Diode Meter Protectors

By A. A. MANGIERI

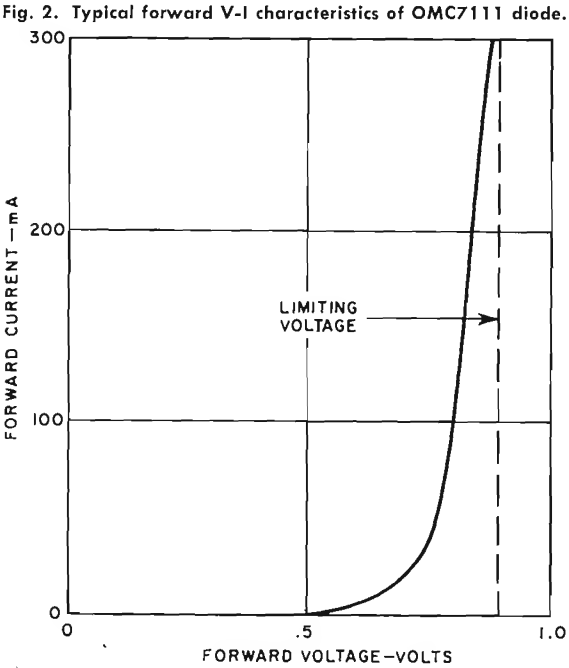
How much protection is afforded by meter-shunting diodes and fuses? What is the effect on meter reading, accuracy?

DIODE meter protectors are an inexpensive means of guarding costly meters against damage. In particular, volt-ohm-milliammeters are most susceptible to damage if the range switch is inadvertently left on a current range when circuit voltages are being checked.

Can we merely connect the diode protector to the meter and then assume it is completely protected? Does the protection afforded depend on the v.o.m. circuit, the range-switch setting, and the meter characteristics? With the diode connected, is meter accuracy dependent on the d.c. voltage and current waveforms? These factors should be considered when using shunt diode protectors.

Fig. 1. Diode meter protector connects directly across meter terminals. Unit shown contains two diodes in one package. Silicon top-hat rectifiers shown below are also usable as effective meter protectors after selection by simple tests.

Fig. 2. Typical forward V-I characteristics of OMC7111 diode.



Diode Characteristics

Diode meter protectors, as shown in Fig. 1, are shunted directly across the meter terminals. Each device contains two silicon diodes connected in parallel and back-to-back, affording protection against overloads of either polarity. The meter is protected by the forward *V-I* characteristic of one diode, while the other diode, being reverse-biased, is inactive.

Fig. 2 shows the measured forward *V-I* characteristic of an *Ohmite* OMC7111 "Metersaver." As shown in the diagram, the diode can be approximated as a voltage limiter which operates at 900 millivolts at rated current.

Meter-protecting diodes have very low forward currents in the zero- to 300-millivolt region and very low reverse current leakage. Below 300 millivolts, the d.c. resistance is above 600,000 ohms. Because meter resistances are much lower, shunting the diode across the meter terminals introduces errors of only about .5% or less, depending upon the meter resistance. The OMC7111 has an absolute maximum and continuous forward-current rating of 300 milliamperes. The *Lectrotech* "Metergard" is rated at 1 A continuous and is surge-rated at 6 A for one cycle.

Meter Characteristics & Overload

Quality d.c. meters can withstand at least a 10× overload (ten times full-scale value) for one-half second and a 1.5× overload continuously. Many can tolerate double or even triple these overloads with no serious damage. Because meter construction varies, there is much uncertainty as to meter overload capability beyond the 10× momentary and 1.5× continuous overloads.

Table 1 lists the electrical characteristics of a number of panel meters up to one milliampere full scale. Full-scale millivolts is obtained by multiplying full-scale current rating times the meter resistance. The method of calculating meter overload current multiplication factors is covered a little further on. These factors represent the overloads in the meter *with* diode protection and *not* the overload capabilities of the meter alone.

The first two instruments given in the table are representative of the high and moderate millivolt sensitivities found in the movements employed in most v.o.m.'s. The costlier low-resistance suspension type listed is found in meters of very low d.c. voltage drop that are used in transistor work.

The meter overload factor is found by dividing the diode-limiting voltage by the full-scale millivolt sensitivity of the meter. As an example, using 900 millivolts from Fig. 2, the calculation for the 50-microampere *Simpson* meter listed is 900 mV/250 mV or 3.6×. The maximum actual meter cur-

D.C. Range (Microamperes)	Simpson 1212			Knight 3½", 4½"			Triplett 320R (Band-Suspension Type)		
	Approximate Meter Ohms	Millivolts Full Scale	Overload Factor*	Approximate Meter Ohms	Millivolts Full Scale	Overload Factor*	Approximate Meter Ohms	Millivolts Full Scale	Overload Factor*
10	....	......	.. ..	....	......	.. ..	7500	75	12X
50	5000	250	3.6X	2000	100	9X	825	41	22X
100	2000	200	4.5X	1240	124	7.3X	360	36	25X
200	1000	200	4.5X	600	120	7.5X	156	31	29X
500	200	100	9X	......	......	.. ..	40	20	45X
1 mA	46	46	20X	46	46	20X	12.5	12.5	72X

*Calculations based on 900-millivolt diode-limiting voltage (see text).

