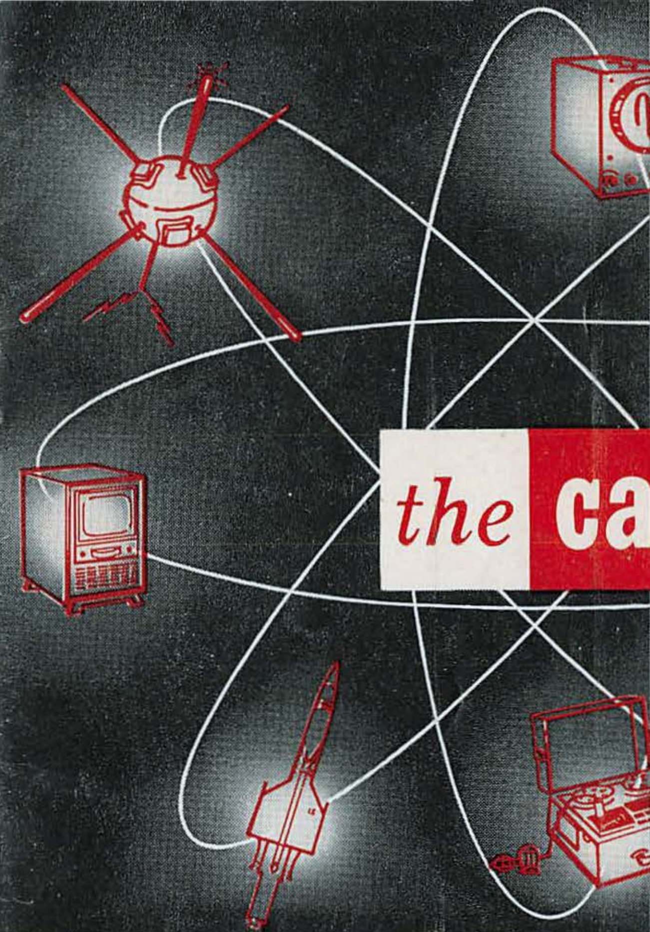


the capacitor

CDE

CORNELL-DUBILIER ELECTRIC CORPORATION

Affiliated with **Federal Pacific Electric Company**

SOUTH PLAINFIELD — NEW JERSEY

VOLUME 25 - NO. 2 — **MARCH - APRIL 1960**

POSTMASTER: If undeliverable for any reason, notify stating reason, on Form 3547 postage for which is guaranteed.

Sec. 34.66 P.L.&R.
U. S. POSTAGE
PAID
So. Plainfield, N. J.
Permit No. 1

FRANK EAMES
5 RICHARDSON AVE.
ATTLEBORO, MASS.

50th Anniversary 1910-1960

D-C METER PROTECTION

Direct-current meters employed in many experimental setups and permanent installations are sensitive, delicate, and expensive. The danger is great that such instruments will be damaged by overload. And very often the overload comes too fast for the technician to save the meter. The prudent operator therefore will provide some means of protecting sensitive meters even if a circuit is assumed to be trustworthy.

Several meter protection schemes are shown here. All except one are fully automatic in operation. Many such circuits have been devised and every laboratory or shop probably has its favorite; but in making the selection for this article, we have tried to avoid the unnecessarily complicated arrangements, as well as the notoriously unreliable ones. The Editors do not feel that there is a best protection circuit; rather, each scheme is suited to a particular environment.

Multiple Meters

One of the simplest schemes is a manual one. By means of separate meters of increasing sensitivity switched into the circuit and removed therefrom successively, the operator satisfies himself that the current is not too high for the most sensitive meter which then is switched into the circuit last. Although not completely foolproof, this method has a long history of reliable performance.

Figure 1 shows the multiple meter method. This arrangement often is used in insulation testing where a delicate millimicroammeter is connected in series with an insulation sample and

