August 1978 $1.50

modern electronics

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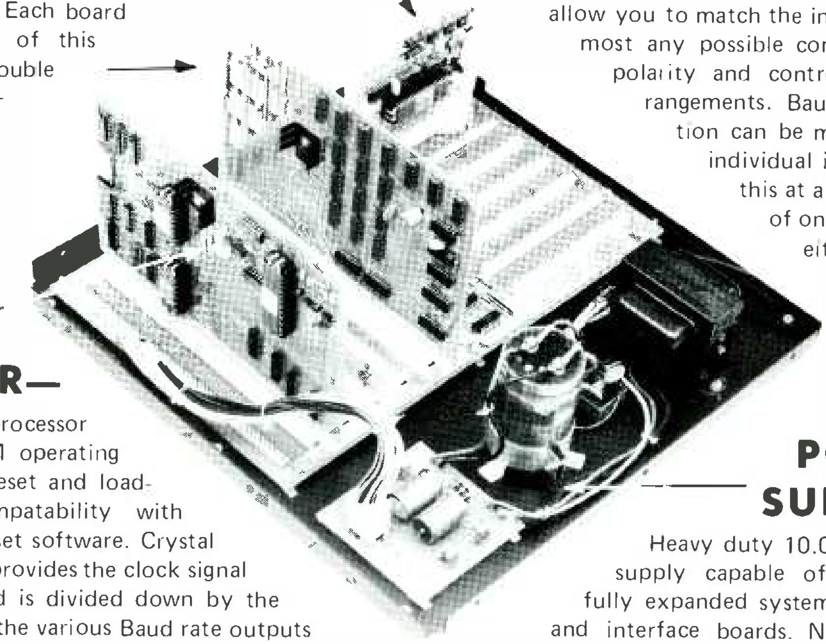

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modern electronics

AUGUST 1978 CONTENTS VOLUME ONE NUMBER SIX

COVER STORY

SPECIAL FEATURES

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PROJECT

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comment

OUTPUT FROM MODERN ELECTRONICS' EDITOR

by Anthony R. Curtis
Editor, Modern Electronics

Test setup. Work bench. Home laboratory. Whatever you call it, any electronics experimenter worth his salt has one in some form or another. Maybe it's a $7 pocket meter in your desk drawer. A fishing tackle box of pliers, screwdrivers and a soldering iron in your closet. Or a first-class Formica-covered bench built into your basement with racks of meters, scopes, digital testers and assorted gear.

Whatever you have, I'll bet you need more. It usually seems to turn out that, whatever you're repairing, you could use just one other piece of equipment to do the job right. To help you know test gear better, we've dedicated a major portion of *Modern Electronics* this month to the complete story of home workbench equipment for electronics: what is available, what it does, how you use it.

Our giant roundup, **page 22,** covers everything of interest to beginners in electronics. One manufacturer, Heath Company, offers a complete outfit of low-priced instruments in kit form. We check them out on **page 38.** Oscilloscopes are explained on **page 54.**

Want to build your own test gear? Try the easy capacitor meter project, **page 78.**

One kind of component which can provide hours of experimenting fun is an integrated-circuit timer. What they are, how they work, how you can use them is on **page 88.**

Specialized test equipment for radio work is explained in detail, starting on **page 40.**

Here are some other goodies we've included this month:

- How to understand computer languages, **page 58.**
- How to install stereo in your car, boat, van, **page 61.**
- World's smallest ham radio, **page 86.**
- How we know what time it is, **page 64.**
- How to improve your stereo listening room, **page 76.**
- How radio receiver AGC works, **page 80.**
- CB accessories you need, **page 10.**

Coming for September: 10 projects under $10; how to build a recording studio in your home; how to computerize the ignition of your car; making a computer keyboard from the Radio Shack ASCII set; plus lots of other exciting reading. Stay tuned!

modern electronics

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radio

HAM, CB, SHORTWAVE LISTENING, MARINE RADIO, SCANNERS, MONITORS

BY JUDY CURTIS, WB3AIQ

The world's smallest ham radio gets the New York City torture track test and comes up smelling like a rose

Radio advertisements say New York City is the toughest proving ground for new cars. Potholes pound suspensions to death. Dodging mad drivers tests a car's handling. Picking your way through the city maze hones your navigating skills.

Similarly, it seems to me, New York City is an *rf jungle* where you can put any two-way radio through a torture test unlike anything available elsewhere in the real world.

Take a CB set, for instance. Where else could you find wall-to-wall sounds 50 miles deep on each of the 40 channels, plus untold thousands of other signals below, above and stuck in between the legitimate channels? Try any channel and you'll know whether or not your radio can coagulate bleed over. Or whether it can survive being stepped on.

Ferry your marine radio onto Long Island Sound this month. You'll soon find out if it's receiver is sensitive enough to hear weak signals struggling through the smog.

It's the same with ham radio. Look at the super-popular two-meter repeaters. There are 100 in the metropolitan area alone. It makes a great place to see just how selective your receiver is. The cement canyons punt, pass and kick your signal around so much it makes a great place to see how sensitive your set is. And jammers and other jerks on the air make for a great test of how powerful your transmitter is. All in all, New York City is a great torture track for a two-meter ham rig.

Talking simplex

A repeater, by the way, is a sensitive receiver coupled to a high-power transmitter atop a tall building or high hill. There aren't any high hills along the coast so skyscrapers make do in New York. In operation, repeaters hear weak signals from mobile and portable ham radios. They retransmit what they hear over a very wide area. Such a system makes possible mobiles and portables talking with other mobile and portable operators up to 50 miles away. And base stations communicating over a 100 mile range (see *Ham Repeaters* in February 1978 *Modern Electronics* and this *Radio* column in March 1978).

Two meter ham radios are not limited to talking through repeaters. They can be used for direct radio-to-radio communication without the benefit of amplification by a repeater. Hams call such direct contact *simplex*.

Considering both direct and repeater frequencies, you can count 800 channels in the two-meter band (144-148 MHz) alone.

With 3000 repeaters on the air across the country, there's lots of interesting two-way ham gear on the market. In-

please turn to page 87

Wilson Mark II handheld portable for the two-meter amateur radio band has a selective, sensitive receiver and a transmitter putting out 2.5 watts. The optional Touch Tone pad, used for making autopatch telephone calls, is installed on the front of the tiny, battery-powered two-way radio.

clinic

READERS WRITE FOR HELP WITH TECH PROBLEMS

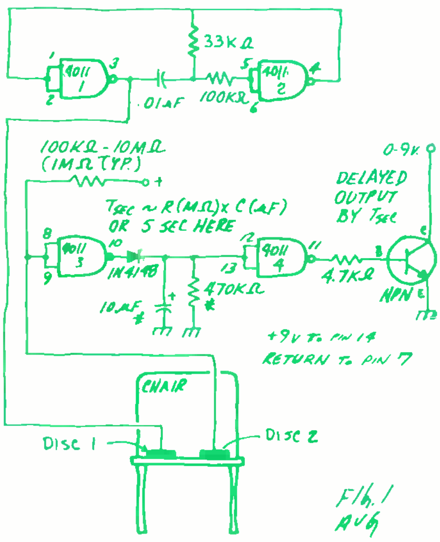
BY JEFF SANDLER

Attention please

I'm doing research on attention spans for my master's thesis. The project involves seating subjects in four isolation booths positioned at 90-degree intervals around a small stage. The subjects watch a performance on the stage from their position inside the booth, filling out a critique. They are instructed to leave the booth when they loose interest in the performance, depositing the critique in a box provided for the purpose. I need to know the exact time the subjects leave their seats. Do you have a circuit I can use to signal their standing? I am using metal folding chairs so a simple pressure switch will not work.

C.T., New Britain, CT

I think you'll find this circuit to your liking. Capacitance is the key to the circuit's operation, so there are no moving parts involved. Two small metal disks insulated from, but



mounted on the chair form a capacitor when a subject is seated on the chair. A low power square wave is coupled through the body capacitor and converted into a dc level, which holds an NPN transitor in its off state. When the subjects rise, the signal path is broken, and after a few seconds, determined by the 10 mfd capacitor and 470K resistor, the transistor turns on, closing a relay. You can use the relay contacts to activate a signal or disable a binary counter. The delay prevents false alarms from subjects shifting their positions in the chairs. The plates should be about six square inches in area. Do not use shielded cable between the plates and your alarm circuit. The 100K to 10M resistor connected to the gate input sets the sensitivity of the circuit. You can substiute a variable resistor if you'd like.

Pins and needles

I'm just getting started in electronics so I'm not ready to printed circuit boards quite yet. Perfboard works well for simple circuits, but I get into trouble with more complicated circuitry. I usually end up with a few wires that have tò be added. I'd like to push them through the perforations, but they just bend and jam. Any suggestions?

R.U., Buffalo, NY

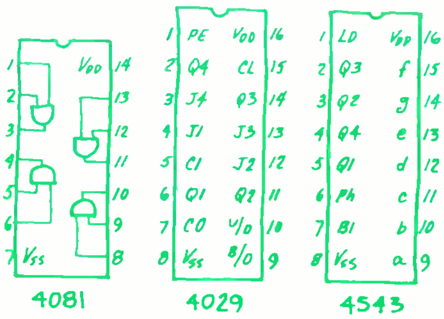
Here's a trick I came across quite by accident. You can use common pins or needles to make probes that will easily slip through even the smallest board perforation. As it happens, most pins and needles take solder quite well. So, you should have no problem soldering your wire lead onto the pin once you've gotten it into place. You can also use pins and needles to add connections to PC boards. The nicest thing about them is that that they're rediculously cheap. You can buy a hundred or more pins in most variety stores for less than a dollar.

Downcounter update

I was about to congratulate you on the forthright simplicity of your projects when I came across the Downcounter in the June issue. Where can I get 4543 ICs? They're not available from any source I know. What about pin numbers for IC connections? Where does the Vc supply come from? And finally, are the LED readouts common anode or common cathode?

R.E.G., Garden City, NY

The Downcounter was the most complex circuit to appear in Modern Electronics, *and we did make a few goofs in the diagram. First, the 4543 ICs are manufactured by Motorla and Solid State Sicentific, so you should be able to get them through a local distributor. As far as pinouts go, here's the data on the three types of IC used in the*



project. The Vc supply rail is taken from the positive terminal of the 220 mfd capacitor at the output of the bridge rectifier. The LED readouts are common cathode. Sorry about the confusion.

Timer is cheaper

My wife has become interested in African Violets and wants to raise them to sell to friends and neighbors. She needs to keep the plants under fluorescent plant-grow bulbs for between 12 and 14 hours a day. Is there a simple electronic timer I can build to control a pair of 40-watt fluorescent bulbs?

R.S., Redford, MI

Although huge strides have been made in electronics during the last few years, there are times when old fashion mechanical devices work better. And this is one of those times. While you can build a nifty timer using an oscillator and divider, or even a clock chip, a simple electric timer will do the job better, and at less cost. A 24-hour timer to do the job you want done can be purchased in almost any hardware or department store for less than $10. The Radio Shack 63-862 timer plugs right into the wall socket and has a recepticle into which you can plug the lamp fixture. It costs about $7.

computers

HOW THEY WORK, HOW YOU USE THEM, WHAT THEY CAN DO FOR YOU

BY PETE STARK

Looking around for a computer for your home? Hard to choose from the rigs on the market? Here's the story on what one expert plays with at home.

Ah, more letters from readers. One question which has come up several times is, *"Do you have your own computer? If so, what kind is it, why did you choose that particular one, and what do you use it for?"* All right, here are some answers.

Yes, I do have my own computer. Actually, I have two different ones. One is in the category of a trainer, while the other is a full-fledged system.

The trainer

The first system I purchased was a single-board computer made by Intersil, called the Intercept Jr. It is a complete, though small system on a single printed circuit board about a foot square. It is made with extremely low-power CMOS *integrated circuits* which take so little power that the entire computer is powered by four D cells. I have had it over a year, and am now on my second set of batteries.

On the printed circuit board is the *central processor* intergrated circuit (the Intersil IM6100), 256 words of *memory*, a twelve-key *keyboard*, eight seven-segment light-emitting diode *displays*, and a read-only-memory which contains a *monitor* program which controls the entire system. The keyboard and display, under the control of the monitor, allow me to enter a program, start and run it, and also observe the results.

This small system is very similar to a number of other single-board systems in the same price range ($200-300), which include the Imsai 8048, the KIM-1, and the Heathkit ET-3400 trainer. A number of manufacturers make similar computer trainers which are cheaper (such as the Cosmac ELF) or more expensive (such as the E&L Instruments' MMD-1).

By comparison with the more advanced—and more expensive—home computers such as the Altair, Imsai, or SWTP systems, these single-board systems are quite limited. For instance, my unit can add and subtract, but doing any calculation whose answer is smaller than 1 or larger than 4095 is difficult. Programming is in *machine language*, which is the most tedious of all the Common languages. So why did I choose it?

My main reason was one of necessity. I teach electronics and computers. If you are going to teach about microcomputers, you must become extremely familiar with them first. The only way to become an expert on something is to use it, so this trainer was an educational investment. As it turns out, the simpler, the less powerful a computer is, the more you must learn about it to use it. Hence, from an educational point of view a simple trainer may be more useful than a large system.

My specific reason for choosing the Intersil system, over a KIM or other system, was the fact that it uses a language I was already familiar with—that of the popular PDP-8 computer. Though this may not apply to others, it was an important consideration for me.

Third, even though such a small computer may be weak at high-powered math, it still makes a very capable controller. With the addition of about $2 of parts, I added an output interface with which I could generate two outputs and control them with a computer program. In my case I had to add a small plug-in circuit board, but other single-board computers are more adaptable to this use. The Imsai 8048, for example, has several built-in input and output circuits for just such a purpose. The Heathkit ET-3400 trainer has a breadboarding socket into which you can install fairly complex control circuits for a variety of tasks. I used these outputs for demonstrating the computer in class (connected to a small loudspeaker, the computer did a fairly good imitation of a bugle call to wake everybody up), and also for generating test signals and teleprinter data for various other experiments.

At this point, this trainer is lying unused. I have gotten about all of the educational value out of it that I expected, and am temporarily devoting my time to other tasks. Eventually, however, it will return to duty, this time as an intelligent controller connected between my other computer system and an IBM Selectric typewriter.

Full-fledged system

My other computer system is a Southwest Technical Products Corp. system based on the Motorola 6800 *microprocessor*. Connected to it is a variety of equipment, all of it obtained used. This includes a surplus keyboard, a HAL video converter which generates a tv signal which is fed to a 9-inch tv monitor, an old and somewhat tempermental Teletype printer, and a Dura model 1041 word processing system. The computer itself has 16K of memory, and a cassette interface made by Personal Computing Corp.

My choice of the SWTPC computer was a highly personal one which was based more on intuition than any sound analysis, but I think it has worked out well for me. The Motorola 6800 microprocessor which it uses is not one of the fastest or most powerful. It is generally agreed that the Z-80 from Zilog is faster and more versatile. Hence, in terms of pure computing power I knew that I was accepting less than was available at the time. Moreover, the 6800 is not as popular, and the bus structure of the SWTPC system is also not as popular as the more common S-100 bus which is used by Altair, Imsai, and many others. Hence I knew that I would have a more limited variety of add-on equipment and programs to choose from than if I went to some other system.

On the other hand, there were some good reasons for going the route of the SWTPC/6800. First, the 6800 is simple. As far as the structure and programming is concerned, it is much more straightforward than most of its competitors. It used a more traditional approach which will make many people familiar with older computers immediately feel at home.

In my instance, I knew that I did not want to limit myself to using other peoples programs; some of my proposed projects required that I write my own programs in assembly language, and so simplicity was a virtue even if it did possibly mean the computer would be slower or not as versatile.

Hand in hand with simplicity is cost. Unlike the 8080 or Z-80 processors, the 6800 requires fewer additional integrated circuits to make a complete system. This implies lower cost for the entire system. Most computers based on the 6800 integrated circuit turn out to be quite reasonably priced.

In the case of the SWTPC system, I would estimate that the price may be as much as 50 percent cheaper than some other similar systems; the only area where this is not true is in the price of add-on memory, which costs slightly more for my system than it might for others.

Another choice I had to make was which bus to use. The bus structure of a computer involves the interconnections between various parts. A standard bus allows the plugging in of a variety of add-on modules without having to rewire the system. The most popular bus is the so-called S-100 bus originally introduced by Altair.

Dozens of companies make computers and add-on components which use this bus structure; having an S-100 based computer allows you to add memory or other products made by other companies and introduces a tremendous versatility of choice. This is an important advantage of S-100 systems.

But I decided to go in another direction; instead of buying an S-100 system, I chose the SWTPC computer which uses another bus structure; this is the SS-50 bus introduced by SWTPC and used by a fairly small number of other companies.

Though this does reduce my expansion possibilities, it does have an advantage. The S-100 bus is so very popular that dozens of companies make products for it, but the problem is that many of these introduce their own variations both in hardware and software.

As a result, some of the supposedly compatible modules are not really compatible without some minor changes. More important, various companies have different ideas of just how to organize memory addressing, and so a program written for one system may require drastic changes to run on another, even though both may use the same bus and even the same microprocessor.

This is a much smaller problem in SS-50 bus systems, since SWTPC is the major user of that bus, and also the major user of the 6800 microprocessor. Hence most other companies that make products for the bus remain compatible with each other and with SWTPC. The programming compatibility was even more important to me than hardware compatibility.

I liked the idea that almost every 6800 program ever published in any of the hobby magazines would run on my system without major changes. The upshot is that, although I might have a smaller variety of hardware and software products to choose from, the ones available would be easier to use without any kind of modifications.

Related to the availability of software is its price. I found that for some systems software—that is, programs like a Basic translator or assembler—was quite expensive. Though many hobbyists solve that problem by sharing programs, I was not sure that I wanted to do it that way; it seemed better to choose a system for which software was available and cheap. Here again, SWTPC seemed a good buy, since language translators and other programs are available for $10-15.

How well does it work?

In one word—superbly. I have had the system for the better part of a year, and have had no problems. During this time I have installed additional memory, additional input-output equipment, changed the main processor board to a newer model, and made a few minor changes. After each change, the system worked just as expected. To a large extent I have been surprised by its reliability. During the time I have had this system, each of the large computers we have in the college where I teach has required some repairs; mine has not.

What is it used for?

Unlike the typical home computer system, mine is not used for playing games. I am attempting to use it only for more serious purposes. It is presently being used for four major tasks:

- Scientific and engineering computations. I have developed several small programs for doing circuit design, but this is hardly a major use. A programmable calculator could do most of this just as well. I am also using it for various scientific calculations involved in revising a textbook on numerical methods.
- Financial computations. This is primarily a set of programs which balances the checkbook and prepares income tax returns from the checkbook data. I did part of my 1977 tax returns on the system, and expect to use it for all of my 1978 taxes.
- Education. We have six similar systems at the school where I teach, and I find it very handy to have a system at home which I can use to prepare exams, lab experiments, and homework assignments. The system is also useful in preparing material for this column and other articles.
- Most important, I am expanding the system into a text editing system. As mentioned earlier, I have a Dura text processing system connected to the computer. The Dura system is about 15 years old, and is an IBM Selectric typewriter which is connected to a paper tape punch and reader, as well as some other control circuitry. It was originally used for writing form letters and for light secretarial work. My system was purchased used from the government, which had used it for some kind of bookkeeping application in a hospital. As orginally designed, a typist would type a letter on the typewriter, which would then be punched into paper tape. This tape could then be read back and edited to remove mistakes; when all corrections were made, the tape would then be read back and a final copy typed on the same typewriter. Because of the large amounts of paper tape used, and the general awkwardness of the system, this was obviously only useful for short documents such as letters.

I intend to use the system to write articles and books. This means I have to bypass the paper tape in favor of computer memory storage and cassettes. I presently have the Dura typewriter connected to the SWTPC computer, and can enter data into the computer from the typewriter keyboard, or print on the typewriter under program control, but more than this is needed.

The major job at this point is to write a good set of programs which will allow writing an article or book chapter using the separate computer keyboard, editing it on the tv screen and then storing the edited text on cassette as well as producing a neat, typed copy. At some later point, I want to be able to read the cassette back in, do more editing, and produce a new typed copy.

At this point, the system is not yet complete. This column is being typed on a standard portable typewriter under human, not computer control. But perhaps in a few months you will be reading a column edited by the computer. When I get that far, I will mention it again and perhaps include photos.

mobile

CAR, BOAT, PLANE, RV: ELECTRONICS IN THE GREAT OUTDOORS

BY RON COGAN

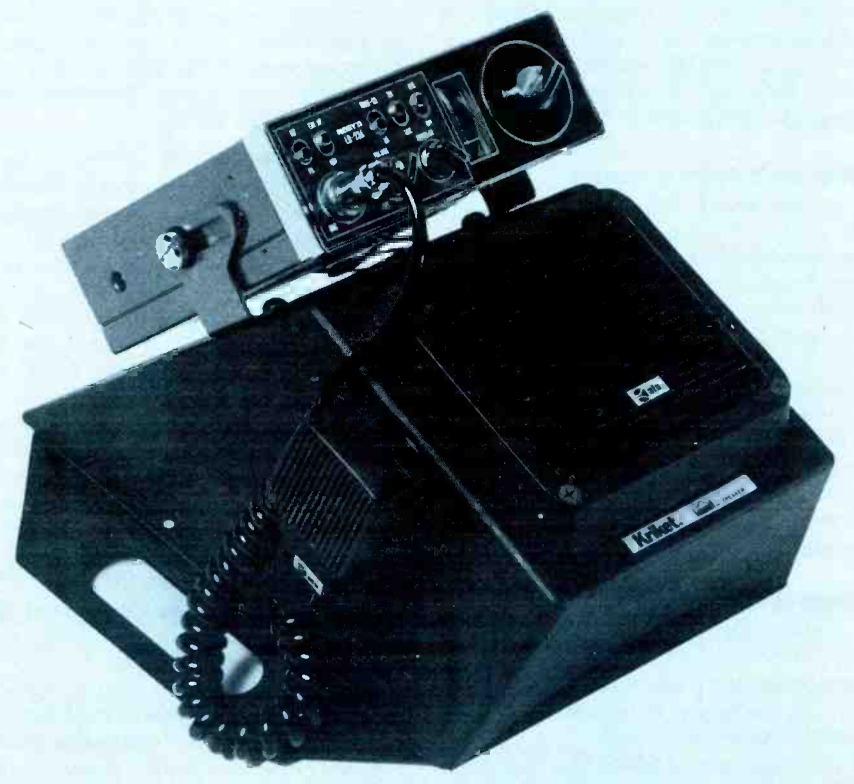
Buying a CB radio is only the beginning. Here's a host of accessories to make operating easier and more rewarding.

Once you lay your hands on a good two-way rig and an antenna, you're ready for the airwaves, right? Perhaps. More often than not, however, CBers find that a doodad here and gadget there will add even more zip to their system and more life to their conversations.

Citizens band manufacturers capitalized on this need some time ago and, as a result, we find an ever-increasing assortment of CB accessories finding their way to the marketplace and into the hands of ardent CBers.

Some of the more popular accessories such as antennas and power microphones can be found in numbers that would boggle the mind, as CB fans search out those components that will help 'em punch out a stronger signal. Like to modulate but hate the hassle of grabbing a mic? No problem; just shell out the bucks for a headset and you're home free. You can even choose different models that offer a power mic, lightweight headset, remote switch, or VAC (voice-actuated switch that operates at the sound of your voice)—it's all up to your individual preference.

Those who would like a better shot at listening in on distant stations may opt



Kamel hump-mount auxiliary speaker from AFS Kriket fits over the transmission tunnel in most automobiles and offers surface for mounting a transceiver, too.

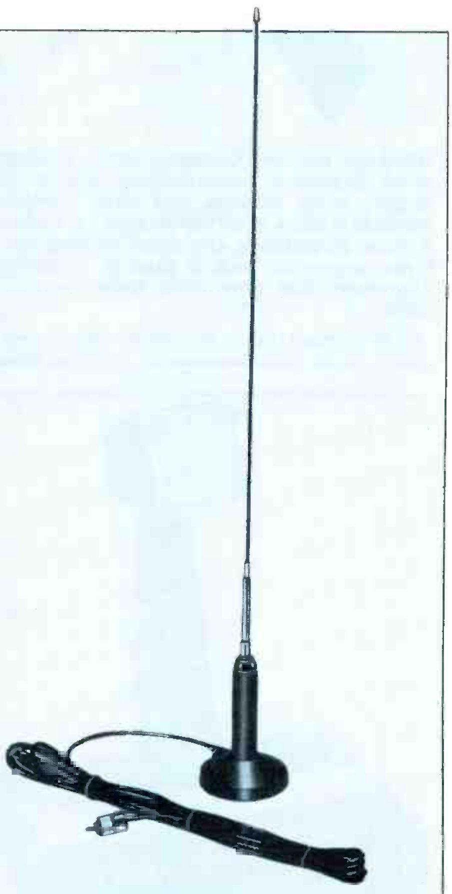
Circle number 101 on our reader service card.

South Shore Trading Corporation offers a 102" whip that folds to a compact 15⅝" in seconds. The SST Whie-A-Way antenna consists of a series of hollow, interlocking steel sections that are "strung" on a spring-loaded cable.

Circle number 102 on our reader service card.

Automatic Radio's model PAS-2103 PA horn is a valuable component for those CBers who wish to utilize their set's public address capability. All weather horn can be mounted underneath the vehicle or in the engine compartment.

Circle number 103 on our reader service card.



Sparkomatic Corporation's model SA-105 is a magnet-mount antenna designed for both 23 and 40 channel use. The large, heavy magnet holds the base-load antenna securely to any flat metallic surface at all legal highway speeds.

Circle number 104 on our reader service card.

Clear Case microphone from Telex boasts a battery powered amplifier with variable gain and voice shaping—all housed in a clear Tenite housing.

Circle number 105 on our reader service card.

CB Monitor, Inc. offers their CB Mobile Monitor for those who wish to monitor CB conversations on any of the available 40 channels without having to purchase a transceiver. Compact receiver clips to sunvisor and antenna offers gutter-mount attachment for portability.

Circle number 106 on our reader service card.

AFS Kriket model KC-3065 is a flush-mount auxiliary CB speaker that can be mounted in car doors, sun visor, dashboard, and more. Speaker features Kriket's "working wall" enclosure for maximum clarity and intelligibility across the entire voice range.

Circle number 107 on our reader service card.

Universal Machine Company offers a line of slide brackets, replacement mounting knobs, hump mounts, and other components that allow easy removal of CB radios from an automobile. Universal's computer-type connector has a built-in housing alignment that eliminates poor connections.

Circle number 108 on our reader service card.

The Telex CB-1200 "over-the-ear" boom mic headset offers sharp, clear CB reception even in a noisy environment. The unit boasts a power microphone, pivoting boom, and a push-to-talk switch mounted on a clothing clip.

Circle number 109 on our reader service card.

Mini auxiliary CB speaker from Audiovox measures 4"x4"x2½" and mounts to a microphone-type clip to offer portable operation.

Circle number 110 on our reader service card.

Radio Shack's dynamic base station mic offers a touch-bar transmit/lock switch, gain control, and a handsome housing.

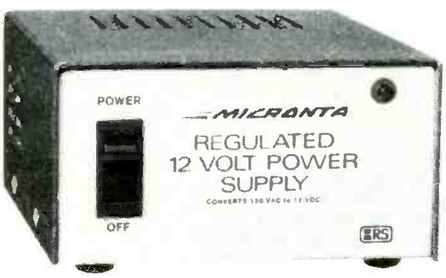
Circle number 111 on our reader service card.

Compact pocket SWR meter by Automatic Radio is a valuable aid in the proper trimming of CB antennas. Unit measures the ratio of reflected power to transmitted power for an accurate check of CB installations.

Circle number 112 on our reader service card.

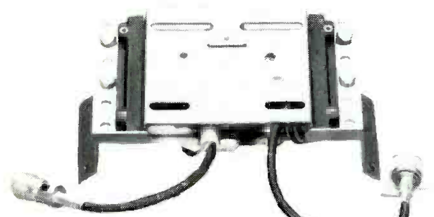
Micronta 3-range power/SWR tester from Radio Shack enables a CB enthusiast to check a transmitter and antenna for top efficiency.

Circle number 113 on our reader service card.



Micronta regulated power supply from Radio Shack allows the use of a mobile CB radio indoors.

Circle number 114 on our reader service card.



This floor-mount bracket from Radio Shack is just one of a fine line that allows easy removal of CB radio to avoid theft.

Circle number 115 on our reader service card.

Mike-Minder Company markets a microphone attachment device that utilizes two peel-and-stick velcro strips. This handy component eliminates the need to drill holes in a car's dash for mounting a conventional-type mic clip.

Circle number 116 on our reader service card.

Archer two-position coax switch allows a CBer to change antenna usage without switching leads. Available from Radio Shack nation-wide.

Circle number 117 on our reader service card.

Sparkomatic Corporation offers their NFS-1000 noise filtration system to eliminate interference from all vehicular sources including ignition spark, alternator/generator, metal to metal contact, and other sources.

Circle number 118 on our reader service card.

Mura Corporation's PRX-300Z base microphone offers high levels of talk power and clarity while substantially reducing background noise. The mic features lighted transmit and receive controls, variable gain slide control, AC power, and more.

Circle number 119 on our reader service card.

for a receiving amplifier, accessory speaker, or perhaps a combination of filters to eliminate static and interference dealt by a car's electrical system. A number of manufacturers produce auxiliary CB speakers specifically designed to increase voice intelligibility and clarity so converstaions can be monitored more effectively.

Many a CBer has found the tiny speaker contained inside his transceiver's smallish housing to offer less than optimum performance during use.

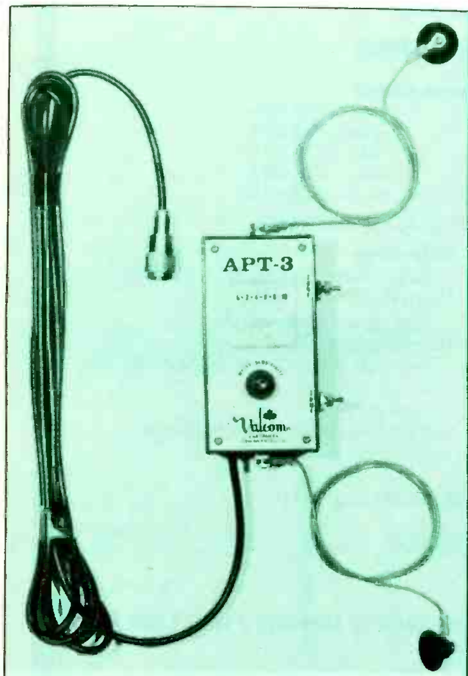
Want to make your mobile rig do double-duty as a base station, too? This can be accomplished easily by powering it with a 110V ac to 12V dc converter and hooking it to a standard base station antenna.

More sophisticated power supplies offer a regulated 13.8 volts of power to run a mobile rig in the home—the same voltage that a car's electrical system will provide with the engine running.

Several versions of tunable indoor antennas are also available for those who live in apartments that restrict the rigging of outdoor antennas.

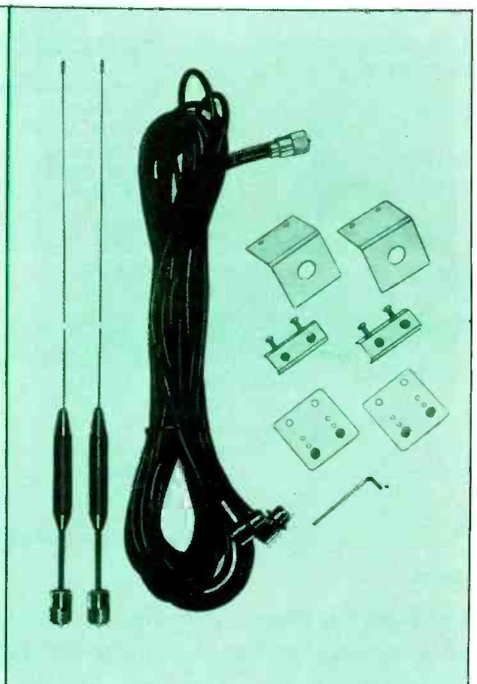
These are just a handful of samples of the accessory equipment found in this field. The list goes on—from inexpensive, tiny components to sophisticated gear you may well want to finance; it's all there for the asking and the right amount of cash.

The selected accessories pictured in this article will give you a quick overview of some of the items you might want to add to your citizens band system.



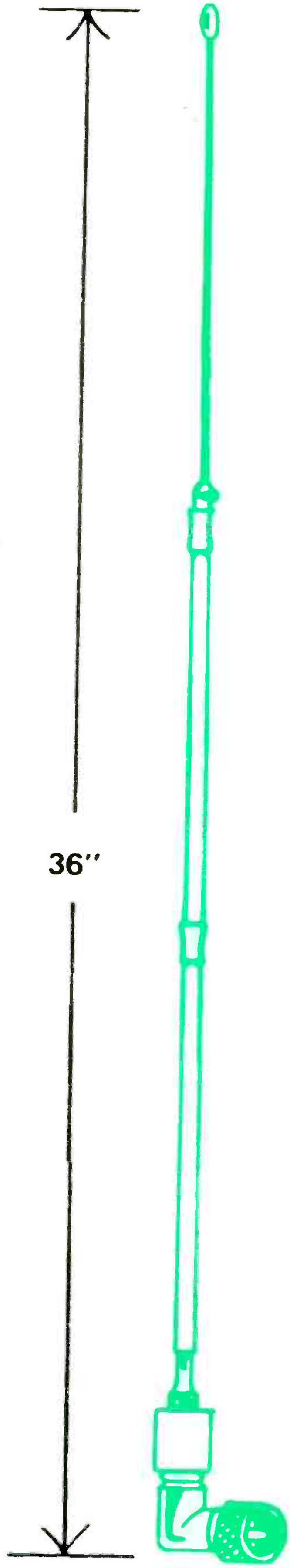
APT-3 shoestring antenna from Valcom is designed for use in apartments, homes, and business offices where it is impractical or impossible to put up an outside antenna. Unit and 33" antenna arms attach to window or wall with suction cups for easy installation.

