how a PROM works

Programmable Read Only Memories are manufactured using various technologies. This article describes each type of PROM and its advantages and disadvantages.

by ROGER L. SMITH

REMEMBER WHEN SOMEONE MENtioned a PROM, we all thought of a high school dance? Well, in today's age of electronics, a PROM is a *P*rogrammable *R*ead *O*nly *M*emory. Incidentally, PROM is a trademark of Harris Semiconductor Div. of Harris Intertype Co.; however, the word has become generic because of its widespread use in describing all field programmable ROM's.

Speaking of ROM's, let's cover some of the basics of memories and the terms used before going any further. The first memories that were used with computers (and a computer is not a computer without a memory) were ferrite-core memories. These core memories—provided they were properly powered down and up—were nonvolatile, meaning the data in them was not lost when power was removed. In a volatile memory, all data is lost in powering down. Most core memories are also classified as DRO, although a few are NRDO. The DRO (*D*estructive *R*ead-*O*ut) uses a read-write cycle to restore data to the cores. An NDRO (*N*on-*D*estructive *R*ead-*O*ut) memory does not require rewriting the data after a read cycle is completed.

With the advent of LSI (*L*arge *S*cale *I*ntegration) techniques and the decreasing cost of semiconductors, the use of semiconductors as memory elements became possible. Various types of semiconductor memories evolved—from simple diodes arranged in a matrix to flip-flops, stored-charge devices and amorphous semiconductors. These new types of memories permitted designers to implement the ROM for cases where the memory was to be used for fixed conditions such as program control.

These ROM's presented logic designers with options not previously available. Now it became possible to replace complex logic circuits with ROM's. You can imagine how difficult it would be to design the logic for a code conversion—a simple job for a ROM. Another unique use for ROM's is in custom waveform generators. A sequential counter feeds the ROM inputs and the outputs go to a digital-to-analog (D-to-A) converter. In another use, the inputs are treated as separate logic inputs and the ROM acts as a Programmable Logic Array (PLA). For more information, refer to the article "What Is A ROM?" in the February, 1974 issue of **Radio-Electronics.**

What PROMs are available?

The simplest PROM's—diode matrices—are available in 14-pin packages (Harris HM1-034-2, a 6 × 8 array) containing diode arrays with fusible links, These diode matrices can be programmed by "burning out" the fusible links and thus can be classified as PROM's. Such memories are used primarily in encoding and decoding functions.

Amorphous semiconductor

An interesting type of memory that is also field-programmable is the amorphous semiconductor memory. This memory consists of amorphous glass semiconductor resistors (called ovonic memory switches by Energy Conversion Devices, Inc.) in series with silicon diodes in a matrix array. The glass semiconductor can exist in either of two phases—amorphous or polycrystalline. The resistors in the amorphous phase show a resistance of about 300K ohms, and in the crystalline phase about 500 ohms. The low-resistance, or set state, is achieved by applying a 15 millisecond pulse to the bit to be set. The high-resistance, or reset state, requires applying 8 to 10 five-microsecond pulses at 80 μs intervals.

These amorphous memories thus have a slow write-cycle time and are called by the manufacturer (Energy Conversion Devices) Ovonic Read-Mostly Memories (RMM). These devices are non-volatile like PROM's but they can also be written into like Random Access Memories (RAM's).

Fusible links

The semiconductor PROM most often used at this time is the bipolar type containing memory elements composed of nichrome fusible-links. Intel is presently making bipolar PROM's (up to 4096 bits) using polycrystalline silicon fuses (instead of nichrome). Advanced Micro Devices also makes 256 bit PROM's with silicon fuses. A look at Fig. 1 will help you to understand the operation of this type of fuse-link PROM. This figure is a block diagram of a 64-word, 8-bit PROM (512 bits). The 6-bit ADDRESS input is buffered and inverted to provide true or complement addresses to each of six inputs on the 64 multiple-emitter AND gates. A seventh input provides the chip enable signal. Since only one of the 64 AND gates will be activated for a particular address, that gate will generate a high level on one of the 64 word lines connected to each gate output. These word lines are connected to the bases of 64 multiple-emitter transistors located in the memory section of the circuit.

The selected (1 of 64) multiple-emitter transistor drives the output transistors thru the eight memory elements. With the proper resistive load connected to their collectors, these transistors will saturate and a low voltage, or logic "0," will appear at the output. Thus the normal output of such a PROM, with the memory elements intact, is a "0." This PROM is programmed by opening the appropriate memory elements and causing a logic "1" to appear at the output for a specific address.

