Manufacturers: Vector Co. or Keystone. A 4.5" x 6.5" (should be sufficient for 3 or more circuits) is PT# V1043.

Heat Sink: A good source for small heat sinks is a dead computer monitor. Digi-Key also carries Aavid brand heat sinks. Size will depend on heat load and ambient temperature. They also carry heat sink compound. ■



Circuit diagram for stable voltage source to replace mercury batteries

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