Circle number 120 on our reader service card.



Model SA-22 system by Sparkomatic is a co-phased, twin antenna setup engineered for three popular mounting applications—truck mirror mount, gutter mount, and camper side mount.

Circle number 121 on our reader service card.



Another fine product from AVA Electronics is the indoor "Rabbit Stix" base antenna. The antenna is adjustable to 36" and features a two-piece construction of fiberglass and stainless steel.

Circle number 122 on our reader service card.

CIRCLE 18 ON READER SERVICE CARD

BY HANS FANTEL

Like to fiddle with tone controls on a stereo? Here's how to get super sound and pinpoint control with one of the new add-on frequency equalizers.

Back in the early days of audio, they used to tell about the hi-fi fan going to his first "live" concert at Carnegie Hall. "Not enough bass," he grumbled and complained because there were no tone controls on his seat.

Seems that audio fans always had an uncontrollable urge to fiddle with the tone controls. They just can't get enough of them and are growing dissatisfied with the simple treble and bass adjustments that have been standard on audio equipment for years. So lately more elaborate tone controls, known as frequency equalizers, have appeared on the market and are fast gaining in popularity. In fact, dealers tell me that they are now the fastest-selling of all add-on items.

Most of these frequency equalizers come in the form of outboard units to be connected between the tape-out and tape-in terminals of an amplifier or receiver. Unlike the standard treble and bass controls, these equalizers permit very accurate, selective adjustments of frequency response.

Treble trouble

The trouble with ordinary treble and bass controls is not that they don't do enough but that they do too much. Their action spreads out over several octaves at once. This makes it impossible, for example, to raise a certain frequency region (for example, the mid-bass around 100Hz, which can add a lot of thrust in rock music) without at the same time greatly boosting the extreme bass, which then would overload the output stage of the amplifier and possibly the loudspeaker.

Or, if you've got a room resonance at a certain frequency, you can't attenuate just that troublesome frequency without spoiling response in adjacent segments of the range.

With a frequency equalizer, solving such problems is a snap. For these equalizers consist of an entire row of tone controls, each one affecting just a small slice of the total range. So it's easy to boost or cut just those frequencies that present a problem and leave all the others untouched.

That way you can correct for dips or peaks in the response of your speakers or phono cartridge, room resonance, hum, or the foibles of old records with weak bass or shrill treble. In fact, the possibilities of tonal changes and corrections are almost limitless.

Sometimes I use frequency equalizers to second-guess the recording engineers. For example, many classical recordings these days are made with very close-up mikes, which often results in shrillness of the basic string sound. In experimenting with equalizers, I found that a slight downward adjustment of midrange frequencies (roughly in the octave between 6000 and 12,000 Hz) creates the illusion of the music being heard from a greater distance, taking the hard edge of the strings.

Sometimes, when playing old jazz recordings made before the days of expert "sound mixing," I can bring into focus musical details lost on the original disk by slightly stressing the frequency region around 4000 Hz. It takes a bit of experimenting with the slide controls on the equalizer to find the right setting for a particular record. After reaching what seems to me the best sound, I usually mark the equalizer setting on the record jacket so I can immediately duplicate it the next time I play the disk.

Equalizers exaggerate

In working with the equalizers, it's important to remember not to exaggerate the many effects you can produce. A change of 3 to 6 db in any of the several control ranges can make quite a difference. Pushing the slides all the way may produce dramatic results, but it won't make the music sound natural. There's no point in cranking up the bass until it booms like a barrel or boosting the highs until Linda Ronstadt comes on like a banshee. A light touch is the key to proper use of the equalizer.

The simplest and cheapest kind of equalizer divides the audible spectrum into five parts. A good example of this type is Radio Shack's Realistic 31-1986 selling for $60. In the most elaborate models each of twenty-seven separate controls covers only one-third octave (or about 2 ⅔ musical notes).

A highly popular type of equalizer has about ten controls per channel, each of which either boosts or attenuates one octave of the total range from 20 to 20,000 Hz. Most of these are designed as so-called "graphic" equalizers. This means that the position of the sliding controls from a visual image—a graph—of the frequency response the equalizer is set for.

In other words, you can "read" the positions of the controls just as you would read a frequency graph. More than a dozen companies now make such equalizers for home use, among them Pioneer, Dynaco, Ace, ADC, Heath, Lux, MXR, Soundcraftsmen, and Technics. Prices range all the way from $200 to $900, depending on complexity and degree of refinement.

Another type of equalizers works differently but with similar results. Known as a "parametric" equalizer, it lets you vary the center frequency of each slide control as well as the width of the band affected by the slide.

SAE makes a 4-band model of this kind ($550) and the Technics Model SH9010 equalizer ($450) combines both graphic and parametric features, making it one of the most versatile units now on the market. It has five graphic controls per channel, but additional controls beneath each slide let you shift the center frequency of each band and also narrow or broaden the bandwidth of each control segment.

The growing popularity of frequency

please turn to page 85

BY CARMINE W. PRESTIA

Keeping a membership list of your computer, ham, CB or garden club? Here's how to program your computer for storage

One of the most useful things that computers can do for us is store large amounts of information and search for specific pieces of that information. This is of particular value when lists of information are long and involved, since our human eyes become weary searching for that piece of data.

This program takes care of just such a job. I wrote it in order to keep the membership list of the local volunteer fire company, to which I belong. It is often necessary to sit down and look up members' names, addresses, and control number. The program does two things at one. First it stores the membership list itself, then it does the searching for me. All of this storage work and programming are done on my Heathkit H-8 Microcomputer. I used Extended Benton Harbor Basic because it allows me to manipulate character strings, which is how we store the data.

The program and data are stored on magnetic cassette tape, and like most of the other programs we've had in this column it takes less than a minute to load it into the H-8. You could use the program to keep a membership list like I do or your Christmas card list, or even a receipt list for your wife.

How it works

OK, how does the program work? I've included the flowchart again, to help us visualize the logic. See figure 1. Since we have already gone into flowcharting (*ME*, June 1978) I won't give an explanation, but you can refer to it to clarify the program.

Now, look at the program itself, see figure 2. Take a quick glance at the entire program and you will see that I have included plenty of the ubiquitous remark (REM) statements to document the

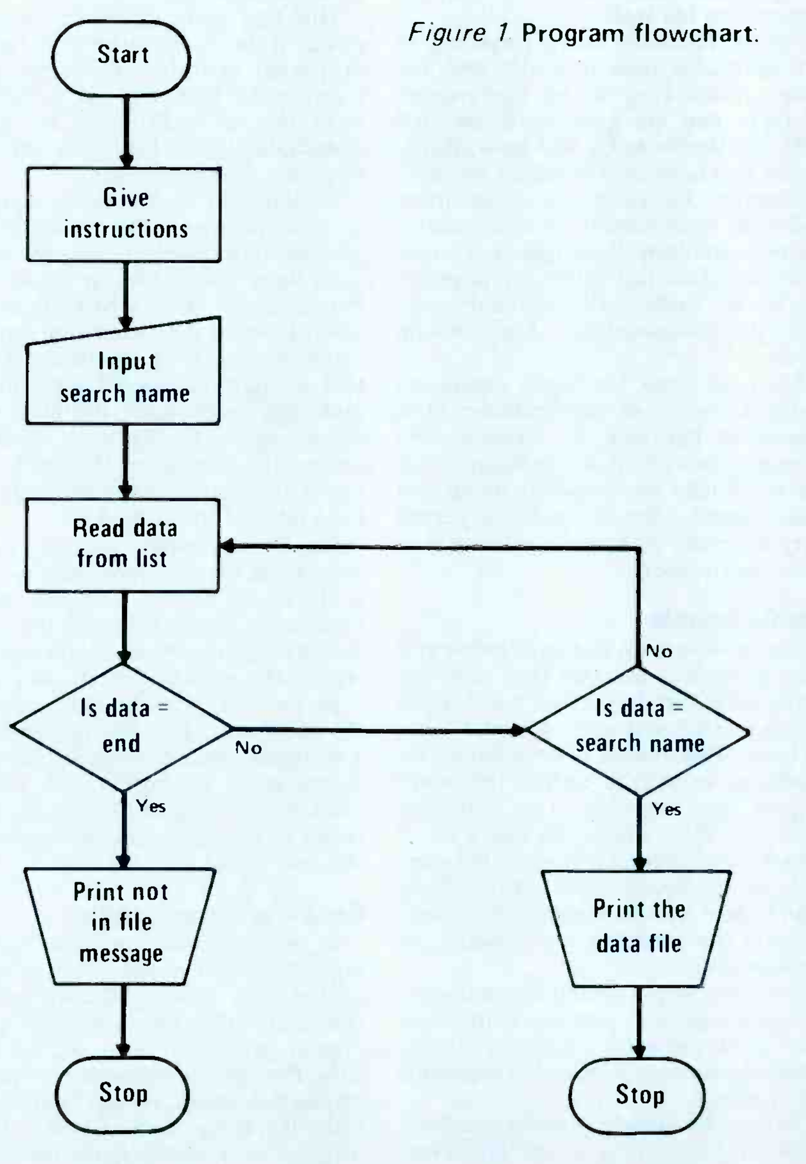


Figure 1. Program flowchart.

Program listing

```
005 REM  ALPHA FIRE LIST, VER 1, 04/05/78, CWP
010 REM
020 REM  A PROGRAM CONTAINING THE MEMBERSHIP LISTING
025 REM  OF THE ALPHA FIRE CO. OF STATE COLLEGE, PA.
030 REM  AND PROVIDING A MEANS OF SEARCHING FOR A
035 REM  PARTICULAR INDIVIDUAL'S INFORMATION.
040 REM
045 REM  INPUT THE NAME TO BE SEARCHED FOR
046 PRINT TAB(25) "INSTRUCTIONS"
050 PRINT "PLEASE SPECIFY THE NAME OF THE MEMBER WE"
055 PRINT "ARE LOOKING FOR.  USE THE FORMAT: LAST NAME,"
060 PRINT "COMMA, FIRST INITIAL, SPACE, MIDDLE INITIAL."
065 PRINT "CAUTION, ANY OTHER CHARACTERS WILL CAUSE ERRORS."
070 LINE INPUT "SEARCH NAME, PLEASE?  ";S$
075 REM  NEXT LINE SETS LENGTH INDICATOR FOR THAT NAME
080 LET X = LEN(S$)
085 REM  READ A NAME FROM THE LIST
090 READ L$
095 REM  SEE IF WE HAVE REACHED THE END OF THE LIST
100 IF LEFT$(L$,3) = "END" GOTO 130
105 REM SEE IF THE NAMES MATCH
110 IF LEFT$(L$,X) = S$ GOTO 120
115 GOTO 090
120 PRINT "RECORD IS - ",L$
125 STOP
130 PRINT "THAT NAME NOT IN FILE!  ",S$
135 STOP
140 DATA "ROE,R E   100 WEST ST   123","DOE,J J   300 SOUTH ST 345"
141 DATA "SMITH,J E   200 EAST DR   234"
142 DATA "END"
143 END
```

program coding.

Lines 43 through 65 print instructions for the user, then line 70 asks for the name we are searching for. Line 80 is a device to make the program a little easier for us to use. "X" is a variable that I use to contain the number of characters in the search name that we entered.

"LEN" is a *function* built into Basic to automatically count the number of characters in the string specified in the parenthesis, in this instance, the search name, S$. Now you are probably wondering about that dollar sign! In Basic the dollar sign after the variable name tells Basic that it is dealing with a *string variable*, or string of characters.

In line 90 we also have something new, the READ statement. READ is always used with a DATA statement. The DATA statements contain a list of DATA items that the READ statement reads out of. A pointer is automatically set by the program to indicate the next piece of data to be read.

The next line of coding, 100, looks at the data read into variable L$, to see if it says 'End'. If it does, we have gone through the list without finding the name we wanted. "GOTO 130" sends the program to line 130 where it prints a message that it did not find the data we were looking for. It also prints the search name, for reference.

If this *relational test* between the two variables is untrue, or "falls through" we drop to line 110. Here is where we use the contents of variable "X", that we got in line 80. It is also a good place to explain the next new item, the *function*, LEFT$. This is another of those built-in functions. It uses the number stored in "X" and counts that many chaaracters from the left end of the character string in variable L$.

Fall through the lines

This part of the string is then compared to the search name S$. If they are equal, the program has found the data we want and goes to line 120 to print it. Because of the way I have structured the data the name of the member is always on the left end of the character string so the program is always looking at the name section of the string.

If this test fails and we "fall through" to the next line, 115, it sends the program back to line 90 to read another piece of data. These comparisons and loopings go on until we find the data we want or we run into the end of the list. The statement, STOP, in lines 125 and 135 halts execution of the program when one of these conditions occurs.

Lines 140 through 142 are our DATA statements. Since we are dealing with character strings each piece of data is enclosed in quotation marks to tell Basic it is a string. The different pieces of data are separated by commas. Line 142 contains the string "END" that tells the program we have reached the end of the list. Line 143 is an END *statement;* it signifies the physical end of the program.

If you are going to try this program on your machine, and I hope you do, you will probably have to make some changes depending on the version of Basic that you use . Most likely, the changes would have to be made in the string *functions* LEN and LEFT$.

Whatever you do, good luck! In the future we will try a similar program that can search the data in a couple of different ways.

Test equipment

What is electronics test equipment? How does it work? What can it do for you? How do you use it? This month, we take a close look at test gear. First, in this article, general equipment for the home workbench. On page 40, radio-frequency test gear. How an oscilloscope works is on page 54. Test equipment you can build for yourself includes a capacitor meter on page 78. Dig in! You'll find everything you always wanted to know about workshop electronics in the next pages.

by Bob Margolin
Assistant Editor

COVER PHOTO BY
Steve Geraci

It's a little past midnight and you've just finished building an egg timer. It's a simple circuit—just a handful of parts and an IC. But it doesn't work. You recheck the wiring again and again. It seems to be wired right—why doesn't it work? Must be a bad component—but which one?

Unless you have some test equipment handy, there's no way to troubleshoot the circuit. You're only course of action is to rebuild the circuit with another set of parts, and hope all of them are good!

If you're building a really complex circuit, or trying to fix a circuit that did work but doesn't now, you really have to have test equipment. How much and what kind depends on the kind of electronics you're into.

One piece of test gear that is an absolute must is a voltmeter. With it, you'll be able to spot shorts and opens in your circuits, and using Ohms Law, calculate current flow and resistance. And from that, you'll be able to track down bad components.

You can save yourself the trouble of calculating current and resistance by using an ammeter, which measures current, and an ohmmeter, which measures dc resistance. Or, you can use a single meter that can measure all three—voltage, resistance and current—the VOM.

Three-in-one

Some VOMs only measure voltage and resistance—VOM is short for Volt-Ohm Meter. But most also measure dc current, and some ac current as well. How useful the current measurements are depends on the sensitivity of the meter. Some VOMs have only one or two current ranges, and these may be as high as 10 amperes full scale. You'll find measuring a few milliamperes somewhat of a challenge on a 10 amp meter.

Many VOMs, however, can measure currents in the microampere range. Those that can usually have several current scales well into the milliamp range; some even into the amp range. You'll find these the most useful.

Although all VOMs measure resistance, some do a better job than others. With very few exceptions, resistance scales are not linear. Changes in needle deflection at the low end of the scale are much greater than at the high end. A typical scale will run from zero to 20 ohms on the first half of the scale, and 20 to 2000 on the second half.

If you want good resolution in a resistance reading, you'll want to use only the first 60% or so of the ohms scale. If the reading is into the last 40%, just change the range to the next higher scale. Most VOMs have at least four, usually calibrated Rx1, Rx10, Rx100 and Rx1000. But there are some that have six or seven ranges.

The greater the number of ranges, the few number of ohms measured per range. And that means greater resolution in your measurement. So, as a rule of thumb, the more resistance ranges a VOM has, the better it is as an ohmmeter.

As important as resistance measurements are, they're probably not the reason you'll buy a VOM. Nor will current measurements. Most experimenters buy VOMs for use as voltmeters.

If you're to use your VOM to measure voltages in very simple circuits, most any will do. But if you're into sophisticated circuits using CMOS ICs, FETs or other high impedance devices, your choice of VOM can be very important.

To measure voltages, the meter must be connected across the component

This Simpson digital multimeter lets you set the range manually, or if you prefer, it will automatically set the range for you, and position the decimal point.

across which the voltage appears. If the component has a high resistance, the current flowing through it will generate a relatively high voltage.

If your meter has a low resistance and you connect it across the high resistance component, the net resistance will drop—it's just like connecting two resistances in parallel. The net resistance will always be less than the lowest resistance in the parallel circuit.

The effect of this lowering of circuit resistance is a lowering of circuit voltage. It's called *loading*, and it causes inaccurate readings. It can even cause the circuit to fail. What you need is a meter with high internal resistance—one that won't load your circuit.

Ohms/volt

The internal resistance of a VOM depends on how sensitive its meter movement is. The lower the current required to move the needle to full scale, the greater the internal resistance can be.

There's another factor involved in the meter resistance, and it's the full-scale voltage. The higher the full scale voltage, the higher the internal resistance. Because of this, voltmeters are specified in terms of their ohms/volt.

If your VOM is rated at 20,000 ohms/volt, for example, you can determine internal resistance by multiplying the range setting by 20,000. So, if you've set your meter to the 10 volt range, the internal resistance will be 200,000 ohms.

But, if you set it to the 1000 volt range, the resistance increases to 20 megohms.

When you select your VOM, keep the ohms/volt rating in mind. Some VOMs have only 5,000 ohms/volt sensitivity; others as much as 100,000 ohms/volt. Most provide 20,000 ohms/volt on dc ranges, 5,000 or 10,000 ohms/volt on ac ranges.

There is no best VOM. It all depends on what you need, and how much money you want to spend. The selection of VOMs to choose from is immense. The two largest VOM makers, Simpson and Triplett, between themselves offer about 30 different models. And Radio Shack catalogs seven more. Prices range from about $10 for a pocket-size multitester to almost $200 for lab-quality VOM.

Which is best

Choosing a VOM involves more than comparing key specs and price. The layout of the range switch, the size of meter and lettering of the scales are important personal factors. Before buying a VOM, write the manufacturer or visit a local dealer and get more information. If you can, take a look at the unit and see if you like its design.

As a guide to the market place, a representative selection of pocket-sized and standard VOMs offered by the leading manufacturers follows. You'll find listed the key measurement specs, the ohms/volt sensitivity, and suggested list price. The full name and address of the manufacturers can be found at the end of the article.

John Fluke's new hand-held digital multimeter is typical of the new generation of pocket-size instruments now available. This meter uses liquid crystal display readouts while most other hand-held multimeters use LEDs.

Pocket-sized VOMs

■ *B&K Model 110 Compact VOM*—measures dc volts in five ranges from 2.5 V to 1000 V to within 3% of full scale. Measures ac volts in five ranges from 10 V to 1000 V to within 4% of full scale. Measures resistance in three ranges from Rx1 to Rx1 megohm. Input resistance is 20,000 ohms/volt dc and 10,000 ohms/volt ac. $30.

■ *Eico Model 1A1*—measures ac and dc voltages in four ranges from 10 V to 1000 V. Measures current in 0-1 and 0-100 ma ranges. Measures resistance on 0-100,000 ohm range. $12.

■ *Lafayette Model 50957V Super-Mini VOM*—measures ac and dc voltages in four ranges from 10 V to 1000 V. Measures dc current on 0-100 ma range. Measures resistance on 0-150K ohms range. Measures slightly over 3 x 2 x 1 inches. $10.

■ *Radio Shack Model 22-027 Pocket Tester*—measures ac and dc voltages in three ranges from 15 V to 1000 V to within 4%. Measures dc current from 0 to 150 ma and resistance from 0 to 100,000 ohms full scale. Input resistance is 1000 ohms/volt.

■ *Simpson Model 355 Midgetester*—measures ac and dc voltages in five ranges from 0.3 V to 1200 V. Measures resistance in four ranges from Rx1 to Rx1000 ohms. Measures slightly less than 5 x 3 x 1. Input resistance is 10,000 ohms/volt. $65.

■ *Triplett Model 310 Hand-size VOM*—measures ac and dc voltages in five ranges from 3 V to 1200 V to within 4%. Measures dc current in four ranges from 600 ua to 600 ma to within 3%. Measures resistance in four ranges from Rx1 to Rx1000. Has 50 ua microammeter. Input resistance is 20,000 ohms/volt dc and 5,000 ohms/volt ac. $55.

Standard VOMs

■ *Eico Model 100A4 VOM*—measures dc voltages in seven ranges from 500 mV to 1000 V. Measures ac voltages in six ranges from 2.5 V to 1000 V. Measures dc current in six ranges from 10 ua to 10 A. Measures resistance in four ranges from Rx1 to Rx1000 ohms. Has dB scale. Input resistance is 100,000 ohms/volt dc and 12,500 ohms/volt ac. $55.

■ *Heath Model IM-105 General Purpose VOM*—measures dc voltages in eight ranges from 250 mV to 5000 V to within

Oscilloscopes are unquestionably the most versatile piece of test gear you can own. Dual-trace scopes, such as this Simpson Model 452, let you compare amplitude, frequency and phase of two different waveforms.

3%. Measures ac voltages in seven ranges from 2.5 V to 5000 V to within 4%. Measures dc current in six ranges from 50 ua to 10 A. Measures resistance in five ranges from Rx1 to Rx10K ohms. Has dB scale. Input resistance is 20,000 ohms/volt dc and 5,000 ohms/volt ac. $75 in kit form. $95 assembled.

■ *Lafayette Model 50965 Multitester*—measures dc voltages in 10 ranges from 60 mV to 1200 V. Measures ac voltages in seven ranges from 3 V to 1200 V. Measures dc current in five ranges from 30 ua to 600 ma. Measures resistance in four ranges from Rx1 to Rx10K ohms. Has dB scale. Input resistance is 50,000 ohms/volt. $40.

■ *Leader Model LT-70A Volt/Ohm Meter*—measures dc voltages in eight ranges from 0.25 V to 1000 V. Measures ac voltages in four ranges from 2.5 V to 250 V. Measures resistance in five ranges from Rx1 to Rx10,000 ohms. Meter is protected against overload and polarity reversal. Input resistance is 20,000 ohms/volt dc and 8,000 ohms/volt ac. Requires two AA batteries. $35.

■ *Radio Shack Model 22-207 Multitester*—measures dc voltages in five ranges from 0.5 V to 1000 V to within 3%. Measures ac voltages in five ranges from 0.5 V to 1000 V to within 4%. Measures dc current in seven ranges from 10 ua to 10 a. Measures resistance in five ranges from Rx1 to Rx100,000 ohms. Has dB scale. Input resistance is 100,000 ohms/volt dc and 10,000 ohms/volt ac. $50.

■ *Simpson Model 260-6 VOM*—measures dc voltages in eight ranges from 250 mV to 1000 V. Measures ac voltages in six ranges from 2.5 V to 1000 V. Measures dc current on 0-10 a range. Measures resistance in three ranges from Rx1 to Rx10,000 ohms. Has dB scale. Input resistance is 20,000 ohms/volt dc and 5,000 ohms/volt ac. Requires one 9-volt battery and one 1.5-volt battery. $85.

■ *Triplett Model 630 VOM*— measures dc voltages in six ranges from 0.3 V to 600 V to within 2%. Measures ac voltages in five ranges from 3 V to 600 V to within 3%. Measures dc current in four ranges from 60 ua to 120 ma. Measures resistance in five ranges from Rx1 to Rx100,000 ohms. Has dB scale. Requires one 30-volt and one 1.5-volt battery. Input resistance 20,000 ohms/volt dc and 5,000 ohms/volt ac. $90.

■ *Triplett Model 60 Rugged VOM*—extra rugged meter can withstand accidental drop from up to five feet. Measures dc voltages in eight ranges from 0.3 V to 1000 V to within 2%. Measures ac voltages in six ranges from 3 V to 1000 V to within 3%. Measures dc current in four ranges from 100 ua to 1000 ma to within 2%. Measures resistance in five ranges from Rx1 to Rx10,000 ohms. Has dB scale. Requires one 9-volt and one 1.5-volt battery. Input resistance 20,000 ohms/volt dc and 5,000 ohms/volt ac. $100.

■ *VIZ Model WV-532A Relay VOM*—has built-in high speed relay and renewable-link fuse to protect meter circuit. Measures dc voltages in eight ranges from 0.5 V to 1500 V to within 2%. Measures ac voltages in six ranges from 5 V to 1500 V to within 3% from 10 Hz to 400 kHz. Measures dc current in four ranges from 50 ua to 500 ma to within 2%. Measures resistance in five ranges from Rx1 to Rx10,000 ohm to within 2%. Has dB scale. Requires two C batteries. $105.

■ *Weston 661 Drop-Proofed VOM*—can withstand accidental drop of up to five feet. Measures dc voltages in seven ranges from 250 mV to 1000 V to within 1%. Measures ac voltages in six ranges from 2.5 V to 1000 V to within 2%. Measures dc current in six ranges from 50 ua to 10 A. Measures resistance in five ranges from Rx1 to Rx10,000 ohms. Has dB scale. Input resistance is 20,000 ohms/volt dc and 5,000 ohms/volt ac. $110.

Vacuum tube voltmeter

If you're really into high-impedance circuitry, none of the VOMs will give you the accuracy you need. One way around the problem is to buy a meter that has the very high internal resistance needed to keep loading to an acceptable level—the vacuum tube voltmeter, or VTVM.

Most VTVMs have an input resistance of 11 megohms on all ranges. This should be high enough to provide acceptable accuracy in all solid-state circuits. One drawback to the VTVM, however, is its dependency on ac power. But, if you expect to use the meter only on your work bench, this shouldn't be any problem.

Although the VTVM is slowly loosing its place in the current scheme of things, a few VTVMs are still available.

■ *B&K Model 177*—measures dc voltages in eight ranges from 500 mV to 1500 V to within 3% of full scale. Measures rms ac volts in seven ranges from 1.5 V to 1500 V, and peak-to-peak ac volts from 4 V to 4000 V, to within 5% of full scale, from 40 Hz to 4 MHz. Measures resistance in seven ranges from Rx1 to Rx10M ohms. Measures audio signals in six ranges from -6 dB to +66 dB where 0 dB =.7775 volts across 600 ohm line. Has seven-inch mirrored 100 microammeter. $150.

Sinclair's DPM 35 measures voltage, current and resistance with a 3½-digit display, yet costs about $60.

B&K Precision's portable DMM is this Model 2800. Except for the 3½-digit display, the 2800 is very similar in appearance to any small VOM.

■ *Eico Model 235 Professional VTVM*—measures dc voltages in eight ranges from 0.5 V to 1500 V. Measures rms ac volts in seven ranges from 1.5 V to 1500 V, and peak-to-peak voltages from 4 V to 4200 V from 30 Hz to 3 MHz. Measures resistance in seven ranges from Rx1 to Rx1M ohms. Has six-inch 200 ua microammeter. Input impedance is 11 megohms dc and 1 megohm shunted by 60 pf ac. $90 in kit form. $120 assembled.
■ *Heath Model IM-5218 VTVM*—measures rms ac and dc voltages in six ranges from 1.5 V to 1500 V, and peak-to-peak ac volts from 0.4 V to 4000 V. Measures resistance in seven ranges from Rx1 to Rx1M ohms. Input impedance is 11 megohm dc and 1 megohm shunted by 35 pf ac. $45 in kit form. $110 assembled.

Electronic VOMs

The VTVMs replacement is a new breed of VOMs. These use solid state amplifier circuits to isolate the metering circuits from the circuit being measured. Usually employing an FET input, these electronic VOMs for the most part have input resistances of 10 megohms. Although slightly less than that of a VTVM, it should be high enough for almost all of your measurements.

The big advantage of the FET-input VOM is the use of battery power. Unlike the VTVM, which must be plugged into a wall socket, you can take your FET VOM anywhere. And since it contains no vacuum tubes, you won't have to wait for the meter to stabilize before using it.

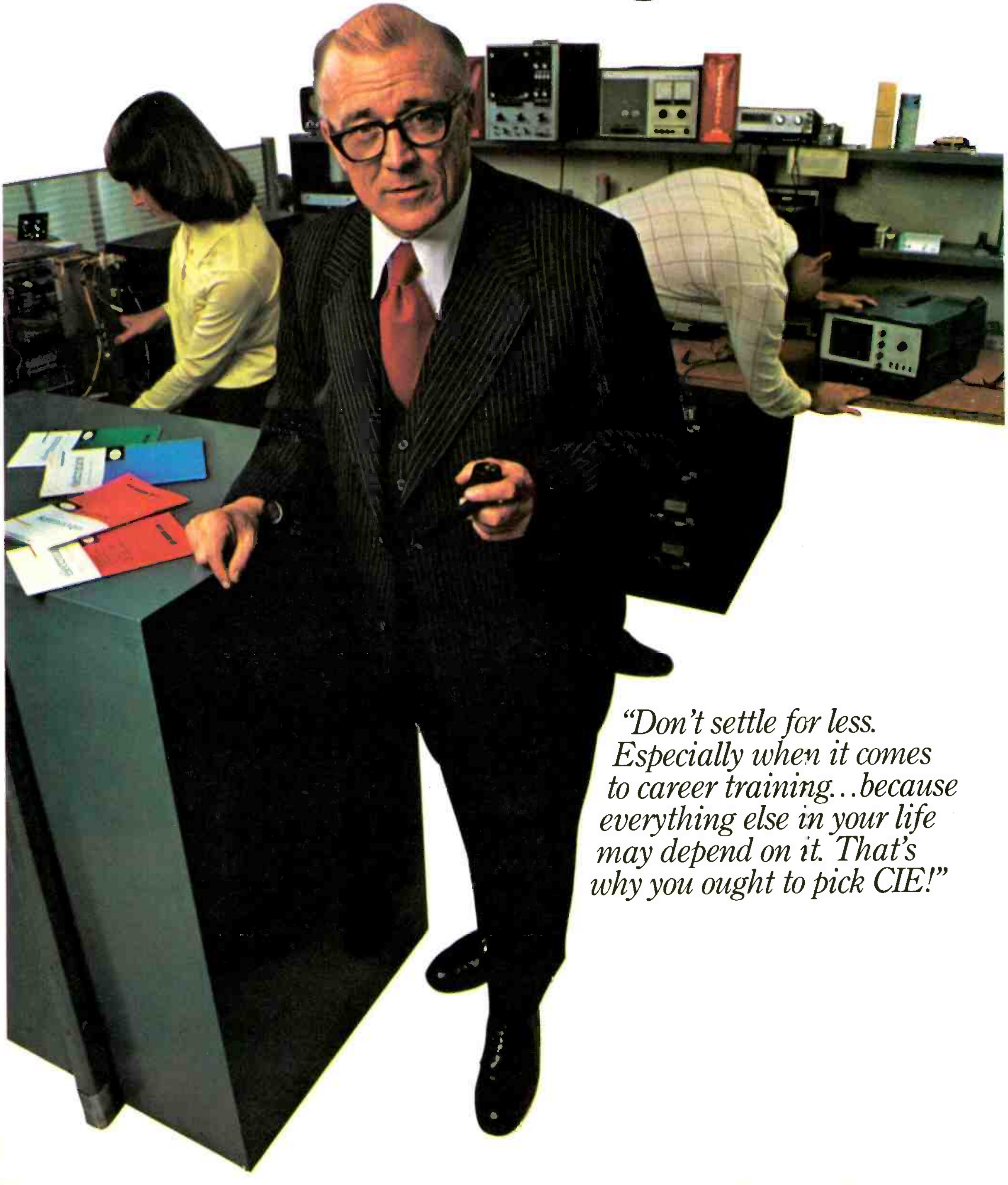
Most of the VOM makers also have FET VOMs in their product line. Here's a sampling of what's available.
■ *B&K Model 277 Electronic Multimeter*—measures rms ac and dc voltages in nine ranges from 100 mV to 1000 V to within 3% of full scale. Also measures peak-to-peak ac voltages from 280 mV to 2800 V to within 3% of full scale from 50 Hz to 150 kHz. Measures resistance in seven ranges from Rx1 to Rx1M ohm. Has dB scale. Requires one 9-volt and one 1.5-volt battery. Input impedance 15 megohms on all dc ranges, 10 megohms shunted by 100 pf on all ac ranges. $130
■ *Eico Model 242 FET-TVOM*—measures rms ac and dc voltages in seven ranges from 1 V to 1000 V. Measures peak-to-peak ac volts from 2.8 V to 2800 V. Measures resistance in seven ranges from Rx1 and Rx1M ohm. Has six-inch meter. Requires 117 V ac or three 9-volt batteries and one D battery. $110 in kit form. $140 assembled.
■ *Lafayette Model 51211V Solid-State FET Multitester*—measures dc volts in seven ranges from 300 mV to 600 V to within 3%. Measures rms ac volts in four ranges from 3 V to 600 V, and peak-to-peak ac voltages from 8 V to 1600 V. Measures dc current in five ranges from 120 ua to 120 ma. Measures resistance in five ranges from Rx1 to Rx1M ohms. Has dB scale. $60.
■ *Leader Model LE-73 FET Multimeter*—measures ac and dc voltages in eight ranges from 0.3 V to 1000 V. Measures ac and dc current in eight ranges from 0.3 ma to 300 ma. Measures resistance in seven ranges from Rx1 to Rx1M ohm. Has mirrored meter with 3% accuracy. $180.
■ *Simpson Model 303-3XL Solid State FET VOM*— measures ac and dc voltages in eight ranges from 30 mV to 1000 V. Measures ac and dc current in five ranges from 30 ua to 10 a. Measures resistance in seven ranges from Rx1 to Rx1M ohms. Has dB scale. $215.
■ *Triplett Model 310-FET Hand-size Solid State VOM*—very small meter measuring 2¾ x 1¼ x 4¼ inches and weighing less than one pound. Measures dc voltages in six ranges from 0.3 V to 600 V to within 3%. Measures ac volts in five ranges from 0.3 V to 600 V to within 4%. Measures dc current in 0-120 ua and 0-1.2 ma ranges. Measures resistance in four ranges from Rx1 to Rx1M ohm. Requires one 7-volt and one 1.5 volt battery. Input impedance is 10 megohms on all dc ranges, and 5,000 ohms/volt on ac ranges. $90.
■ *VIS Model WV-534A VoltOhmyst V*—measures ac and dc voltages in 10 ranges from 50 mV to 1500 V to within 3% dc and 4% ac. Measures ac and dc current in nine ranges from 150 ua to 1.5 a to within 3% dc and 4% ac. Measures resistance in seven ranges from Rx1 to Rx1M ohm to within 3%. Has dB scale. Has mirrored 50 ua microammeter with automatic dc polarity selection. Requires one C battery and eight AA batteries. $150.