Memory elements of this type (as in the Motorola MCM5003) are fused open by connecting a negative voltage (−6V) to the output collector of the desired bit, applying a voltage (+5V) to V_{cc}, grounding pin G2, and connecting G1 to a negative voltage (−6V). Then the desired word is addressed (with −6V as a "0" and −4V to +5V as a "1"). Notice in Fig. 1 that this forward biases the program transistor for that bit so that when the address is

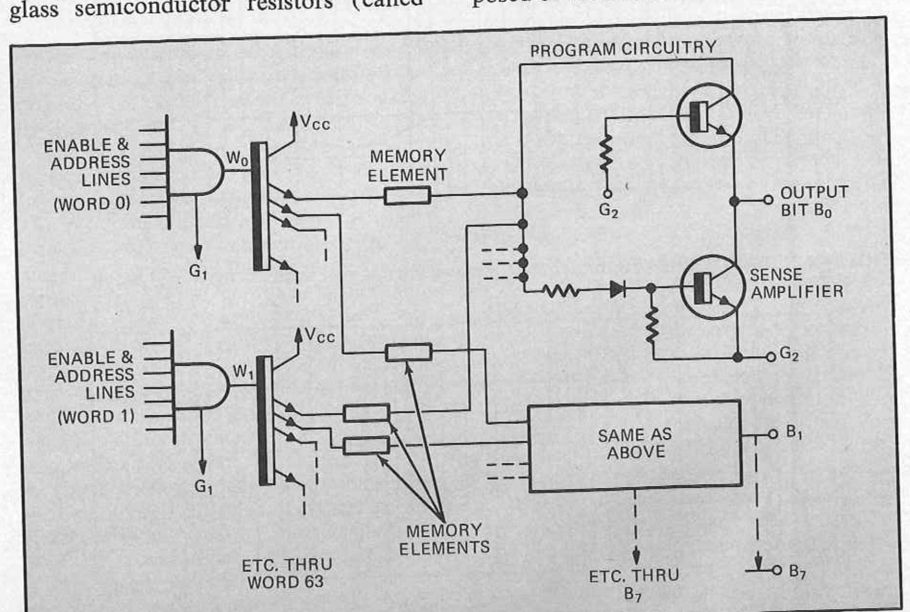


FIG. 1—512-BIT PROM schematic shows the word transistors (64 of them) connected to the sense and program circuits via memory elements.

TABLE 1

Manufacturer	Part No.	Organization	Bits	Supply Voltage Normal	Supply Voltage Program	Memory Element	Special Notes
Advanced Micro Devices	AmS08	32x8	256	+5V	10V to 15V	polysilicon	open col. out. } +2 words
	AmS09	32x8	256	+5V		polysilicon	3 state out. } 9th bit,
Harris Semiconductor	HPROM-0512	64x8	512	+5V	+5V,+15V	nichrome fuse	Program similar to
	HPROM-1256	256x1	256	+5V	+5V,+15V	nichrome fuse	Signetics.
	HPROM-8256	32x8	256	+5V	+5V,+15V	nichrome fuse	
	HPROM-1024/A	256x4	1024	+5V	+5V,+15V	nichrome fuse	3 state out, A=open coll.
	HPROM-2048/A	512x4	2048	+5V	+5V,+15V	nichrome fuse	3 state out, A=open coll.
Intel Co.	1602A/1702A	256x8	2048	+5V-9V	+12V,−45V	FAMOS device	1702A is erasable
	3604	512x8	4096	+5V	+10V,+15V	polysilicon	all outputs norm. high (1)
	8702A	256x8	2048	+5V-9V	+12V,−45V	FAMOS device	3 state out
	3601	256x4	1024	+5V	+10V,+15V	polysilicon	
Intersil	IM5600C/IM5610	32x8	256	+5V	+5V,+28V	"AIM" device	open coll. 5610=3 state
	IM5603A/IM5623	256x4	1024	+5V	+5V,+28V	"AIM" device	special pulse programmer
	IM5604/IM5624	512x4	2048	+5V	+5V,+28V	"AIM" device	
Motorola Semiconductor	MCM5003AL	64x8	512	+5V	+5V,−6V	nichrome	9th bit. Prog. manually
	MCM5004AL	64x8	512	+5V	+5V,−6V	nichrome	has 2K on output
National Semiconductor	MM5202A	256x8	2048	+5V-9V	+12V,−45V	FAMOS device	Q suffix has quartz lid
	MM5203	256x8	2048	+5V-9V	+12V,−45V	FAMOS device	for erasing.
	MM5204	512x8	4096	+5V-9V	+12V,−45V	FAMOS device	
Signetics	8223	32x8	256	+5V	+5V,+12.5V	nichrome	open coll. Prog. manually
	82S23/82S123	32x8	256	+5V	+5V,+12.5V	nichrome	82S123=3 state
	82S26/82S29	256x4	1024	+5V	+5V,+12.5V	nichrome	26=open coll. 29=3 state
Texas Instr.	SN74186	64x8	512	+5V	+5,−5V	nichrome	9th bit & extra word tested
	SN74188A	32x8	256	+5V	+5V,+10V	nichrome	by mfg. Prog. manually. open collector output.
							All types are 0° to 75°C