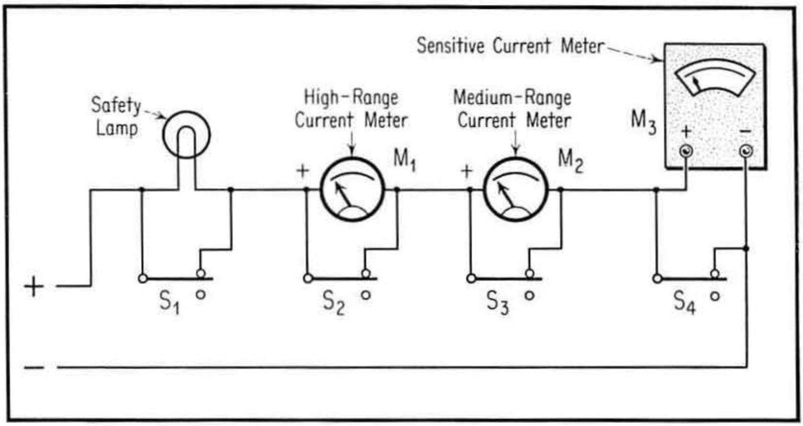
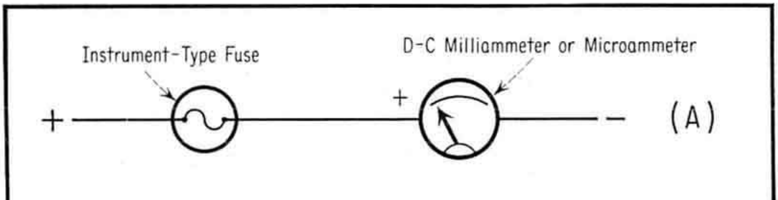


Fig. 1. Multiple Meter Method.

a high-voltage source (500 v to several kv) to measure tiny leakage currents. If no protection were used and the sample were short-circuited or very leaky, the high voltage would quickly destroy the meter. In the arrangement shown in Figure 1, all of the switches first are closed. Then the following procedure is carried out: (1) Open S_1. This connects the safety lamp (usually a 115-volt incandescent type) into the circuit, but the closed switches keep the other meters safely out of the circuit. If the lamp glows, there is excessive current flow. (2) If the lamp does not glow, close S_1 and open S_2. This inserts the high-range current meter M_1 only into the circuit. If the deflection of this meter is high, both M_2 and M_3 would have been damaged had their switches been opened. (3) If the M_1 deflection is zero or low close S_2 and open S_3. This inserts only the medium-range current meter M_2 into the circuit. If the deflection of this meter is high, M_3 would have been damaged had S_4 been opened. (4) If the M_2 deflection is zero or low, close S_3 and open S_4. Now, only the sensitive current meter M_3 is in the circuit. At this point, take the desired reading with M_3 as quickly as possible, and close S_4 immediately after.

Some attempts have been made to substitute overload relays for the switches so as to do the job automatic-



(B)
TYPE 8AG
FAST-ACTING
INSTRUMENT
FUSES

MANUFACTURER'S AMPERE RATING	CORRESPONDING OPERATING MILLIAMPERES	BLOWOUT POINT (Milliamperes)
1/500	2	3
1/200	5	8
1/100	10	16
1/32	31 1/4	40
1/16	62 1/2	85
1/8	125	155
1/4	250	270
3/8	375	380
1/2	500	520

Fig. 2. Meter Fusing.

ally. However, sensitive microammeters often are damaged by pulses which occur too quickly for the appropriate relays to close and short-circuit the meter.

Meter Fusing

The simplest automatic protection device is a fuse, and its use is strongly recommended where feasible. But fuses are not available for all instrument ranges and they are not desirable in all instances (chiefly because of their resistance). A fuse is inexpensive, easily replaceable, and reasonably quick acting.

Figure 2(A) shows the simple circuit for fusing a d-c milliammeter or microammeter. For this purpose, miniature glass tubular fuses are available in the fast-acting type. The table in Figure 2(B) lists those Type 8AG instrument fuses which are useful with milliammeters of the sensitivity commonly encountered in electronic setups.

The resistance of the fuse increases as the ampere rating decreases. At the very low current ratings, the resistance is high enough that it might cause serious error if not taken into account. The meter usually must be recalibrated with the fuse in the circuit. Furthermore, the fuse resistance is nonlinear at low current levels, and this may cause square-law crowding in some part of the meter scale.

All of the fuses listed in Figure 2(B) are rated at 250 volts.

Diode Circuits

The nonlinear resistance of semiconductor diodes is a useful mechanism for meter protection. Figure 3 shows several circuits.

The forward characteristic of a high-current germanium diode (such as a gold-bonded type) may be utilized to bypass excess current around a d-c milliammeter or microammeter. In this application, the diode functions as an automatically variable shunt resistor, connected as shown in Figure 3(A) with its anode positive. The forward resistance of the diode decreases with increasing current or voltage, as shown in Figure 3(B), thus increasing the meter range automatically as the current increases.