Digital VOMs

It's been more than 25 years since the first *digital* voltmeter made its appearance. In the early years of the DVM, the instruments were physically large and heavy. Their circuitry consisted of row

This Data Precision Model 248 has a 4½-digit display. The additional digit provides better resolution, and reduces the need to change ranges. The unique pedestal stand converts the portable multimeter into a stable bench model.

"If you're going to learn electronics, you might as well learn it right!"



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At CIE, we believe theory is important. And our famous Auto-Programmed® Lessons teach you the principles in logical steps.

But professionals need more than theory. That's why some of our courses train you to use tools of the trade like a 5 MHz triggered-sweep, solid-state oscilloscope you build yourself—and use to practice troubleshooting. Or a beauty of a 19-inch diagonal Zenith solid-state color TV you use to perform actual service operations.

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after row of mechanical stepping switches that automatically switched in resistance in tiny increments until a sensitive bridge circuit was balanced.

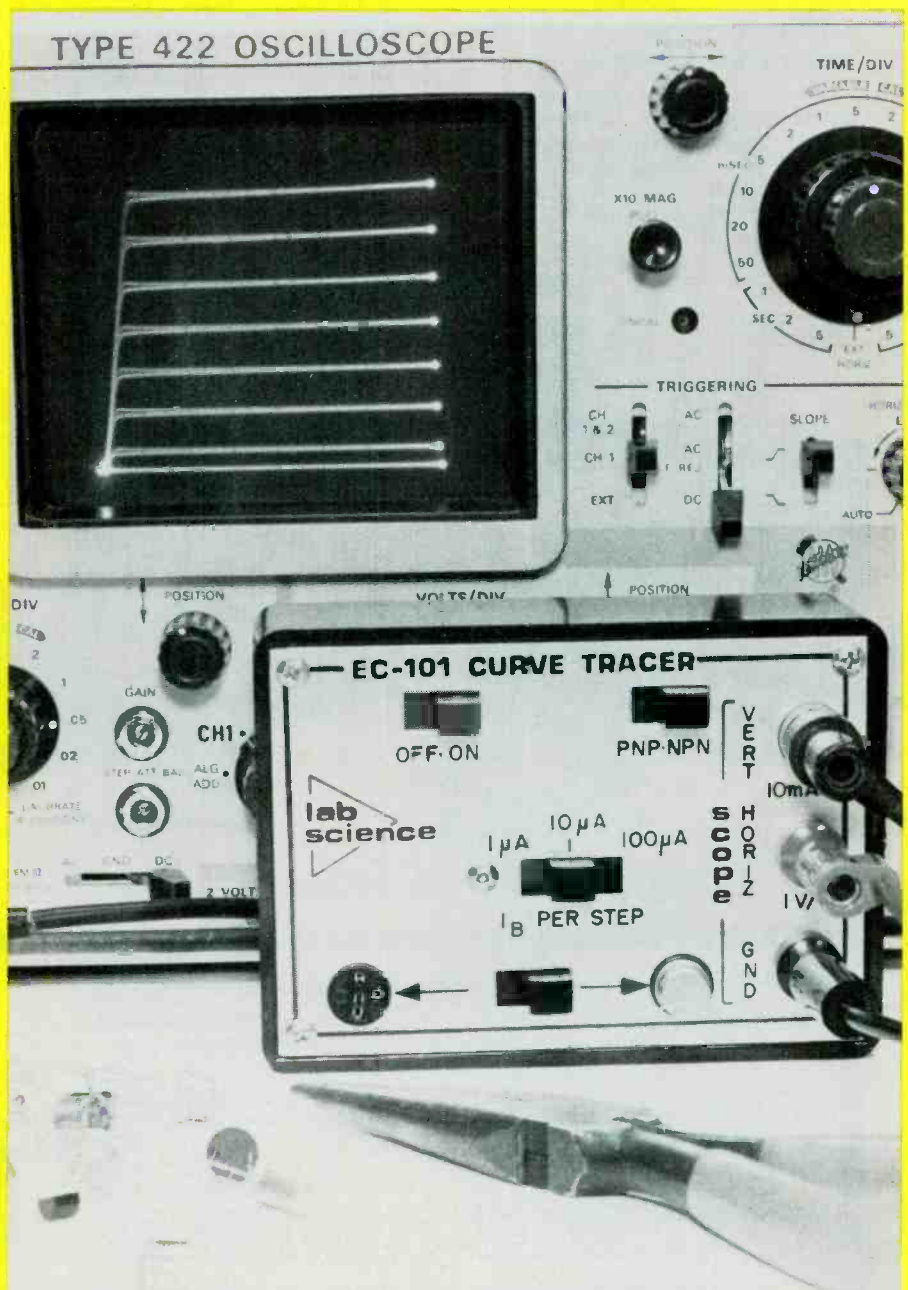
Today, DVMs use high-speed computer switching techniques to digitize and display the measured voltage—or current or resistance. For about twice the price of a comparable VOM, you can get a decent 3½ digit DVM.

That's right, three and one-half digit. That extra half-digit isn't really half a digit. It's the numeral one, and it gives you an automatic range extension.

If, for example, you were expecting to find 0.75 to 0.90 volts in your circuit, you'd set your DVM to the one-volt range. But, if there were in fact 1.037 volts present, the meter would indicate an overflow and fail to give you a reading. With the extra half-digit, however, you get the 1.037 reading. You won't get a 2.037 reading, though, even if there were 2.037 volts present. The half-digit can only give you that one extra step.

There is one exception to this half-digit rule, the Data Tech Model 30A. The 30A's half-digit is a true half-digit; it gives you 50% more range. So, if you set the 30A to the one volt range, it will give you a reading of any voltage up to 4.999 volts.

Whether this extended range makes the 30A the instrument of choice depends on many other factors. For one thing, it's a bench model. That means its relatively large. You might find one of the hand-held portable DVMs much more convenient to use, and considerably less expensive to buy.



If you really want to know what kind of transistor you have and how it's working, you need a curve tracer such as this EC-101 by Lab Science. Just connect to your scope, and plug in your transistor. You'll then see a complete family of curves such as those shown here.

The input resistance of most DVMs is 10 megohms on all voltage ranges. So, they load circuits about as much as a FET VOM will. Most also measure resistance and current; many give you ac current measurements too.

The accuracy of a DVM is usually better than that of the meter-type, or analog, VOM. And, of course, it's a lot easier to read. Although some DVMs are more accurate than others, all should be more than accurate enough for your purposes.

Choosing a DVM is a personal matter. The size and shape, weight, size of display, number of ranges and general layout will all influence your decision.

In general, DVMs can be classified as portable or bench models. The distinction is one of size since most bench models are battery powered and can easily be carried around. Most of the portable units have LED displays about a third of an inch high. A few have liquid crystal displays of about the same size. Bench models usually have slightly larger displays.

The DVM market is growing rapidly, and your choices are almost as numerous as for VOMs. And, as the price of DVMS drop, they will soon outnumber VOMs by a wide margin. Although by no means complete, here's a representative listing of what's available.

Portable DVMs

■ *B&K Model 2800 Portable Multimeter*—a 3½-digit DVM that measures ac and dc voltages in four ranges from 1 volt to 1000 volts to within 2.5%, ±1 digit. Measures ac and dc current in four ranges from 1 ma to 1000 ma to within 3%, ±1 digit. Measures resistance in five ranges from 0 to 10 megohms to within 2%, ±1 digit. Weighs two pounds and measures slightly more than 6 x 4 x 2 inches. Runs on four C batteries or 117 volt ac with extra-cost adapter. $100.

■ *Eico Model 272 Portable Digital Multimeter*—has three digit 0.3-inch LED display. Measures ac and dc voltages in four ranges from 1 V to 1000 V to within 0.5% dc and 1% ac, ±1 digit. Measures ac and dc current in four ranges from 1 ma to 1000 ma to within 1%, ±1 digit. Measures resistance in four ranges from 1000 ohms to 1 megohm to within 1%, ±1 digit. Weighs 11 ounces and measures slightly less than 6 x 4 x 2 inches. Runs on four AA batteries. $70.

■ *Data Tech Model 21*—has 3½ digit 0.27-inch LED display. Measures dc voltages in four ranges from 2 V to 1000 V to within 0.1%, ±1 digit. Measures ac voltages in four ranges from 2 V to 800 V to within 0.5%, ±1 digit. Measures resistance in four ranges from 2000 ohms to 2 megohms to within 0.15%, ±1 digit. Measures capacitance in four ranges from 2 nf to 2000 nf—.002 mfd to 2 mfd to within 0.15%, ±1 digit. Weighs about 11ounces and measures about 7 x 3 x 2 inches. Runs on four AA batteries. $140.

■ *Data Precision Model 248 Portable Multimeter*—has 4½ digit, 0.33-inch LED display with overflow indication. Has automatic polarity switching. Measures dc voltages in five ranges from 100 mV to 1000 V. Measures ac voltages in five ranges from 100 mV to 500 V. Measures ac and dc current in five ranges from 100 ua to 1000 ma. Measures resistance in five ranges from 1K to 10M ohms. Weighs 1.3 pounds and measures less than 6 x 4 x 2 inches. Runs on 6 NiCad batteries. $345.

■ *Fluke Model 8020A Multimeter*—3½ digit liquid crystal display with automatic zero and polarity. Has overflow indication. Measures dc voltages in five ranges from 200 mV to 1000 V to within 0.25%, ±1 digit. Measures ac voltages in five ranges from 200 mV to 750 V to within 1% below 1 kHz, and to within 5% up to 5 KHz, ±2 digits. Measures ac and dc current in four ranges from 2 ma to 2000 ma to within .75%, ±1 digit dc, and to within 2%, ±2 digits ac. Measures resistance in six ranges from 200 ohms to 20 megohms. Also measures conductivity in 0-200 nanomho and 0-2 micromho ranges. Weighs 13 ounces and measures about 7 x 3 x 2 inches. Runs on one nine-volt transistor battery. $170.

■ *NLS Model LM-350 Volksmeter*—3½ digit liquid crystal display. Measures ac and dc voltages in four ranges from 1 V to 1000 V to within 1%, ±2 digits. Maximum ac input is 1000 V peak. Measures ac and dc current in four ranges from 1 ma to 1 a to within 2%, ±2 digits. Measures resistance in five ranges from 1 ohm to 10,000 ohms to within 1%, ±2 digits. Runs on three AA batteries. Weighs a little over 9 ounces and measures about 4 x 3 x 2 inches. $125.

■ *Sencore Model DVM36*—3½ digit, 0.3-inch LED display with automatic decimal, polarity and overflow indication. Measures ac and dc voltages in four ranges from 2 V to 1000 V to within 1%, ±2 digits. Measures ac and dc current in four ranges from 2 ma to 2000 ma to within 1.5%, ±1 digit. Measures resistance in six ranges from 200 ohms to 20M ohms to within 1%, ±2 digits. Weighs 1.1 pounds and measures about 6 x 4 x 1 inches. Runs on six AA batteries. $160.

■ *Sinclair PDM 35 Digital Multimeter*—3½ digit LED display with automatic polarity selection. Measures dc voltages in four ranges from 1 V to 1000 V to within 1%, ±1 digit. Measures ac voltages on 1000 V range to within 1%, ±1 digit. Measures dc current in six ranges from 0.1 ua to 100 ma to within 1%, ±1 digit. Measures resistance in five ranges from 1000 ohms to 10 megohms to within

This Eico Model 685 is typical of the meter-type transistor tester. Although not as versatile as the curve tracer, most transistor testers can give you an accurate measurement of gain, and some gain-bandwidth product as well.

2.5%, ±1 digit. Weighs 6.5 ounces and measures 6 x 3 x 1.5 inches. Runs on one nine-volt transistor battery. $60.

■ *Triplett Model 3300 Digital VOM*—a 3½-digit DVM that measures dc voltages five ranges from 200 mV to 600 V to within 0.5%, ±1 digit. Measures ac voltages in four ranges from 200 mV to 200 V to within 1%, ±2 digits, and 600 V to within 1.5%, ±2 digits. Measures dc current in three ranges from 2 ma to 200 ma to within 1.25%, ±1 digit. Measures ac voltage in three ranges from 2 ma to 200 ma within 1.5%, ±1 digit at up to 50 kHz. Measures resistance in six ranges from 200 ohms to 20 megohms to within 1%, ±1 digit. Weighs 10 ounces and measures slightly less than 3 x 5½ x 1½ inches. Runs on four AA batteries. $175.

■ *Weston Digital Multimeter 6000*—has 3½ digit liquid crystal display. Measures ac and dc voltages from 0.1 mV to 1000 V with full autoranging. Measures ac and dc current from .001 ma to 199.9 ma with full autoranging, and with lead connection change from .001 a to 10 a with full autoranging. Also measures resistance from 0.1 to 1.999 ohms, .001K to 199.9K, and .001M to 19.99M ohms, each with full autoranging. Weighs 22 ounces and measures about 7 x 6 x 2 inches. Runs on two nine-volt batteries. $200 to 225, depending on display.

■ *VIZ Model WD-751A Digital DVM*—has a 3½-digit liquid crystal display. Measures ac and dc voltages in 0-2, 0-200 and 0-1000 volt ranges to better than 1%. Measures ac and dc current in 0-2 and 2-200 ma ranges to better than 1.5%. Measures resistance in 0-20,000 ohm and 20,000 ohm to 2 megohm ranges. Weighs about one pound and measures approximately 6 x 3 x 2 inches. Runs on four AA batteries. $150.

Bench-model DVMs

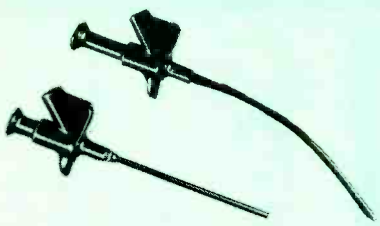
■ *B&K Model 283 Digital Multimeter*—a 3½-digit meter that measures ac and dc voltages in four ranges from 1 volt to 1000 volts to within 1.5%, ±1 digit. Has automatic polarity switching on dc ranges, and reads sine wave rms on ac ranges. Measures ac and dc current in four ranges from 1 ma to 1000 ma to within 2%, ±1 digit. Measures resistance in six ranges from 0 to 10 megohms to within 2%, ±1 digit. Runs on 117 volt ac. $185.

■ *Data Precision Model 1350*—has 3½-digit, 0.43-inch LED display with overflow indication. Measures ac and dc voltages in five ranges from 100 mV to 1000 V to within 0.1%, ±1 digit dc, and to within 4%, ±1 digit ac. Measures ac and dc current in five ranges from 100 ua to 1000 ma within 0.5%, ±1 digit dc, and to within 1.5%, ±1 digit ac. Measures resistance in five ranges from 100 ohms to 10 megohms. Runs on 117 V ac. $170.

■ *Data Tech Model 30A Digital Multimeter*—has 3½ digit .033-inch glow tube display giving up to 4999 readout. Measures ac and dc voltages in five ranges from 500 mVto 1000 V to within 0.15%, +0.4% of full scale setting. Measures ac and dc current in five ranges from 500 ua to 5 a to within 0.3%, +.05% of full scale dc, and to within 1.2%, +0.1% of full scale ac. Measures resistance in six ranges from 500 ohms to 50 megohms to within 0.15%, +.05% of full scale. Runs on 4 D batteries. $290.

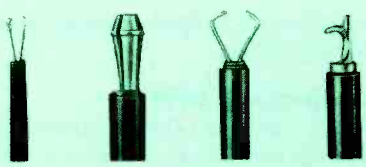
■ *Fluke Model 8030A Digital Multimeter*—3½ digit LED display. Measures dc

Picky probes



When you think of test equipment, you naturally think in terms of meters and scopes, and lots of money. But one of the most important kinds of test equipment you can have costs about a dollar each. And if you don't have a few on hand when you need them, you'd probably be willing to pay 10 or 20 times their cost.

What are these marvels? Spring loaded test probes! That's right, test probes. But not the ordinary rod-tipped probes that come with VOMs and scopes. These probes have long, slender, insulated tips that can be pushed through a maze of bare wires without shorting out. And at the end, a small, hook-like spring loaded tip that locks itself around the lead you want to investigate.



ITT Pomona calls their probes *Grabbers*. Rye Industries calls their's *Kleps*. But whichever you get, they can save you a lot of time and frustration. Just clip the probes onto the wires or component leads you want to test, and forget about the connections. Instead of holding the test leads in place, or worrying about a wedged probe slipping out of position and short circuiting, you can worry about taking the measurement.

Pomona's Grabbers come in a wide variety of sizes and with or without test leads attached. Those without leads have banana jacks built into their bases. To use them, you'll need a test lead with a banana plug at one end and the appropriate plug at the other to mate with your meter or scope. All have the hook-style tip. Prices range from 85¢ for a 2½-inch probe to about $8 for a pair of probes with cable and double-pin banana plug.

Rye's Kleps come in rigid and flexible styles. These are ideal for working around obstructions to reach those almost impossible to get to test points.

Kleps come with a variety of tips as well. Some have the hook-type tips, others a dual-tip seizure clamp or three-piece clamp similar to a drill chuck. There's even a Klep especially designed to mate with automotive and applicance flat-plate connectors. The prices range from 99¢ to $2.59 each.

You can get more information about the Grabbers from ITT Pomona Electronics, 1500 East Ninth Street, Pomona, CA 91766. For information about Kleps, write to Rye Industries, 125 Spencer Place, Mamaraneck, NY 10543.

voltages in five ranges from 199.9 mV to 1100 V to within 0.1%, ±1 digit. Measures ac voltages in five ranges from 199.9 mV to 750 V to within 0.5%, ±2 digits from 45 Hz to 1 kHz, and to within 2%, ±3 digits from 1 kHz to 5 kHz. Measures ac and dc current in five ranges from 199.9 ua to 1999 ma to within 0.35%, ±1 digit dc, and to within 3%, ±2 digits. Measures resistance in five ranges from 199.9 ohms to 1999K ohms. Runs on 117 V ac or battery pack. $250.

■ *Heath Model IM-1210 Digital Multimeter*—2½ digit LED display. Measures dc voltages in four ranges from 2 V to 1000 V. Measures ac voltages in four ranges from 2 V to 700 V from 50 Hz to 10 kHz. Measures ac and dc current in four ranges from 2 ma to 2000 ma. Measures resistance in five ranges from 200 ohms to 2M ohms. Runs on 117 V ac. $70 in kit form. $110 assembled.

■ *Leader LDM-851 Digital Multimeter*—3½ digit, 0.5inch LED display, with LED overflow indicator. Measures ac and dc voltages in four ranges from .001V to 1000 V. Measures dc current in two automatic decimal-shift ranges up to 199.9 ma. Measures resistance in six ranges from .001K to 19.99M ohms. Accuracy for all readings better than 0.5%, ±1 digit. Runs on four C batteries. $200.

■ *Sencore Model DVM38*—3½ digit, 0.4-inch LED display with automatic polarity, decimal, mV or V, and overflow indication. Measures dc voltages in five ranges from 200 mV to 2000 V to within 0.1%, ±3 digits. Measures ac voltages in five ranges from 200 mV to 1000 V to within 0.5%, ±3 digits. Measures ac and dc current in five ranges from 200 ua to 2000 ma to within 0.3%, ±2 digits dc, and to within 1%, ±2 digits ac. Measures resistance in seven ranges from 20 ohms to 20M ohms to within 1%, ±2 digits. Runs on 117 V ac. $350.

■ *Simpson Model 461 Digital Multimeter*—3½ digit, 0.3-inch LED display with automatic zero, polarity and overflow indication. Measures dc voltages in five ranges from 200 mV to 1000 V to within 0.25%, ±1 digit. Measures ac voltages in five ranges from 200 mV to 200 V from 50 Hz to 5 KHz, and 600 V from 50 Hz to 400 Hz. Accuracy is 1%, ±2 digits to 1 kHz, and 5%, ±2 digits from 1 kHz to 5kHz. Measures ac and dc current from 200 ua to 2000 ma to within 1%, ±1 digit dc, and to within 2%, ±5 digits ac. Measures resistance in six ranges from 200 ohms to 20M ohms to within 1%, ±1 digit. Runs on four AF NiCd batteries. $150.

■ *Sinclair Multimeter DM2*—3½ digit, 8-millimeter LED display with automatic polarity and overflow indicators. Measures ac and dc voltages in four ranges from 1V to 1000 V to within 0.5% dc, ±1 digit dc, and to within 2%, ±2 digits ac. Measures dc current in five ranges from 100 ua to 1000 ma to within 2%, ±1 digit. Measures ac current in four ranges from 1 ma to 1000 ma to within 2%, ±2 digits. Measures resistance in five ranges from 1K to 10M ohms to within 2%, ±1 digit. $100.

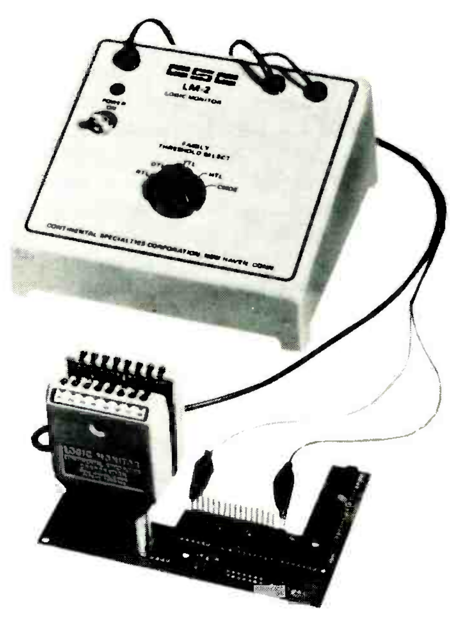
■ *Weston Model 1242 Digital Multimeter*—has 4½-digit display with overflow indicator. Measures dc voltages in five ranges from 0.1 V to 1000 V to within .05%, ±1 digit. Measures ac voltages in five ranges from 0.1 V to 500 V to within 0.2%, ±1 digit. Measures ac and dc current in five ranges from 100 ma to 1 a to within 0.2%, ±a digit dc, and to within 0., ±1 digit ac. Measures resistance in five ranges from 1K to 10M ohms. Runs on 117 or 230 V ac. $740.

■ *VIZ Model WD-705A Digital VoltOhmyst*—a 3½ digit meter that measures ac and dc voltages in five ranges from 200 mV to 1200 V to within 0.1%, ±1 digit dc, and within 0.75%, ±1 digit ac. Measures ac and dc current in five ranges from 200 ua to 2000 ma to within 0.3%, ±1 digit dc, and within 1%, ±1 digit ac. Measures resistance in six ranges from 200 ohms to 20 megohms to within 0.3%, ±1 digit. Runs on 117 volt ac. $270.

How it looks

Of course, knowing how much current is flowing, or how much voltage is present is just half the story. You'll also want to know what kind of signal is flowing from point to point in the circuit—especially if you're working on audio circuits. But even if you're strictly into digital projects, you'll appreciate being able to see the shape of various pulses and comparing timing.

To see what's happening in your circuits, you'll need an oscilloscope. Scopes come in three categories—simple scopes with recurrent sweep, advanced

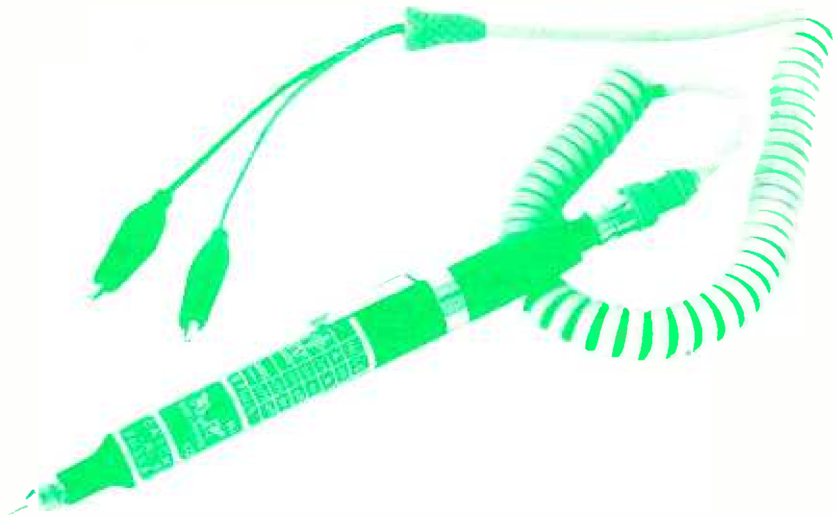


This unique logic monitor by Continental Specialties snaps around 16 pins of any dual-inline IC and show you the logic state at each pin.

scopes with triggered sweep, and dual-trace scopes that you see two different signals at the same time.

Dual-trace scopes are very similar to advanced triggered-sweep models except for the extra trace. You'll find an interesting discussion of the differences between simple and advanced scopes, and how they operate, in this month's *How it Works* column, elsewhere in the issue.

The number of scopes available on the market is considerably less than the number of VOMs and DVMS, especially in the lower price range most experimenters are limited to. But, even so, there is still enough choice to let you choose a scope that fits your own special needs.



Logic probes such as this Catch-a-Pulse by AVR Electronics lets you determine the logic state at any point in your circuit, and lets you know if a pulse train is present. A built-in pulse stretching circuit holds the LED indicator on long enough for you to see it even when the pulse being detected lasts just a few nanoseconds.

Simple scopes

■ *B&K Model 1403A three-inch oscilloscope*—has dc to 5 MHz frequency response. Has recurrent sweep from 10 Hz to 100 kHz selectable in five 1:10 ranges, plus external sweep. Vertical sensitivity is 10 mV/cm with 1/10 and 1/100 attenuation switch selectable. $230.

■ *Eico Model 435 three-inch oscilloscope*—has dc to 4.5 MHz frequency response. Has recurrent sweep from 10 Hz to 100 kHz selectable in four 1:10 ranges plus external. Vertical sensitivity is 50 mV/cm with 1/10, 1/100 and 1/1000 attenuation switch selectable. $180 in kit form. $240 assembled.

■ *Heath Model IO-4560 Oscilloscope*—has dc to 5 MHz frequency response. Recurrent sweep is adjusted with a single, uncalibrated control from 0.2 us/cm to 20 ms/cm. Vertical sensitivity is 100 mV/cm with 1:10, 1:100 and 1:1000 attenuation switch selectable. Available in kit form only. $130.

■ *Leader Model LBO-310A three-inch oscilloscope*—has dc to 4 MHz frequency response. Has recurrent sweep from 10 Hz to 100 kHz in four 1:10 ranges with vernier. $230.

Triggered-sweep scopes

■ *B&K Model 1461 five-inch oscilloscope*—has dc to 10 MHz frequency response with a 35 ns risetime. Linearity is better than 3% unmagnified. Sweep selectable in a 1-2-5 sequence from 1 us/cm to 0.5 s/cm with vernier. Has x5 magnifier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. $500.

■ *Eico Model 480 ten-centimeter oscilloscope*—has 10 x 6 centimeter display with dc to 10 MHz frequency response. Rise time is 35 ns. This excellent instrument has sweep selectable in 1-2-5 sequence from 0.1 us to 0.5 s with vernier. One of the best in its class, it has vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. A top-notch scope. $450.

■ *Heath Model IO-4541 Oscilloscope*—has dc to 5 MHz frequency response with 70 ns rise time. Sweep selectable in x10 steps from 0.2 us/cm to 200 ms/cm with vernier. Vertical sensitivity selectable in 1-2-5 sequence from 20 mV/cm to 10 V/cm. $190 in kit form. $330 assembled.

■ *Leader Model LBO-507 five-inch oscilloscope*—has dc to 20 MHz frequency response with 17.5 ns rise time. Sweep selectable in 1-2-5 sequence from 0.5 us/cm to 200 ms/cm with vernier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 50 mV/cm. $500.

■ *NLS Model MS-15 Miniscope*—has dc to 15 MHz frequency response with 23 ns rise time. Sweep selectable in 1-2-5 sequence from 0.1 us/div to 0.5 s/div with vernier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/div to 50 V/div. Has 1 x 1.25 inch display. $290.

■ *Simpson Model 455T five-inch oscilloscope*—has dc to 12 MHz frequency response with 30 ns rise time. Sweep selectable in 1-2-5 sequence from 0.5 us/cm to 0.5 s/cm with vernier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 5 V/cm. $435.

■ *VIZ Model WO-572A five-inch oscilloscope*—has dc to 15 MHz frequency response with a 23 ns rise time. Sweep selectable in 1-2-5 sequence from 0.5 us/cm to 0.5 s/cm with vernier. Has x10 magnifier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. Has special pushbutton control section simplifying television service work. $525.

Dual-trace scopes

■ *B&K Model 1471B dual-trace five-inch oscilloscope*—has dc to 10 MHz frequency response with 35 ns rise time. Linearity is better than 3% unmagnified. Sweep selectable is 1-2-5 sequence from 1 us/cm to 0.5 s/cm with vernier. Has x5 magnifier. Display automatically switches between chopped and alternate mode as sweep speed is changed. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. $600.

■ *Eico Model 482 dual-trace ten-centimeter oscilloscope*—has 10 x 6 centimeter display with dc to 10 MHz display. Rise time is 35 ns. Sweep selectable in 1-2-5 sequence from 0.1 us to 0.5 s with vernier. Display automatically switches between alternate and chopped mode as sweep speed is changed. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. $550.

■ *Heath Model 4550 dual-trace oscilloscope*—has dc to 10 MHz frequency response with 35 ns rise time. Sweep selectable in 1-2-5 sequence from 200 us/cm to 0.2 s/cm. Has x5 magnifier. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/cm to 20 V/cm. $400 in kit form. $565 assembled.

■ *NLS Model MS-215 dual-trace Miniscope*—has dc to 15 MHz frequency response. Sweep selectable in 1-2-5 sequence from 0.1 us/div to 0.5 s/div with vernier. Manual selection of alternate or chopped mode. Vertical sensitivity selectable in 1-2-5 sequence from 10 mV/div to 50 V/div. Has 1 x 1.25 inch display. $400.

■ *Simpson Model 452 dual-trace five-inch oscilloscope*—has dc to 15 MHz frequency response with 24 ns rise time. Sweep selectable in 1-2-5 sequence from 0.2 us/cm to 0.5 s/cm with vernier. Has x5 magnifier. Display automatically switches between alternate and chopped mode as sweep speed is changed. Vertical sensitivity selectable in 1-2-5 sequence from 5 mV/cm to 10 V/cm. $675.

If you use a large number of transistors in your projects, there are bound to be times when you want to use a set of matched devices. And if you use really large numbers of transistors, those 100 and 200 piece assortments can be a real bargain.

But how do you exactly match a set of transistors, FETs or zenars? And how to determine the characteristics of an unmarked transistor. The answer is simple, if you have an oscilloscope.

All you have to do is add a curve tracer. Just connect to your scope's input, plug the transistor or diode into the front panel socket on the tracer, set a few controls, and presto, you'll see a family of characteristic curves displayed on your scope.

By comparing the curves, you can easily match a set of transistors or diodes. And by comparing the curves of unknown transistors against some transistors you're familiar with, you can easily sort out an assortment of bargain-basement transistors.

Curve tracers aren't inexpensive. A versatile, sophisticated model will run well over $200. But, if you use a lot of semiconductors, a curve tracer can pay for itself in a year. And, if you can use a less-sophisticated model, much sooner. Here's a list of the more popular curve tracers on the market.

■ *B&K Model 501A Semiconductor Curve Tracer*—Sweep voltage variable from 0 to 100 volts dc peak at 100 ma maximum. Has 130% automatic current limiting. Step generator selectable in 1-2-5 sequence from 1 ua to 2 ma, accurate to within 3%. $200.