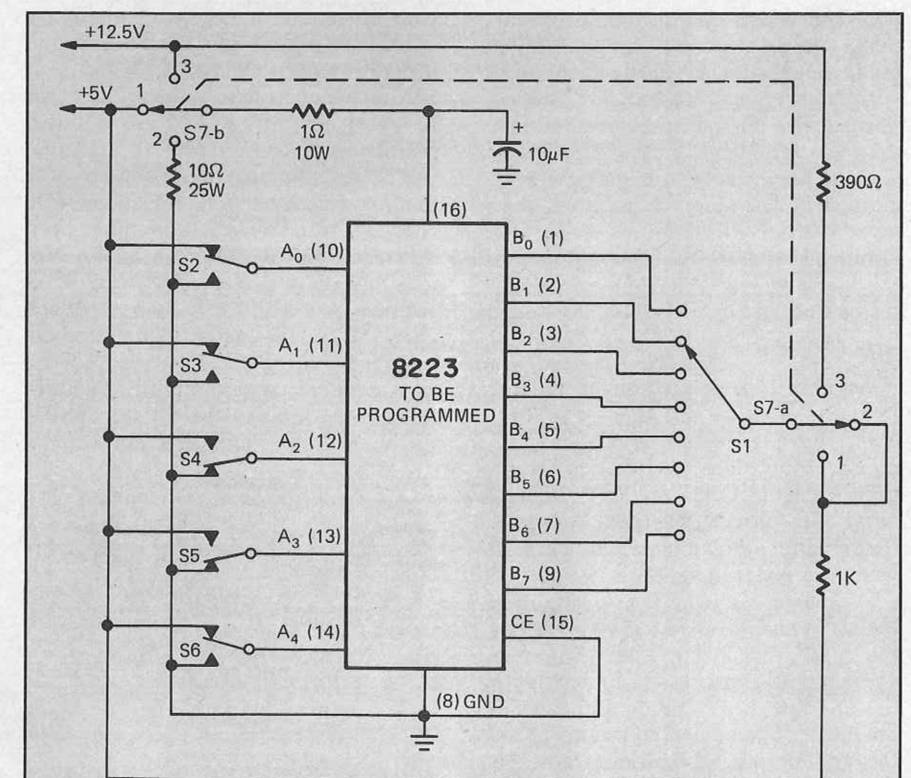


FIG. 2—MANUAL PROGRAMMER schematic. During programming, switch S7 is moved to position 2 long enough to discharge the 10-μF capacitor. Switch S7 should not be in position 3 for longer than one second.

selected, current thru the memory element is increased (to 30 mA). This is sufficient to cause the metal fuse to flow and separate. The current is applied as a ramp and limited to 60-mA maximum to prevent sputtering, metal splatter, or oxide damage.

Programming voltages for other nichrome type PROM's such as Signetics' 8223, vary somewhat. However, the basic idea is to allow a heavy current to pass thru the nichrome "fuse" to a program transistor that is biased into saturation. Figure 2 shows a manual programmer that can be used to program the Signetics 8223. When using this programmer, current should not be applied to a bit for over one second.

Two precautions should be observed when programming this type of PROM. One is to limit the application of programming current to one output at a time. This current passes thru the multiple-emitter "word transistor" whose design doesn't allow it to conduct more current than required to open one element. Another precaution is to maintain the case temperature of the PROM at or below 75°C. This is easy to do if you program manually and remove voltages as soon as the memory element opens. Automatic programming may require a heat sink.

