A Digital Milliohmmeter Adapter

Lets you accurately measure less than 1 ohm with a DMM

By Mike McGlinchy

Ordinary 3½-decade digital multimeters do not have the resolution required for you to measure very-low resistance values. Consequently, such an instrument will not measure any value less than 1 ohm with any degree of accuracy. In this article, we will show you how you can use the ordinary DMM in its dc volts function to accurately measure resistances down to about 1 milliohm.

This is an adapter that just about anyone who has a serious interest in electronics and owns a 3½-decade DMM will want to have handy. It can be used to check whether a ground connection in a circuit is really at zero ohm or that battery-cable connectors in a car or truck are making the required low-milliohm connection and not the near-1-ohm value that can fool an ordinary ohmmeter function of a DMM into indicating a short circuit.

Measuring Resistance

Ordinary DVMs (and the dc volts function of DMMs) measure resistance indirectly, by measuring a voltage dropped across a resistive element, as shown in Fig. 1.

When unknown-value resistor R_x is connected between the output and inverting (–) input of an operational amplifier as shown, the negative feedback that results holds the inverting input at 0 volt, or virtual ground potential. Since *R1* has a fixed potential of –2 volts across it, the current through *R1* is constant. This current flows through R_x to give an output voltage that is sent to the succeeding analog-to-digital (A/D) converter in the meter. This current is very small, too small, in fact, to produce an appreciable voltage drop across R_x of less than 1 ohm.

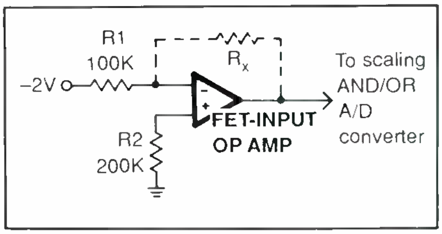


Fig. 1. Inside a DVM or DMM, unknown-value resistor R_x connects from the output to the inverting input of an op amp.

An obvious solution to the above problem is to pump a relatively large current through R_x to force a greater voltage drop and then use a DVM to measure the drop. This is exactly what is done in our milliohmmeter accessory. A current of 1 ampere was chosen so that there would be no need to have to juggle a conversion factor when taking measurements. Thus, all readings taken with the DVM are read out directly—as, for example, when a measured voltage drop is 36 millivolts, R_x would be directly read as 36 milliohms.