■ *Heath Model IT-3121 Semiconductor Curve Tracer*—tests all NPN and PNP bipolar transistors, FETs, diodes and SCRs. Voltage sweeps from 0 to 40 V at 1 a or from 0 to 200 V at 200 ma. Base current steps increments selectable from 2 ua/div to 10 ma/div in 1-2-5 sequence. $100 in kit form only.

■ *Lab Science Model EC-101 Curve Tracer*—tests NPN and PNP bipolar transistors, FETs and diodes. Collector voltage swept from 0 to nine volts every 2 ms with the base changing input current in eight steps after each sweep. Total trace time is 16 ms. Built-in current limiting protects device under test. Uses CMOS circuitry. $50.

■ *VIS Model WC-528B Quick Tracer*—tests all NPN and PNP bipolar transistors in or out of circuit. Can be used with any general-purpose scope. Uses single test waveform. Has power limiting built-in to prevent damage to device under test. Can also be used to test diodes. Requires 117 volts ac. $20.

Simple testers

Although a curve tracer is *the* way to test semiconductor devices, you may not need such a sophisticated piece of gear. And if you don't have a scope, the total cost of scope and tracer may put it out of reach. If that's the case, try a transistor tester.

Most of the testers are built in cabinets similar to standard VOMs. They have a relatively large meter and range switches, and usually a set of test leads. The major difference in appearance is the set of sockets provided for out-of-circuit testing of the devices.

Transistor testers aren't inexpensive either. Except for a very simple model from Radio Shack, all sell for more than $100. But they're completely self-contained so you won't need a scope to use them.

■ *B&K Model 510 Portable Transistor Tester*—go/no go in-circuit tester also tests out of circuit with good/bad indication. Also tests FETs and SCRs in or out of circuit. Identifies FETs as N or P channel, and the gate lead. Identifies all SCR and bipolar transistor leads. Base drive is selectable between 1 ma or 250 ma. Weighs one pound and measures slightly less than 2 x 4 x 7 inches. Runs on AA batteries. $100.

■ *Eico Model 685 Transistor Analyzer*—tests NPN and PNP bipolar transistors, FETs, SCR's and triacs, zener diodes, and diodes and rectifiers. Measures beta in and out of circuit in 2-100 and 2-1000 at collector currents of either 2 ma or 20 ma. Measures FET transconductance in 0-5000 and 0-50,000 micromho ranges. Tests diodes and zener diodes to 20 volts. Measures turn-on voltage for SCR and triacs. Requires 117 V ac. $130 in kit form. $180 assembled.

■ *Leader Model LTC-906 Transistor Checker*—tests NPN and PNP bipolar transistors, FETs and diodes. Automatically identifies device polarity and leads in or out of circuit. Gives good/bad indication by LED readout and audible tone. Measures beta in three ranges to 10,000 and leakage current out of circuit. Runs on nine-volt transistor battery. $160.

■ *Radio Shack Model 22-024 Dynamic Transistor Checker*—indicates current gain and both opens and shorts. Checks low, medium and high power NPN and PNP transistors in and out of circuit. $15.

■ *Sencore Model TF46 Portable Super Cricket*—makes good/bad in-circuit test. Tests gain and leakage of bipolar transistors and FETs out of circuit. Has automatic lead and type selection, and polarity indicator. Has built-in chirper that signals when transistor is good. $195.

■ *VIS Model WT-524A Dynamic Transistor/FET Tester*—tests bipolar NPN and PNP transistors and all FETs in and

This portable transistor tester by Sencore is no larger than a typical VOM, but can give good-no good indications in-circuit, and can measure transistor gain out-of-circuit.

out of circuit. Measures ac beta of all transistors, including Darlintons, in three ranges to 5000 with collector currents of up to 200 ma. Measures collector-to-base leakage up to 100 ua, and collector-to-emitter up to 200 ma to within 3%. Measures transconductance of all FETs up tp 100,000 micromhos to within 3%. Tests all diodes at 200 ma. Requires 117 volts ac. $180.

Other equipment

A multimeter of one kind or another, a scope, and a transistor tester or curve trace will handle most of your test equipment needs. But there are some other gear that you may find very handy to have around.

If you repair audio amplifiers or am radios, one of the handiest gadgets you can have, and inexpensive too, is a signal injector. It's a self-contained oscillator-probe that generates a signal you can inject into the circuit.

Working from the output end towards the input, you simply touch the probe tip to the input of each stage. When you reach a stage where there is no output, you've found the location of your trouble.

Most signal injectors produce a 1 kHz signal that is rich in harmonic content. These harmonics usually extend into the rf range, making the injector useful on circuits up to CB frequencies. Eico makes a signal injector not much larger than a scope probe that gives you 50 volts of peak-to-peak signal. It's their Model PSI-1, which costs about $11 assembled.

The compliment to a signal injector is a signal tracer. It's nothing more than an audio amplifier and diode detector contained in a small hand-held probe. You use it just like a signal injector, except you work from the input end. If you find a signal present at the output of a stage, you know it's good. When you lose the signal, you've found the trouble spot.

Both Eico and Radio Shack make signal tracers. Eico's Model PST-1 has a usable bandwidth of 500 Hz to 200 kHz as-is, and up to 200 MHz with its snap-on detector tip. It costs $20 in kit form; $30 assembled. Radio Shack's Model 22-010 is physically larger, but has a built-in speaker and volume control. It costs $14.

Signal injectors and tracers are used in audio and radio circuits. If you are more involved in digital work, they won't be of much use to you. But there are digital counterparts.

Continental Specialties makes a digital pulser, which serves the same purpose as the signal injector. The pulser, Model DP-1, can inject a single 100 ma pulse, or a train of pulses at a 100 Hz rate. A built-in switch lets you set the pulse for DTL/TTL or CMOS logic. The DP-1 costs $75.

The digital counterpart of the signal tracer is the logic probe. It lets you know what the logic state is, or if a pulse train is present at some point in the circuit. Most use LEDs as indicators.

If you enjoy building your own gear, both Heathkit and Eico offer a variety of test equipment in kit form. This 2½-digit multimeter can measure voltage up to 1000 V, current up to 2 a, and resistance up to two megohms. In kit form, the price is $70; an assembled version costs $110.

Logic probes usually have built-in pulse stretchers that keep the LED on long enough for you to see it, even if the circuit pulse is in the nanosecond range. Here's a sampling of logic probes currently available.

■ *AVR Catch-A-Pulse II*—built-in pulse stretcher flashes LED for 50 ms to indicate pulses as short as 10 ns. Compatible with RTL, DTL, TTL, MOS and CMOS logic. Frequency response from dc to better than 50 MHz. Input protected to ±70 V dc. $40.

■ *Continental Specialties Model LP-2 Logic Probe*—detects pulses as short as 300 ns, and flashes at 3 Hz rate to indicate pulse trains at rates up to 1.5 MHz. Uses three LEDs to indicate logic states. Has 300,000 ohm input resistance. $25.

■ *Eico Model DLP-6 Digital Logic Probe*—detects pulses as short as 50 ns. Uses three LEDs to indicate logic state. Can be set to hold indication indefinitely after detecting short-duration pulse. The DLP-6 costs $20 in kit form; $30 assembled.

Of course, as handy as a logic probe is, it can only indicate the logic state at one point in the circuit at any given time. If you want to see what's happening to several of the elements inside a single dual-in line IC, for example, you'll need several probes—or the Continental Specialties Model LM-2 Logic Monitor.

The LM-2 has a special logic clip that fits onto any dual-inline IC up to 16-pin. Each pin is represented by a separate LED indicator. This lets you see the logic state of every pin in the IC at the same time.

The control box has its own power supply built-in. A front-panel switch lets you set the threshold voltage of RTL, DTL, TTL, HTL or CMOS logic. It costs about $130 complete.

The test equipment listed here is just a sampling of what's available today. And, although it's not inexpensive, test equipment is a real must if you expect to get into electronics. You can get more information from your local electronics store, or from the manufacturer. Here's a list of the manufacturers whose instruments appear in this article:

AVR Electronics, Box 19299, San Diego, CA 92119

B&K Precision, Dynascan Corporation, 6460 West Cortland Avenue, Chicago, IL 60635

Continental Specialties Corporation, 70 Fulton Terrace, New Haven, CT 06509

Data Tech, Penril Corporation, 2700 South Fairview Street, Santa Ana, CA 92704

Data Precision Corporation, Audubon Road, Wakefield, MA 01880

Eico Electronic Instruments Co., 108 New South Road, Hicksville, NY 11801

Heath Company, Benton Harbor, MI 49022

John Fluke Manufacturing Company, P.O. Box 43210, Mountlake Terrace, WA 98043

Lafayette Radio Electronics Corporation, 111 Jericho Turnpike, Syosset, NY 11791

Lab Science, P.O. Box 1972, Boulder, CO 80306

Leader Instrument Corp., 151 Dupont Street, Plainview, NY 11803

NLS–Non-Linear Systems, Inc., Box N, Del Mar, CA 92014

Radio Shack, 2617 West 7th Street, Fort Worth, TX 76107

Sencore, 3200 Sencore Drive, Sioux Falls, SD 57107

Simpson Electric Company, 853 Dundee Avenue, Elgin, IL 60120

Sinclair Radionics, Inc., 115 East 57th Street, New York, NY 10023

Triplett Corporation, Bluffton, OH 45817

VIZ Test Instruments Group, 335 East Price Street, Philadelphia, PA 19144

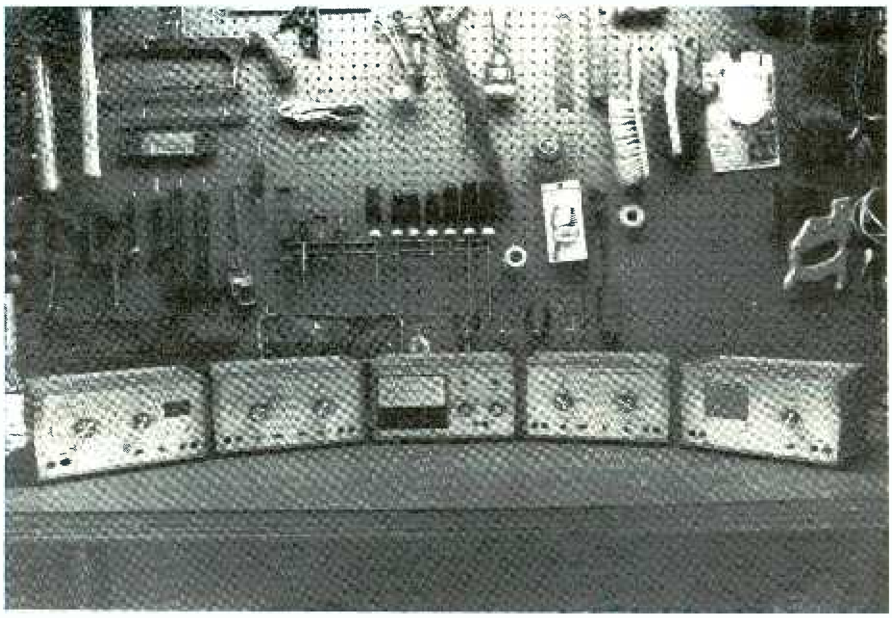
Weston Instruments, Inc., 614 Frelinghuysen Avenue, Newark, NJ 07114

Before making a purchase, make sure you understand what the instrument can and cannot do. If you have a friend with the kind of gear you want, ask him about special features or problem areas. Talk to dealers. Talk to service people who use test equipment routinely. Then, when you have the facts, select the model that will best fill your needs. ■

Complete beginner's test bench in easy-to-build kits

Here's one good way to cut costs to the bone and still start up a top-notch electronic test bench. Build this new line of tester kits today and begin repairing radios tonight.

by Carmine W. Prestia



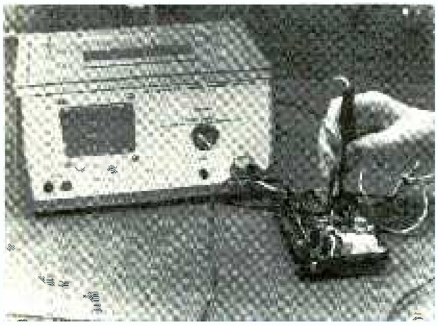
Heathkit's beginners test bench

Any electronic hobbyist, be he amateur operator, CBer, swl (shortwave listener), tinkerer, or whatever has to have some test equipment in his shop. You just cannot get along without having to do trouble-shooting or making adjustments on your gear.

For the beginner, this can be a real dilemma, since it is often easy to spend so much money on test equipment that there is nothing left for the rest of the hobby. You can spend as little as $5 for a simple volt, ohm, milliamp meter (VOM), or as much as $5000 for the service monitors that professionals use. Of course the hobbyist usually spends somewhere in between those extremes. In fact, my first piece of test equipment was one of those inexpensive VOMs.

Since you will undoubtedly want to dip into some of this trouble-shooting you will have to buy a few pieces of test gear. Heath Company has long made many pieces of test equipment to cover just about all the amateur or professional needs, unfortunately the prices of this gear have not always been within reach of the beginner or amateur. To overcome this problem Heath has just introduced a line of inexpensive test equipment aimed at the beginner, the 5280 series.

There are six units in the series; an audio oscillator, an rf oscillator, a multimeter, a signal tracer, an RCL bridge, and a power supply for the five units. Each kit is $37.95, except for the power supply which is $24.95. At first thought the price was just too good to be true, but after building all six kits it seems that Heath had done a good job of designing some very useful equipment for the price. Overall the kits were easy to build and work well, so let's take a look at each one.



Signal tracer

Power supply

Heath has designed each unit for battery operation. However if you get the power supply, parts are included to convert the units so they can be switched from battery to power supply operation as needed. Since I don't need portability I got the power supply and wired it up right away for use as each kit was completed.

It took only three hours to build the supply, definitely a one evening kit. The only problem I had was with the assembly of the case. It is separated into two pieces and is extremely hard to put together because of the way the power leads must snake out between the top and bottom halves. Heath should take another look at this and perhaps try a different design. The supply will power all five units simultaneously so it is all you need to get them going.

Multimeter

This is a bench style VOM with ac and dc voltage ranges to 1000 v, an ohmmeter, and a milliampmeter that reads up to one amp. This should be enough metering to cover all your needs.

The multimeter took seven hours to build, the circuit board was very easy, but the many wires running from the range and function switches require that you use time and patience. Calibration was very easy, and required no additional instruments. After calibration I checked the meter out against some known values here in my shop and found it well within Heath's specifications for accuracy.

If you do buy more than one kit, follow Heath's suggestion and build the multimeter first so that you will have it available for set up and testing of the other units. A meter is a must for any test bench, so this would be a good first choice if you don't want to buy more than one unit.

This kit provides a radio frequency

signal generator with output from 310 kHz to 110 MHz and 100 MHz to 220 MHz using harmonics from the fundamental signal. Part of the generator is a 1000 Hz audio oscillator that will modulate the rf output or provide a separate audio output.

RF oscillator

The only real problem with the kits turned up after I finished construction on this one. There was no output from the oscillator, so I started tracing the circuit board components against the schematic. Heath forgot to include an instruction to install R15, a 47K Ohm resistor, on the circuit board. After installing the resistor the kit worked fine.

To calibrate the rf output I used the Heath IM-4130 (see *Modern Electronics*, July 1978) frequency counter and checked the quality of the output waves on an oscilloscope. The frequency was quite stable and both the af and rf waves were clean and symmetrical. The rf output retained its quality even into the higher frequency ranges.

Of course you can't get absolute accuracy with the analog dial but it should be close enough for most of your work. If necessary you can hook it up with a frequency counter to get the exact frequency you need. The rf oscillator is what you will need for tuning up receivers for maximum accuracy and sensitivity.

Heathkit rf oscillator

Audio oscillator

This was the easiest of all the kits to build, it took only four hours, and there were no problems at all. Both sine and square wave outputs are provided from 10 Hz to 100 kHz. This unit should be particularly attractive to stereo buffs, especially with the square wave output since it can be used to check distortion in audio amplifiers. Once again, to make sure the outputs were good I hooked up the oscilloscope and found both waves clean and symmetrical.

Signal tracer

The signal tracer was another easy kit, only four hours. The tracer is what I call a "poor man's oscilloscope." You can use it to trace a signal through the various stages of a receiver somewhat like an oscilloscope. The problem is isolated when you get to a stage that has no output. Combined with the rf generator this is a good way to start trouble-shooting ailing receivers.

Heath has also designed in some other features to make the tracer more useful. The output speaker can be used as a spare with terminals right on the front panel of the tracer. This saves searching through the junk box for a spare when you are working. Also, a rough volt-ohm meter is provided. When the tracer probe is applied to a voltage point an audio tone from the speaker increases in frequency if the voltage increases.

The same thing happens if the probe is applied across a resistance and the resistance decreases. This is a very course measurement, but it is handy for making quick comparisons and continuity checks. In addition you don't have to look up from the circuit to read a meter, you just listen!

RCL bridge

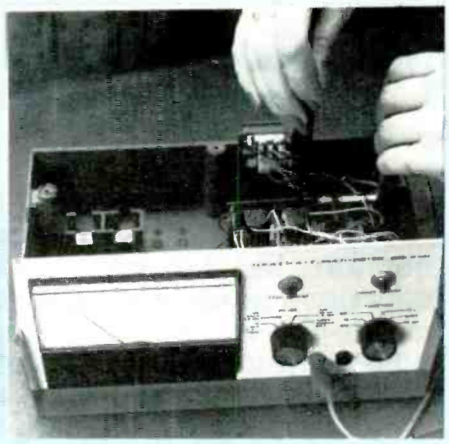
This kit was the most complex to build, it took seven hours, and had many components mounted right on the range switch. The bridge worked fine, first time.

It's used to find unknown values of resistance (R), capacitance (C), and inductance (L) or to find closely matched values of components for your experiments. An ac signal is applied across an unknown and a known value component, then the master dial is tuned for a null on the meter.

For resistances, a known is not required and you can read the value right off the dial. However, if you are trying capacitances and inductances the known value and the reading from the dial are placed in a formula to calculate the unknown value.

It should be of interest to the experimenter or tinkerer, especially if they have a well stocked "junque" box. It eliminates a lot of guesswork and component substitution in your projects.

The kits are all styled to match, using the same plastic case with a biege front panel. They are designed to stack neatly if space is a problem on your bench. There is even a convenient snap open compartment in the top of the case for test leads or other accessories. Depending on your needs and interests, one or all of these kits would be a good addition to your test bench, especially for the beginner. They provide acceptable quality at an attractive price and still leave some cash left over for the rest of the hobby. ∎



Multimeter

Audio oscillator

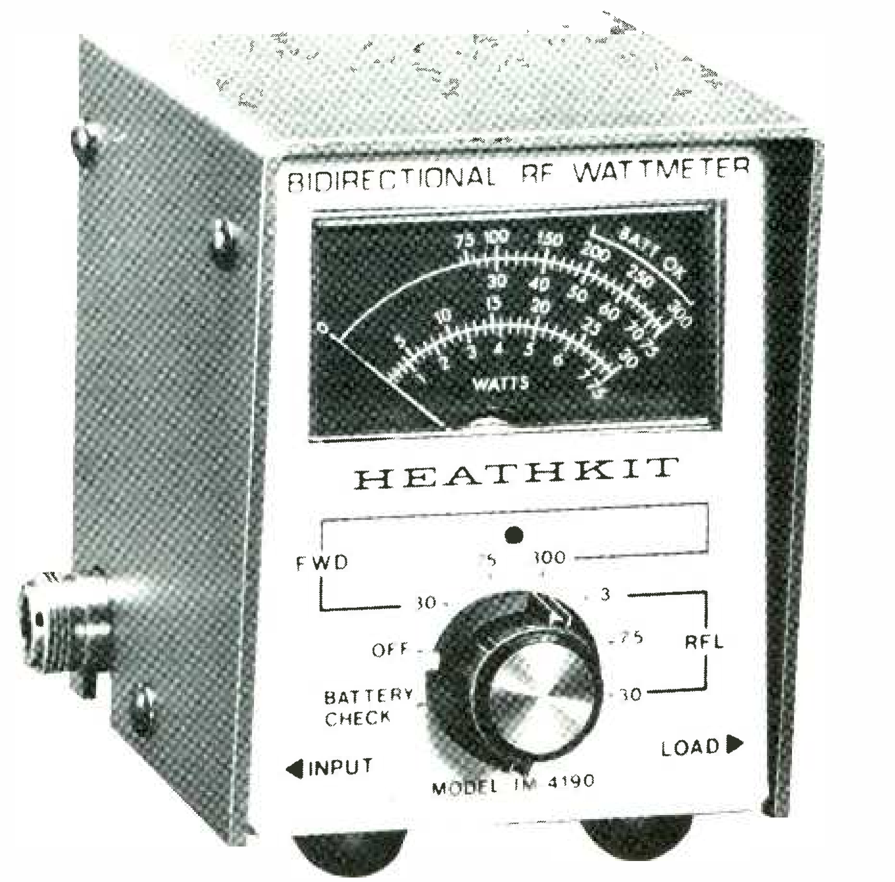
rf test equipment

CB radio operators, shortwave listeners, scanners and monitors, hams, boatmen with two-way radios, lots of folks need radio-frequency test equipment today. But it's hard to tell one piece from another. From an amateur radio operator who has used it all, here's the complete story on rf test gear: where we've been, where we are now, what's down the road. Read on for everything you will need to know to check out your own receivers, transmitters and antennas.

by Karl T. Thurber Jr., W8FX/4

It's a fact—most of us buy our equipment ready-made these days. But have you ever wondered if your transceiver was *really* working right—was it properly adjusted, tuned, coupled and matched into your antenna? If so, you're not alone, as most of us have at one time or another wondered a great deal about this very thing.

There are ways to check on your equipment's performance. They range from using the simplest of field strength meters to laboratory instruments such as spectrum analyzers and temperature-controlled frequency counters.



Heath company has a new wide-band vhf and uhf bi-directional wattmeter, model IM-4190. It's a self-contained meter to measure radio transmitter power up to 300 watts and power reflected back from an antenna up to 300 watts and power reflected back from an antenna up to 30 watts. IM-4190 covers 100 MHz to one gigahertz frequency. It's good for tuning up marine antenna systems, general mobile radio service 450 MHz CB radios, ham radio use in the two-meter, 220 MHz, 450 MHz and higher bands. A single nine-volt battery powers the meter, which is also available factory wired and tested as model number SM-4190. So-called "N" type coax cable connectors are built into the meter which comes with adaptors for rf connectors. As a kit, it's $115. Wired, it's $195, from Heath Company, Benton Harbor, MI 49022.

For most applications, the simpler instruments will do just fine, but if you broaden your hobby base into single-sideband (ssb), radio teletype (RTTY), amateur television (ATV), and other exotic modes, the value of good test equipment becomes very apparent. It's no secret that one of the *best* investments you can make is in good, reliable (though not necessarily expensive) test equipment.

Why is this? Simply because good test gear is so useful, and it rarely becomes outdated or obsolete. Such instruments as rf ammeters, field strength meters, swr bridges, grid-dip oscillators, and signal generators have been with us for many years, and are not soon to become obsolete.

Newer instruments, such as crystal calibrators, digital frequency counters, antenna noise bridges, and other specialized equipment will be with us for many years to come. The point is: it's not too hard to justify a few dollars for good test gear, even if you may not need the equipment *at the moment*.

If you do make the investment, you'll at least have what you need when an ailing rig or antenna needs some help.

While it doesn't make much sense to load up on a workbench full of test equipment if you're just starting out in radio. It *does* make sense to be familiar with the many different types of test gear that do exist and which you may encounter. Let's first look at some basic test equipment from the early days of radio.

The early days

In the early days of ham radio, there was little need for sophisticated test equipment of any sort. Either one's *rig* and antenna "got out," or it didn't. You could see and hear its spark, and you had no trouble detecting the presence of rf all around the neighborhood, and especially in your neighbor's broadcast set! But times have changed since then.

By the 1940s and 1950s, it became apparent that one should be able to measure the *quality* of his signal and the characteristics of his antenna. Hams of these periods developed a lot of test equipment that is still with us today, much of which can have a place in your shack. Let's look at some of this gear, including rf ammeters, absorption wavemeters, twin-lamps, and modulation monitors. We'll also quickly review early frequency meters, Lecher wires, antennascopes, and the like—a great deal of which is still useful in today's solid-state environment, and which you may still see (and sometimes acquire for a "song") at hamfests and swap meets.

Lunar Electronics has combined a 30 MHz rf generator and a 220 MHz frequency counter in a single unit, their DX-555. Not only does this give you a cost savings over a separate generator and counter, but lets you use the the counter to set the generator frequency.

RF ammeters

If there ever was a piece of rf test equipment that was absolutely *basic* to the radio shack, it was the rf ammeter. While today the most basic instrument would probably be the swr bridge, twenty years ago most hams used to rely almost completely on the ammeter as the "final guesstimator" as to how much rf was really going to the antenna and being radiated.

The rf ammeter is by no means a mysterious instrument. It is simply a device that indicates the radio-frequency current (amps) in an antenna circuit. Most of them are really *thermocouples* used in conjunction with an ordinary dc meter. The thermocouple is heated by a resistance wire through which the rf current flows; it causes a dc current to be generated which in turn drives the meter to *indirectly* indicate the amount of rf which is flowing through the circuit.

While the swr bridge has stolen the action these days, the ammeter is still popular in tuning up antennas and in making rf power measurements. For example, if you feed your transmitter into a *dummy load* and read out the current on an rf ammeter, you can estimate the *power output* of your transmitter (or transceiver) using Ohm's Law ($P=I^2R$, or power equals current, squared, times resistance).

If you use parallel-conductor transmission lines, such as twin-lead or open-wire line feeding a multi-band dipole, you may also find the ammeter useful in trimming or "balancing" each side of the antenna for proper length (nearby objects can unbalance your antenna system so that even if it is resonant, it's not *electrically symmetrical*. In doing this, two rf ammeters are usually used, one in each side of the feedline, and each leg of the antenna is cut or *pruned* until the currents are about equal.

Today, the ammeters would best be used in conjunction with an swr bridge connected in the line between your transmitter or transceiver and your antenna coupler or balun coil. While the antenna coupler would be adjusted for lowest swr (best "match"), the antenna would normally be pruned for maximum (or equal) currents in the two legs of the transmission line, as read on the ammeters.

There are other uses for the rf ammeter, too. For example, you can determine just how much power is lost in your transmission line by first taking a current reading with your dummy load connected directly to your transmitter's output connector, and then taking *another* reading at the far end of the transmission line with the dummy load being connected there. The difference in readings is the amount of power that is being lost in your transmission line.

An ammeter having a full-scale deflection of two amperes will do for ham transmitters having power inputs up to about 250 watts, while a five amp meter will handle all amateur power levels.

The absorption wavemeter was a test instrument designed to measure or determine frequency by absorption of energy from the source under test. It had a tuned circuit which was loosely coupled to the transmitter or oscillator; maximum energy was absorbed from the rf source (as indicated by the meter or a flashlight bulb) when the circuit was adjusted to resonance with the rf source. The frequency could then be determined by referring to a calibrated dial on the meter face or by using a separate chart.

For the beginner in radio, the absorption wavemeter was hard to beat, though it is little-known today. Emphasis has shifted to swr bridges, wattmeters and drip-dip meters (most of the latter instruments can double as wavemeters). Most wavemeters were either bandswitching, or they used a set of plug-in coils to cover the ham bands from 160 or 80 meters up to at least the 10-meter band.

Depending on how accurate the dial calibration was, the wavemeter could do a number of jobs very well, such as checking the fundamental frequency of oscillators and VFOs, detecting harmonics (useful in tracing out-of-hand radiations and tvi), checking for parasitic oscillations, and adjusting final amplifier neutralization. You could often make the meter double as a field-strength meter and am modulation monitor, too.

Probably the best use for the wavemeter was in checking for harmonics, especially since many home-brew circuits were capable of being tuned over two frequency bands without bandswitching. This meant that it was very easy to accidentally tune up your rig for, say, 40 meters when you intended to tune up on 80—which, of course, invited (and still does invite) "pink tickets" from the FCC and a strange lack of replies to one's CQs.

A simple field-strength meter or rf monitor will rarely give an indication that you're on the wrong band, but the wavemeter can give you a *positive* check on which band you're actually transmitting on.

You may see a number of older, commercially-made wavemeters at swapfests. If you see one in good condition and at a price you can afford, buy it—you'll likely not regret the modest investment. A real standout among

If you're into rf, you'll find an rf generator an absolute must. This Heathkit IG-42 is typical of most low-cost generators. You get the frequency by a combination of range switch and dial settings. The output level, which is monitored by an output meter, is adjusted with step and vernier attenuation controls. Another control lets you choose between a pure rf carrier or a carrier with amplitude modulation.

these instruments was the Bud Model GM-79 "Gimix," a calibrated bandswitching absorption wavemeter that covered from 3.5 to 30MHz.

The Bud unit was fairly representative: it had a pilot-lamp "resonance indicator," although a milliammeter or microammeter could be plugged into it for greater sensitivity, as could a pair of headphones be inserted for aural monitoring.

If you use the wavemeter with your equipment, you should observe two cautions: Be careful in "probing around" a *live* transmitter to insure that you don't touch any high voltage points in the rig. Be sure not to "overcouple" the wavemeter to the rf circuit under test, to prevent excessively broad, inaccurate readings caused by overloading the device. Usually, a short wire "loop probe" in the vicinity of the circuit you're investigating will feed enough signal to the wavemeter, to do the job.

Twin-lamps

The so-called "twin-lamp" was a very popular gimmick in the fifties, in the heyday of parallel (twin-lead) transmission lines. It was in truth a very inexpensive *swr device* that would give a rough, seat of the pants indications of the standing waves on 300-ohm twin-lead transmission line.

It was nothing more than two flashlight bulbs, a short piece of twin-lead, and a bit of Scotch tape, the two lamps were inductively coupled to the line in such a way that the *forward power* caused the bulb nearest the transmitter to light, while the *reverse power* (caused by any mismatch) lit the other bulb.

The idea was to tune the transmitter so that the forward bulb glowed brilliantly, and to adjust the antenna so that the reverse bulb was dim or fully extinguished. This condition would indicate that reflected waves were nil—in other words, swr was at or near 1 to 1. That's all that there was to this simple, "prehistoric" swr indicator, and it cost less than a dollar to build.

As coax came into favor in the sixties, the twin-lamp dimmed out as a major item in the well-equipped ham shack, although there were several ingenious designs which appeared in the radio magazines for *coax* twin-lamps (the problem here was to get inside the coax without ruining it!). I mention the twin-lamp mainly as an item of curiosity, but I'll bet that there are still hundreds of hams using them with old-style link-coupled final amplifiers and folded dipole antennas who swear by them.

Twin lead

Perhaps you're using twin-lead for your transmission line. If so, you may ask, "How, then, do I measure swr if I'm using twin-lead?" True, there aren't many 300-ohm swr bridges on the market. But you can *approximately* determine swr on parallel lines by routing the line through a *balun coil transformer* and measuring the swr on a regular coax swr bridge. This method is indirect, but it works fairly well.

Lecher wires

Something of a novelty today, Lecher wires were parallel conductor wires that were coupled to a transmitter or oscillator circuit in order to *physically* measure wavelength. The two wires formed a transmission line that had very pronounced resonance effects on which standing waves appeared. The wavelength of the frequency being measured was equal to two times the distance between any two consecutive current *loops*, or maximums.

This handy device, usually practical only at *vhf* and *uhf* frequencies due to the dimensions, was normally constructed on a two-by-four or some kind of wooden planking. The two wires were tightly stretched between end-pieces using turnbuckles. For determining the transmitter's frequency, a little wire loop and flashlight bulb were loosely coupled to the rig's output "tank" (tuned) circuit.

The Lecher wire apparatus was also loosely coupled to the tank. A shorting bar was then moved down the wires until a pronounced dip was observed in the lamp brightness, and the position was marked. The shorting bar was then run down the wires until a second dip was observed. Voila!

The distance between the two points was equal to a half-wavelength, and by means of a sharp pencil or a slide rule (no calculators then!), the wavelength could be converted to frequency.

Although the process was cumbersome, it was precise—after all, you were physically measuring the wavelength. While many vhf and uhf experimenters undoubtedly use Lecher wires today, such instruments as the grid-dip oscillator, antenna noise bridge, and frequency counter have pushed this interesting device off center-stage.

Frequency meters

The frequency meter is an instrument that indicates the frequency of a signal applied to it. The most common kind is the *heterodyne* frequency meter, which contains a frequency generator or oscillator that is tuned to beat (heterodyne) with the frequency to be measured. The two signals are the same at zero beat, and they can be read out on a meter or by using a conversion chart.

Fairly few hams ever built their own frequency meters, since for them to be really accurate, they had to be very stable—both electrically and mechanically. Most fellows relied on the more easily constructed absorption wavemeter (described earlier) for routine transmitter checking, and on their receivers for an indication of the frequency of their signals and their transmitted quality.

However, many hams did own stable and well-calibrated vfos, and they used them to good advantage in adjusting equipment onto frequency in conjunction with their regular station receiver and a *band-edge marker* (the forerunner to the modern-day crystal calibrator).

Some hams who saw a good deal in

the surplus market bought the war-surplus BC-221 frequency meter (sometimes known as the Navy "LM"). This little unit could be depended on for surprisingly accurate frequency measurements, and it could be purchased for as little as $40 or $50. It had an annoying tendency to drift, however, and it had to be used in connection with a complicated calibration book to make actual frequency readings.

