Portable Voltage Standard

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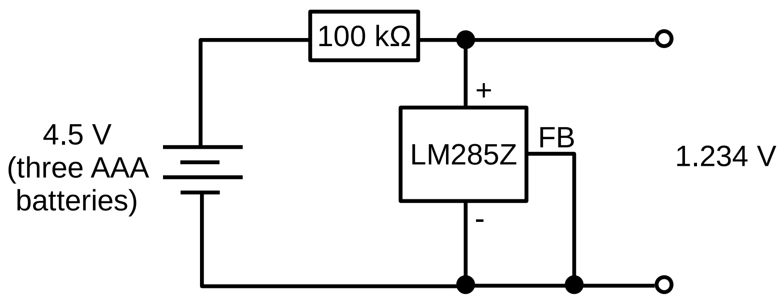
Here's a handy voltage standard that will take under an hour to make and only cost a few dollars. The nominal output will be about 1.234 V and it is nicely stable at room temperature. It will maintain its output voltage to within ±0.1% (i.e., 1.2 mV) over a temperature range of 0 ºC (32 ºF) to 40 ºC (105 ºF).

I use mine as a portable standard to check digital multimeters and other meters. About the only thing you need to remember is to not connect a load less than 100 kΩ; otherwise, the output voltage will change by more than 0.1%.

It is powered by three AAA batteries. The current draw is about 32 µA, so the batteries should last for about 4 years, assuming an AAA alkaline battery can output 1200 mA*hr. Even if the output terminals are shorted, the output current only rises to about 45 µA, so you'll still get years of use. Because the current draw is so small, no power switch is needed. Of course, you can include a power switch and get longer battery life.

You can use two AAA batteries if you want and it will still work fine. I'd recommend replacing the batteries when their output voltage drops below 2 volts.

The best part is the low cost, because it only uses two electrical components besides the battery. The heart of the device is the LM285Z voltage reference from National Semiconductor. You can buy these on the web for around a dollar. A 100 kΩ resistor is the only other component:



I built mine in a small plastic box from Maxim that some sample parts came in. I used two 3/8" long 4-40 screws for the terminals (with star washers to hold them tight). They also hold the components' leads, which reduces the amount of soldering.

The picture shows the details. I clamped the three batteries in a vise and taped them together using electrical tape. Then I soldered them in series. The positive terminal had the 100 kΩ resistor soldered to it. A small wire was soldered to the negative terminal.

Figure 1

The red arrow points to the LM285Z integrated circuit.

I soldered the two outside leads (FB and -) of the LM285Z to the wire from the negative battery terminal and these were then clamped to the negative output terminal. The middle lead of the LM285Z went to the positive output terminal, along with the free end of the 100 kΩ resistor.

The box came with a piece of antistatic foam in it that was the perfect thickness -- when the lid is closed, the batteries are held against the foam so they don't move.

I wrapped the box with tape to hold it closed. I wrote the output voltage on the tape so I wouldn't forget it.

Update 12 Jun 2011

The LM285Z has a specified temperature coefficient of less than 150 ppm/°C. To check this, I put the whole box in our freezer for a few hours; the measured voltage output was 1.23624 V for a freezer temperature of 15 °F (-9.4 °C). The temperature was 72 °F for the standard voltage. Thus, the measured temperature coefficient in ppm/°C is

$$10^6\left(\frac{1.23454-1.23624}{\frac{1.23454(72-15)}{1.8}}\right)=-43\ \text{ppm/°C}$$

which is about a third less than the spec.

Update 13 Jul 2012

I just replaced the AAA batteries in my unit after 4.8 years of use. Over that time frame, the measured standard deviation of the output (**including** the effect of room temperature variations and the variance of my HP 3456A voltmeter) was 170 μV or a coefficient of variation of 236 ppm. Pretty good for an IC that can be had for about a buck or so.