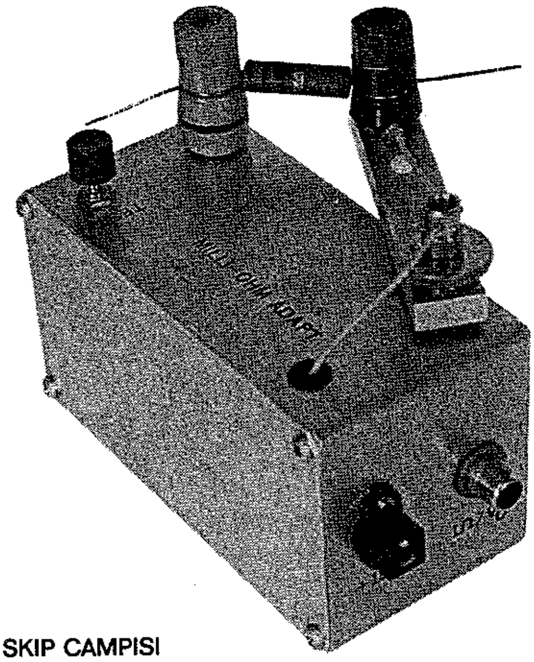


Build This MILLI-OHM ADAPTER

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 accurately 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 1.0-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 1.0-ampere pulse applied to R_X, 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 +12 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 power-pack 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, IC1, 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 10 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 C1 (100 µF), which is recharged via R1 (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