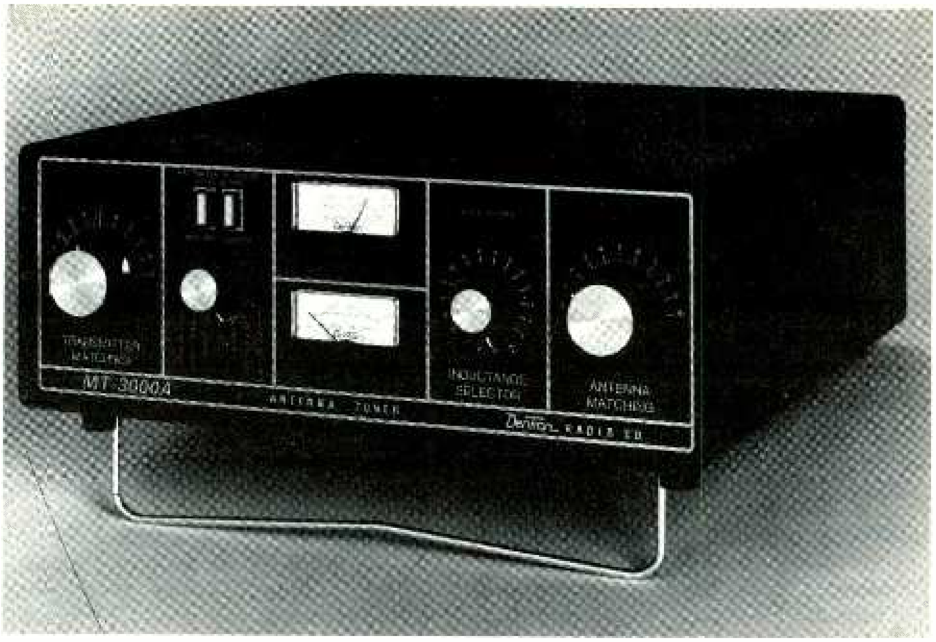
Nevertheless, there are a lot of these units around today, and they are still fair investments if you don't have the money or inclination to invest in a digital frequency counter.

Proud operators

One point that should be made here is that hams always have been proud of the fact that they like to know the frequency on which they are transmitting. In the present era of digital-readout dials, crystal calibrators, and frequency counters, it's not often remembered that 20 or 30 years ago, it was not nearly as easy as it is today to know your exact transmitting frequency with certainty.

Out-of-band operation was a real problem up until the 60s, and resulted in much embarrassment and many citations from the FCC from such transgressions. When incentive ham licensing came into being, and later when novices were allowed vfo operation, *out-of-sub-band operation* became a minor problem, but the availability of well-calibrated receivers and inexpensive crystal calibrators (capable of putting out accurate markers every 25 kHz or less) made this a lesser problem than it might otherwise have been.

The point is that there is today little excuse for out-of-band operation, considering the many tools we all have to work with to insure on-frequency transmission.



Although not strickly test equipment, an antenna tuner is a must if you want to get the last watt of power into your antenna system. Some tuners, such as this Dentron MT-3000A, have built-in SWR/power output meters. Others require an external meter.

Modulation monitors

The modulation monitor is a device used at the transmitter to indicate the percentage of carrier modulation (in am transmitters) or the frequency deviation (in fm transmitters). The monitor itself is usually a calibrated meter of some kind, but it can also be an oscilloscope or other indicator, such as the old "magic eye" tube often used as a tuning device on broadcast sets.

Most modulation monitors were designed for use in the heyday of am transmitters, where it was very important to check the quality and the quantity of modulation on the rf carrier wave. Particularly with home-brew gear and with surplus equipment, ensuring that the transmitted signal was of sufficiently high qulaity was not the easiest thing to do. Hum, ripple, buzz, and distortion often crept into the signal to make it a far cry from the desired broadcast quality.

Most am modulation monitors did two things—they rectified or detected a portion of the signal in order to make it capable of being *aurally monitored* by plugging in a set of headphones. They also normally sported a modulation meter that indicated the relative *percentage of modulation*, so that overmodulation could be detected, and resultant splatter eliminated or at least reduced.

Many CBers make good use of this instrument, since most 11-meter rigs use am; but with ssb, the modulation meter isn't too useful, since there isn't any *carrier* to detect and demodulate, and the concept of 100 percent modulation doesn't have the same meaning because of the lack of a carrier wave.

On the other hand, fm modulation meters are handy instruments to have around the shack, particularly if you want to adjust and service vfh-fm equipment. This instrument, more accurately known as a "deviation meter", had been around for many years, it measures the *frequency deviation* caused by modulation of your transmitter or transceiver, and it is a great deal more precise than just talking in the deviation adjustment on your vfh rig for best audio through a local repeater station. *Under-deviation* results in low audio as received by others listening to your signal, while *overdeviation* makes your signal overly broad and often difficult to copy, especially when working through narrow-band repeaters.

Deviation meters

Many older deviation meters (long used in adjusting police and fire fm radio equipment) are usually available to the sharp shopper at very reasonable prices, but for the average ham fm'er, they probably don't justify the investment. However, a good deviation meter makes an excellent club investment project, since all the members can share in its use when needed

A club-owned meter would be especially handy in adjusting members' gear to fit the exact bandwidth of their club's repeater. This is a particularly good idea when the repeater is equipped with the autopatch feature, since badly over- or under-deviated tone signals usually do a good job of royally messing up the patch's operation!

The antennascope

In the September 1950 issue of *CQ*, Wilfred M. Scherer, W2AEF, described an instrument that hams had been waiting for many years—a package that would do a number of tricks, such as determining antenna resonance and impedance, matching transmission lines for minimum swr, finding the input impedance of communications receivers, and a host of other useful operations around the shack.

This device, about the size of a grid-dip meter, was later marketed commercially by Eldico and some other firms. It was actually an *rf impedance measuring meter* which was designed to be driven by a grid-dipper as the signal source.

In its original form, it could measure antenna impedances from 10 to 1000 ohms, and it could be used up to 200 mHz—not bad for 1950! Some of the things it did for hams was to enable them, for the first time, to accurately adjust the length of dipoles and verticals, prune mobile antenna loading coils, adjust beams and matching stubs, determine standing wave ratios, tweak up low-pass filters, and accomplish several other tasks which either were just not possible before, or which were crudely approximated by neon bulbs or rf ammeters. A handy instrument indeed!

Antenna bridges

Refinements of the basic antennascope came on the market several years later in such forms as the *antenna bridge, antenna null detector*, and still later, the *Macromatcher* (described in *QST* for January 1972). These designs allowed amateurs to learn a great deal more about their antenna systems than just swr.

However, you should know that one of the problems with these units is that they need an *external* driving source, such as a grid-dip meter, signal generator, or vfo (variable frequency oscillator); they don't have an internal source of rf. This makes operation a bit cumbersome, since it takes two instruments to make measurements. And, regardless of how accurate the bridge is as an impedance-measuring instrument, it is dependent on the calibration of the grid-dipper or other signal source for the overall accuracy of measurement.

And, unfortunately, the dipper and the signal generator are usually not the most accurately calibrated instruments in the ham shack. However, as we shall see, a further development—the *antenna noise bridge*—takes care of most of these drawbacks.

Other gear

We've covered most of the main rf test equipment from earlier eras that you're likely to encounter and want to use in your shack. And, while we're talking mainly about *rf* test equipment here, there are a few other simple pieces of vintage equipment that you might want to use for routine testing.

For example, the lowly *headphone*, preferably of the high-impedance type, can be used in a number of ways. It can be used for signal tracing in receivers, in conjunction with a blocking capacitor. It can also be used for finding shorted capacitors, open resistors, and even dirty relay contacts as a sort of "poor man's ohmmeter."

In addition, you will find that the ordinary *neon bulb* is handy for indicating the presence of rf, and the ac/dc circuit testers sold in hardware and discount stores find many uses around the shack.

Of course, the basic instrument in the ham shack is the *multimeter*, in one form or another: the V-O-M (volt-ohm-milliammeter), VTVM (vacuum-tube-voltmeter), or the DMM (digital multimeter). No shack, however humble, should be without one of these simple but essential pieces of test equipment—but more on them later on.

Modern test equipment

So far, we've talked mainly about older kinds of test gear. Now let's turn to more contemporary rf test equipment that can add considerably to your operating enjoyment and convenience. And, while we'll be talking mainly of factory-made equipment, much of the test equipment we'll discuss is fairly simple, and can be home-brewed.

If you'd like to try your own hand, peruse the back issues of *CQ, QST, Ham Radio*, and *73 Magazine* for construction articles—just about all of the instruments in the *Radio Amateur's Handbook* should round out any designs you can't locate in the magazines.

Now, let's take a look at some modern test gear, beginning with some basic equipment—and, there's no more basic instrument to begin with than the *swr bridge*.

Swr bridges

If you entered ham radio through the CB ranks, you almost certainly have an idea as to its function. As you probably know, the swr (standing-wave-ratio) bridge is a test device that allows you to determine how good or bad the match is between your transmitter, transmission line, and antenna.

Without getting buried in the math, the swr bridge measures the ratio of forward voltage to reflected voltage in your antenna system. These voltage relationships depend on the impedance of the equipment, the transmission line, and antenna; a perfectly matched system is said to have an swr of "1 to 1," sometimes written as "1:1."

When, for example, you connect your transmitter to one end of a 75-ohm transmission line and a load equal to the transmission line impedance to the other end, such as a 75-ohm *dummy load*, you have a perfect match between the two and the swr is a nice 1:1.

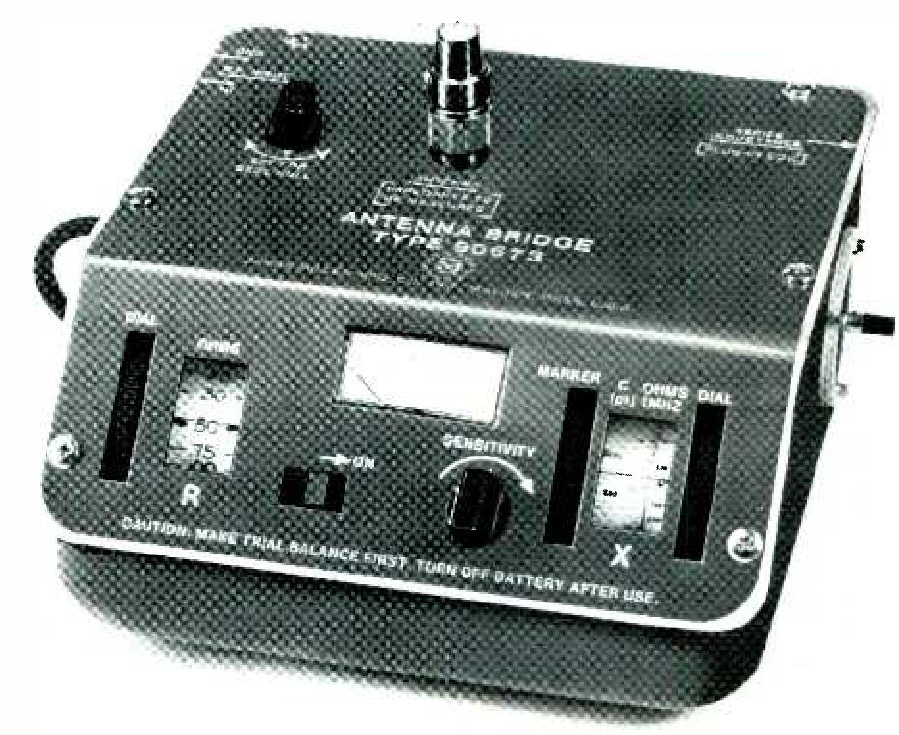
But, if you mismatch your line and load or antenna, such as when using a mistuned or nonresonant aerial, part of your power is wasted in the mismatch. The swr bridge helps you to know when your equipment is properly matched; it helps you to deliver optimum power to the antenna so that it can radiate your signal properly.

There are several kinds of swr bridges. For example, there are ones which measure relative swr only, so that you have to consult a separate chart to come up with the actual swr of your antenna system. Fortunately, this kind is rapidly disappearing. Most meters sold today allow you to directly measure swr on the meter itself.

Some allow you to observe both forward and reflected power without using any calibration charts. Also, some early meters could only handle a few watts, so they had to be carefully protected against regular power levels. This meant that they had to be removed and reinstalled in your transmission line whenever you wanted to take swr readings.

Most modern instruments are high-power units, although not all will handle full amateur levels, say, 2000 watts PEP ssb. Surprisingly, many inexpensive CB swr bridges will handle high powers and will do a fairly decent job even at two meters, so don't assume that you have to spend a great deal of money for a decent meter.

I'd suggest looking over the CB market, from a price standpoint, carefully checking the power-handling capacity and highest usable frequency of the unit that strikes your fancy.



This Millen 90673 antenna bridge is a sophisticated version of the simple R-X noise bridge, such as the Palomar Engineers unit. While it does require an external rf source, it provides a meter readout and better calibrated R and X dials.

A few points in using the swr bridge are in order. Remember that no matter what adjustments you make to the transmitter, they will have no effect on the match as long as you keep the frequency of your transmitter the same. And, if you use an antenna coupler, no matter what adjustments you make to your coupler you can't affect the match at the antenna. Only adjusting the antenna itself, and not the coupler or even the transmission line length, can change this.

While it's convenient to have the swr bridge connected between coupler and transmitter, all you're really doing is making sure the transmitter "sees" the proper load impedance. Remember that to affect the swr of your antenna, you have to make adjustments to the antenna itself.

If you're using a multiband antenna fed with low-loss open wire line or twin-lead, or if you're using a single-wire antenna, it's a different story—the swr of the antenna isn't too important.

One last point about swr meters: if you own a high-power unit, leave it in your transmission line *at all times* in order to give you a quick indication of any malfunction in your antenna or a drop in transmitter output—any such problems will show up right away on your swr bridge. (A good match is usually considered to be 2:1 or better.)

The slight loss of power in the bridge circuit won't be noticed. Also, as we'll see, it makes sense to combine the swr bridge with other multi-purpose rf test instruments, such as directional wattmeters, dummy loads, and antenna couplers—more on these interesting hybrids later on.

The rf wattmeter is a measuring device that indicates the radio-frequency power in a transmission line, in terms of watts. Most of them are, essentially, dc voltmeters connected across a known load which is the same as the transmitter's output impedance.

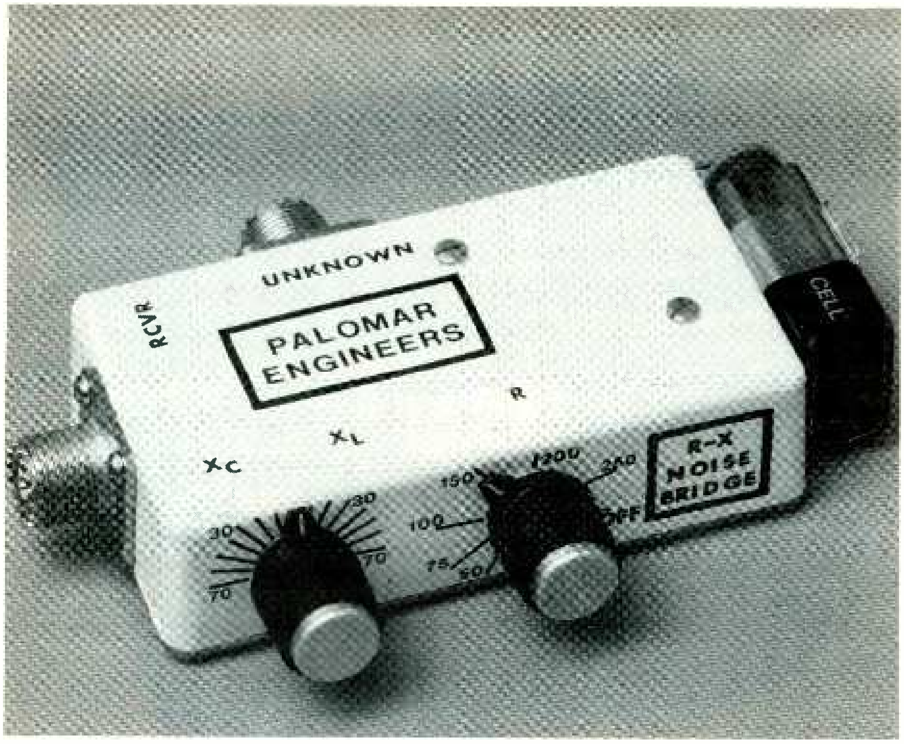
While the meter itself may actually be reading voltage, using the Ohm's law relationship between the indicated voltage and the load impedance, usually 50 or 75 ohms, the meter can be *calibrated* to read in watts.

The rf wattmeter is an especially handy instrument since it directly reads the actual power output of your transmitter without bothersome calculations. You can easily see if you're getting the proper efficiency out of your rig by comparing your input power readings of the final amplifier stage (voltage times current) with the rf wattmeter readings.

You'll find that output efficiencies are usuallly around 60-75 percent, depending on the type of rf power amplifier in your equipment.

Scouting for a wattmeter

This instrument is usually combined with some other form of rf test equipment, such as a dummy load or an swr bridge. In scouting for a wattmeter, look



This Palomar Engineers R-X noise bridge is used to measure antenna impedance and resonant frequency. Since it requires no external rf source, it's ideal for the SWL.

for one that will handle at least 1 kw (they're not much more expensive than lower-power units) and which will work well up to at least 30 MHz with an accuracy rating of at least plus or minus 5 percent. If you're interested in vhf work, consider a *separate* unit—usually power handling capacity isn't so important, whereas accuracy at the higher vhf frequencies *is*.

Finally, look for one that allows you to read reverse power also. This is known as a *directional wattmeter*. Now you've got yourself an swr bridge as well, all in one package. The most versatile units have two meters—one to allow you to monitor forward power, the other to allow you to monitor reverse power simultaneously.

Following current trends, even the rf wattmeter has been "digitized." If you'd like to have your measured power output flash in bright leds in front of your eyes, Swan Electronics has both hf and vhf versions for you. The hf model digitally displays power up to 1,999 watts and reverse power, swr, to 19.99 to 1.

The vhf version reads up to 199 watts forward power and can digitally display the same swr range as its hf counterpart. What more could you want?

Grip-dip meters

The grid-dip meter, sometimes known as the grid-dip oscillator, or abbreviated as the "ODO" or "GDM", is a very versatile instrument that uses a tuned rf oscillator and meter to indicate the absorption of energy from the unit's resonant tank circuit by the circuit under test.

The frequency at which this indication occurs is the *resonant* frequency. The meter can be used in either an active (oscillating) or "passive" mode (like a wavemeter) depending on whether the circuit being investigated is active or passive.

Resonant frequency

Space does not permit cataloguing all the capabilities of this intriguing instrument. But suffice it to say that its primary function is to allow you to determine a circuit's resonant frequency—whether that circuit be a coil-and-condenser combination, a loading coil, or an antenna system. Its other uses include checking capacitance, inductance, circuit "Q," bandwidth, crystals, transmission lines, and filters.

Besides these main functions, when used in its "active" or oscillating role, it can double as a signal generator or marker oscillator for receiver alignment. Some hams, and swls, not owning receivers with bfo's, beat-frequency oscillators, necessary for tuning in cw and ssb transmissions, have even used their grip-dip meters as an "outboard" *local oscillator* by coupling it to the antenna to produce the carrier necessary to receive cw or ssb.

Others have found unique adaptations for their GDOs, such as code-practice oscillators and even metal detectors! The dipper can also be used to detect parasitic oscillations in transmitters, and it can be used to "neutralize" the final amplifier tubes of home-built amplifiers. When used in its "passive" role, the grid-dipper has all the features of the absorption wavemeter. It can be used, for example, as a field strength meter or as a modulation monitor for am transmitters.

Grid dippers

The one big problem with grid-dippers is their usually "so-so" calibration accuracy, particularly if home-brewed or constructed from kits. The calibration of most of them is only approximate, close enough for most purposes, but not for all split-hair applications. But they can be used in conjunction with a calibrated communications receiver, frequency meter, or frequency counter to dramatically increase accuracy.

For my dollar, the grid-dip meter is one of the most capable test instruments you can own—yet few hams who own them make use of all of their capabilities. There are many other applications for this very useful piece of test equipment.

In fact, the GDO is probably the least expensive single test oscillator you can buy that covers the rf spectrum all the way from the low-frequency (LF) band up to uhf in one package and also offers both the "dipper" and absorption wavemeter functions in one compact package.

If you're considering the purchase of a grip-dipper, bear in mind that the most useful ones will offer high calibration accuracy, cover a wide range of frequencies, and be battery-operated so that you can carry them right to your antenna or mobile rig where and when they're needed.

You'll find that the grid-dipper is one of the most versatile, simple, reliable, and inexpensive instruments you can own.

Antenna noise bridge

This unique tool is actually an updated version of the earlier instrument, known variously as the Antennascope, antenna bridge, impedance bridge, or Z-bridge. The big difference between it and its predecessors is that it's not only an impedance-measuring bridge, but it also includes a broadband noise *signal source*.

It does not have to be driven with an external signal, such as that from a grid-dip oscillator or your transmitter. When used with a communications receiver that tunes the desired frequency, both antenna resonant frequency and impedance at resonance can be measured easily and accurately.

As with the earlier units, any type of mobile or fixed station antenna can be rapidly adjusted and tuned for optimum performance without the use of additional equipment, other than the receiver. The fact that no external signal source is required makes it especially good for use on your tower near the antenna, or in checking your mobile unit on the spot.

In normal use, when adjusting your

antenna system for a specific impedance and resonant frequency, your receiver is set to the operating frequency and the bridge is set for the desired impedance. The necessary antenna adjustments are made that result in a distinct noise "null," as indicated either by your ear or by the receiver's S-meter; you can also use the bridge to find the actual impedance and resonant frequency of your existing antenna.

Other more novel uses for the bridge are in tuning rf matching networks or antenna couplers (without having to apply transmitter power) and measuring the "velocity factor" of transmission lines. The bridge can even be used as a handy signal source for receiver alignment, adjusting bandpass filter circuits, and making rf gain measurements, since it puts out several hundred micro-volts of wideband noise.

Extreme accuracy

Most commercial units work well over the range of about 1 to 100 MHz. Many are good up to 300 MHz or more, meaning that they can be used in adjusting your 2 or 1¼ meter antennas. Their beauty lies in their high accuracy, which is limited not by the calibration of a grid-dip meter or signal generator, but by the accuracy of your own receiver or transceiver. Some very competitive ANB's are offered by MFJ, Palomar Engineers, and Electrospace Systems—the latter firm makes the popular "Omega-T" bridge.

One disadvantage is that they are low-power devices—they're not intended to be left in the line. Instead, they are mainly for one-time use in adjusting antennas, and once the basic adjustments are made, the in-line swr meter is the best bet for continuously monitoring performance.

But for the initial tune-up, the noise bridge is invaluable, since it tells you a great deal more about your antenna's characteristics than does the swr bridge, and so can save you the frequently long and tedious process of cutting and trying in getting your antenna system properly adjusted

The field strength meter indicates the strength or intensity of radio waves from a particular station or antenna system, in effect simulating the action of the receiver. It does this by picking up a small amount of the actual signal radiated by the antenna, rectifying it with a crystal diode, and applying the resultant dc to a sensitive meter.

While costly laboratory instruments are usually calibrated in *absolute* units, such as "micro-volts per meter," most CB and ham FSMs merely indicate "relative" signal strength, quite adequate for making routine transmitter and antenna adjustments.

Without doubt, the FSM is one of the handiest instruments you can own—and one of the simplest, since in reality it is little more than a "crystal set" tuned to your transmitter's output frequency.

Before the widespread use of swr meters and antenna bridges which allow you to more accurately "fingerprint" your antenna's performance characteristics, hams relied on the FSM to indicate when maximum power was being radiated by the antenna. Many use the FSM even today in preference to the more sophisticated instruments, particularly when "pruning" long-wire antennas and in accurately adjusting beam antennas for optimum gain.

It's fair to say that no ham shack is complete without the field strength meter, if for no other reason than to give you some idea that your transmitter is actually radiating.

By noting the meter's normal reading you can quickly detect any deterioration of performance in your transmitter or transceiver, as indicated by reducing meter readings. Besides its use as an overall monitoring instrument, it can be used for trouble-shooting rf amplifiers and oscillators, and in helping to track down tvi-producing harmonics.

Dentron's W-2 Watt Meter gives you both forward and reflected power readings simultaneously, eliminating the constant switching between the two required of single-meter units. A remote sensing unit can be connected in the antenna feedline at any convenient location while the indicator is left in view.

Field strength meters

FSMs can be built from a few inexpensive parts, or they can be purchased for as little as about $10. Heath sells a nice kit, the HD-1426, that makes an excellent first project—there's little to go wrong in constructing the field strength meter. The less-expensive, untuned meters are fairly insensitive, though, and will have to be placed near the antenna or transmitter if you're using low power.

More costly wavemeter-like units use a small, self-contained solid-state amplifier circuit and they can be tuned, much like the wavemeter.

They're much more sensitive instruments, particularly useful if you're into QRP (low power) work, or if you want to bird-dog harmonics and spurious oscillations in your equipment. The more sensitive ones can be used much farther from your antenna, so you can even plot your mobile's radiated signal pattern if you like.

In any case, you'll probably find the FSM an indispensable piece of simple test equipment both for your fixed station and your mobile "shack." Its light weight, portability and small size makes it quite convenient—and it's probably the most trouble-free instrument you'll ever possess.

Crystal calibrators

The crystal calibrator is a quartz crystal-controlled oscillator that produces a known reference signal that is used to check or set the tuning of a transmitter, receiver, or transceiver.

It is more properly known as a *secondary frequency standard*, since it is usually calibrated or "set" against a *primary* standard, such as station WWV or WWVH, operated by the National Bureau of Standards. The search for accuracy in your station equipment is just about at an end if you use a calibrator. Modern equipment equipped with crystal calibrators shouldn't be sneezed at as "frequency checkers," and they constitute the next best thing to owning a frequency counter.

A relative field strength meter, such as this Heathkit HD-1426, is ideal for casually monitoring your transmitter and antenna system. Some field strength meters have built-in telescoping antennas. Others, including this Heath unit, require a length of hookup wire for the antenna.

A dozen or more manufacturers make add-on calibrators, and many include them as standard equipment. In most standards, the frequency is controlled by a precision 100 or 1000 kHz quartz crystal; a switch normally controls the operation of frequency circuits which are dividers driven by the oscillator to give outputs at 1000, 100, 50, or 25 kHz. Some devilishly ingenious calibrators even give outputs down as low as 10, 50 or 1 kHz—sometimes even lower.

Most of the commercial units produce a *rectangular wave*, rather than a sine wave, which is very rich in harmonic content. Thus the signal can be heard loudly at every 100 (or every 50, every 25, etc.) kHz throughout the rf spectrum, well up into the vhf bands. A "zero-adjustment" allows you to precisely set the frequency by comparison to WWV or another known standard.

Usually, you can adjust your calibrator to an accuracy of .0001 percent or better (this works out to 10 Hz at 10 MHz, or 15 Hz at 15 MHz) which is good enough to keep your transmitter and receiver "on frequency" regardless of what bands you work.

Most crystal calibrators are very simply adjusted. If you own a general-coverage communications receiver, or a transceiver with a "WWV receive position", you simply tune to WWV on either 2.5, 5, 10, or 15 MHz—the higher the frequency, the more accurate the calibration you can attain. When the station stops transmitting its audio tone, adjust the zeroing control on the calibrator for "zero beat" (either aurally or by watching the S-meter on your receiver).

That's all there is to it! If your receiver won't tune to WWV, you can calibrate against a local *standard broadcast station* using a transistor radio. The accuracy won't be as great as if you had used WWV, but it should still be within about .001 percent, still good enough for most HF ham work.

In searching for a calibrator, look for one that generates useful harmonics well into the vhf range, that produces outputs down to at least 25 kHz (for checking sub-band edges), and which produces what is called a *gated output*. This latter feature, which is a special modulation applied to the calibrator's output, allows you to clearly identify your calibrator's own signal against the backdrop of a crowded band—since it's all too easy to mistake an unmodulated carrier for your calibrator's signal.

You'll undoubtedly use your calibrator, mainly, to check your receiver and transmitter. But you'll also find the little units handy for calibrating your grid-dip meter, signal generator, and your oscilloscope, should you acquire these instruments.

Frequency counters

The quest for frequency accuracy in your equipment—transceivers, transmitters, and receivers—has been aided in the past few years by the frequency counter, which makes possible unprecedented frequency readout and calibration of your equipment, even at vhf and uhf.

While the crystal calibrator, which we've already described, will allow you to calibrate your equipment at certain "marker intervals," it falls short of being able to give you precise, linear readout of frequency *between* the markers where it really counts—like in adjusting or "netting" crystals, aligning tricky tuned circuits, and performing similar chores.

Buying or building a frequency counter is the best way to be able to do such work. It is a far cry from having to use the complicated, intricate calibration charts that went with most frequency meters of just a few years ago.

The most precise frequency measuring instrument in general use is the counter, which has special circuitry that "breaks down" and "counts" the signal applied to its input. While it's highly rated "digital accuracy" is only as good as its calibration and the stability of its reference oscillator (which, like the crystal calibrator, is usually "zeroed" against WWV), it's a top-notch tool that's hard to beat for convenience.

A few years ago, the counter was seen in only the laboratory, and when introduced on the general electronics market, it was in the $500 and up category. But their story is much like that of calculators—every day they seem to become less expensive, and yet boast expanded features.

Today, you can buy a 500 or 600 MHz counter for about $150 (possibly less), and a 30-MHz counter (perfectly good for 160 to 10-meter work) for under $100—even factory wired and tested. Kits can be had for even less. How prices have tumbled in just a year or two!

The pages of ham magazines and mail-order catalogues are packed with descriptions of highly competitive counters. Discriminating between them is no easy task. But in looking for a counter, some things you might want to consider are the size of its digital display (half-inch or larger), the number of digits (6 is about minimum for good resolution), its frequency accuracy (at least .001 percent), its sensitivity, time base stability, and many other factors which are too detailed to go into here.

Some of the more expensive counters sport such useful features as *display hold*, in which you can "freeze" a reading so it can be examined at leisure after the signal is removed; others have *blanked displays* which light up only when a signal is present.

Still others allow for operation from either 110 vac for home use, internal rechargeable Nicad batteries for portable work, or from an external battery or cigarette lighter cord for mobile or even maritime use.

If you're buying a counter "on a budget," consider purchasing one that has the features you want but doesn't claim extremely tight (and expensively obtained) frequency tolerance specifications—accuracy is probably the most expensive driver of cost in the frequency counter.

You will find that in HF work, say to monitor the transmitted frequency of your transceiver, extremely fine accuracy just isn't needed, since errors are very small in relation to the frequencies used.

You will find that for those few occasions when you need *high accuracy*, such as when "netting" crystals for your vhf transceiver or handi-talkie, you can attain a very high degree of "instant" accuracy with an inexpensive counter simply by placing it near or on your communications receiver (thus lightly coupling the counter's frequency-determining oscillator to it), tuning to WWV, and continuously adjusting your counter as you use it.

You'd be surprised at how good a job a moderately-priced counter can do if this procedure is followed.

Something else: some of the newest counters aren't designed to be calibrated against WWV at all, but rather against your tv set! They use the popular tv "color burst" frequency of 3.58 MHz (3.579545 MHz to be exact) for a time-base.

This feature can give you accuracies even better than you can attain using WWV for calibration, since the tv networks maintain a high degree of stability in their color-burst frequencies, and the frequencies they use are directly derived from the National Bureau of Standards (NBS) in Boulder.

Before closing on the subject of frequency counters, I'd like to mention one accessory you may find quite useful. It's the *counter preamp*, a wide-band general purpose amplifier (usually contained in a small minibox) that boosts your counter's gain by 20 db or more. This is particularly useful if you use your counter a great deal at vhf and uhf, since most counters' sensitivities drop off quite a bit on the higher ranges.

The preamp will allow you to do many things your counter normally can't do—I use a preamp to adjust the *receive* trimmer capacitors on my two-meter handi-talkie, since the counter and preamp are now sensitive enough to pick up the "pipsqueak" local oscillator in the hand-held.

Other uses are in QRP "milliwatt" power meters, rf voltmeters and oscilloscopes. I use an inexpensive ($35) unit made by Pagel Electronics, 6742-C Tampa Avenue, Reseda, CA 91335, and find it works wonders with inexpensive counters.

A spin-off of the counter is the accessory *digital frequency display unit*. This accessory usually hooks into a special socket on your receiver or transceiver, and allows you to digitally display your working frequency as read on the regular analog dial.

They're nice, and allow you to see at a glance exactly what your operating frequency is—remember that regular frequency counters, when used to monitor your transmitter's signal, will *flicker* as you modulate your ssb rig or key your cw transmitter; the digital display units won't.

However, as accessories they're about as expensive as their close relative, the frequency counter, so why not buy a counter instead and be able to use the thing as a test instrument as well? Some farsighted manufacturers now make *dual-function* units which can convert from display units to frequency counters at the flick of a switch. (Note: Hufco makes an inexpensive converter that allows you to adapt your present frequency counter for use as a digital display unit for your receiver or transceiver. It is compatible with almost all transmitting and receiving equipment and frequency counters.)

