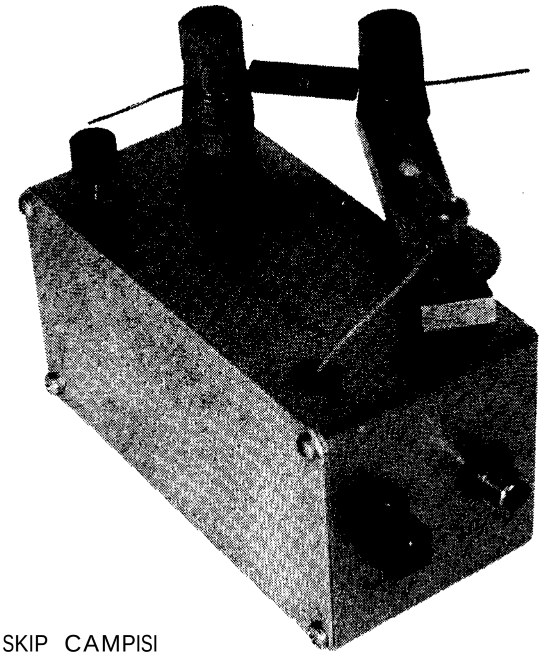


Build This Milli-Ohm Adapter

Extend the range of your DMM down to the milliohm level with this inexpensive, easy-to-build adapter.

SKIP CAMPISI

Have you ever tried to measure accuratety a low-value resistance, only to find that your test leads had a higher resistance than the device you were measuring? Even with a meter capable of nulling out the lead resistance, the null is never stable due to the hooks or clips used for the connections.

The Milliohm Adapter was specially designed to get around that problem and to do it with an accuracy of ± 1% for readings over a range of 10 milliohms (0.01 ohms) to 5.0 ohms. Used with a 4½-digit DVM, the adapter can resolve resistances as low as 10 microohms, and be able to measure the resistance of a short length of hookup wire! Checking switch-contact resistance is a breeze with the adapter plugged into your DVM.

When measuring a resistance below 1.0 ohm, the leads of a resistor contribute significant error to the reading. Thus, a novel circuit approach was taken in designing the adapter. To generate an output-signal voltage high enough to be measured easily, a current of about 1.0 ampere is desirable. That current could easily fry some circuit components and damage the unit under test. However, by applying a low duty-cycle, 1 .0-ampere pulse, no damage will occur. By using Kelvin voltage sensing probes right at the connections to the resistance, all of the other voltage drops due to the l.O-ampere pulsed current in the other leads are essentially eliminated.

About the **Circuit.** The schematic diagram (Fig. 1) for the adapter can be partitioned into four sections: power supply, oscillator, current source, and peak detector. The R_X (resistance to be measured) is connected between BP1 and BP2, and with the lO-ampere pulse applied to R,, the resulting output transfer function appearing at J1 is 1.0 ohms-per-volt output to the DVM.

The power supply consists of IC2, a 78L12 voltage-regulator chip that provides regulated +I2 volts to the circuit, and a 2N2222 transistor, Q2, which provides – 0.7 volts to IC3 and a virtual power ground to the rest of the circuit. Transistor Q2 is used as a diode-connected transistor; that type produces only half of the ripple voltage that would appear if a standard rectifier were used. Battery B1 is user selectable and, although 18 volts is specified in the schematic diagram, it also can be any voltage source from 15-volts DC to 25-volts DC. For example, two series-connected 9-volt batteries will power the adapter quite nicely. Further, note that the prototype shown in the photos does away with B1 entirely; it uses a 117-volt AC powerpack adapter rated at 17.4-volts DC at 50 mA plugged into a jack on the instrument. Power switch S2 was not used on the prototype,

A TLC555 CMOS timer, ICI, is configured as an astable multivibrator operating at a frequency of about 100 Hz. The components used provide a duty-cycle of 99%; thus, a negative-going pulse of about 100 µS results at the output, which in turn gates [switches) the current source on for 100 µS at a duty-cycle of 1%. The resulting average current is lO mA-safe for almost all circuits and circuit elements,

Light-emitting diodes LED1 and LED2 are standard red LEDs that have a forward voltage of about 1.75 volts each, and they are used as the voltage-reference diodes. As Q1 (a TIP125) has a forward voltage of about 1.5 volts, about 2.0 volts appears across R2 and R3, whose net resistance is 2.0 ohms; thus, a current pulse of 1.0 ampere is generated at Q1's collector. The current pulse is supplied via a capacitive-discharge type setup, from Cl (100 µF), which is recharged via Rl (33 ohms) during the 99% off state.