This simple scheme has two drawbacks. First, the meter is always shunted by some value of resistance supplied by the diode. However, at the low voltage drop of the meter (approximately 100 mv for a 0-1 d-c milliammeter) the diode resistance is relatively high (2500 to 10,000 ohms, depending upon diode type and manufacture) and the shunting effect at a given current level would alter the meter calibration only slightly. Second, and more serious, however, the diode resistance varies nonlinearly. (See Figure 3B.) This means that the meter must be recalibrated with the diode in place.

When some additional circuit complexity can be tolerated, the need for a special dial calibration to offset the diode nonlinearity may be overcome with the silicon diode circuit shown in Figure 3(C). Here, the diode is biased to a d-c voltage corresponding to the normal full-scale voltage drop of the meter (say, 100 mv) by a potential developed across a very low resistance (e.g., 1 ohm) R_2 by current from a 1½-volt cell, B. This voltage is set exactly by means of rheostat R_1.

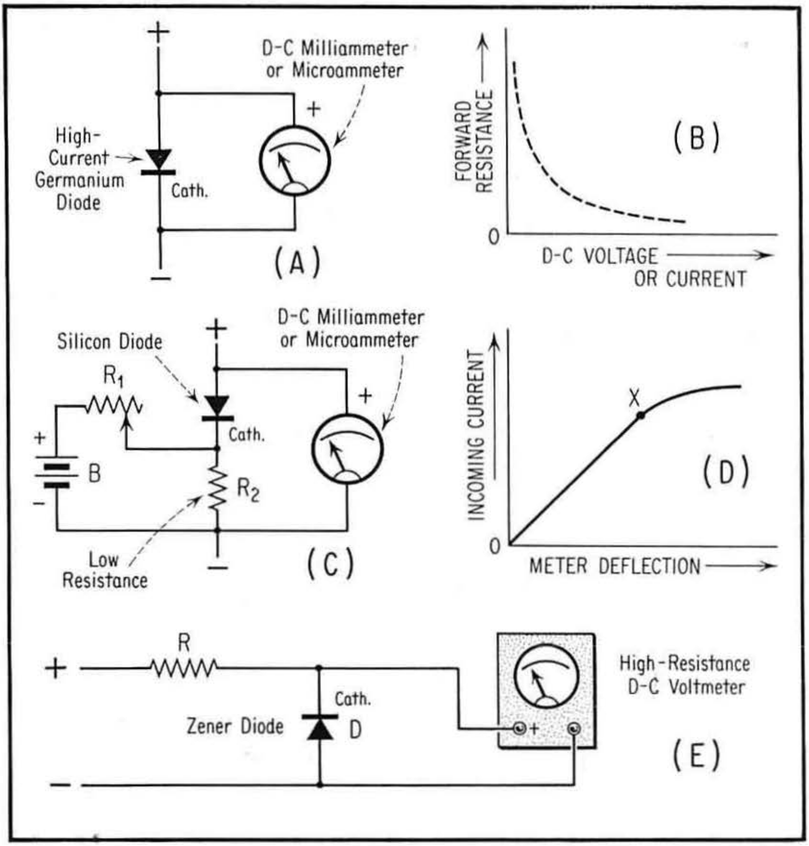


Fig. 3. Diode Protector Circuits.

The very high back resistance of the silicon diode prevents the voltage drop across R_2 from initially deflecting the meter.

As a result of the bias, no current can flow through the diode until the voltage at the anode and the positive terminal of the meter exceeds the bias. Thus, the diode is effectively switched-off until the applied voltage reaches this level. The meter deflection therefore increases linearly to full scale (point X in Figure 3D) and no special calibration is required. Thereafter, current flows through the diode, and the meter is shunted, preventing its deflection from increasing to an unsafe point above full scale.

The sharp reverse breakdown of a zener diode may be utilized to protect a d-c voltmeter in the circuit shown in Figure 3(E). The current limiting resistance, R, is chosen very low with respect to the internal resistance (multiplier plus movement) of the voltmeter, and to limit the diode current to the maximum continuous zener level. The zener breakdown voltage must correspond to the full-scale deflection of the voltmeter.