The above description of programming the fuse-link type of PROM illustrated a manual technique. Manual programming is possible with most types of nichrome fuse-link PROM's *provided* that the currents are limited in some manner. Most often, the rise time must be controlled and the duration and amplitude of the programming current must be limited. This is easily done with a pulsing technique. All of this of course, can be accomplished with an automatic programmer that also sequences thru the addresses and bit patterns. Automatic programmers are desirable when more than three or four PROM's are to be programmed, and are required equipment for some of the PROM's to be described next.

AIM

Another type of memory element is used by Intersil in their PROM's. They have patented *A*valanche *In*duced *M*igration (AIM) programming system. Each memory element in an open-base NPN transistor whose base-emitter junction is shorted out when it is programmed.

A partial schematic of an AIM matrix is shown in Fig. 3. Notice that the matrix is constructed using conventional TTL processes. Collectors on the "X" lines are common and emitters on the "Y" lines are common, allowing for simple fabrication steps. No connection is provided for the bases. To program an element, a high current is forced thru it from emitter to collector. The emitter-base junction is forced beyond normal avalanche and into a second breakdown mode. Aluminum moves into the junction and causes a short. The result is a low-resistance path to the base and a base-collector diode as shown in Fig. 3.

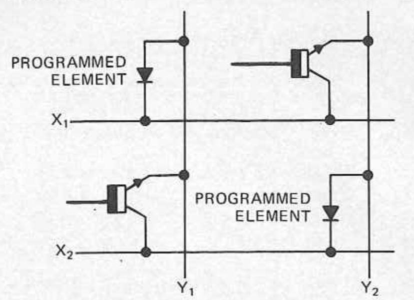


FIG. 3—PARTIAL AIM PROM matrix with two bits programmed as "1".

The programming is done using a 200 mA pulse (at about 32V) of about 2.5 μs duration followed by a 20 mA, 1.5 μs sense pulse. These pulses are repeated a number of times until a change in the bit has been detected. The programmer then moves on to the next bit automatically.

FAMOS

The last type of PROM we will investigate is the stored-charge type made by Intel and National Semiconductor. This type of PROM falls in the same category as the ovonic amorphous semiconductor type mentioned earlier in that it can be *re*-programmed (however, not electrically). The advantage of this type of PROM is obvious. If you make a mistake, or change your bit requirements, you can change your PROM by erasing all bits and programming it over again! Erasure is accomplished with ultraviolet light or X-rays (although X-rays are not recommended).

The memory element consists of a floating-gate avalanche-injection MOS charge-storage device (which has been shortened to FAMOS transistor). Notice in Fig. 4 that the FAMOS transistor is essentially a P-channel silicon gate MOS field-effect transistor in which no contact is provided to the silicon gate. In programming, a voltage pulse in excess of −30 volts is applied to the drain or source PN junction resulting in the injection of high-energy electrons from the PN junction surface avalanche region to the floating silicon gate. This negative charge on the gate results in current flow between source and drain of the P-channel FAMOS transistor.

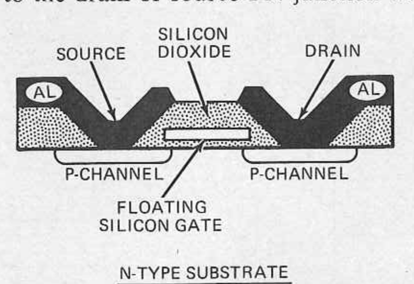


FIG. 4—CROSS-SECTION OF FAMOS structure. Negative charge on floating gate causes conduction between source and drain.

The FAMOS transistors are arranged in a matrix on the silicon chip along with an X and Y decoders, input drivers, output sensors and buffers to form the complete MOS memory device. Programming these PROM's (typically the Intel 1702A, 2048-bit PROM) requires special programmers that pulse the device with a minimum of 32 program pulses for each 8-bit word to be programmed. Note in this PROM that all 8 bits of a word are programmed simultaneously. In addition to the program pulse, voltages V_{GG} and V_{DD} are also pulsed. The Intel Company will furnish you schematics for the MP7-03 PROM Programmer, or of course, you could buy an assembled unit.