Adequate compensation for any temperature drift by Q1's two base-emitter junctions are provided by LED1 and LED2, and calibration is provided via CAL potentiometer R4, which adjusts the LEDs' forward voltage by varying the bias current. The prototype adapter uses a one-turn potentiometer for R4; you might wish to use a multi-turn trimmer instead. Also, you can trim fixed resistors R2 and R3 to adjust into R4's calibration range.

The TLC272 CMOS dual op-amp, IC3, is configured as a positive voltage-peak detector, which converts

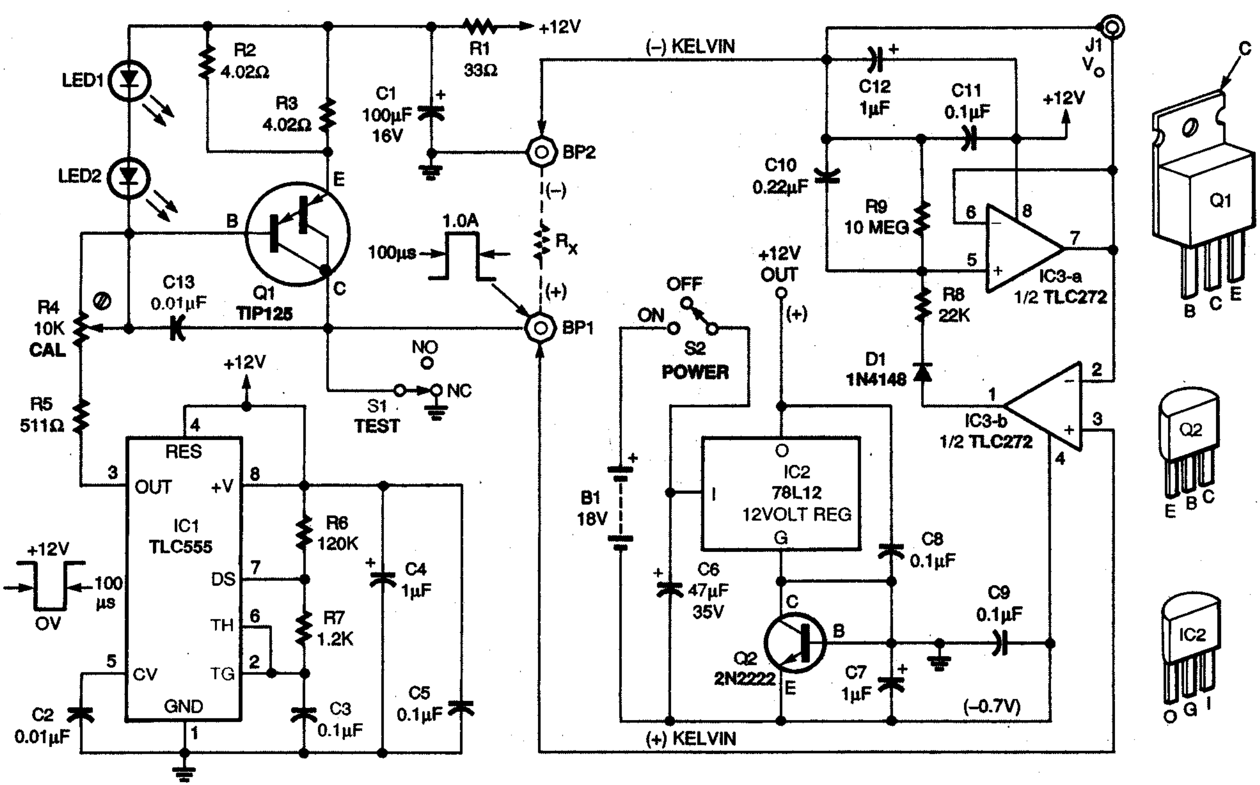
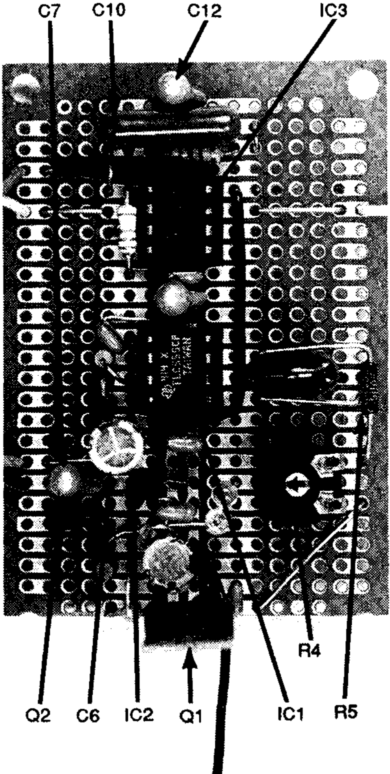
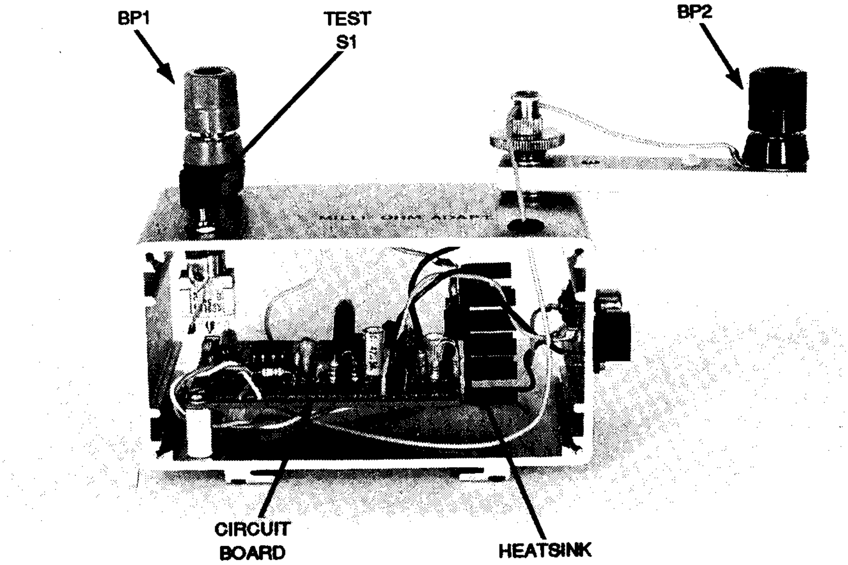