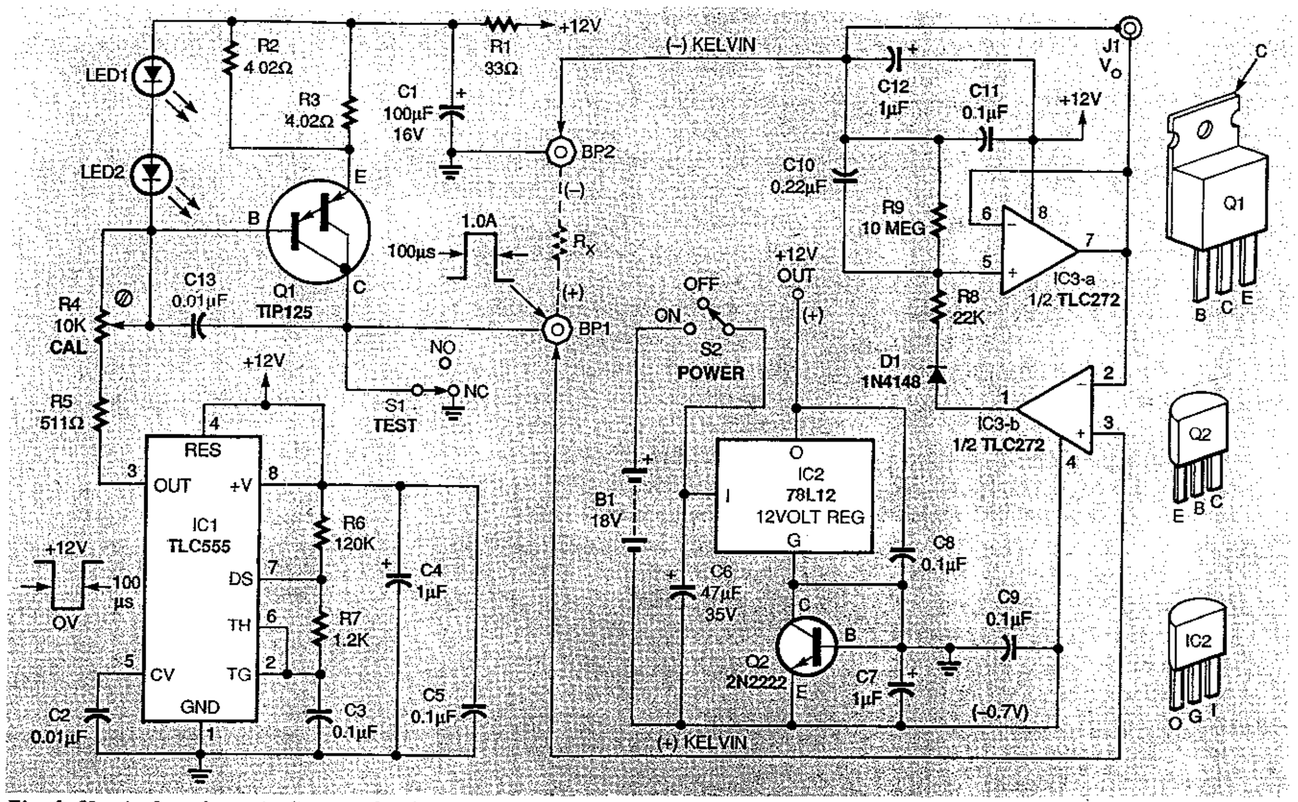
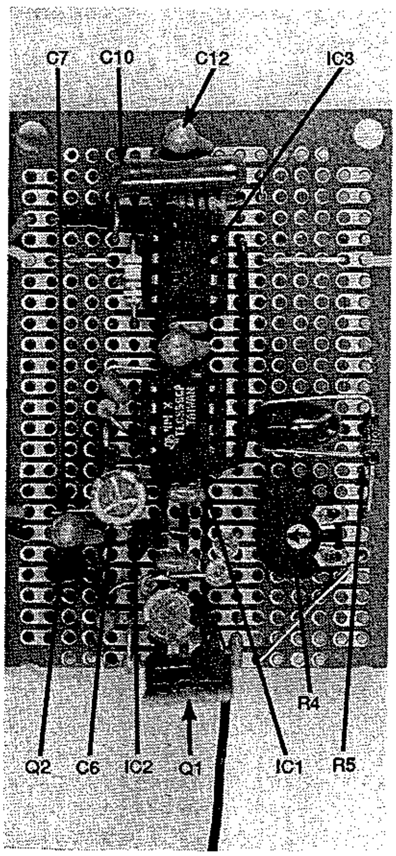
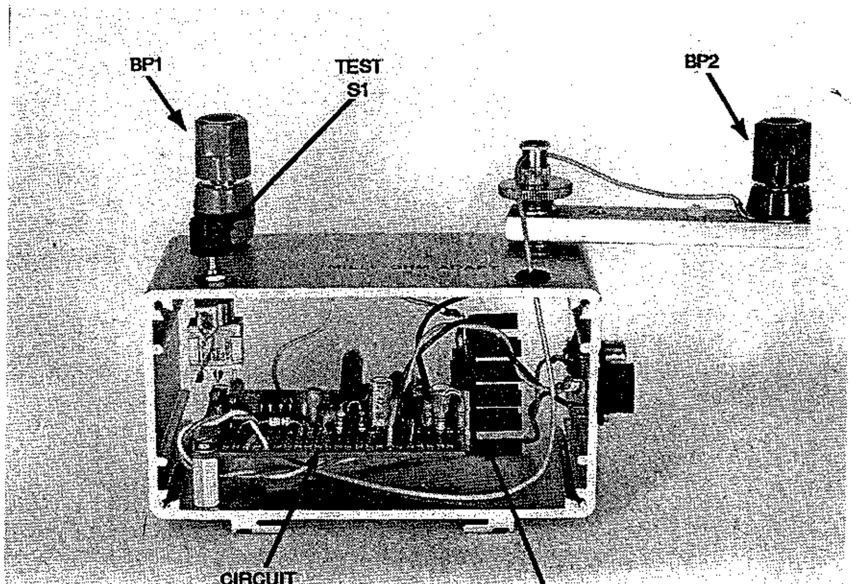


Fig. 1. Here's the schematic diagram for the Milliohm Adapter. The circuit can be separated into four sections power supply, oscillator, current source, and peak detector.



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

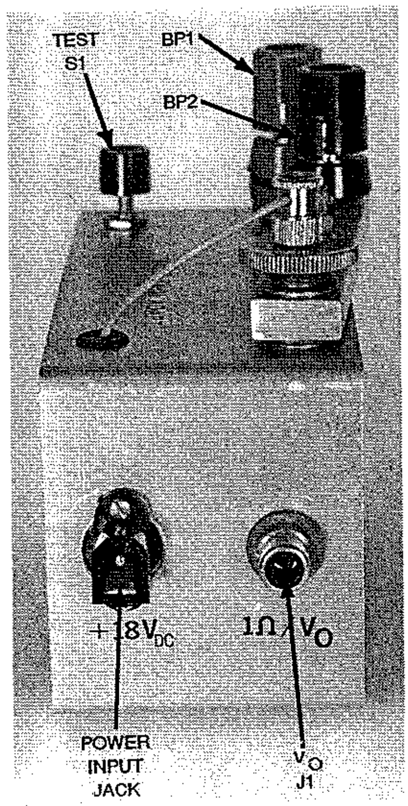
the 1% duty-cycle voltage pulse generated across "R_X" to a steady DC voltage having the exact magnitude of the pulse's peak voltage value. Thus, the output at J1 is a DC voltage with the transfer function of 10-ohm-per-volt across R_X