Most frequency counters make use of an rf probe to pick up the signal to be measured. This Pagel Electronics Model 7 Hertz Meter can be put into the signal path to measure the frequency of the rf passing through it. The Model 7 can also be used in the conventional way, and with the Pagel Preamp, can accurately measure the frequency of very low level signals.

Monitor 'scopes

One of the most versatile tools in the ham shack is the oscilloscope. You can make a multitude of measurements using one, such as frequency, voltage, and even time.

To the serious ham, the 'scope is a must, particularly if he operates ssb (single-side-band) or RTTY (radio-teletype), where adjustments can be critical. The 'scope can also be useful in detecting nonlinearity in amplifiers, improper drive levels, key clicks, poor sideband suppression, and parasitics.

Probably the most useful kind of oscilloscope to the ham is the *specialized instrument* that is specifically intended to be used in the shack. Such instruments are made by several manufacturers, including Heath, Yaesu, and Leader Instruments.

Typically, they are designed for "on the air" signal monitoring through at least 6 meters. Their main function is to display the transmitted signal pattern, rf "trapezoid," or RTTY cross-pattern. Most of them have provisions for internally attenuating your transmitter's signals, so that you can connect them directly across the transmitter's output without fear of damage to either your equipment or the 'scope.

Most of them can also be used to display and analyze *received signals* from other stations when used in conjunction with your receiver. Some even have a two-tone audio generator (usually around 1500 and 1950 Hz) built into the unit for ssb adjustment and "tune-up," and other test purposes; others can be used as regular oscilloscopes, too.

Most come with a detailed manual that graphically shows a number of possible displays and indicates what malfunctions may be causing particular patterns to appear, much like the familiar "tv troubleshooting guides" that show a variety of "boob-tube" photos and which point you to the probable source of the problem.

Most of the units on the market today are fairly expensive. $160 up, but older 'scopes such as the Heath HO-10 and SB-610 are very dependable units which may be obtained at reasonable prices on the used-equipment market for under $100.

Dummy loads, such as this B&W Model 334A, let you run tests on transmitters under full operating conditions without having to worry about causing interference. Just connect it to the antenna terminal and it radiates the rf output in the form of harmless heat. This load will handle up to 1000 watts and has a built-in watt meter.

Closely related to the monitor oscilloscope is the *spectrum monitor*. This interesting instrument has gone out of favor to some extent today, but it was very popular in the late 60's and early 70's with sharp operators who wanted a graphic picture of band activity not just at their operating frequency but up and down the band, as well.

The spectrum monitor visually displays all signals within a selected range above and below the frequency which is actually tuned in. This allows the operator to "go after" isolated activity on an otherwise dead band, and so is a particular favorite of some vhf DX'ers who want to be able to instantly "scan the band" for signals.

The disadvantage of most of these units is that they were designed to work *only* with receivers having certain if (intermediate frequency) ranges, which usually limited their use to compatible equipment made by the same manufacturer. Probably the most popular such unit was Heath's HO-13 "Ham-Scan," which originally sold for about $83. If you own a receiver with a 455 kHz if, or have one which uses one of the Heath's standard if frequencies, you may find such a device fun to use.

Like the HO-10, they're often seen on the used equipment dealer's shelves and at hamfests. Don't confuse the *spectrum monitor* with *spectrum analyzer*; the latter is a very sophisticated and expensive wide-band device something like an oscilloscope which is used in accomplishing complex tuning procedures in transmitting equipment.

Most hams will not see the need for this piece of test gear, unless they want to work extensively with frequency synthesizers and complicated filter circuitry.

RF signal generators

The rf signal generator is an electronic instrument which contains oscillators and associated circuits to produce variable reference signals for transmitter and receiver calibration, alignment, testing, and servicing. Many also contain built-in audio generators for modulating the rf carrier.

The signal generator is much like the grid-dip meter, but it is usually a shop-type instrument rather than being "hand-held" like most GDOs. It is normally a bit more stable and fancier, and includes not only an rf oscillator but a buffer or isolation stage, an audio oscillator and modulator, as well as an attenuator to allow its rf output level to be adjusted.

It is useful in aligning, testing and servicing receivers and transmitters, and just about any other time you might need a convenient source of rf. Commercial-quality units are very expensive, costing at least $400 or more, but for most ham applications, relatively inexpensive, under-$100 kits usually fill the bill.

Like the grid-dipper, the main problem is in coaxing sufficient *accuracy* out of inexpensive units. But they can be calibrated with the aid of a regular communications receiver, using signals from WWV or the receiver's crystal calibrator. As with GDOs, accuracy can also be increased by using it along with a frequency counter as a running check on the output frequency.

In shopping for a signal generator, look for one with a high output (at least 100,000 microvolts), decent accuracy (plus or minus 3 percent or better), and outputs on fundamental frequencies to at least 30 MHz and usable harmonics up to 150 MHz (higher if you plan to use it for uhf work).

If you want to build your own from a kit, the Heath IG-5280 and IG-42 are inexpensive units that are not too hard for the beginner to construct, as are the Eico 324 and 330 kits. If you're considering acquiring a "suite" of test equipment for your workbench, I'd rank the signal generator next in line after the multimeter, power/swr meter, and grid-dipper.

Other equipment

So far, we've talked mostly about *rf* test equipment. While there are a lot of other kinds of test gear, we'll save them for another time. But because of its importance, let's discuss one class of test instrument that is an absolute *necessity* in your shack—before you think of swr bridges, frequency counters, grid-dip meters, and other very nice-to-have accessories.

First and foremost on your shopping list should be a suitable *multimeter*—either a portable volt-ohm-milliameter (V-O-M), a vacuum-tube-voltmeter (VTM) or one of the newer digital multimeters (DVMs).

The selection of the proper instrument for your shack is up to you, of course, and there are hundreds to choose from. The point is that you need some sort of device that will enable you to make *simple measurements* of resistance, current, and voltage in order to perform basic checks on your equipment, your antenna, and around your shack in general.

Without such a meter, you cannot check for shorted or open transmission lines, detect short circuits in your gear, or locate components that have gone bad. In short, you're about helpless without one of these inexpensive little gems.

In any case, decide to buy a multimeter if you don't already possess one. Look for one that has a least 15,000 ohms per dc volt resistance; enough meter scales to allow good readability; a large meter face; conveniently positioned controls, portability; and good accuracy.

Of these features, accuracy and a high input resistance are probably the most important features. A high-resistance meter is essential in order to draw little power from the circuit under test and to make accurate measurements; a high-resistance (50,000 ohm) V-O-M or a good VTVM, with its very high input impedance, will do the best job for you.

There are so many multimeters on the market that it's hard to choose from among them. But, if you want an inexpensive, highly portable unit, consider the straight V-O-M. You can usually buy a very good one for under $25; a lab-quality unit will be considerably more expensive.

If you plan to do mostly bench work, where you're handy to an ac outlet, then the *VTVM* may be your best choice. These are often seen at hamfests at very reasonable prices.

If you want the latest in state-of-the-art convenience, consider the *digital multimeter;* it gives you an LED-type readout much like that on your digital watch. They are definitely the coming thing, though they're usually quite expensive.

Recently, however, some kits have been put on the market for well under $100 which bring the DVM within reach of most hams and electronic hobbyists. Excellent DVM kits are available from manufacturers such as Heath, Gary McClellan & Co., and Sabtronics. But because they are complicated and use easily damaged components, best not to construct a digital kit as your very first electronic undertaking!

Many hams find other uses for their VTVMs. For example, if you own one that has a fairly good frequency response on the ac ranges, you can measure the *power output* of your hf transmitter without using a power meter.

For example, if you run your transmitter into a 50-ohm dummy load and measure the *voltage* across it, you can calculate the power using ohm's law (power equals voltage squared divided by resistance, or $P = E^2/R$). Of course, you should only make this kind of a direct measurement with low-power equipment, for safety reasons.

You can also increase the utility of your VTVM by using an accessory *rf probe* with it. This will enable you to make direct ac measurements well up into the vhf bands; the probe is also handy for signal tracing and troubleshooting in receivers.

Before leaving the subject of "other equipment," suffice it to say that there is a lot of other test gear that you'll eventually want to have for your shack—equipment that may not really fit in our category of "rf" test equipment.

Some such gear would be audio oscillators, function generators, oscilloscopes, sweep generators, bench power supplies, battery chargers, capacitance bridges and a multitude of other test equipment and related accessories. But obtain the *basic* service and rf test equipment first, then add the "peripherals." One day you'll have it all!

So far, we've described some of the most useful rf test equipment, but on an *individual* basis. It can, however, be advantageous to "marry up" some equipment for reasons of convenience and economy.

For example, the familiar antenna tuner can house other rf equipment, such as an swr bridge, rf ammeter, and dummy load; and so-called "station consoles" can house a table-full of convenience-type test gear in one package. It also makes sense to take advantage of the fact that the same power supply and LED display may be used to serve two or more related pieces of equipment, such as signal generators, digital clocks, and frequency counters.

And, with modern solid-state technology reducing the size and increasing the portability of test equipment, it's now possible to have such "neat" devices as hand-held frequency counters that can be taken right to the job at hand—whether indoors or out. Let's take a look at some novel ideas in rf test equipment you may want to consider for your workbench.

Tuner and bridge combos

The antenna tuner or coupler, of course, isn't a piece of test equipment at all. But it makes sense to *mate* the tuner with an rf meter of some sort for an indication of proper loading and transmitter tuning. While rf ammeters can be used, particularly for low-power equipment feeding single-wire antennas, the swr bridge or directional wattmeter is the ideal test instrument to house in the same cabinet as your antenna coupler.

The swr bridge, of course, can give continuous indication of best "match" between the antenna tuner and the transceiver or transmitter. Having the swr bridge as an integral part of the antenna coupler is very convenient and is usually cost-saving.

Probably the "ideal" antenna coupler combo would be one that would match all kinds of antennas (coax-fed, parallel-line, and single wires), allow for continuous monitoring of both forward and reflected power (requiring two meters, of course), provide for either straight-through operation or operation through the antenna coupler matching circuit, and have a front-panel selection of several antennas.

Some of the newest antenna couplers, such as the Dentron MT-3000A, also have a built-in dummy load that can be switched in and out of the circuit for instant transmitter tune-up and adjustment. Of course, such "do-everything" tuners don't come cheap; but since it is the power-handling capacity that has the greatest impact on price, look for a *medium-power* unit that has the *most features* for your dollar. If you run 250 watts, for example, you don't necessarily need a 2 kw tuner!

Clock/frequency counters

As we said, it makes sense to combine related pieces of gear, such as digital clocks and frequency counters which can make use use of common power supplies and display leds. A good example of this technology is the Teknik series of frequency counters, which are designed for either base or mobile frequency display, with a clock feature thrown in to boot.

For example, the firm's model FC-106B is designed to operate from either 12 volts dc or 110 volts ac (using an external adapter/charger); it can also operate from self-contained, rechargeable Nicad batteries. With a six-digit frequency display readable to 100 Hz, the unit can be used to indicate your actual transmittted frequency up to 10 meters.

The clock portion can either be set for 12 or 24-hour format, and it can display either four or six digits. Since it is designed primarily for dc operation, it contains a built-in crystal timebase for the clock, rather than sampling the 60-cycle house current for synchronization.

The same timebase doubles as the oscillator for the frequency counter; much of the circuitry is shared between the two functions, and it is designed so that even when the counter is in use, the unit "remembers" the correct time (which can be recalled and displayed by the flick of a switch).

The unit is distributed by Aldelco, 2281 Babylon Turnpike, Merrick, N.Y. 11566, and sells for about $100 less the ac adapter and Nicad batteries.

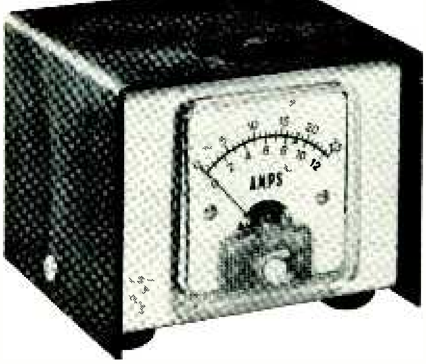
The same company also markets an interesting "dual digital" clock which allows you to display, side-by-side in the same cabinet, both local and Greenwich (Universal) Time, or to display on one readout panel 12-hour time and on the other, 24-hour time format. These features reduce or eliminate the "mental gymnastics" involved in computing time differences when working DX, making log entries, and especially important, in contest work where time is of the essence.

Another combination frequency counter/clock is made by Pride Electronics. Their TF-1000 is very similar in function to the Teknik unit, but features *automatic switching* from clock to frequency counter when transmitting. The 6-digit clock continues to function and its time display returns automatically when the transmitter is unkeyed.

The Pride unit is designed for "thru-line" operation. This means that it is connected in series with the transmitter or transceiver rf power output line, much like an swr bridge; it "samples" a minute portion of your signal for display purposes. The two-pound unit can handle power levels up to 250 watts to 40 MHz; it is designed for base station use and is ac-powered.

At least a third combination "frequency and time machine" is now on the market. It is a 30 MHz thru-line unit that has some impressive specs, including a calibration time-base accuracy of three parts-per-million. It is manufactured by Communications Power, Inc., 2407

Dip meters, such as this Waters Model 331A by Barker & Williamson, let you determine the resonant frequency of rf circuits and antennas. You just hold the dipper next to the circuit being tested and turn the dial. When the meter reading deflects downward, or dips, you've found the frequency.



Although an rf ammeter won't give you as much information about your antenna system as an SWR/power meter, it will let you know exactly how much rf current you're pumping into the line. This End-Tec rf ammeter is designed for use with low-power equipment, but ammeters are also available with much higher ranges.

Charleston Rd., Mountain View, CA 94043, and sells for $200.

Signal generator/counter

Another "hybrid" test insturment has recently made its appearance: the combination signal generator and frequency counter. The best way to describe this unique device is to describe a newly-marketed unit. The Lunar Electronics DX-555P signal generator/counter has no frequency dial, unlike most signal generators.

Instead, it uses the counter's LED read-out to display the actual rf output frequency of the generator. It is tuned by a large main tuning knob and a small bandspread knob, with the frequency indicated by its 5-digit LED display. The advantages of accurate frequency read-out are obvious, and overcome the main drawback of hobby-style signal generators—poor calibration.

With good calibration accuracy (limited mainly by the stability of the frequency counter), the unit can be used for precise alignment of transceivers and receivers.

The signal generator in the Lunar unit covers 440 kHz to 30 MHz in three ranges; the frequency counter covers all the way up to 220 MHz (using a built-in "prescaler," or range extender). The vhf coverage makes it suitable for checking out 6, 2, and 1¼-meter transceivers and walkie-talkies. The little unit is sold by Lunar Electronics, Box 82183, San Diego, CA 92138.

Miniaturized counters

It's a pleasure to be able to take your test equipment right to the scene, rather than having to remove mobile equipment and bring it into the shop when adjustment and calibration is needed. Until very recently, the frequency counter was one instrument that just didn't lend itself to extreme portability.

However, in recent months, a number of popular-priced, precision miniature counters have appeared on the market which have tremendous application in "on-the-spot" calibration of mobile and portable gear, walkie-talkies, and other equipment that doesn't readily lend itself to bench testing.

The Digitrex 6600 counter, sold by Digitrex, 4412 Fernlee, Royal Oak, MI 48073, is a factory-assembled miniature counter housed in a plastic case of the kind used to hold small digital automobile clocks. Initially, it was offered as either a kit or ready-built, but its small size made construction difficult for the "average" ham, and there were also some design problems.

The company re-engineered the counter, and came up with a six-digit unit that will count to 600 MHz with an accuracy of .0002 percent and a resolution of 100 cycles. The sensitive unit is powered by six penlite cells and a 9-volt transistor-radio type battery. It sells in the $120 price class.

Another miniature unit that offers "bench counter" performance in a hand-held package is the Gary Model 303. The 5 X 3 X 1¼-inch, 2-pound unit is powered by a internal 5-volt rechargeable Nicad battery. It boasts a factory-set accuracy of .0001 percent, and will count to 200 MHz with good sensitivity. Its cost is $129.95 factory assembled, from Gary McClellan and Co., P.O. Box 2085, 1001 W. Imperial Highway, La Habra, CA 90631.

Another interesting, sensitive 250-MHz hand-held counter is sold by DSI Instruments, Inc., 7914 Ronson Road No. G, San Diego, CA 92111. Its specs are competitive with those of the Digitrex and Gary counters.

These counters are made possible by using modern LSI (large scale integration) solid-state circuitry. For example, in the Gary counter, two ICs do the bulk of the counting "chores." While the prescaler usually limits the portability of most counters because of high current consumption, usually around 200 ma or so, in this unit a special PCL logic prescaler is used that draws only 20 ma, so that battery life is conserved.

The hand-held counters probably are destined to become almost as popular as the walkie-talkie. They're a natural for portable communications work; the handy size plus wide frequency range makes them "super" for field day purposes.

In most cases, you can get adequate signal pickup even from low-power gear by attaching a short pickup wire to the counter's input connectors.

We've only scratched the surface with our survey of some of the new ideas in rf test equipment. Thumb through the pages of your favorite ham magazines and you'll find more new and unusual instruments being introduced each month—including some sophisticated "do-everything" transceiver testers which may represent the wave of the future in ham test equipment.

Test points

Most test equipment can be bought either in kit form or ready-made. If you're a beginner, it's probably best to limit your home-brewing and kit-building to such relatively simple pieces as multimeters (V-O-Ms), vacuum-tube-voltmeters (VTVM's), grid-dippers, swr bridges, and field strength meters.

All these provide good vehicles for learning good construction practice and basic test equipment theory, and there's very little expensive damage you can do if you end up with mistakes in wiring. Both Heath and EICO make a variety of good kits that can get you started; as we suggested, a multimeter is probably the ideal *first* kit.

Unless you've had the experience of building a few simple kits, it's a good idea to stay away from complex solid-state "black boxes" such as frequency counters and the like. They're touchy to build, their components (such as IC's and LED's are easily damaged, and soldering must be done with extreme care.

If you haven't already discovered, they can be hard to build and get working properly even with good instructions, such as those by Heath and EICO. They're even more difficult and frustrating to assemble when working with *poor* instructions, which, unfortunately, are too-often furnished by many lesser kit manufacturers. So beware, and choose your test equipment kits carefully if you decide to build.

If you'd like to home-brew, the same cautions apply. Plus, you're strictly "on your own." Again, if you're a beginner, stick with simple, basic test equipment; the back issues of *QST*, *73*, *CQ* and *Ham Radio* are chock full of designs for practically every kind of rf test gear we've described in this article.

Needless to say, if you build your own, you will likely become much more familiar with your equipment and will understand its functions much better than if you bought it outright or built it from a kit.

Of course, you can often save a good deal of money in acquiring basic test gear by buying *used* equipment. The usual cautions apply: know your seller and the condition of the equipment before you buy. If you purchase test equipment at a hamfest or swapmeet, be sure to try it out for proper operation—at least give it a good visual check if you can't actually plug it in for a "smoke test." Beware of used "CB-type" test gear; it's often misused by its owner, much like CB transceivers are. Be careful, too, in buying *surplus* gear.

Much of the military surplus equipment available today is far out-of-date and is overly-specialized for practical ham use. In any case, be sure that you obtain instruction manuals (complete with schematics) for each piece of test equipment you own—test gear sometimes needs servicing itself. It's a good idea to keep the instruction manuals in a safe place along with the manuals and schematics for your station equipment.

What should it cost?

Good test equipment costs money—sometimes more than the gear it is intended to service. Yet, one of the best investments you can make is in good, *dependable* test equipment. As we mentioned, it rarely becomes outdated, and it may save expensive factory servicing on what may be minor equipment problems.

Of course, it doesn't make much sense to make yourself "test equipment poor" by buying beyond your needs. Very few hams, for example, need a spectrum analyzer or a frequency counter that will count to 1 Gigahertz! Your decision to purchase more or less-expensive test equipment should be based on your *needs* and the *frequency* with which you anticipate having to use it.

For example, it pays to get a good precision multimeter, VTVM or swr bridge, because you'll probably use them almost every day, and they'll likely never go out of style. But to invest in frequency counter good to an accuracy of .05 parts per million would not be wise if your are but a casual vhf or uhf operator.

After deciding on what kind of test equipment you need and expect to use sufficiently to justify its purchase, you should carefully select it by evaluating performance, features, and price. Shop the ham magazines, the electronics distributors in your area, and send for comparative spec sheets. Like anything else you may buy, comparison-shopping test equipment really pays off.

It's amazing how the same number of dollars will buy vastly differing quality and specs from different manufacturers. And, while you can usually save a great deal by buying kits, they're not *always* the best buy; this suggests that you shouldn't shop *only* on price. Check the specs carefully!

For example, you may find that it's less expensive to buy a precision wired-and-tested frequency counter from one of the newer firms that *specialize* in digital test equipment, than it is to purchase an equivalent *kit*.

A good club project is the purchase of a high-quality set of rf test equipment for use by the members—this is not particularly cost-cutting for the more inexpensive items, but when it comes to complex, costly equipment like frequency counters, deviation meters, and the like, it's a good way to allow *all* the members to share the benefits of the higher-priced gear on a cooperative check-out basis.

If your club goes this route, buy only the best, most rugged instruments, as shared equipment tends to get much rougher treatment than one-owner gear.

In any case, it's better to pay a few dollars more for your test equipment and get accurate, dependable gear than to try to use "cheapies" whose accuracy and reliability is questionable. Too, the day may come when you'll want to pick up that second-class FCC ticket and do some CB and ham repair work on the side, and that means having a well-equipped bench.

Power sources

Some rf test equipment you'll buy won't need power at all, such as wattmeters, swr bridges, and dummy loads. Most test equipment, however, is intended for bench operation and is designed to work off of 110 to 130 vac house current.

This is changing, however. Most solid-state gear is designed to operate on dc voltages of 12 volts or less. This makes it practical to operate test equipment from your auto battery for some mobile repair jobs right in your vehicle; external ac adapters are used to run the equipment on house current.

Many of the newer frequency counters and digital multimeters have built-in rechargeable Nicad power supplies so that they can be used indoors or out, and are simply recharged when the need arises.

While on the subject of *power*, consider this: if you own a mobile unit, you may at some future date have to bring the unit inside for major repair work or for modifications. When doing this, you'll need a source of dc power for operating the equipment. You *can* use an old storage battery in conjunction with a charger. But it's a lot more convenient to have a workbench power supply that will provide the necessary voltage at the current rating you need.

Best is a unit that has both a high-current, variable-voltage output for use in testing mobile radio equipment, *and* a couple of fixed low-voltage, low-current outputs you can use in powering any experimental solid-state circuits that you may build. This kind of power supply is fairly inexpensive.

Maintenance

In selecting a power supply, good regulation and filtering are paramount, so be wary of cheapie "CB mobile battery eliminators"; most of these supplies have insufficient current output and regulation under load, and they often suffer from inadequate hum filtering. Look for a supply that is specifically designed to be used for workbench testing and servicing.

Most test equipment needs little maintenance. For the most part, your test gear will just sit there doing its thing for a long time without needing any calibration or servicing of its own.

However, it pays to have a program of preventive maintenance and calibration on your test equipment to keep it in tip-top shape for that time when you *need* it. This program needn't be fancy, but there is nothing more frustrating than to have your ham rig go up in smoke and to set out to fix it, just to discover that your test equipment *itself* needs fixing!

Some things you can and should do is to *periodically inspect* your test equipment, both internally and externally. Check the lubrication of any moving parts; clean switch contacts and terminals; test any vacuum tubes for performance; and occasionally "dust" the unit's innards. It's a good idea to "spot-check" the calibration of your equipment, such as frequency counters and crystal calibrators by checking them against WWV.

You can check your swr meter or antenna noise bridge against your dummy load, and your grid-dip meter dial accuracy against your communications receiver.

Periodically check the batteries in your multimeter or VTVM, and replace them when weak—certainly before they become "sour" and make a mess of the interior of the instrument. Better yet, replace them with Nicads if possible, and keep the unit on continuous "trickle charge" when not in use.

If you make an honest effort to care for and maintain your test equipment, you can usually keep it up to par and working to factory specs with ease.

Wrapping it

In this article, we've taken a look at some early ham test equipment, and have shown that much of the early rf test gear is still useful today. We've taken a look at each of the more commonly used pieces of rf test equipment currently in use, and have suggested that such instruments as the swr bridge, field-strength meter, and crystal calibrator are "musts" in the well-equipped ham shack in addition to the basic V-O-M or VTVM.

We've also mentioned some "double-duty" test gear such as combination digital clocks, frequency counters, and signal generators, as well as integrated swr bridges and antenna tuners. In addition, we've presented some hopefully useful suggestions as to whether you should build or buy your test equipment, and have listed some tips on purchasing and maintaining your "tools of the trade."

Any high-quality test equipment you build or buy will serve you well over many years, so put some thought into its purchase and maintain it with care. After all, the life of your ham gear may depend on the quality of your workbench!

how it works

ONE PIECE OF GEAR EXPLAINED

BY CLAYTON HALLMARK

An oscilloscope may be the most useful piece of test gear you can own. Also the most complex. Here's an easy-to-understand explanation.

Everyone knows that the oscilloscope is one of the most useful of all test instruments. But the oscilloscope is the most under used of all test equipment. Many newcomers to electronics put off buying a scope because they believe it's difficult to use. Veterans of the field resist stepping up to new triggered models thinking them too hard to master.

The fact is, if you can use a meter, you can use a simple scope. And, once you have used a simple scope, you'll have no trouble using an advanced one. All you need is a basic understanding of how a scope works. Then you'll see how easy it really is to use an oscilloscope.

The simple recurrent-sweep scope illustrated in figure 1 is not the latest or hottest thing for the test bench, but there are still a lot of these around. If a simple scope will meet your needs, then its low cost and easy operation may outweigh its limited functions.

Most simple scopes are remarkably similar and have the same controls, although the same controls often go by different names. Table 1 shows the functions of the controls and how to adjust them to observe waveforms.

Some simple scopes have an INT/EXT switch that selects either an internal or external synchronization signal. Normally the switch is left in the INT position, and the sweep is synced to the signal applied to the vertical-input terminals. With the switch in the EXT position, the sweep is synced to a separate signal applied to the EXT SYNC terminals. Your scope may have an EXT SYNC AMPLITUDE control. It works only on external synchronization and should be set just above the *lowest* setting that will give you a stable display.

The Heath Model SO-4510, whose front-panel controls are shown in figure 2, is an example of a new breed of sophisticated oscilloscopes that are becoming increasingly affordable and popular. It's a triggered dual-trace scope with a frequency response of 15 MHz and a sensitivity of 1 mV/cm. It has just about all of the features and controls you'll find on any advanced model.

Figure 2 **The Heath SO-4510 is typical of the sophisticated dual-trace scopes now in use. The simple layout and intelligently labeled controls make it easy to operate.**

Examining the front panel, you'll notice that some of the controls are the same as those on the simple scope, although renamed. The labels on some other controls are self-explanatory. The rest are discussed below.

Vertical controls

In dual-trace operation two signals are displayed, one above the other. The vertical or Y input connectors are labeled Y1 and Y2, for channel 1 and channel 2. In some scopes the channels are designated A and B.

An input switch, labeled AC-GND-DC, is provided for each channel. In the DC position the signal is connected directly to the vertical-deflection amplifiers. In the AC position the signal is fed through a capacitor first. In the GND position the input is disconnected, and the vertical-amplifier input is grounded. This is useful for positioning the baseline without disconnecting the signal source.

Most scopes have a vertical-attenuator control that lets you observe a wide range of signals without overloading the scope. You adjust the attenuator with a multi-position switch, which adds attenuation in a 1-2-5 or 1-10-100 sequence, and a potentiometer, which provides fine control between the steps. Each position of the switch is marked as the amount of voltage required to deflect the trace a unit distance, such as VOLTS/CM, or as to the amount of attenuation given to the signal, such as 100, 10, or 1. When the pot is mounted on the switch, it is usually marked VARIABLE; when it's mounted separately, it is often marked GAIN or FINE GAIN.

Since it is difficult to accurately calibrate a potentiometer, the VARIABLE control usually has no scale numbers. The attenuator switch, however, can be accurately calibrated to the front-panel designations. To do this, the VARIABLE control is turned fully clockwise to cut it out of the attenuator circuit. This position is usually marked CAL on the front panel.

Note that some of the controls are duplicated on the advanced oscilloscope shown. Since this is a dual-trace model, two sets of vertical controls are provided—a set for each channel.

Most scopes provide an accurate calibration signal through a front-panel CAL, LINE, or TEST SIGNAL connector. You can use it to periodically check the vertical calibration. Once calibrated, a lab-grade oscilloscope becomes a voltmeter, accurate to within 3 percent, in the case of the Heath SO-4510.

Horizontal controls

In the modern triggered scope the sweep or time-base control also takes the form of a multiposition switch and a potentiometer. The switch is usually labeled TIME/CM or TIME/DIV and numbered in a 1-2-5 sequence. Front-panel markings group the settings into microseconds (uS), milliseconds (mS), and seconds (SEC).

The potentiometer is labeled VARIABLE, and an arrow shows the direction to turn the pot to the CAL position. To accurately measure the time of one cycle of a signal, you set the VARIABLE control to the CAL position and the TIME/CM switch to select the appropriate sweep time.

In most scopes, when the TIME/CM switch is rotated fully clockwise to the EXT position, the sweep generator is disconnected from the horizontal-deflection amplifiers, and a front-panel connector marked HORIZ or EXT HORIZ is connected to the input of the amplifiers. This lets you compare phase and frequency of one signal to the vertical-input signal. The VARIABLE sweep control becomes a gain control letting you establish the width of the display.

Triggering controls

The triggered oscilloscope, in which the sweep is usually started or triggered by the signal to be observed, lets you make accurate time measurements. It also gives you a more stable presentation than a simple scope. The triggering controls synchronize the sweep generator with the input signal.

The TRIGGERING or TRIG SELECT switch lets you choose the source and polarity of the triggering signal. When you select LINE, the 60 Hz power-line frequency is used for triggering. When you select INT, internal, the input signal is used to trigger the sweep. When you select EXT, a signal from an appropriate external source is connected through the front-panel EXT connector to the sweep-generator circuit.

A TRIGGER SLOPE or +/– switch lets you determine whether the sweep will start on the upward, +, or downward,–, slope of the waveform. On a dual-trace scope, the switch lets you select either the signal of channel 1 or channel 2 as the internal-trigger source.

The LEVEL potentiometer lets you set the amplitude at which the triggering signal starts the sweep generator. When the related STABILITY control, a screwdriver adjustment on some models, is misadjusted, or when no triggering signal is available, the scope screen will be blank.

When the LEVEL control is fully counterclockwise, in the AUTO position, the sweep generator will be free running. As you turn the LEVEL control clockwise, the trace will disappear. Continue slowly turning the control until the trace just reappears. At this point you'll have a stable presentation.

The TRIG MODE switch on some scopes controls the trigger-input bandpass. In the ACF or AC FAST position unwanted low-frequency triggering signals are eliminated. The DC setting allows the sweep to be triggered from DC level changes or very low frequency AC signals. In the AC position the DC component of the triggering signal is blocked.

The DC BALANCE control is a screwdriver adjustment to keep the trace from shifting vertically as the VARIABLE VOLTS/CM control is changed. It's a service control that need not be adjusted every time the scope is used.

Other controls

The MAG control, or x5 or x10 on some models, lets you effectively increase the screen width from 10 cm to 50 or 100 cm. By so doing, the width of the waveform you see on the scope is magnified five or ten times. The new sweep speed is then one-fifth or one-tenth the setting of the TIME/CM switch.

The ILLUM or GRATICULE control lets you vary the brightness of the grid lines. Often the oscilloscope's ON-OFF switch is associated with this control.

The ASTIGMATISM and GEOMETRY controls are frequently screwdriver adjustments. The ASTIGMATISM control is adjusted so that the spot produced on the screen by the electron beam is round. To adjust the GEOMETRY control, you set the oscilloscope to produce a vertical line. Then move the line to the left and right sides of the screen, in turn, adjusting the GEOMETRY control for minimum bowing.