In this circuit, the diode is reverse-biased by the applied voltage. Until the zener voltage is reached, the reverse resistance is very high and the voltage division resulting from R and D in series is negligible. At full-scale deflection voltage, however, the diode reaches its zener point and suddenly conducts heavily. The diode resistance consequently drops to a low value and the voltage division through R and D increases to a practically constant value. The resulting voltage regulation limits the voltmeter deflection substantially to full-scale, while the input voltage increases beyond this point.

In designing this type of protection circuit, the first task is to select a zener diode whose breakdown voltage is equal to the full-scale deflection of the meter. Zener diodes presently are available in a wide variety of stock values of voltage breakdown.

Relay Circuits

Meter protector circuits which depend upon sensitive d-c relays for their operation are recommended principally for permanent installations, such as switchboards and test panels. Such relays usually cost from two to several times the price of inexpensive panel-type meters. But their cost is justified in most installations, since the possibility of several meter burnouts and attendant down-time is serious.

Figure 4(A) shows the simple series-relay circuit. The relay closes just slightly above the full-scale current of the meter and short-circuits the instrument. As soon as the current falls to a safe value, the relay opens, inserting the meter again into the circuit. Here, the resistance of the relay coil must be low, to prevent excessive voltage drop; milliampere- and microampere-type relays are available with coil resistances between 5 and 100 ohms.

In some instances, it is not desirable to short-circuit the meter, since the instrument then reads zero as long as the current overload continues, and there is confusion as to whether absence of deflection means zero current or excessive current. Instead of shorting the meter, the relay contacts in Figure 4(B) connect a shunt resistor R across the meter to boost its range when the current exceeds the full-scale deflection of the basic movement. Thus, a 1-ma meter may be switched to 10 ma. An extra pair of contacts on the relay can be used to switch-on a pilot light to warn the operator to read the high range of the meter.

Often, a sensitive relay available for a given full-scale meter deflection unavoidably will have a high-resistance coil. Such a coil would introduce an objectionable voltage drop ahead of the meter in the series-type circuit. Figure 4(C) shows how a high-resistance unit might be used. Here, the current meter is connected in parallel with the relay coil, but the coil resistance is so high with respect to the internal resistance of the meter that the shunting effect is too slight to alter the calibration materially. (For example, a 5000-ohm, 1-ma relay coil in parallel with a 0-1 d-c milliammeter having an internal resistance of appromimately 100 ohms would increase the full-scale deflection only to 1.02 ma, an error of plus 2%.)

As in the earlier circuits, the relay sensitivity (pull-in current) is chosen equal to the full-scale deflection of the the meter (or slightly higher). Currents higher than the full-scale value then will close the relay, connecting the shunt resistor R across the meter to boost its range. A second pair of contacts on the relay may be utilized to turn-on a pilot light signalling that the meter is switched to its higher range.

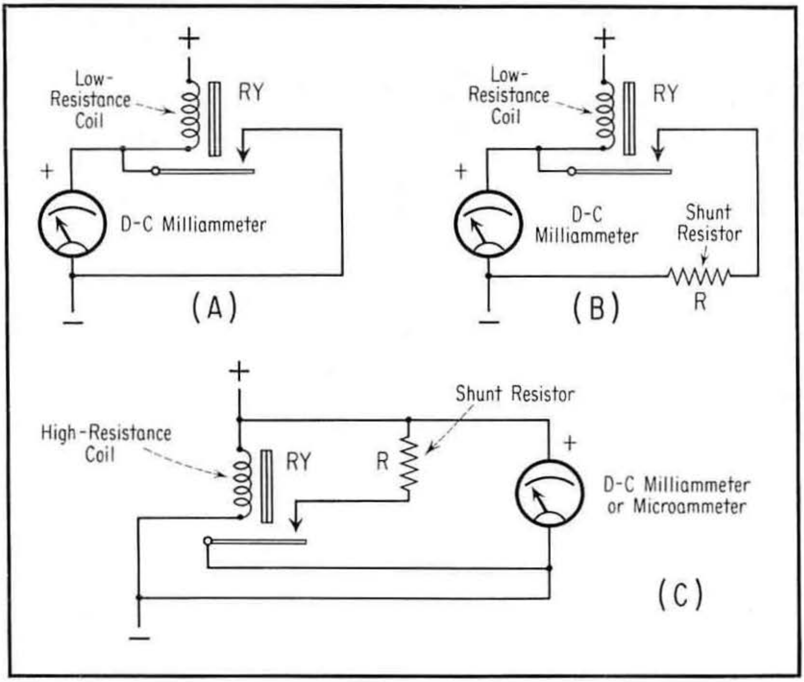


Fig. 4. Relay Protector Circuits for Current Meters.