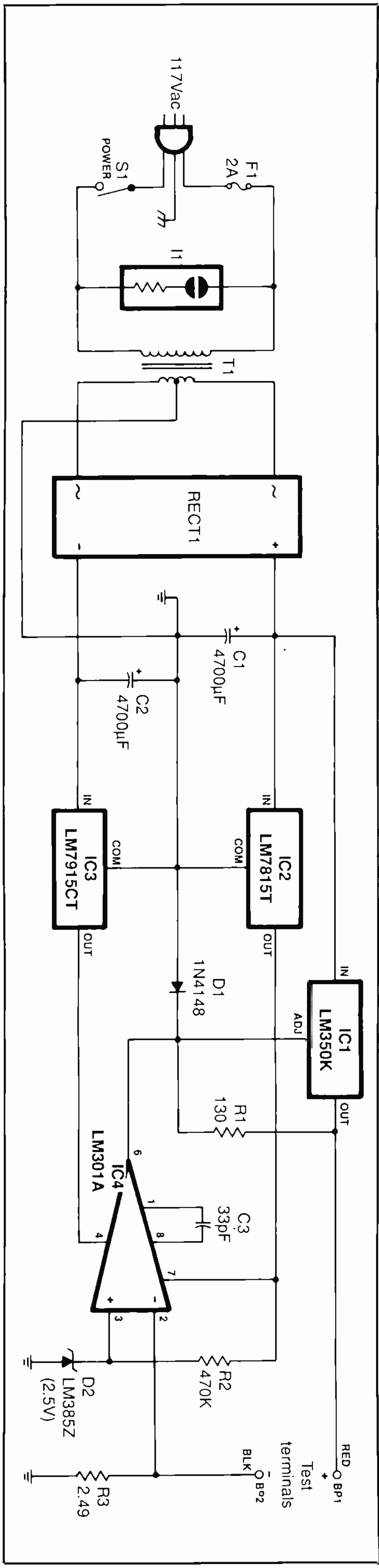
About the Circuit

Shown in Fig. 2 is the complete schematic diagram of the Digital Milliohmmeter Adapter's circuit. Adjustable positive voltage regulator *IC1* is capable of supplying 3 amperes over a 1.2-to-33-volt range. The output from this LM350K regulator is the potential of the adjustment (ADJ) terminal plus 1.2 volts. If the adjustment terminal is grounded, the chip will act as a simple 1.2-volt positive voltage regulator.

The decided-upon 1 ampere test current is pumped through unknown-value resistor R_x by *IC1*. The current is sensed by *R3*, a 2.49-ohm, 1% tolerance, 20-watt resistor. This sense voltage appears at the pin 2 inverting input of LM301A op amp *IC4*, which is configured here as a dc error amplifier.

The 2.5-volt reference potential at noninverting (+) input pin 3 of *IC4* is provided by two-terminal precision reference *D2*, an LM385Z device. Since *IC4*, *IC1* and R_x make up a negative-feedback control system, the voltage at the inverting input of *IC4* is equal to V_{ref}. Therefore, 2.5 volts will be maintained across *R3*, forcing 1 ampere of current to flow through it and R_x, which is in series with *R3*. The maximum value of R_x is limited only by *IC1*'s output potential minus the 2.5-volt reference.

Because of the amount of current required for making measurements with this circuit and the relatively high dc voltages needed to drive the op-amp circuit, the only practical power supply for the accessory is an ac-line-operated one. This consists of power transformer *T1*, bridge rec-



PARTS LIST

Semiconductors
D1—1N4148 or similar silicon small-signal diode
D2—LM385Z 2.5-volt precision reference
IC1—LM350K adjustable positive voltage regulator
IC2—LM7815T +15-volt regulator
IC3—LM7915CT −15-volt regulator
IC4—LM301A operational amplifier
RECT1—4-ampere, 100-volt bridge rectifier

Capacitors
C1,C2—4,700-µF, 35-volt electrolytic
C3—33-pF Mylar or ceramic disc

Resistors
R1—130 ohms, ¼-watt, 5% tolerance
R2—470,000 ohms, ¼-watt, 5% tolerance
R3—2.49 ohms, 20-watt, 1% tolerance

Miscellaneous
BP1,BP2—Five-way binding post (one red, one black)
F1—2-ampere slow-blow fuse
I1—Neon-lamp assembly with built-in limiting resistor
S1—Spst slide or toggle switch
T1—25.2-volt, center-tapped, 2-ampere power transformer (Radio Shack Cat. No. 273-1512 or similar)
Printed-circuit board or perforated board with holes on 0.1" centers and appropriate Wire Wrap or soldering hardware; suitable enclosure; ac line cord with plug; fuse holder; small rubber grommet; ½" spacers; machine hardware; hookup wire; solder; etc.

tifier *RECT1*, filter capacitors *C1* and *C2*, +15-volt regulator *IC2* and −15-volt regulator *IC3*. Neon indicator lamp *I1* with built-in current-limiting resistor wires across the primary of *T1* as shown and turns on when POWER switch *S1* is closed.

Construction

This is a fairly simple circuit in terms of component count. It can be wired on a printed-circuit board of your own design or on perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware. Whichever way you go, be sure to use a socket for *IC4*. When you plan your layout, be sure to make provisions for mounting the power transistor off the board inside whatever enclosure you choose.

Wire the project on the circuit board exactly according to Fig. 2. Components that mount off the board are *F1*, *S1*, *T1*, *BP1* and *BP2*. Start wiring the board by installing and soldering into place the socket for *IC4*. Do *not* install the IC in the socket until after you have made voltage checks.