Setting up a simple or advanced scope for operation is similar. Note that in the setup procedure given below, the procedure is the same for both except step 6, where 6R applies to recurrent sweep scopes and 6T applies to triggered sweep scopes. As you use your scope, always observe the cardinal rule of oscilloscope operation—never permit a high-intensity spot to remain stationary on the screen for any length of time. If you do, you may burn a permanent dark spot on the screen. The setup procedure is as follows:

- Initialize the controls as in Table 1 or 2.
- Allow 2 minutes for the scope to warm up. If your scope has a HORIZ GAIN control, set it so the baseline extends across the screen.
- Turn the POSITION controls, one at a time, to see if the trace can be moved to the edges of the screen, and then center the trace.
- Adjust the INTENSITY and GRATICULE controls for comfortable viewing and the FOCUS control for a thin, well-defined line.
- Connect the output from the voltage calibrator to the vertical input.
- Adjust the FREQ VERNIER or FINE FREQ control for a stable display and

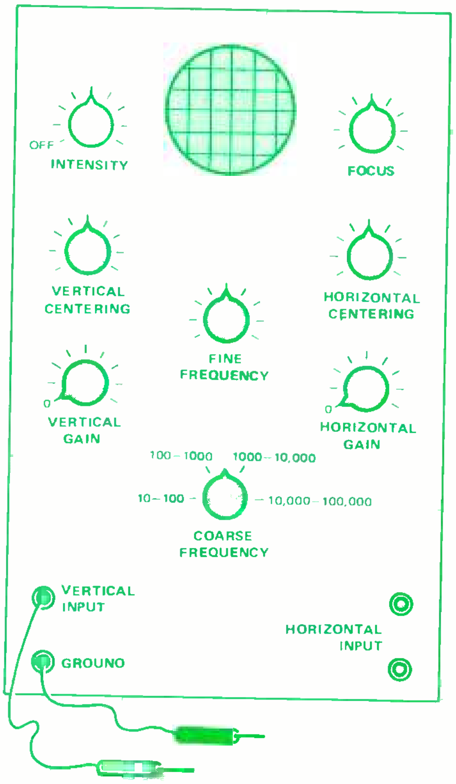


Figure 1 **Front panel layout of a simple oscilloscope showing typical placement and markings of the front panel controls.**

Table 1 Control functions and initial settings for simple scopes

Control	Function	Initial setting
Intensity	Varies trace brightness	Centered
Focus	Varies trace sharpness	Centered
Vertical position	Moves trace up and down	Centered
Horizontal position	Moves trace left and right	Centered
Vertical gain	Varies trace height	Fully counterclockwise
Horizontal gain	Varies trace width	Fully counterclockwise
Horizontal frequency	Varies display repetition rate	Fully counterclockwise
Fine frequency	Makes wave stand still	Centered

adjust the VERT GAIN control until the waveform has a height of one division. Assuming a 1-volt peak-to-peak standard and assuming that the VERT GAIN control is not disturbed, one vertical division will equal 0.1 volt on the x1 range, 1 volt on the x10 range, and 10 volts on the x100 range.

- Turn the LEVEL control from the AUTO position and note that the trace disappears. Continue turning until the trace reappears. The display should be a stable display of several cycles, 2 cm in height assuming a 1-volt calibration signal.
- Disconnect the lead from the voltage calibrator.
- Turn the input attenuator to the highest attenuation setting.
- Connect the input signal and rotate the attenuator control until the display occupies approximately two-thirds of the screen height.
- Adjust the sweep controls and LEVEL control, if present, to select the desired number of cycles of the input signal and to stabilize the display.

Triggered operation

Some of the displays you can see with various trigger-level and trigger-slope settings appear in figure 3. The usefulness of these controls is illustrated in figure 4. Imagine you wanted to observe

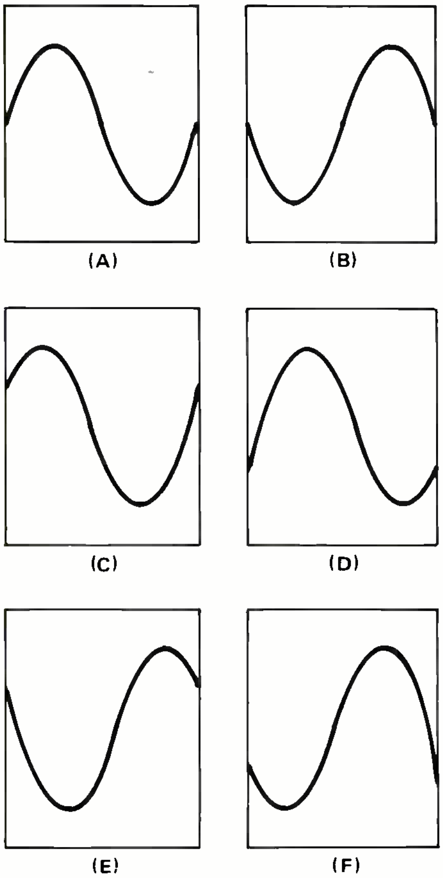


Figure 3 **Effects of the trigger controls on the display of a triggered-sweep scope.**

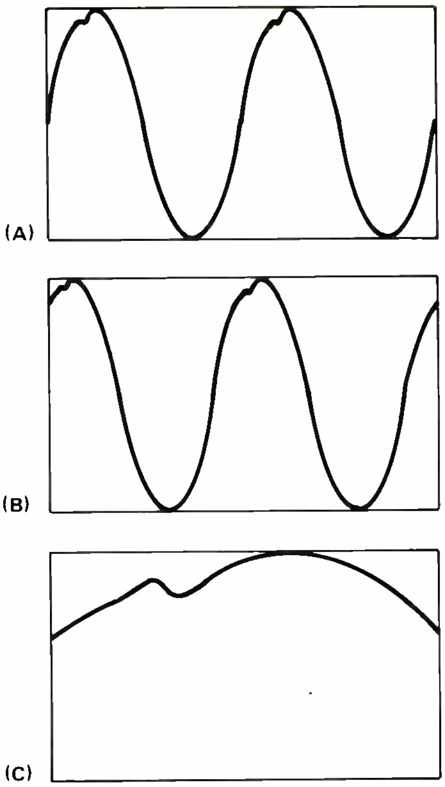


Figure 4 **The effect of transients can easily be seen on an oscilloscope. When set for normal operation (A), the transients can be seen at the peaks of the waveform. Adjusting the Trigger Level control (B) shifts the transients near the beginning of the sweep. Then, by using the x5 magnifier (C), the transient can be stretched for a more detailed view.**

the glitch on waveform *A*. To do this, you'd set the TRIG SELECT switch to the negative-slope position and adjust the LEVEL control so the sweep starts just before the glitch, as in *B*. Then you'd decrease the setting of the TIME/CM switch or pull the x5 switch, or both, to expand the sweep.

The x5 feature would expand the sweep around the center 2 centimeters. This would spread the glitch across a large area of the screen for closer observations, as shown in *C*. To measure time in the x5 mode, you'd have to divide the setting of the TIME/CM switch by 5.

Dual-trace operation

Suppose you wished to observe the outputs of a sine/square generator, the output of which is in-phase 1 volt rms sine and square waves at 1 kHz. To do so, you'd proceed as follows:

- Connect the sine-wave signal to the channel 1 input and the square-wave signal to the channel 2 input.
- Set the two input VOLTS/CM switches to 1 volt and both INPUT switches to AC.
- Set the TRIG SELECT switch to Channel 1+ to trigger on the positive slope of the sine wave. Set the LEVEL control fully clockwise to the AUTO position. This triggers the scope at the zero crossing of the sine wave.
- Set the TRIG MODE switch to AC and the TIME/CM switch to 0.2 milliseconds.
- Adjust the channel 1 and channel 2 POSITION controls so the two waveforms are separated on the screen.

Setting the scope in this manner should give you the display shown in figure 5. Note that triggering occurs at the point on the sine wave selected in step 3. If you were to turn the LEVEL control clockwise until triggering occurred at the peak of the sine wave, the entire display would shift to the left, as shown in *B*. The positive peak of the sine wave would still occur at the midpoint of the positive portion of the square wave, however.

In the scope of this example, either channel may be turned off by turning its POSITION control fully clockwise, to the OFF position. When both controls are advanced from the OFF position, the scope's circuits automatically switch to dual-trace operation.

Some scopes have a MODE switch that lets you select channel 1 only, channel 2 only, or the chopped, CHOP, or alternate, ALT, mode of dual-trace operation. In many advanced scopes, such as the one shown, the appropriate dual-trace mode—alternate or chopped—is automatically selected by the setting of the TIME/CM control. Handy operating features like this are things to look for when you are shopping for a scope.

The circuit ground and case of an

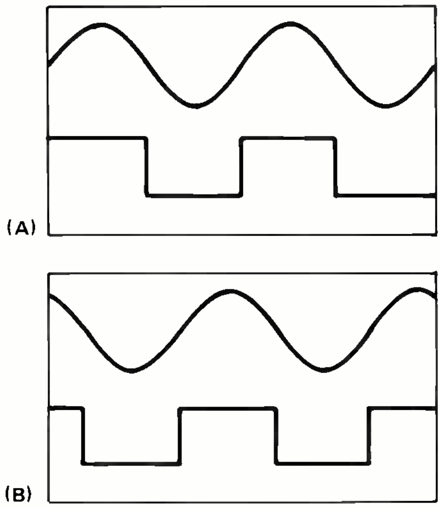


Figure 5 **Dual-trace scopes let you look at two different signals at the same time. By adjusting the level control, you can shift the display from triggering on the zero crossing (A) to triggering at the peak (B) of the waveform.**

oscilloscope are often both connected to the power-line ground through the line cord. Because of this, you should connect the scope's ground test lead to the chassis ground of the circuit being tested or measured.

At high gain settings and without a signal source connected to the oscilloscope's input, stray-field pickup may produce patterns on the screen. This is normal and is equivalent to noise pickup by a high-gain audio amplifier when its input is disconnected.

When adjusting the FOCUS control for minimum spot size, you may see some deflection of the electron beam, even with the horizontal and vertical gain turned all the way down. This is due to external magnetic fields. To check for this, rotate the scope around its vertical axis and note whether the shape of the finely focused spot changes. Likely sources of the fields include soldering guns, power transformers, motors, and ac conductors carrying large currents.

The magnetic fields may also cause a hum-modulation effect on the display when the sweep is operating near 60 Hz or one of its harmonics. To check for this, vary the sweep speed slightly to display one cycle more or one cycle less than before, and note whether the modulation rate changes.

If you set the vertical deflection too high, part of the pattern may appear on the curved portion of the screen, causing the waveform to distort. Some screens are masked to prevent operation on curved portion. If your scope isn't masked, keep the maximum deflection within the linear portion of the screen.

At sweep rates below 30 Hz the display on some scopes may flicker. This is because the phosphor used on the screen has insufficient persistence to provide a steady display. This is a design characteristic, and shouldn't cause concern.

Table 2
Initial setting for triggered scopes

Control	Initial setting
Itensity	Centered
Focus	Centered
Graticle	Centered
Horizontal position	Centered
Trigger mode	AC
Time/cm	0.5 millisecond
Variable	fully clockwise
x5 multiplier	pushed in—off
Trigger select	Channel 1, + slope
Trigger level	fully counterclockwise
Channel 1 position	Centered
Channel 1 volts/cm	0.5 volts
Channel 1 variable	fully clockwise
Channel 1 input	AC
Channel 2 position	fully counterclockwise
Channel 2 volts/cm	50 millivolts
Channel 2 variable	fully clockwise
Channel 2 input	GND

At very high sweep speeds with high intensity settings, an indication of the retrace may appear, usually at the left side of the screen. Again, this is a design characteristic of some scopes.

Some fuzziness of the trace may be observed at signal frequencies above 1 MHz in some scopes. At signal frequencies approaching the response limits of the scope, the setting of the FINE FREQ or FREQ VERNIER control may become critical and require great care.

An overshoot or ringing effect may occur with square-wave signals if their frequency is sufficiently high. The frequency where these effects begin depends on the bandwidth of the scope. With a 5 MHz scope the effects may occur at frequencies of 100 kHz and higher. Before you blame your scope, remember that square-wave generators themselves are prone to these problem.

At low intensity settings and low sweep speeds, you may notice some intensity modulation of the trace. You can eliminate this by turning up the intensity.

When the sweep frequency is increased beyond the flat portion of the horizontal amplifier's frequency response, you may note a reduction in the attainable sweep amplitude. At the maximum sweep rate, horizontal deflection may attain only 80 percent of the screen width, even with the horizontal gain turned all the way up.

On some oscilloscopes there may be a slight defocusing at the extreme right edge of the trace that is not a fault of the CRT. This is a design characteristic and should not cause any problems in operation.

If a scope is operating with a horizontal-sweep width nearly equal to the screen width and the horizontal-gain setting is increased the intensity of the trace may be reduced. This is because the trace intensity decreases as the writing rate of the electron beam increases to produce the wider sweep. The oscilloscope is operating normally if it provides adequate intensity under normal room lighting with the total sweep width equal to the screen width.

High-performance oscilloscopes with sensitivities in the millivolt region are very useful for accurately measuring small signals. However, there are certain caveats that apply.

Even with solid-state circuitry, an oscilloscope may require a warmup period of 15 minutes or so before the trace stabilizes. This is especially true on the more sensitive voltage ranges. The trace may also move slightly on these ranges when the input switch is switched to ground and when measurements are made at different source impedances.

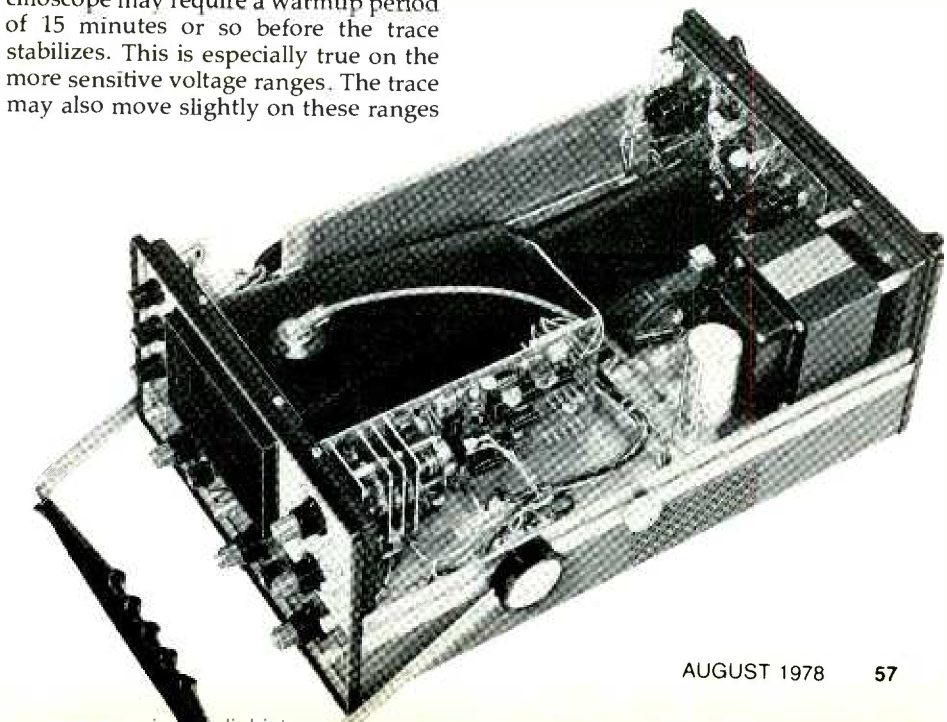
Placement of a sensitive oscilloscope's ground clip may be critical if the signal-source ground carries an appreciable current. There may be a difference of several millivolts from one side of a chassis or ground foil to the other. Accordingly, take care to place the ground clip at the point that gives the least error—usually nearest the signal source. You may have to move the ground clip as you measure different points.

Stray fields are also a problem with sensitive scopes. Stray 60 Hz pickup may be hard to eliminate when you are measuring high-impedance circuits. Shielded cables will help, and it may be necessary to shield the signal source as well. Radio-frequency interference from a transmitter or other equipment may also cause problems. And random noise on the input signal may cause false triggering, particularly on the most sensitive ranges.

Wideband noise generated by the input circuits of the scope itself may cause a widening or defocusing of the baseline in measurements in the millivolt region. Noise on the baseline that appears as hash or spikes can be caused by ignitions, appliances, and other electrical devices. Any kind of noise can cause false triggering.

The baseline may drift when the scope's input is connected across a semiconductor. This can happen because the conductivity of the junction changes as its temperature changes.

The foregoing are some of the many gremlins that may plague your oscilloscope measurements. A knowledge of them and a thorough understanding of your oscilloscope will help you to get the most out of your scope without expecting more than it was designed to deliver.



Computer languages

What is a computer program? How would you set out to write one for your own machine? And what is machine language? Here's the complete story on computer languages and how you can make them work for you.

by Peter A. Stark
Contributing Editor

Half the fun of owning a home computer is having it do something useful—the other half is playing with it to see what else it can do. The first half is easy to do with the many computer programs available from dealers, manufacturers, magazines, and other computer owners you may meet at computer shows or through your local computer club. But playing with a computer to discover what it can do and how to do it requires some knowledge of programming.

The program is a set of instructions telling the computer exactly what to do. Computers are extremely fast, but they can only do whatever they have been told to do. That is, to use a computer to solve a problem, you must tell it exactly what to do at every step, using instructions which are both precise and unambiguous.

Every single step must be written down as a specific instruction; the complete set of instructions then becomes the program.

Since these instructions must be clear and exact—they can have one and only one meaning—they cannot, as yet, be written in English; our language is much too vague for such an exacting job.

Instead, we use a man-made language called a computer language, which has been specially designed to be simple for the computer to digest, yet powerful enough to cover all the possible kinds of instructions we might want to use. Some computer languages may use English words but with a special way or order in using them; other languages may use abbreviations or just plain numbers. Computer languages can be grouped in three types—*machine* language, *assembly* language, and a third group sometimes called *higher-level* language, *problem-oriented* language, or *procedure-oriented* language.

Every computer system has what is called a *machine language*. Since computers work with binary numbers, the machine language also uses binary. The circuitry inside the computer is wired to recognize specific patterns of binary digits, or *bits*, to mean specific operations; a table of *operation codes* tells us which binary code corresponds to which internal operation, so that we can translate the job we want done into the binary numbers the computer needs to understand what it needs to do.

The machine language of the computer is wired into it; that is, the circuits which recognize what each binary code means and control the resulting action, are part of the wiring within the control portion of the computer, and cannot easily be changed.

Although, to be exact, we should mention that some machines have an internal decoding section called a *microstore* which does the actual decoding of these codes, and can be thought of as a second computer within the larger computer.

But from the point of view of a single user, this portion of the system is not usually accessible and so is, for all practical purposes, unchangeable. Thus as you might expect, different computers tend to have different machine languages, although it is possible to intentionally design one computer to have a machine language similar to, or even identical to that of another computer.

So, in general, different computers have different machine languages. Not only are the binary operation codes different, but there may be great differences in what kinds of operations are possible.

Although internally these operation codes are handled in binary, externally we often treat them as octal or hexadecimal numbers (see the explanation of computer numbering systems on page 11 of the June 1978 issue of *ME*.) As a result, a machine language program written in hexadecimal might look like this:

```
0017    9601
0019    8B01
001B      19
001C    8160
001E    2601
```

Since all these instructions are stored in the computer's memory, the left column of such a program lists the *address* of the place or *location* in memory where that instruction may be found, while the right column lists the instruction itself.

For instance, in the above machine language program, the instruction 19 is found in location 001B of the computer's memory. This particular short program is written for a Motorola 6800 microprocessor, but programs for other machines would look similar.

Although it is possible to write programs directly in machine language, in practice this is an awkward and time-consuming job. With a very small computer there may be no other choice, but if the computer has more than a few thousand memory locations, it may be possible to write the program in another language, and then use the computer itself to translate from this new language into machine language. Ultimately, though, the program must be in machine language if it is to be understood by the computer.

The conversion of a program from some other language into machine language is handled by a program loosely called a *translator*. Computer people have different names for these translators, depending on just how they work and what kind of language they translate from.

The translator which converts from assembly language to machine language is called an *assembler;* translators which convert from higher level languages may be called *compilers* or *interpreters*, depending on the translation procedure. The translator program itself is in machine language; it has to be if the computer is to run it. But that does not mean that each user has to write his own.

Translators are readily available for most home computers. All that is required to use one is to have enough memory on the computer so that the entire translator program will fit into it, and also have the right kind of input and output devices so that the translator can be fed the right information.

Assembly language

One step up from machine langauge is assembly language. Also sometimes called *symbolic* language, assembly language is actually very similar to machine language, but it uses letters and abbreviations instead of the binary operation codes of machine language. Because of its similarity to machine language *assembling* it, that is, translating, into machine language is a fairly straightforward process. As a result, an assembler is probably the simplest of all the translator programs.

To understand the idea behind assembly and machine languages, we need to know a bit about the structure of a typical computer. The computer consists of three main parts; the memory, a *central processing unit* (also called a CPU), and some *input* and *output* equipment, more commonly just called I/O.

The memory stores instructions as well as words or numbers being processed, the CPU does the processing, and the I/O equipment inputs and outputs instructions, results, and data.

The memory is divided into hundreds or thousands of separate memory locations, each of which can store one number or letter. To identify individual locations and specify where everything is stored, each location has an *address* which is simply a binary number.

The address for a particular location is different from every other address, so that referring to a specific number by the address of the location which holds it is a simple and unambiguous way of keeping data and programs from being mixed up.

The CPU's job is to perform various kinds of simple operations on the numbers in memory. For instance, the CPU can add two numbers in memory and store the answer in another memory location; it can compare two numbers in memory and perform different steps depending on which is larger; it can modify the numbers stored in memory in various ways.

It can also control the I/O equipment so as to enter information from an input device such as a keyboard into memory, or perhaps output results from memory to a printer or tv screen. All of this is done under control of a program.

In order for the CPU to be able to manipulate numbers from memory, it has a number of internal *registers;* these are simply groups of electronic logic elements called *flip-flops*, which can store a binary number.

These registers are not intended for long-term storage—that is the function of memory. Instead, these registers are used for temporary storage of numbers while they are being worked on by the CPU, or else they may be designed to act as helpers—helping the CPU do a particular job. Registers used for holding numbers being worked on are usually called *accumulators* or *general-purpose* registers.

"Helper" registers generally have names such as *index* register, *status* register, *stack pointer*, *program counter*, etc. The main differences between computers are in the types of registers they have, and what each can be used for.

As a result, most machine language and assembly language programs consist mostly of instructions which shuffle data back and forth between memory and CPU registers, and do some simple operations on them in the meantime.

For example, a simple program to add two numbers and store the sum somewhere in memory might look like this:

Step 1: Bring the first number from memory into the accumulator.

Step 2, Bring the second number from memory, and add it to the number already in the accumulator.

Step 3: Store the result back into memory.

Step 4: Stop.

Although this would be a feasible program, in real life it would not be too useful. Before the two numbers could be added, they would have to be somehow stored in memory; moreover, there should be some way of printing the result on paper or at least displaying it on some kind of display.

As a result, most programs are quite a bit longer than just four steps. Unfortunately, the steps required to enter data through a keyboard or output through a printer are quite a bit harder to write and understand than those that just do the addition, but there is a good point to remember—once you figure out how to do it on a particular computer, you can copy those steps into other programs without having to reprogram them.

As a matter of fact, in many systems the program steps needed to do input and output are permanently stored in a *read-only* memory in such a way that they can be used by other programs whenever needed, and are always available without having to be reprogrammed.

How they differ

With this idea of what the computer is and does, we can tackle the difference between machine and assembly languages. In each of the two languages, the above four-step program would require four instructions, one for each step.

Each instruction, except for the stop at the end, would consist of two parts; an operation code which specifies the type of operation to be done, and an *operand* which tells the computer what to do the operation with.

For instance, the first step in the addition program would have an operation code to mean "bring from memory", and an operand which would specify where the first number is located. But machine and assembly languages differ in how the operation code and operand would be specified.

In machine language, the operation code would be a binary number, although as written down by the person writing the program it might appear as either octal or hexadecimal. Likewise, the operand would also be a number.

In assembly language, the operation code would be written as an abbreviation; the most common code for "bring from memory" is LDA, which means "LoaD Accumulator." The operand would be another abbreviation such as N01 or any other short name which would apply to that number.

Keep in mind, though, that before the program can be run by the computer, it must be translated from assembly language into machine language by an assembler.

It is the assembler which translates an operation code such as LDA into its numeric code, and also translates an operand such as N01 into some numeric address or other number which the computer can understand.

This translation could be done by a human, but having a translator program to do it is much more convenient and also less likely to introduce errors.

Most assembler programs can provide a printout of both the original assembly-language program as well as its translated machine-language version; comparing the two is usually interesting. A typical printout looks like this:

Machine Language		Assembly language		
0000	BD EOAA	START	JRS	INHEX
0003	B7 0010		STA	A N01
0006	BD EOAA		JSR	INHEX
0009	BB 0010		ADD	A N01
000C	BD E06B		JSR	OUTHEX
000F	3E		WAI	

Such a printout is produced by the assembler while it is translating from assembly language into machine language. In most programs, each assembly language instruction translates into one machine language instruction, and the assembler printout lists them side by side.

The machine language portion consists of three columns, which contain the address of the location where the instruction is stored, the operation code, and the operand.

For instance, the first instruction is stored at memory location 0000, has the operation code BD (remember, all of these numbers are in hexadecimal code, and so may contain not only the digits 0 through 9 but also the letters A through F) and the operand EOAA.

The assembly language portion also contains three columns, which have the same meanings: in the first instruction, the word START indicates where that instruction is stored, JSR is shorthand for an operation code called 'jump to subroutine', and INHEX refers to the operand.

Notice that the assembly and machine languages are related. For instance, there are three operation codes of JSR, and all have a BD code in machine language. In the same way, each operand of INHEX is translated into EOAA, and each N01 translates into 0010. ■

Here is a simple program which allows you to type in two one-digit numbers from the keyboard, and prints out their sum; this is an actual printout made by an assembler as it was translating from an assembly-language program into machine language, for a typical home computer system. Only the left three columns were generated by the assembler; everything else is just as it was written by the programmer.

Let's go through it line by line to show exactly what it does:

ORG 0000 was written by the programmer to tell the assembler program that he wanted the following program to be stored in computer memory starting at memory location 0000. In response, the assembler printed the number 0000 at the left; you can also see that the actual program, along the left edge, starts at 0000 and continues at 0003, 0006, and so on.

***START OF PROGRAM is called a *comment:* this is a comment put in by the programmer just so that anyone reading the program will have a hint of what is going on. This particular assembler allows comments to be put in in two ways-either in a line all by itself if it starts with a star (*), or at the end of another line after the instruction. Thus the three lines starting with * are all comments, and all of the explanations at the right end of the printout are also comments.**

START JSR INHEX is the actual beginning of the program. In this particular computer, a Southwest Technical Products system which uses the Motorola 6800 microprocessor, a read-only memory (ROM) holds various programs which can be used for input and output tasks; these programs are called subroutines.

The JSR instruction means that we want the computer to Jump to SubRoutine called INHEX, which inputs a hexadecimal digit from the keyboard into one of this computer's two accumulators, the A accumulator.

In the machine language program, this instruction is located at memory location 0000, the JSR operation code had been translated in to BD, and the location of the INHEX program is changed to the number EOAA, since several lines lower we had told the assembler that the name INHEX EQUals the hexadecimal number EOAA.

STA A NO1 means that the contents of accumulator A should be stored into a memory location called NO1. At the very end of the program NO1 is defined to EQUal the hexadecimal number 0010, so the translated instruction becomes B7, which stands for the STore Accumulator A, followed by 0010, which is the address of NO1.

JSR INHEX repeats the same operation performed earlier—a jump to subroutine INHEX, this time to enter the second number. At this point the first number is in memory location 0010 and the second number is in the A accumulator.

ADD A NO1 means ADD to accumulator A the number in location N01. The assembler translates the ADD into the code BB, and N01 is again translated as 0010.

JSR OUTHEX calls another subroutine within the read-only memory, this one printing the number which was in the A accumulator. Notice that OUTHEX is defined three lines lower.

WAI stands for WAIT, and in this particular computer tells the computer to stop. This is an important part of any program, since the computer is not intelligent enough to know when to stop. It would simply continue looking for more instructions and use whatever may still be left over from previous programs for its instructions. The result, though unpredictable, would almost certainly not be what we wanted.

INHEX EQU $EOAA simply tells the assembler that the label INHEX is EQUal to the hexadecimal number EOAA: the $ is a signal to this assembler that the number which follows is a hexadecimal one. Most assemblers are 'smart' enough that they can accept as inputs decimal, hexadecimal, binary, and perhaps even octal numbers. OUTHEX and NO1 are defined in exactly the same way.

END means just that: end of program. Stop translating.

You may wonder at this point how the assembler 'knows' that JSR should translate into BD and so on. In the case of operation codes, this choice is easy—the assembler program has been written so that there is an internal table within the program which gives all the equivalents between machine and assembly languages.

Each time the assembler meets a new assembly language instruction, it 'looks up' the code in this table much as a human being might look into a dictionary to find the right word in a foreign language.

The names for operands are a different story. Each programmer can define whatever names he wants to use for his operands, and specify those names as part of the program. You might say that the assembler 'learns' new names as it goes along.

When a name, more properly called a *label* by computer experts, is defined as referring to a particular number, the assembler will always translate that name into that number whenever it occurs in the program. As a result, the complete assembly language program must really contain more lines than just the six shown. See the box on page 00 for a complete example of this program.

Now that you have an idea of what machine and assembly languages look like, let's look at some of their features, good as well as bad.

Machine language is fundamental, to every computer, no matter how small. Even if a translator program is not available, the computer can still be programmed in machine language, since the computer will understand such a program just as written.

Moreover, anything that the computer is capable of doing can be programmed in this language. On the other hand, machine language is certainly not simple for us humans. Even a fairly simple computer may have so many different instruction codes that it may be hard to remember them. Moreover, it is difficult to keep track of where every number in a program is stored.

Assembly language is very similar to machine language in that usually eash assembly instruction translates into just one machine instruciton. This means that anything that can be programmed in machine language can also be done in assembly language.

Assembly language has a further advantage that it is easier to write, remember, and understand since it uses easy-to-use symbols instead of numbers, and the assembler keeps track of which name or label stands for which number. But of course this means that an assembler has to be available.

But the biggest disadvantage of both machine and assembly languages is that they both require a good knowledge of the construction of the computer. In order to program anything, you must know all about the various registers, memory locations, possible operations, and all of the other details of just how the computer works.

It's not necessary to be familiar with the actual wiring of the computer, but a thorough understanding of its basic functions is an absolute necessity for a good programmer.

Higher languages

Higher-level languages are often called problem-oriented because they are tailored to fit particular kinds of problems, not particular computers. That is, program instructions are written in a way which describes the job that has to be done, not how the computer is going to do it.

The job of tailoring the problem to the particular computer on which it is to be performed is handled by the translator program.

There are thousands of higher-level languages, but only a few of them are really popular. Probably the best known of all is *Basic*, a language developed in the 1960's at Dartmouth College (see *ME*'s simple prime on Basic on page 46 of the May 1978 issue).

Basic also has some key words which describe the operations to be done, but these are used in a much simpler way. Instead of a complex series of steps to add a few numbers, Basic can do the same task with a simple instruction such as LET A = B + C; printing the answer could be done by saying PRINT A.

The tremendous advantage of Basic is that it does not require any knowledge of how the computer works. When we say LET A = B + C, we do not care where in memory the answer is stored, or just which register is used to do the addition in. In fact, the same instruction might be performed in completely different ways on different computers.

We leave the details of exactly what happens to the translator program. But since the translator program is now doing much more of a job for us, it is also going to be more complex than just a simple assembler so that a larger computer may now be required than if we used assembly or machine language.

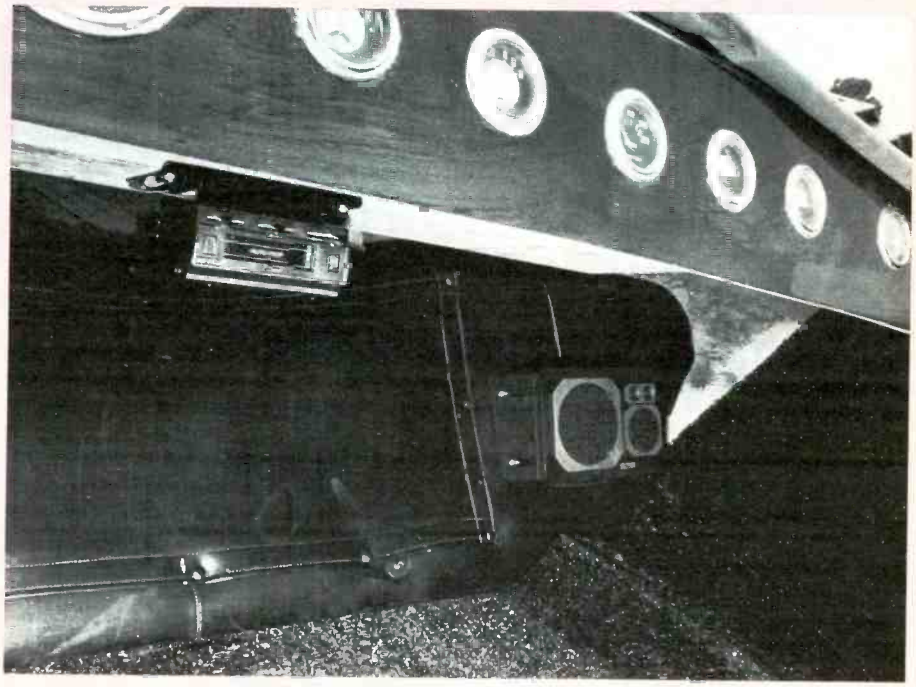
Translator programs for higher level languages are called either compilers, or interpreters, depending on how they work. A compiler is a true translator, which takes an entire program in a lan-

please turn to page 86

Super sounds afloat

Here's a versatile stereo sound system you can install in your boat, tow vehicle or even at home.

by Ron Cogan



Adding a sound system to your boat can provide untold pleasure on the water. The Kraco stereo gear used here was installed under the bow of this boat and away from potentially damaging spray.

There's nothing quite like the healthy roar of your boat's powerplant when taking in a favorite waterway, or the sound of churning water as you slice a wet path with a good ski.

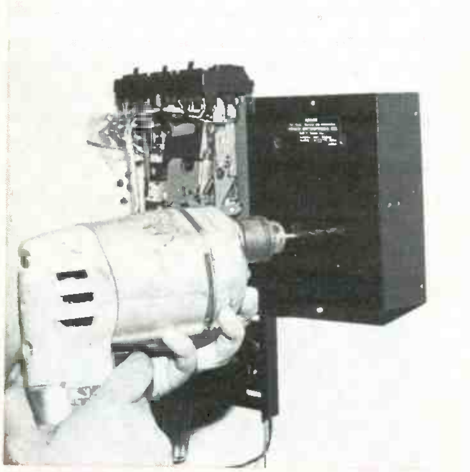
But once you've anchored or beached the boat and it's time to catch some sun and pure relaxation, the absence of sound can be bothersome, and a portable radio a valuable asset in the day's enjoyment.