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 contacts that make the physical and electrical securing of "R_X" very good Once you have selected the binding posts, the next thing you must decide is how to mount them The spacing between BP1 and BP2 must be mechanically variable to allow easy adjustment for various resistor sizes, wire lengths, etc

The best method for mounting the binding posts is to leave the positive terminal (BP1) fixed, and have the negative ground terminal (BP2) movable There are three different options to accomplish this: leave BP2 dangling from its leads without any mechanical mount; cut a slot in your cabinet so that BP2 can slide back and forth in the slot; or mount BP2 on an arm that pivots on a stud, thus rotating away from BP1 for adjustment The last method was used for the prototype Pick any of the methods and mount the binding posts so that they are level with each other, using shims or washers where needed Be sure to insulate BP1 from the cabinet (which has to be aluminum), while BP2 should be electrically connected to the cabinet

The prototype uses a cabinet made from extruded aluminum having a 3⁄32-inch thick wall for drilling and tapping for machine-screw attachments For chassis boxes made from aluminum sheet metal, you can use ordinary machine screws, lock washers, and nuts

The prototype cabinet measures 2-inches wide by 4⅜-inches long by 2⅜-inches high Binding post BP1 is mounted at one end of the cabinet top, with a 10-32 × 1-inch screw protruding out of the other end On this stud rides the swing arm, which is made from a piece of ¼-inch thick by ⅝-inch wide by 3-inch long aluminum bar One end of the arm has a clearance hole for the 10-32 stud, and BP2 is mounted at the other end, along with a lug for the Kelvin connection The arm rides on washers and is locked in place with a ¾-inch diameter, 10-32-thread knurled nut (a wing nut works fine, also) At its closest position, the binding post terminal spacing is



The power input jack (optional, see text) and insulated RCA phono jack (J1) that supplies the output signal to the DVM mounts on one side of the case

about ¾ inch apart, which can be opened to a maximum of about 5½ inches Output jack J1 and an optional power-input jack are mounted on one end of the cabinet with normally-closed push-button switch S1 (TEST) mounted on the top, near BP1 Jack J1 has to be isolated from ground Use fiber shoulder washers or an insulated phono jack made for the purpose If you use POWER switch S2, mount it near S1 for the most convenience

Assemble the circuit board, following the parts location shown in the photos, on a 1⅞-inch by 2⅞-inch circuit board (see Parts List) starting with Q1 on one end of the board Attach a small heat sink to Q1 Install two 8-pin DIP sockets and potentiometer R4 as shown; then add the rest of the components and interconnects leaving long leads for connecting the jacks and switches The positive Kelvin lead is a separate wire connected directly from pin 3 of IC3 to binding-post BP1, and the collector tab of Q1 is also connected directly to BP1 via a separate wire

(Continued on page 79)

PARTS LIST FOR THE MILLIOHM ADAPTER

SEMICONDUCTORS

IC1—TLC555 or TLC555CN CMOS timer integrated circuit
IC2—78L12 12-volt, 100-mA, positive-regulator integrated circuit
IC3—TLC272/TS272CN CMOS dual op-amp, integrated circuit
Q1—TIP125 PNP Darlington transistor
Q2—2N2222 PNP general-purpose transistor
D1—1N4148 switching diode
LED1, LED2—Light-emitting diode, red, T1 case

RESISTORS

(All fixed resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—33-ohm
R2, R3, R_C—4.02-ohm, 1%, metal film
R4—10,000-ohm, one-turn potentiometer, PC mount, cermet (see text)
R5—511-ohm, ¼-watt, 1%, metal-film
R6—120,000-ohm
R7—1200-ohm
R8—22,000-ohm
R9—10,000,000-ohm

CAPACITORS

C1—100-µF, 16-WVDC, electrolytic
C2, C13—0.01-µF, monolythic ceramic
C3—0.1-µF, polyester (Mylar)
C4, C7, C12—1-µF, 35-WVDC, solid tantalum
C5, C8, C9, C11—0.1-µF, monolythic ceramic
C6—47-µF, 35-WVDC, electrolytic
C10—0.22-µF, polyester (Mylar)

ADDITIONAL PARTS AND MATERIALS

B1—See text
BP1, BP2—Binding post, insulated, 30 ampere (H.H. Smith #257)
J1—RCA phono jack, isolated (Mouser#16PJ050, or equiv.)
S1—Mini-push-button, spdt, momentary, 3 A
S2—Mini-toggle switch, spdt, 1-amp (optional)
Protyping board (RadioShack 276-150, or equiv.), 8-pin IC socket (2), TO-220 heat sink, post spacers (2, threaded holes at ends with matching screws), threaded ends with screws to match, aluminum cabinet (see text), aluminum bar (see text), wire, phono plug, DVM plug, etc.