Fig. 2. Complete schematic diagram of project's circuitry, including its ac-operated power supply.

Once the socket is in place, install and solder into place the resistors. Because *R3* will be dissipating considerable power and, thus, heat up, mount this resistor so that it sits about ¼ inch above the board's surface to allow air to circulate around it. Then install the capacitors and diodes, making sure that they are properly oriented before soldering their leads into place.

Mount the bridge rectifier assembly to the circuit-board assembly with suitable machine hardware and follow with installation of the regulators. Make sure the latter are properly based before soldering their leads into place.

Now wire the + and − lugs of the rectifier assembly into the circuit. This done, strip ¼ inch of insulation from two heavy-duty 5-inch lengths of hookup wire. Tightly twist together the fine conductors at both ends of both wires and sparingly tin with solder. Connect one end of each wire into the appropriate points on the circuit-board assembly and solder both connections. The other ends of these wires will be connected later.

You can use any enclosure that will accommodate the circuit-board assembly and power transformer and that has panel space for mounting the indicator lamp and POWER switch on the front panel and the fuse holder and entry hole for the line cord on the rear panel. Suitable enclosures include an all-aluminum utility box and a plastic project box that has a removable metal top panel.

Machine the enclosure as needed. That is, drill mounting holes for the circuit-board assembly and power transformer through the floor panel, mounting holes for the POWER switch and indicator lamp through the front panel and a mounting hole for the fuse holder and entry hole for the ac line cord through the rear panel. Deburr all holes as needed. Then line the ac cord's entry hole with a small rubber grommet if this hole is drilled through a metal panel.

Feed the free end of the ac line cord through its hole and tie a knot in it about 6 inches from the free end inside the enclosure. Tightly twist together the fine wires in both conductors and tin with solder. Connect the secondary leads, including center-tap lead, of the transformer to the appropriate points in the circuit-board assembly and solder all three connections.

Use suitable machine hardware to mount the transformer into place. Then mount the circuit-board assembly in its location, using $\frac{1}{2}$-inch spacers and 4-40 × $\frac{3}{4}$-inch machine screws, nuts and lockwashers. Mount the fuse block on the rear panel of the enclosure and the switch, binding posts and neon-lamp assembly on the front panel. Label the binding posts + for red and − for black.

Now crimp and solder one line-cord conductor to one fuse holder lug and the other conductor to one switch lug. Crimp but do not solder one primary lead of *T1* to the other fuse holder lug and the other *T1* lead to the other switch lug. Use hookup wire to lengthen the leads of the neon-lamp assembly as needed, insulating the connections. Crimp and solder one lead to the fuse-holder lug to which *T1*'s primary lead is connected. Do the same with the other lamp lead and the switch lug to which *T1*'s other primary lead is connected. Finally, crimp and solder the free ends of the two heavy-duty stranded hookup wires to the lugs of the binding posts, the one coming from *IC1*'s OUT pin to red and the other one to black.

Checkout & Use

Insert a 2-ampere slow-blow fuse into the fuse holder and then plug the project's line cord into an ac outlet. Clip the common lead of a dc voltmeter or multimeter set to its dc volts function to the negative lead of *C1* or positive lead of *C2*. Touch the "hot" meter probe to pins 7 and 4 of the *IC1* socket and note the readings obtained. If they are not +15 and −15 volts, respectively, power down the project and unplug it from the ac outlet. Rectify the problem before proceeding.

Once you are certain that the project is properly wired, power it down and allow sufficient time for the charges to bleed off *C1* and *C2*. Then install *IC4* in its socket. Make certain it is properly oriented and that no pins overhang the socket or fold under between IC and socket as you push the op amp home.

The procedure for using the Digital Ohmmeter Accessory is simple. Just plug its line cord into an ac outlet, connect your DVM (or DMM set to its dc volts function) between the binding posts. Observe proper polarity. Then connect the unknown resistance between the two binding posts, turn on the project and meter and observe the reading in the latter's display. If you wish to use this project for in-circuit tests, use short test leads to bridge from the binding posts to the circuit under test. **ME**