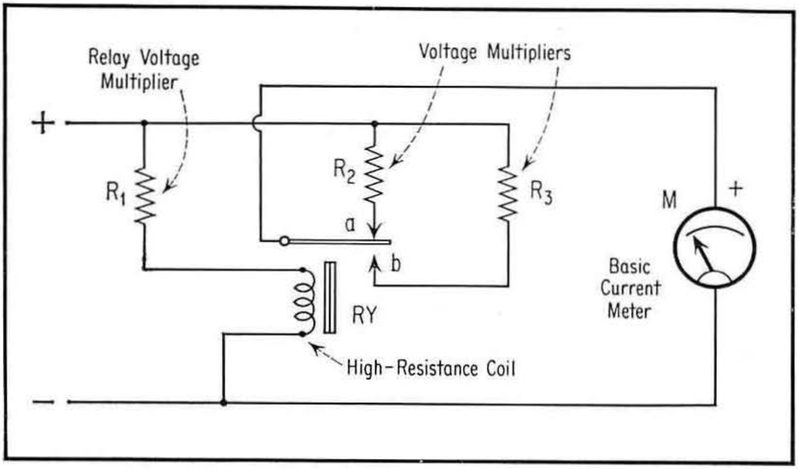


Fig. 5. Relay Protector Circuit for Voltmeter.

Figure 5 shows a relay-type protector circuit for a d-c voltmeter. (The voltmeter is composed of a basic milliammeter M and a multiplier resistor R_2 or R_3.) The relay is chosen for low current operation, say 50 to 100 microamperes. This application calls for a high-resistance relay coil, to minimize loading of the voltage source. The relay must also have two contacts, with closure normally to the upper contact a.

When the relay is unenergized for closure, multiplier resistor R_2 is in series with the current meter, and the resulting voltmeter has its lowest range (full-scale voltage $=$ E). The relay multiplier resistor R_1 is adjusted so that the relay closes at a voltage just slightly higher than E. When the applied voltage exceeds E, the relay closes, disconnecting R_2 and switching-in a higher-resistance multiplier R_3 in series with the meter to boost the latter's range. If available, a second armature and contact on the relay may be employed to close a local voltage through a pilot lamp to signal that the meter has been switched to its higher range. When the voltage subsequently falls to a safe value, the relay drops out, switching the meter back to its lower range.

Conclusion

The circuits shown in this article are typical but do not exhaust the possibilities by any means. Tubes or transistors may be employed in place of relays and provide nonmechanical, but somewhat more complex, circuitry. In some applications, thermistors or Thyrite resistors may be used instead of diodes. Other combinations suitable for particular applications will suggest themselves to the ingenious technician.

NUMBER 2 OF A SERIES

CDE

50TH ANNIVERSARY
PROMOTIONS!

30% - CDE - 30%

SMALLER — MORE RELIABLE

SUB-MINIATURIZED CDE ALUMINUM-FOIL ELECTROLYTIC CAPACITORS

Cornell-Dubilier aims a 30-30 promotion at you for a big birthday bull's eye — and hits the mark with "Electomites"® — the sub-miniature, *metal-cased* electrolytic capacitors that are *30% smaller* and 30% more reliable than conventional electrolytics. Fabricated from selected highest-purity aluminum foil and unsurpassed in performance, "Electomite" tubulars also have a "short"-preventing plastic sleeve which makes them perfect for those close-fitting coupling, bypass and filter applications you come across every day in low-voltage, transistorized and printed circuitry.

HERE'S THE PROMOTION:

Quantity	Type No.	Capacitance (mfd.) Tolerance: —10%, +150%	Voltage
4	NLW 40-3	40	3
4	NLW 10-15	10	15
3	NLW 50-15	50	15
3	NLW 100-15	100	15

ALL 14 for $8.67

This 30-30 promotion is good for 60 days. So get the full story —*and the promotion*—from your Cornell-Dubilier Distributor today! Or write Cornell-Dubilier Electric Corporation, South Plainfield, New Jersey. Also ask about C-D's complete, special capacitor line for industrial electronic maintenance.

CDE **CORNELL-DUBILIER ELECTRIC CORPORATION**

AFFILIATED WITH FEDERAL PACIFIC ELECTRIC COMPANY

Printed in U.S.A.