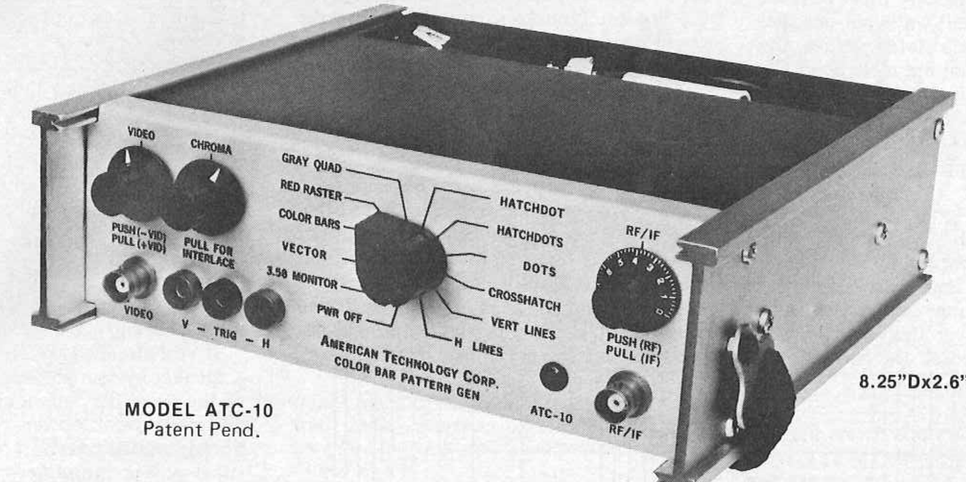
The Intel 1702A PROM comes with a transparent quartz lid which permits you to erase the bit pattern. You can erase a device by exposing it to high intensity ultraviolet light at a wavelength of 2537 A. Just put the 1702A about 1 inch away from the lamp tube for 10 to 20 minutes. Recommended lamps are Models UVS-54 or S-52 ultraviolet lamps manufactured by Ultra-Violet Products Inc., San Gabriel, CA. Physically, the erasing action creates an ionizing effect that causes the excess electrons on the floating gate to flow back to the substrate.

You have no doubt noticed that many of the PROM's we have covered use irreversible memory elements. Aside from the fact that such a PROM cannot be reprogrammed, there is also the problem of testing the PROM initially. If you order a ROM, the manufacturer programs it to your specification and tests it to be sure the bit pattern and output circuits are OK. However, if you buy a PROM, there most likely was no way for the manufacturer to test it so you won't know if it is any good until you program it. Most manufacturers build PROM's with experience and quality control. Several PROM manufacturers have decided that this method is not good enough (Motorola and Advanced Micro Devices among them). They have solved the testing problem by adding a ninth bit to all 8-bit PROM's. Some have even added several extra words to the memory. In the Motorola MCM5003 there are 32 of these ninth bits that have already been programmed to "1s," and the remaining 32 bits may be used by the customer to check out the capabilities of his programming circuitry.

Table 1 has been prepared to help

(continued on page 119)

Introducing... the Money Generator



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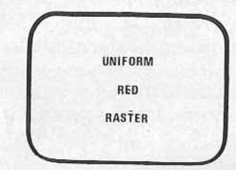

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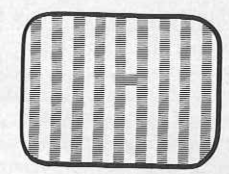
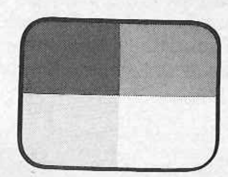
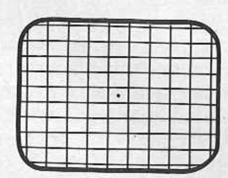


COLOR BARS
Sixth bar marked for identification.
Luminance pedestal shows color fit.



GRAY QUAD
Gray scale tracking checks/adjustments.
Yoke orientation.
L.F. video response.



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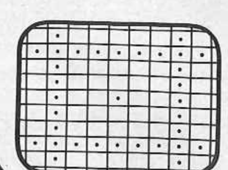

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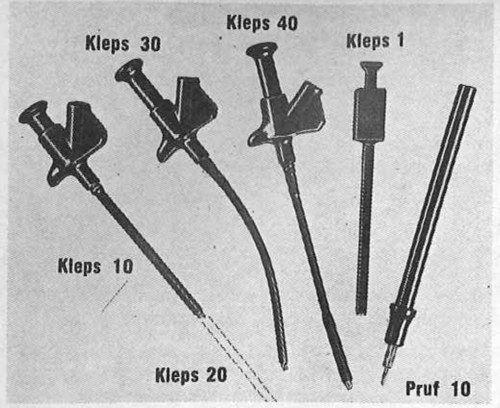

