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A Linear Scale Milliohm Meter; another look...

In the July/August 2012 issue of QEX, Steve Whiteside, N2PON, described the design and construction of a stand-alone milliohm meter for general use.

I had been looking for something similar, to make it easier to check some ground connections and some coax connections on a group of older ARES 2M antennas, built for emergency deployment.

I too had found that my trusty Fluke Digital Multimeter (DMM) was unreliable at the low end, for example when trying to measure 1 or 2 ohms or less.

Like N2PON, I wanted a no-nonsense, small, portable, milliohm meter that I could pick up anytime and put to use.

Other than that, my main design goals were:
1. use standard components as much as possible
2. simplified design, with minimum component count
3. temperature/drift independence
4. AA battery power supply, 3 v max
5. tolerant of up to 20% battery discharge
6. single linear scale, 0 – 2.0 ohms

Design:

At first thought, I planned to use the old reliable LM314T adjustable voltage regulator IC. One popular adaptation of this device is use it as a constant current source, and this is well described in various manufacturers data sheets, example. See Fig 1. below:

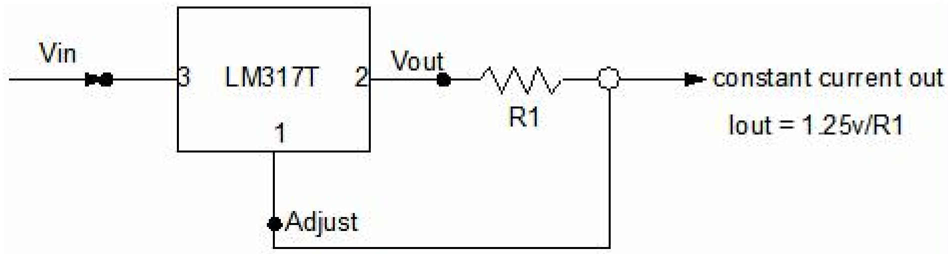


Fig. 1 LM317T constant current circuit example

This simple circuit with just 2 the components shown, is capable of providing a surprisingly accurate and drift-free constant current source, despite varying input voltage or ambient temperature. The catch however, is that the minimum input voltage Vin for the LM317T is 3 volts, most of which is lost in this configuration to the combination of drop-out voltage and the forced Vref voltage of 1.25 V across R1.

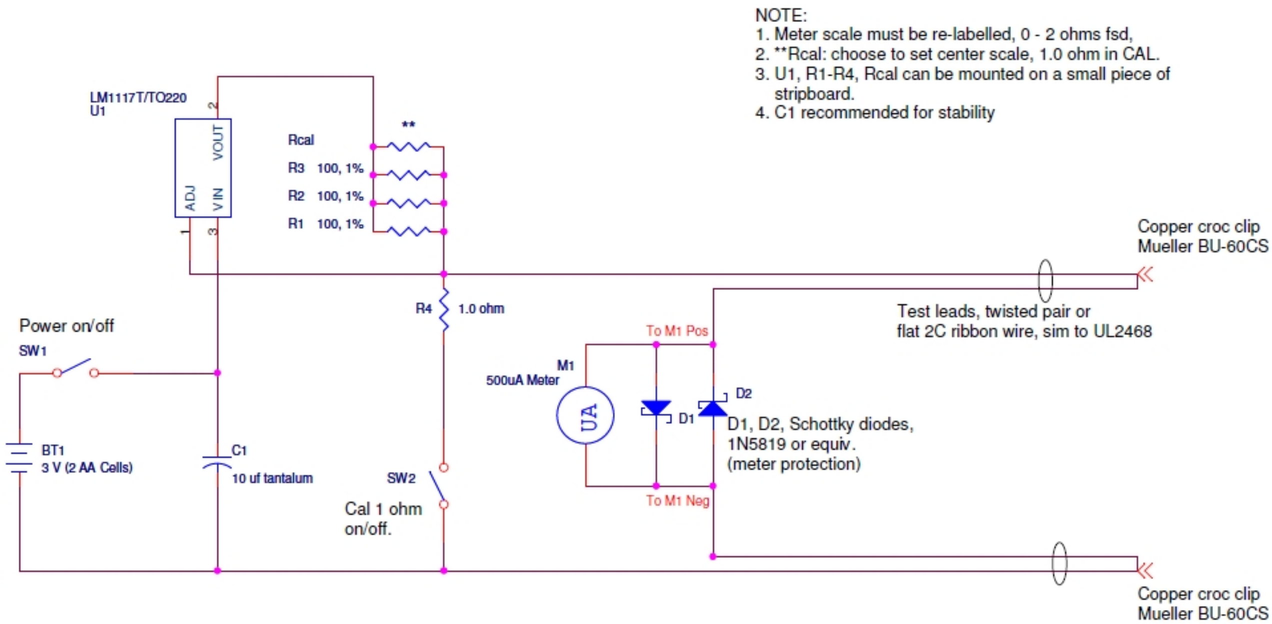
I eventually chose to use the LM1117T, which is also a low drop-out regulator and has the same pin-out and TO-220 package as the LM317T. The LM1117T has a specified drop-out voltage of only 1.2 V max. In this case Vdrop-out + Vref is 1.2 + 1.25 = 2.45 volts. Therefore, using a 3 V double AA cell power source, there is adequate margin for battery aging and the maximum 0.078 v full-scale meter voltage.

The final circuit is shown in Fig 2. below. It consists of a simplified constant current source using the LM1117T. The constant current source drives the unknown resistance to be measured, and the resultant voltage drop is displayed on a small moving coil meter movement. Other than just the simplicity, an advantage of using this type of IC is the stability of the regulated output. Constant current variation due to temperature over the range of 0 to 50 ºC is negligible. The circuit maintains regulation until battery voltage drops to about 2.5 V, as tested on my bench.