Note: The semiconductors and precision resistors are available from Mouser Electronics and other sources. All other parts are available at most local electronics stores and electronics mail-order houses.

USING THE 7107

(Continued from page 60)

Hz While it is not well-suited for frequency counters, it is an excellant choice for automobile tachometers, audio-frequency meters, pulse- and function-generator displays, and other such applications. The 2917 interfaces directly with the 7107, but might require a simple op-amp buffer at the input If the output is erratic, a 0 1-µF Mylar capacitor connected in series with the positive input will usually correct the problem

For frequency counting the LM555 timer is a better choice, as that chip will handle higher frequencies Figure 12 is the schematic for a 555 frequency-to-voltage converter that can display up to a maximum of 1 999 MHz The 100,000-ohm potentiometer (R4) functions as calibration, and S1 selects one of three resistors that determines range

The display reading is multiplied by 10 for range 1, 100 for range 2, and 1,000 for range 3 A 1999 reading in range 2 would be equivalent to an input frequency of 199,900 Hz A display of 0865 in range 3 would represent 865,000 Hz.

The range of the counter can be further expanded through the use of input pre-scalers. Those ICs will divide an input frequency, usually by 10, before applying it to the counter A single pre-scaler would increase the input capability to 19,990,000 Hz, while cascading two pre-scalers would take it up to 199,900,000 Hz Again, there is the multiplication factor to consider. When using pre-scalers, the displayed value is multiplied first by the range factor, then by the pre-scale factor to get the actual measurements

The 11C90 and 95H90 ICs are two common pre-scalers, but the drawback with them is their expense Those chips are not exactly economical, although the 95H90 can sometimes be found on the surplus market for as little as $6 to $10

Other applications. Now that you're an expert on the 7107, the knowledge gained will perhaps prompt you to expand projects, designs, or equipment, and possibly inspire ideas for future projects LED and LCD displays are highly informative, and can add to the functionality of many types of electronic equipment A project that takes advantage of the 7107's voltage-measuring capabilities is the author's "Versatile Power Supply" article in the December, 1995 issue of **Electronics Now** That project is a bench-type power supply with a 7107-driven LED readout that displays the level of the output voltage.

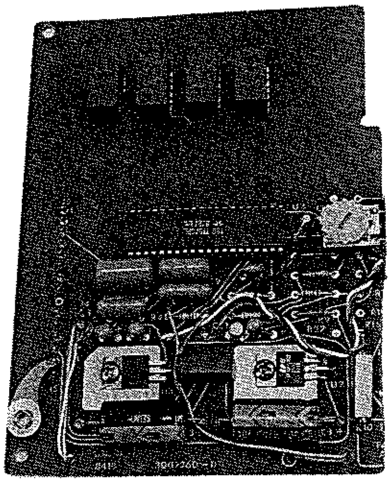


Fig 13 A section of an alarm board bought through surplus, that contains a 7107 This particular board also contains the ± 5-volt power supply

Only a few applications were covered in this article. With a little thought or as practical needs arise, many other ideas will present themselves For example, the Intersil data book illustrates a circuit for a digital torque meter, using a resistance-dependent strain gauge.

One area to watch for an economical source of devices is the surplus market, as the 7107 and 7106 can be found on many circuit boards. The surplus circuit board in Fig 13 is an example of that type of source The chip is usually mounted in a socket, and can be removed for use in one of your own projects Frequently, the basic meter circuit is intact, and can be used as is with minor modifications The 7107 can be found in some alarms, satellite receivers, antenna-positioning units, salvaged digital panel meters, counters, controllers, and a variety of other equipment Be sure and keep an eye out for them when surplus "bargains" are advertised

So, pick up a couple of 7107s and try adding one to your next project. The chip is quite easy to work with, and the results you could achieve can be very gratifying Ω

MILLI-OHM ADAPTER

(Continued from page 42)

Run a wire directly from the ground connection of C1 on the board to a lug on the 10-32 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 C12 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 anywhere from 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 (R_X) 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 Ω