Fig. 1. Here's the schematic diagram for the Milliohm Adapter. The circuit can be separated into four sections: power supply, oscillator, current source, and peak detector.



A piece of a PC board that matches a solderless board supports most of the circuit's parts. Layout is not critical; however neatness is important.



A view of the Milliohm Adapter before the side covers are installed. Note that the heat sink has been attached to the Darlington transistor Q1 and stands free of any metallic contact.

the 1% duty-cycle voltage pulse generated across "R_X" to a steady DC voltage having the exact magnitude of the pulse's peak voltage value. Thus, the output at J1 is a DC voltage with the transfer function of 1.0-ohm-per-volt across R_X.

Construction. The only critical sections of the adapter are the binding-post connections to the resistance to be measured. Use a pair of jumbo (5-way) binding posts rated for 15 amps or more; the posts specified in the Parts List have large-area gold-plated

Run a wire directly from the ground connection of Cl on the board to a lug on the IO-32 stud supporting the swing arm. The common connection including C10, C11, C12, R9, and J1 is the negative Kelvin lead, which is not to be connected to ground on the board. Connect the Kelvin lead in this fashion: Run an insulated lead from the common connection of C10, C11, and Cl2 through a grommet located in the top of the cabinet near the stud, then through an "eyelet" located on the stud itself, and finally make the connection to the lug on BP2.

Mount the completed board on a pair of ½-inch spacers in the bottom of the cabinet and connect the remainder of the panel components to the board. Install the ICs in their sockets and close the cabinet, Prepare an output cable using a twisted pair of wires (do not use coaxial cable) with an RCA phono plug on one end, and a suitable plug for your DVM on the other end. A 12-inch length is sufficient.

Calibration. Power up the adapter and allow it to warm up for about five minutes, allowing the temperature to stabilize in the cabinet. Connect the adapter to your DVM, open the cabinet, and connect a clip-lead jumper from the base lead of Q1 to its emitter lead. The resulting voltage, which can now be read on your DVM, is the offset voltage of IC3; make a note of that voltage, which can be anywherefrom 0 volt to ±10 millivolts, Remove the clip lead. Using your DMM, measure the exact value of R_C (4.02 ohm, 1%), minus your test lead resistance. Connect R_C to BP1 and BP2, push the TEST switch, S1 and adjust CAL potentiometer R4 so that the output from J1 (about 4.02 volts) indicates the exact value of R_C *added* to IC3's offset voltage. Re-assemble the cabinet and the milli-ohm adapter is complete and ready for use.

In actual use, connect the unknown resistance (Rx) at the exact points on its leads from which you want to measure, take the reading, and subtract IC3's offset voltage for the proper value at 1 ohm/volt. That procedure will ensure the best possible accuracy.