Table 1. Characteristics and overload factors for various types of basic panel meters discussed by author.

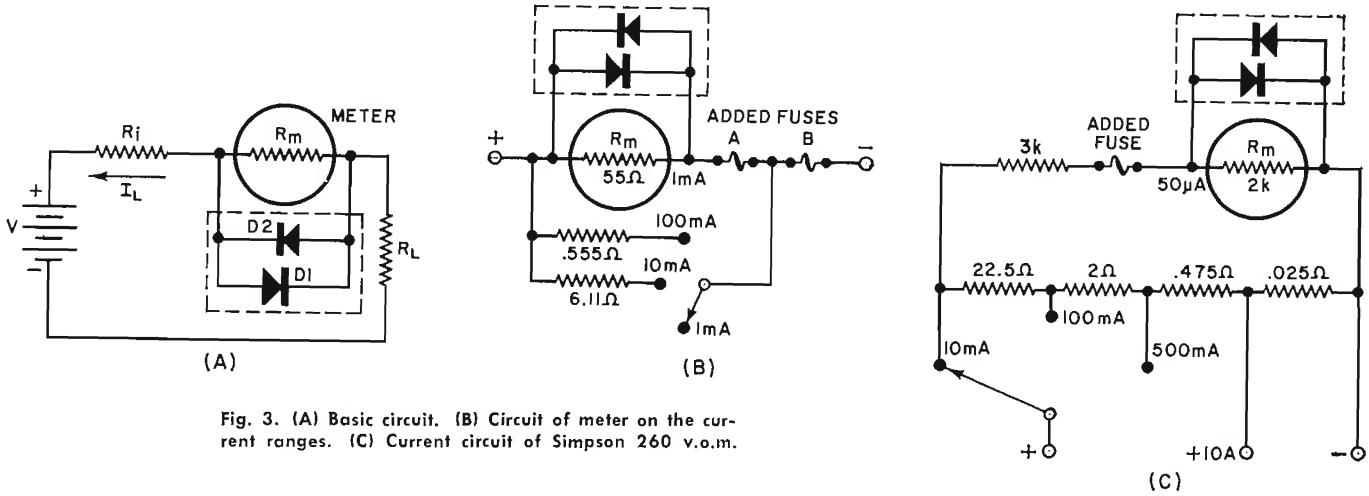


Fig. 3. (A) Basic circuit. (B) Circuit of meter on the current ranges. (C) Current circuit of Simpson 260 v.o.m.

rent permitted by the protector is 3.6 times 50 or 180 microamperes. Refer to the v.o.m. manual for the meter resistance and basic current sensitivity and then calculate the millivolt sensitivity and overload factor.

For momentary overloads, a 10× factor is safe; however, when the factor is well above 20×, a meter could be damaged. In an original circuit, it is possible to reduce the overload factor by adding resistance in series with the meter and shunting the diode across both. This increases the meter's millivolt sensitivity or meter drop.

Meter and Diode Fusing

Fig. 3A shows a voltage source V having an internal impedance R_i delivering load current I_L to load R_L. $D1$ and $D2$ are the shunt diodes of the meter protector. If R_L is shorted, the short-circuit current is $(V - .9)/R_i$ for diodes limiting at 900 millivolts. Currents can easily rise to several amperes or more and destroy both diodes and meter unless the current is limited by a resistor or interrupted by a fuse.

Many v.o.m.'s, on current ranges, use the circuit of Fig. 3B. Note that the diodes are *directly across* the plus and minus test leads of the instrument and are therefore exposed to the full voltage that may be inadvertently placed across the meter. Such circuits require fusing.

Other v.o.m.'s, such as the *Simpson* 260, use the circuit of Fig. 3C. Note that the diode is not across the test leads because of the presence of the 3000-ohm resistor. This resistor acts as a current limiter tending to protect the diode, although this is not its primary circuit function. Fusing is optional, though preferable.

For maximum protection and because many of the overload factors in Table 1 are near or above 10×, it is necessary to interrupt the overload current within one-half to one second. This avoids overheating delicate meter hairsprings and is done by fast-action fusing.

Fuse ratings are based on the diode current ratings, allowing the use of low-cost, low-resistance fuses. Table 2 lists fast-blow instrument-fuse characteristics in the ⅛- to 1-ampere range. Use a ⅛-ampere fuse for the *Ohmite* OMC7111, as it will clear within once second at 220 milliamperes. Use a ¼-ampere fuse for the *Lectrotech* "Metergard." Surge-rated diodes permit use of larger fuses if this is necessary to reduce fuse resistance. Either the .01- or 1-second clearing times in Table 2 may be employed, depending upon how the diode is surge-rated.