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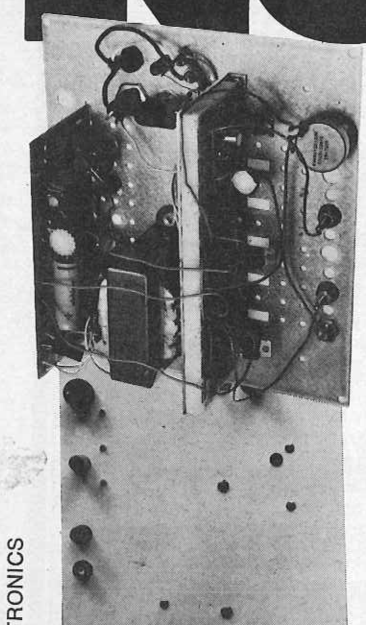

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HOW A PROM WORKS

(continued from page 74)

you in selecting a PROM. This table includes most of the presently available PROM's along with the number of bits and the bit organization of each. Also included are voltage requirements for both the read and write (programming) modes. Comments in the special notes column may also be helpful in choosing a PROM that exactly fits your requirements.

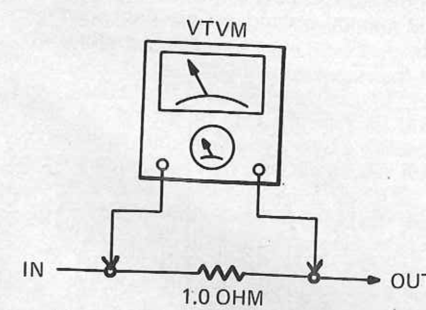
The main thing for you to remember in selecting a PROM is how you are going to program it. Unless you are prepared to spend some extra time and money for automatic or pulsing type programmers, it is advisable to stick with the fuse-link PROM's that can be programmed manually (Signetics 8223, Motorola MCM5003 etc.). Whichever way you go, remember to proceed slowly. Once you decide on your bit pattern (program), set it aside and check it over from the beginning the next day. It's easy to change an error on paper, but impossible in most PROM's.

Another hint for those of you who want to try out some PROM's: several of the PROM's we have mentioned in this article are available from companies advertising in the back pages of **Radio-Electronics.** For instance, the Signetics 8223 was noted in a couple of ads for under $5, and the National Semiconductor MM203 (similar to Intel's 1702A) can be found for around $20. **R-E**

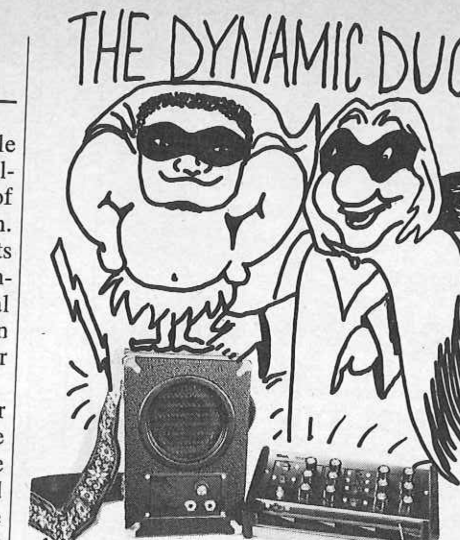
READ CURRENT ON VTVM

I've got an old vtvm without any current ranges. How can I read current with this instrument?—C.B., Bronx, N.Y.

Make up an adapter with a small value, precise resistor. Connect this into the circuit, and read the voltage drop across it. For example, a 1.0-ohm resistor will show 1.0-volt drop if there is 1.0 ampere flowing, and so on.



This will work on AC or DC. If you want to read low currents, in high impedance circuits, use a 1000 ohm resistor. Now, you'll read 1.0 volt for each milliampere of current. This works only in circuits with high resistance, so that the added 1000 ohms won't upset things. **R-E**



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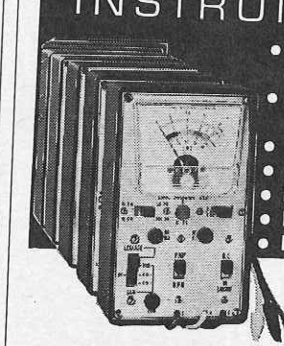

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