The design actually starts with the meter movement that is chosen, and requires us to first determine what it's full scale voltage is. This can be done in several ways, but I took the direct approach and used a digital voltmeter to measure the meter terminal voltage while I connected a 10k resistor in series with a 5v adjustable power supply and the meter. I adjusted the power supply carefully so that the meter read its full scale value of 500 uA and noted the DVM reading.

With the meter movement I used, the fullscale voltage was found to be approximately 0.078 volts.
Since I wanted my milliohm meter to have a single 2.0 ohms full scale, the constant test current needed is calculated as: Iconst=0.078 V/2.0 ohm, or approximately 39 milliamps.

Fig 2. Schematic



Parts used:

Component	Description	Source
BT1 battery	1.5 V AA alkaline cells	Any good quality cell…
Battery holder	BC12AAL or equiv.	Digikey BC12AAL-ND
SW1, SW2	Mini toggle switch	3 amps min., silver contacts
Meter	0 – 500 uA, 2.5” wide	eBay
U1	LM1117T adjustable	Digikey LM1117T-ADJ/NOPB-ND
D1, D2	1N5819 Schottky diodes	Digikey, various mfrs.
C1 (optional)	10 uf, 10V tantalum cap.	Digikey 478-1838-ND
R1, R2, R3	100 ohm 1% MF .25W	Digikey 100XBK-ND
Rcal	Tba (I used 1k, 5%, CF)	Junkbox
R4	1.0 ohm 1%, 1 watt, MF	VishayCPF11R0000FKEE6 Digikey CPF100CTR-ND
Heatsink for U1	Avid, 20 ºC/watt, 5070 type	Digikey HS112-ND
Alligator clips, 2	Mueller BU-60CS	314-1034-ND
Case	4.7” x3.1” x 2.3”	Hammond 1591TSBK, Digikey HM110-ND
4ft flat 2C ribbon wire	UL2468 style, no. 18 or 20 AWG	

Construction notes and details:

Many of the parts I found in my junk box, with the exception of the LM1117T. None of the other parts are especially critical. The regulator and the resistors are mounted on a small piece of Veroboard epoxy fiber copper strip-board. Since the regulator power dissipation is very low, it doesn't really need a heatsink, but I thought it would be useful in assuring thermal stability. A square inch of aluminum would likely do just as well.

I included C1 on the schematic as the IC manufacturer recommends it, but I found the circuit operated fine without it. The photo also shows a screw terminal connector strip I mounted on the perf-board, but direct wiring works too.

D1 and D2 are Schottky diodes with a voltage drop of about 0.30 volts. They serve to protect the meter movement should you turn the power on with no test resistor or the Cal switch on.

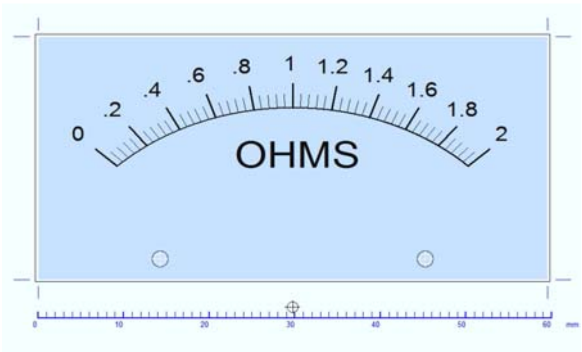
The current setting resistors are made of 3 - 100 ohm, 1%, ¼ watt metal film resistors connected in parallel, thereby acting as a single 33.3 ohm part. Without further adjustment, this would program a constant current of 1.25v ref/33.3 ohms, or 37.5 mA.

Recall that we actually need about 39 mA, so it is necessary to add a 4th parallel resistor I called Rcal. The easiest way to find this value, is to connect a decade resistance box across the R1,2,3 combination, and switch the 1.0 ohm Cal test resistor in circuit. Adjust the decade box for best center scale reading, and solder a part of that value across R1,2,3. In my unit, a value of 1000 ohms turned out to be perfect.

R4, the 1.0 ohm resistor used to check the 1.0 ohm center scale, is ideally a 1% part. However I had difficulty finding such a part and ended up using a 5% 1 watt device I had on hand.

New Meter Scale:

The custom scale I laid out with the easy to use program "Meter", from Tonne software. (http://tonnesoftware.com/) Printed on good quality paper, it is glued to the back of the aluminum scale panel in the meter and then carefully re-installed.



Test clips

I first used a pair of ordinary plated-steel alligator clips from my junk box. They did work ok but I thought that for the long term copper clips would be better. The photo below shows them. The ribbon wire pair were stripped, bare copper ends twisted, then inserted into the screw hole in the copper clip, and soldered.

This has been fine, with the 2.0 ohm scale I used which has a single "tic" resolution of 0.04 ohm. I suspect that if you choose to change or add a scale where the resolution is greater, say 0.01 ohm per "tic", you may want to consider separating the soldering point of the 2 leads, with the meter wires closer to the clip tips. Should you choose to use the steel clips instead, I would recommend this method of connection to minimize the small resistance of the clip in your measurements.

Lastly, a note on th ewire used for the test leads. Wire gage is not particularly important. I ended up using some 2 conductor ribbon wire cut-offs, that came from a wall-wart power supply. They happen to be #18, and are fairly robust, but several gage sizes smaller should work as well. Some might argue that a twisted pair might be better in avoiding unwanted pick up etc. I have not seen that as an issue.