In multi-range v.o.m.'s, when the highest current range is less than the selected fuse rating, (*Continued on page* 76)

Fuse Rating (Amperes)	Approximate Resistance* (Ohms)	Blow Current for Clearing .01 sec	(Amperes) Time of 1 sec
⅛	8	.5	.22
¼	2.3	1.3	.42
½	.92	3.0	.80
¾	.45	4.4	1.1
1	.31	7	1.5

*Cold resistance at 10% rated current of Bussmann AGX (formerly 8AG) fast-action instrument fuses. Resistances of standard AGC (formerly 3AG) types are close to these values.

Table 2. The nominal resistances along with the blow characteristics of Bussmann instrument fuses.

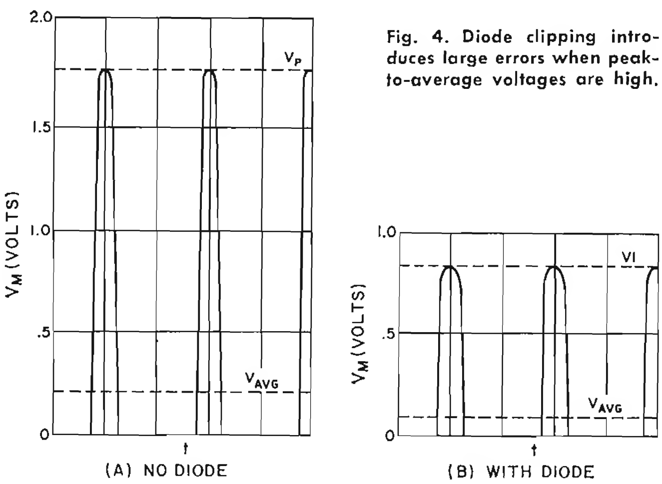


Fig. 4. Diode clipping introduces large errors when peak-to-average voltages are high.

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fusing at *B* in Fig. 3B sidesteps fuse resistance problems and also protects the meter shunts. If the highest selectable current range is above the fuse rating, place the fuse at *A* as shown. Fusing at *A* requires that the fuse resistance be no larger than 1% of the meter resistance to avoid excessive decalibration.

For a v.o.m. using a 1-milliampere, 50-ohm meter, use a ¾- or even 1-ampere fuse at *A*, along with a diode having at least a six-ampere surge rating. Fuse resistance is no problem in Fig. 3C due to high meter resistance.

Diode Clipping

D.c. currents in pulse and multivibrator circuits, unfiltered battery chargers, and unfiltered d.c. SCR power supplies often have very high peak-to-average values. Typical d.c. meters respond to average values. By voltage-limiting action, the diode protector will clip the peaks, resulting in very large meter error, particularly near full scale.

Fig. 4 shows the voltage waveforms observed across the load current meter of an unfiltered half-wave battery charger in operation. Peak voltage (V_p) to average (V_{avg}) is 9 to 1 in this case. Upon connecting the diode, it clipped at voltage *V*1 and introduced a meter error of nearly 50%. (Compare V_{avg} in Fig. 4B with V_{avg} in Fig. 4A.)

To detect clipping, switch the v.o.m. to a higher current range and compare readings. A large difference indicates diode clipping, which can be reduced or eliminated by using a higher current range and restricting readings to the lower portions of the scale.

An effective remedy is to connect a capacitor across the meter terminals which will act like a filter for the a.c. components. Sizes may vary from .01-μF disc types to 50-μF transistor electrolytics, depending upon repetition frequencies and meter and circuit resistances. To be certain of obtaining the desired results, compare meter indications with the diode removed, diode attached, and with diode and capacitor connected. A capacitor permanently connected across the meter terminals has little or no effect on the v.o.m. a.c. ranges but this should be checked for the particular instrument being used.

Two diodes in series will double the meter's immunity to diode clipping. It will also reduce diode insertion error by more than one-half. However, it will double the overload factor by doubling the limiting voltage. But this is an acceptable compromise for meters having a low factor around 3× with one diode.

Diode Selection

The lower current rated diodes are

preferred for use with the more sensitive high-resistance meters. This reduces diode insertion errors to a minimum. The higher rated diodes are preferred for the lower resistance meters because they have high current-handling ability.

Ordinary top-hat and epoxy diodes are often suitable for use as protectors but may introduce larger diode insertion errors than the commercial protectors. Select the most suitable by noting the meter error at full scale on the *lowest* current range. Use two diodes back-to-back for v.o.m.'s, as in Fig. 3A.

When the meter current range is not very small compared with the diode rating, the diode is less able to carry the major part of the short-circuit current. Higher rated diodes such as stud types can be used to effect an improvement. One exception is the circuit of Fig. 3C in which the diode always sees a fairly large resistance regardless of the range-switch setting. Higher current meters are adequately protected with fast-action fusing alone.

To conclude, v.o.m.'s should be safeguarded by a properly matched diode-fuse combination for maximum protection of the costly meter. ▲