Taking this situation just a bit further, you might consider adding a more sophisticated stereo system to the boat itself. Many companies offer automotive sound systems that work just as well in a boat as a car, including the gear used in our sample from Kraco Enterprises, 505 E. Euclid Ave., Compton, California 90224.

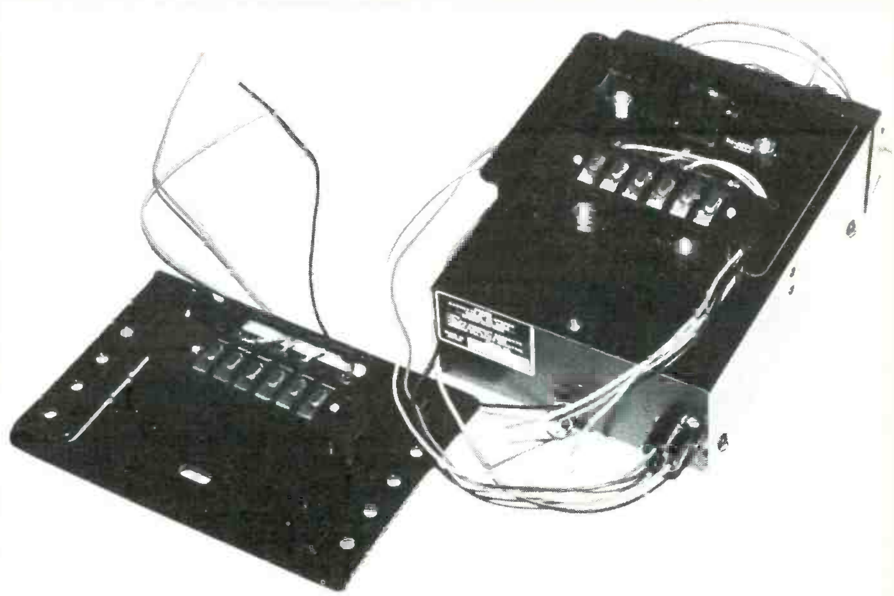
The basic components utilized here, which include a model KS-960A mini cassette deck and a pair of MAG IV surface mount speakers, can be purchased at a nominal cost that will be justified by the untold hours of listening pleasure that will be experienced during your boating excursions.

One valid argument concerning the addition of stereo gear in a boat involves its effective value with regard to frequency of use. For the most part, it would be safe to assume that the boat will be used primarily during the summer months, and most likely only on weekends; therefore, the stereo will experience infrequent use and possibly represent a questionable purchase.

Our answer to this is an approach that



First step is to mount the male slide bracket half to the tape deck. This can be attached with mounting hardware to the deck's mounting bracket or, if you choose, the slide bracket can be bolted directly to the case. Make sure there is adequate clearance for bolt heads inside the deck before you proceed. Mark and drill holes through the case for the bracket half, then attach with hardware supplied.



A slide bracket is basically a simple component that allows you to install and remove your stereo deck quickly. Once the male half is secured to the deck and the female half (pictured on left) mounted in the boat or car, just slip the male half into the female and the deck is ready to use.

The deck's power plug should be inserted into the receptacle at the rear of the unit, then joined to the appropriate leads at the slide bracket. Use insulated connectors or wire nuts to provide a safe splice.

will suggest setting up a versatile system that can be utilized in the home during the week, transferred to your tow vehicle for the trip to your favorite lake, and then again transferred to your boat for listening pleasure on the water.

This type of system will enjoy full-time usage that will represent a sound investment (excuse the pun) regardless of how much cash you spend for the stereo gear.

Along with the basic stereo deck and at least one pair of speakers for the boat, you will need a set of speakers for the house, a set for your tow vehicle, a 110-volt ac to 12-volt dc converter, an interesting little component known as a slide bracket, and two accessory (female) slide bracket halves.

Costs can be cut even further if you opt for surface mount speakers that can be transferred from home to vehicle to boat. You'll still have to route speaker wiring for each system, but the same speakers can be used in each system by simply removing four mounting screws, unclipping speaker terminal leads, and then reversing the procedure when transferring them.

There are no unsightly holes left after

Find a suitable location for the speakers inside your boat. Since keeping these out of the way of water spray is of utmost importance, the speakers were installed on a divider panel that lies underneath the deck (in the bow compartment). Secure the speakers with four screws and route the wiring to the location where you'll be mounting the female slide bracket half.

the speakers are removed, since surface mount speakers have their own enclosures and do not require cutting a large mounting hole.

After purchasing all of the needed equipment from your local stereo outlet or department store, you should familiarize yourself with the gear by reading the instructions and owner's manuals that accompany the packaging.

Male mount

Next, attach the male half of the slide bracket to the top of the stereo's housing with the mounting hardware provided. Plug the stereo's wiring plug into the receptacle at the back of the stereo deck and splice its color-coded wires to the appropriate leads at the slide bracket.

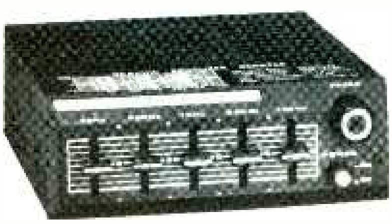
Red and black leads are generally coded at hot and ground, respectively, while speaker leads are often green, grey, or brown. More specific wiring instructions should be included with the stereo owner's manual.

Align the slide bracket against a handy surface and install with the hardware provided. It's a good idea to keep the bracket within easy reach of the driver's seat for convenience later.

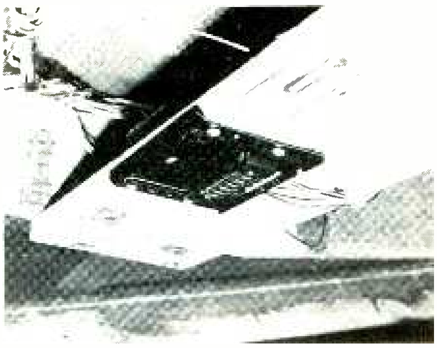
Your next task will be to locate mounting positions for the female slide bracket halves in your boat, tow vehicle, and home. The brackets in the boat and car should be located close to the driver's seat so the stereo will be within easy reach of the driver. The bracket in the home can be mounted under a shelf or desk in a convenient location as you choose. After each of these bracket halves have been bolted in position with four self-topping screws, you should determine suitable locations for the speakers and mount them in place.

These are also secured with four self-tapping screws. Although speakers can be mounted almost anywhere in a car or home, it is important to note that they should be located out of the way of spray in the boat. Speakers that get wet have a rather short life expectancy.

Now you're ready for the wiring ph-



You might also consider the addition of a graphic equalizer booster to your system if you need to boost the sound level above that of your boat's powerplant. Kraco's model KE-5 shown gives your system 30 watts per channel power output and allows you to fine-tune the highs, lows, and midranges for outstanding stereo reproduction.



And now the bracket is ready to accept the tape deck. This system is now wired and ready to go, lacking only the deck—which you can be utilizing elsewhere until boating time arrives.

For total versatility you might consider adding a power converter, extra set of speakers, and another female slide bracket half in your home. Put this type of system together and you'll end up with a very inexpensive stereo system for your house, too!

By outfitting your tow vehicle with another set of speakers and a female slide bracket half, all you have to do is slide in the deck and you'll have instant stereo. Transfer the deck from tow vehicle to boat when you reach the lake for some super floatin' sounds.

ase. In the boat and tow vehicle, find a suitable hot wire and splice this to the *fused* hot lead at the female bracket half. Also, select a ground wire in the boat and car's electrical system and splice this to the ground lead at the slide bracket.

Hot wire

These connections should be made with insulated connectors for lasting safety against short circuits in the future. Connections for your home system are made in a similar manner, though you'll be tying into the hot and ground terminals of a 12-volt converter instead of a standard 12-volt electrical system.

Speaker connections are also important and should be "in phase" for optimum sound reproduction. In simple terms, this means that the color-coded speaker leads at the female bracket halves should be connected to the positive terminal at each speaker.

These terminals are most often designated with a "+" sign or a red dot near the terminal. The remaining terminal on each speaker should be wired to a ground source, either near the speaker or at the stereo deck. Again, all necessary wiring and more specific instructions for this are included in the owner's manual.

Extra speakers

Once you have completed the steps covered the system is ready for use. During the week, the stereo can be slipped into the slide bracket in either the car or home in just a moment and be ready for use. If, however, you choose to utilize a single set of speakers for all of the applications, some extra time will be required to remove and remount each speaker where desired.

I recommend that a set of speakers be purchased for each system unless cash is really tight, as this extra time involved in transferring speakers could prove to be a hassle in the long run.

Now the stereo can be pulled from the home or car and slipped into the boat's slide bracket for waterway cruisin'—it's that simple.

Stereo fanatics might consider adding any number of stereo accessories to their basic system to fit their individual tastes, two particular accessories that enhance a boat sound system are a stereo headphone setup and a power booster.

Both of these will aid stereo enjoyment when listening to your favorite tunes, especially when powering down the lake with your exhaust producing some heavy decibels.

The power amplifier will raise the music's sound level while earphones will shut out surrounding noise just about completely.

And there you have it—a viable, versatile stereo system that stretches your hard-earned bucks into three separate systems for the price of one. Making a triple investment of this type should help you enjoy those stereo sounds even more during your next boating excursions and in the years to come.

Who knows what time it is?

Man has tracked it for a very long time. We've used the sun, the moon, the stars to establish our time frame. Nowadays we use super new physics techniques to know when we are. Here's the story behind the ticks.

by Karl T. Thurber Jr.

Station ZUO provides time and frequency signals for South Africa from its main building at Olifantsfontein. It's operated by the National Physical Research Laboratory on 2.5 MHz and 5 MHz. ZUO operates 24 hours a day, 365 days a year, a distinction shared only by WWV and WWVH of the U.S. and BPV of the People's Republic of China.

The really *precise* determination of time is not all that easy, and it's in fact possible to come up with many *different* measurements of "time," each of which may be perfectly correct and best for a special purpose. In this article, we will point out some of the different ways time is calculated, show how precision time is generated today, and discuss how time is "put together" on a world-wide basis by the International Time Bureau. (BIH)

Evolution of time

The measurement of time has had a very long history. Man has used various celestial bodies such as the sun, the moon, the stars, and nearby planets to establish "time frames" since the dawn of history. Ancient civilizations used these light emitting (or reflecting, as the case may be) sources to determine seasons, months, and years.

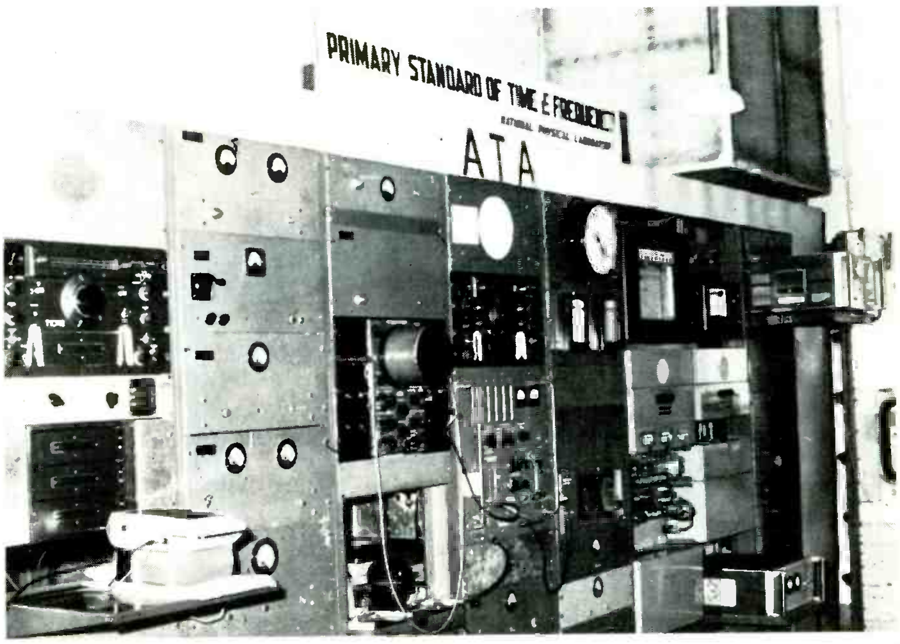
In anceint times, the sun's position in the sky was the only truly reliable indicator of the time of day, and this indicator was useful only when the sun was visible, and of course, it was not very well "calibrated." People later developed *sundials* to help them determine with greater accuracy just what time it was. Sundials gave way to water clocks, and later, to weight-operated clocks, and eventually to spring-driven timepieces (ordinary watches and clocks), which—at least for precision purposes—have begun to be replaced in turn by electrically or electronically regulated devices (such as crystal-controlled oscillators or tuning forks).

Eventually, very high-precision laboratory and scientific work required even more accurate standards of time. The so-called "atomic clock" is now used for the most exacting purposes. In it, atoms of the elements *cesium* or *rubidium* provide the oscillation frequency (and therefore, *time*) control for these ultra-stable and accurate timepieces.

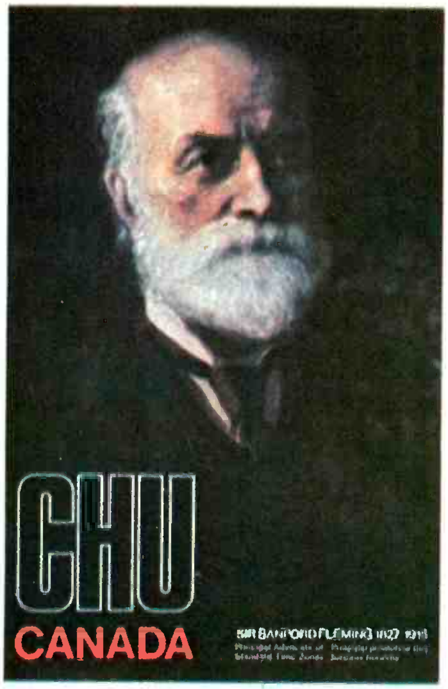
Going back a bit into history, recall that astronomical observations form the basis for man's knowledge of time—observations of the sun, stars, planets, and moon. Controlled observations by astronomical observatories generated daily and nightly time information, and were usually considered accurate enough for such purposes as ship and aircraft navigation, power and telephone companies, radio stations, shortwave listeners, and radio hams.

Star maps

In years past, time measurement was based on the *rotation of the earth*, which was shown to lack uniformity. The time scale developed was known as *Ephemeris Time*, and it formed the basis for most



Accurate time is used throughout the world of science. One source is the control room of station ATA in New Delhi, India. ATA signals are similar to WWV signals familiar to North American listeners. ATA provides accurate frequency and time for the Indian subcontinent on 10 MHz and 15 MHz. It cross-checks signals with JJY in Japan and RKM and RWM in Russia as well as with WWVH in Hawaii. ATA transmissions are based on a Hewlett-Packard cesium clock, originally synchronized by the Smithsonian Astrophysical Observatory, Cambridge, Mass. ATA is operated by the National Physical Laboratory of India.



The QSL card sent to shortwave listeners by Canadian time and frequency station CHU shows Sir Sanford Fleming, principal advocate of standard time zones. CHU is familiar to listeners around the world.

common *astronomical* measurements of time. It was, in fact, originally based on the period of revolution of our planet around the sun for the year 1900.

As far back as 1830, however, the U.S. Naval Observatory provided *Sidereal* (star-related) and *Universal Time*, for the use of ships which navigate using celestial bodies as "stellar maps" and as references for determining local earth time and position. The universal time scale is based not on the earth's orbital motion, but rather on the earth's *rate of rotation* on its axis. As we have indicated, this rate *does* change or fluctuate (by a few milliseconds each day), and since ship and aircraft navigators must depend on earth-related time, this time scale must reflect any changes in the earth's rotation, or errors will result.

Because of this, the U.S. Naval Observatory has as one of its major jobs the publishing of special almanacs that summarize all the astronomical corrections that must be taken into account in order to navigate accurately.

In the 1840's, a standard time zone for all of England, Scotland and Wales was set up which replaced several "local" time systems; it was known as Greenwich Standard Time. In 1884, an International Meridian Conference was held in Washington which pegged "mean solar time" to the 24 standard meridians that gird the earth, based on 15 degree longitude increments east and west of Greenwich.

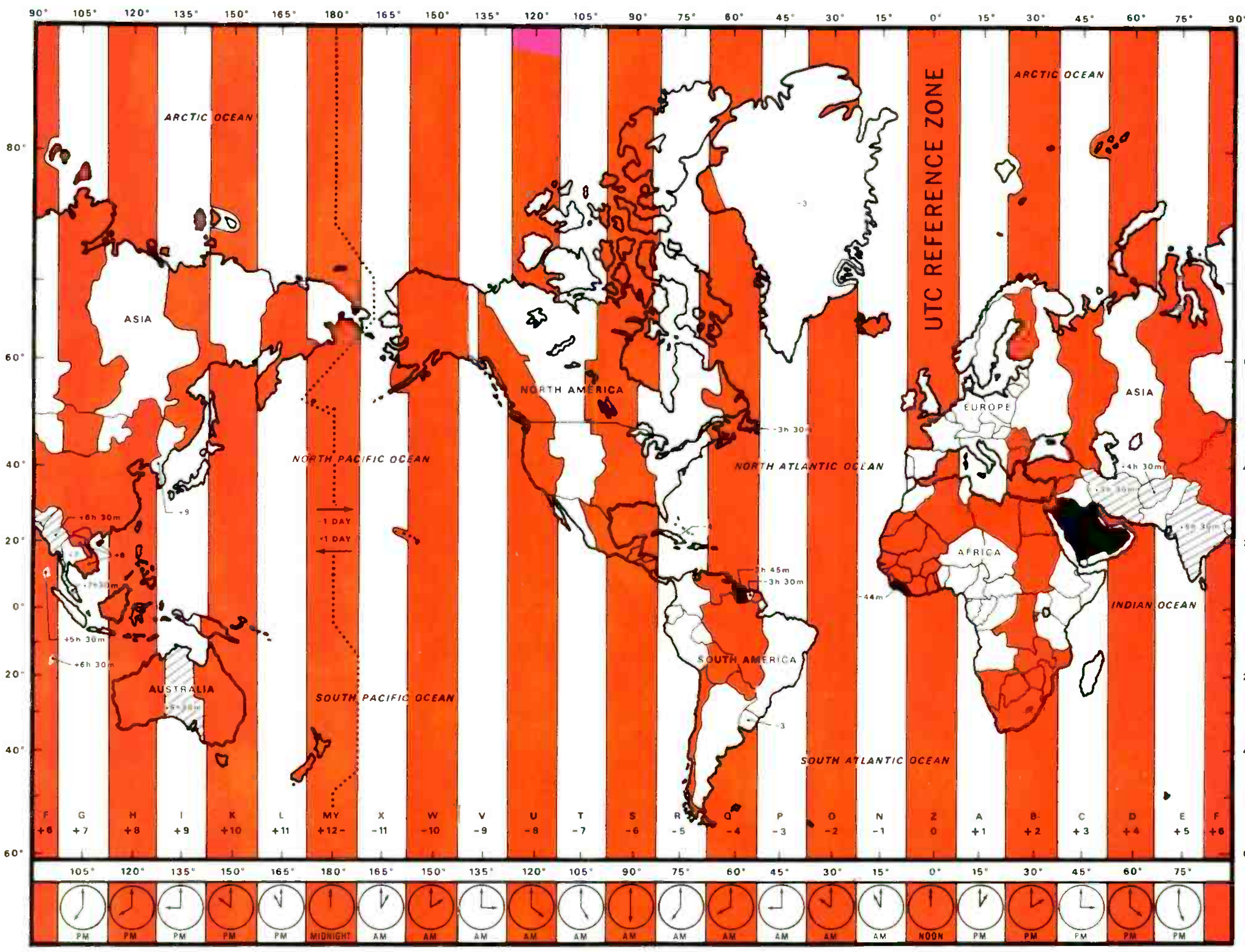
The center of the first time zone was set so as to run straight through the Greenwich Observatory—it was located on the zero-longitude meridian. On the other side of the earth, 180 degrees and 12 hours away from Greenwich, the International Date Line was also set up to roughly bisect the Pacific Ocean.

Most of the time zones still follow the same boundaries as originally drawn, but the lines separating one time zone from another frequently zig-zag to allow individual states, small countries or even islands to have their whole territory conveniently in one time zone.

Atomic time

We've mentioned that Ephemeris (or "heavenly") Time is dependent on the orbital motion of the earth around the Sun, while Universal Time is dependent of the earth's spin on its axis.

But a newer "time scale" is based on *atomic time*, which depends on the fundamental properties of atoms. This latter



Even numbered zone

Odd numbered zone

Half hour zone

Countries and areas which have not adopted zone system, or where time differs other than half hour from neighboring zones.

Figure 1 **Standard time zones of the world**

kind of time is the most precise and uniform. Atomic time can, with the present state-of-the-art, be determined to within a few *billionths* of a second in a minute. Universal time, on the other hand, can only be determined to a few thousandths of a second per day, and its cousin, Ephemeris time can only be held to about .05 second for a nine-year average (due to measurement problems associated with the very slow orbital motion of the earth— one cycle per year.)

Between 1956 and 1960, joint experiments were conducted by the U.S. Naval Observatory, the National Physical Laboratory in England, and our own National Bureau of Standards, which operates the time and frequency stations WWV and WWVH, to establish the "natural resonance frequency" of the cesium-133 atom for possible use as a standard of time.

The NBS was successful, and built the first cesium atomic beam clock in 1957. In 1960, this "resonance characteristic" of the cesium atom became our national standard of time.

In 1967, the International Bureau of Weights and Measures (another standards-setting organization) precisely defined the second in atomic terms. It was agreed to be 9,192,631,770 oscillations or *cycles* of the cesium atom. Thus, the resonance characteristic of the element cesium became the *world's standard* for atomic time.

Important time and frequency stations in the Orient are stations BSF, Taiwan, JJY, Tokyo, and BPV, Shanghai, China. BSF's QSL card is sent to shortwave listeners who send in reception reports. BSF is operated by Taiwan's Telecommunications Laboratories, broadcasting on 5 MHz and 15 MHz in the shortwave portion of the radio spectrum. The station uses rubidium and cesium atomic standards to maintain a very high degree of accuracy. Like most stations, BSF cross-checks its signals with others such as WWV in the U.S. and very-low frequency transmissions from WWVB, JJY and LORAN-C navigation stations. Experts from the U.S. Naval Observatory visit BSF with portable cesium clocks to assure calibration.

Different times

From 1958 through 1971, the time broadcast by WWV and WWVH was based on a time scale known as Coordinated Universal Time (UTC). This was a sort of "modified" atomic time—it was controlled by atomic clocks, but its actual value was *offset* slightly for special purposes.

The identification and dissemination of different kinds of time scales became a knotty problem because the earth's rotational fluctuations affected univeral time but *not* atomic time.

By 1972, there were several of these time scale families in existence, each being essential to certain users of special-purpose time scales, such as navigators and satellite tracking stations. It was evident that a new, "compromise" time scale was needed, and so on January 1, 1972, a *new* Coordinated Universal Time (UTC) time scale was put into use to allow for better precise time synchronization.

Under this new time scale, all time signals (such as those broadcast from WWV and WWVH) are kept in synchronization with earth-derived time scales, by means of *leap seconds*: as changes in the earth's rotational pattern occur, leap seconds are inserted (or deleted) in the time scale to keep the UTC time "in synch."

Thus, it's possible to keep clocks in step with the sun by the as-needed insertion or deletion of the leap second. There is the surprising possibility of special situations occurring in which a "minute" contains *not* 60 seconds, but actually *59 or 61 seconds!* This should not occur, however, more often than once a year.

However, because of the fickle nature of the variations in the rate of rotation of the earth it's not possible to accurately predict far in advance when the leap-second adjustments are needed.

Keepers of the watch

Just *who* does the "adjusting" of the world's time scales? This responsibility falls, by international agreement, to the Bureau International de l'Heure, the International Time Bureau or "BIH." Founded in 1913, the BIH has its headquarters in Paris, France.

Our own National Bureau of Standards and the U.S. Naval Observatory are two of the seven contributors to the atomic time scale maintained by the BIH, the other contributors being government laboratories and observatories in France, England, Canada, Switzerland and West Germany.

Each of the seven "contributes" time

scales to the BIH which smoothes out the seven inputs it receives to produce a *composite* UTC time scale that virtually the entire world accepts as the basis for most time measurements. For most *everyday* purposes, UTC is synonomous with the older form, Greenwich Mean Time, sometimes referred to as "Zulu" time in the military. If you place a "Z" behind a time given in the 24-hour system, e.g., 1600Z, it's assumed to be GMT or UTC, rather than local time.

All this doesn't mean that because world time is now based on an international atomic scale, there is no further need for astronomically-derived time. A person doing celestial navigation, as an example, must know earth position-related time, such as *UT1*.

By international accord through the BIH, UTC is maintained by all the "contributors" to the atomic time scale to be within 0.9 seconds of the navigator's earth-related basic time scale, known as UT1, a time that is "inferred" from astronomical observations and which actually "speeds up" and "slows down" with the earth's rotation rate.

We mentioned that the BIH has the job of putting together all the world's "best estimates" of time to produce a single time scale. It does this by working closely with the seven laboratories and observatories we mentioned, the International Telecommunications Union (ITU) and the International Radio Consultative Committee (CCIR), to ensure both efficient collection and coordination of time measurement "input" as well as effective *dissemination* through the nearly 50 time-and-frequency stations scattered throughout the world.

The BIH's job is a very challenging technical one, and it includes the following important tasks:

- Establishing and "supervising" the International Atomic Time Scale.
- Determining and publishing the current values of Universal Time, the angular velocity of the earth's rotation, and the operational coordinates of the earth's poles (they change!) that are used for time computation purposes.
- Dissemination of the correct UTC time by helping to coordinate time-signal transmissions (such as by WWV and WWVH).
- Providing needed information and data for scientific users of time.
- Performing scientific research for the improvement and refinement of measurements of time.

The BIH recommends standards of time (and frequency, as well) that its seven "contributing" labs should follow to ensure accuracy of the overall time scale. In addition, the Bureau publishes standards for the world's time-and-frequency stations to follow to ensure that their transmissions are coordinated one with another (that is, that they're broadcasting the *same* "synchronized" time information). For example, the BIH suggests that time-signal transmissions shouldn't be off from UTC by more than *one millisecond*, and that the standard frequencies transmitted (such as the 2.5, 5, 10, and 15 MHz signals of WWV and WWVH) shouldn't vary more than 1 part in 10^{10}, or one part in 10,000,000,000.

Thanks to the work of the BIH, we can be quite sure that our familiar references of time and frequency are as accurate as man can make them.

Making better time

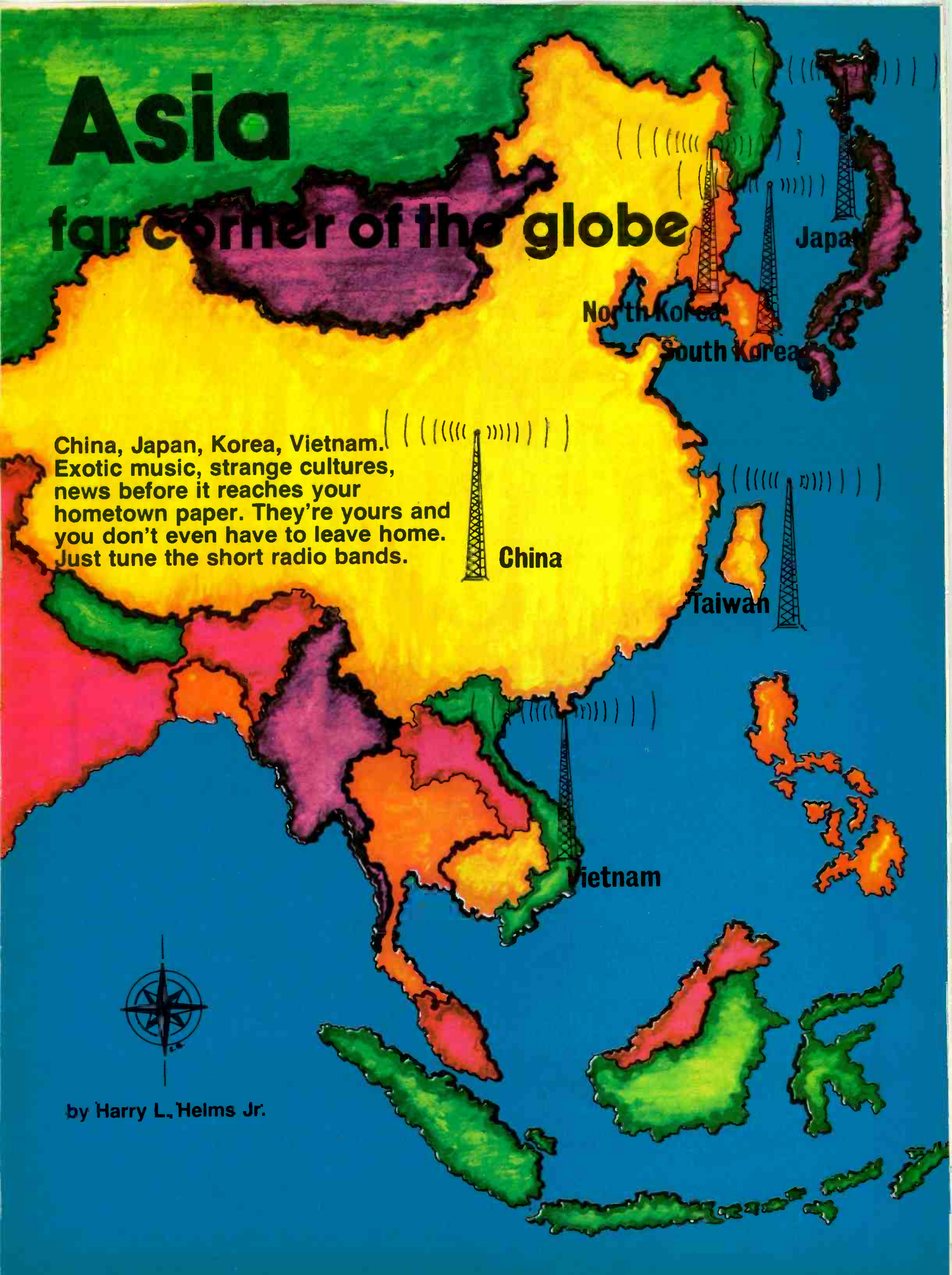
The measurement of time has become more sophisticated with each passing year, and has become much more so since the first efforts at standardizing world time measurements in the early years of this century. Time measurements will become more complex in the future, as new techniques of radio astronomy, laser tracking technology, Doppler ranging of satellites, and other techniques afford even more progress in defining just *what* time is and how to best *measure* it.

The next time you make a time check with WWV, remember that there is much more behind the sound of the "tick" than meets the eye! ■

Asia

far corner of the globe

China, Japan, Korea, Vietnam. Exotic music, strange cultures, news before it reaches your hometown paper. They're yours and you don't even have to leave home. Just tune the short radio bands.



by Harry L. Helms Jr.

Why do you tune the shortwave bands? It may be to keep up with world events, for exotic music and cultural insights, or simply to hear and verify rare DX stations. Whatever the reason, there's a section of the globe that can supply plenty of good listening and rare catches—Asia.

Unfortunately, most of the news out of Asia in the past two decades has been negative, concentrating on the wars in Korea and Vietnam. Lost in all this has been the fact that Asia is also home to a large portion of the world's population, rich in history and varied cultures. It is a changing continent, one that promises to be a major factor in world affairs in the years to come. Through shortwave radio, you can listen in as the nations of Asia speak to the world!

Nippon Hoso Kyokai is not something you order in an Oriental restaurant. But you can get it on your shortwave receiver!

That's the original Japanese name for the Japan Broadcasting Corporation, whose *Radio Japan* is a listening favorite of SWLs everywhere. Radio Japan beams programs to North America on 11705 and 15270 kHz daily at 2345-0045 GMT (6:45-7:45 pm EST).

These English language broadcasts consist of news, commentaries, and much traditional Japanese music. Try to tune in these programs from the beginning so you can catch Radio Japan's opening music, a hauntingly beautiful tune called *Sakura*.

If you're an early riser you can also tune for the general service of Radio Japan, which transmits fifteen minute long English newscasts on 5990 kHz beginning on the hour at 0800 GMT (3:00 am EST) until 1800 GMT (1:00 pm EST). The transmissions at 1000 and 1400 GMT are extended to a full half hour.

Radio Japan welcomes reports from listeners and responds with some of the most spectacular QSL cards found anywhere. Cards are changed several times each year and are a favorite with QSL collectors. You can send your reports to Radio Japan, Nippon Hoso Kyokai, 2-2-1 Jinnan, Shibuya-ku, Tokyo, Japan. Return postage is not necessary.

The giants

Asia's other big radio voice is *Radio Peking*, the English language service of the Peoples Republic of China. Those SWLs interested in world affairs have long been avid listeners to Radio Peking, as the station mirrored the turmoil of the great Cultural Revolution and the internal upheavals following the death of Mao Tse-tung.

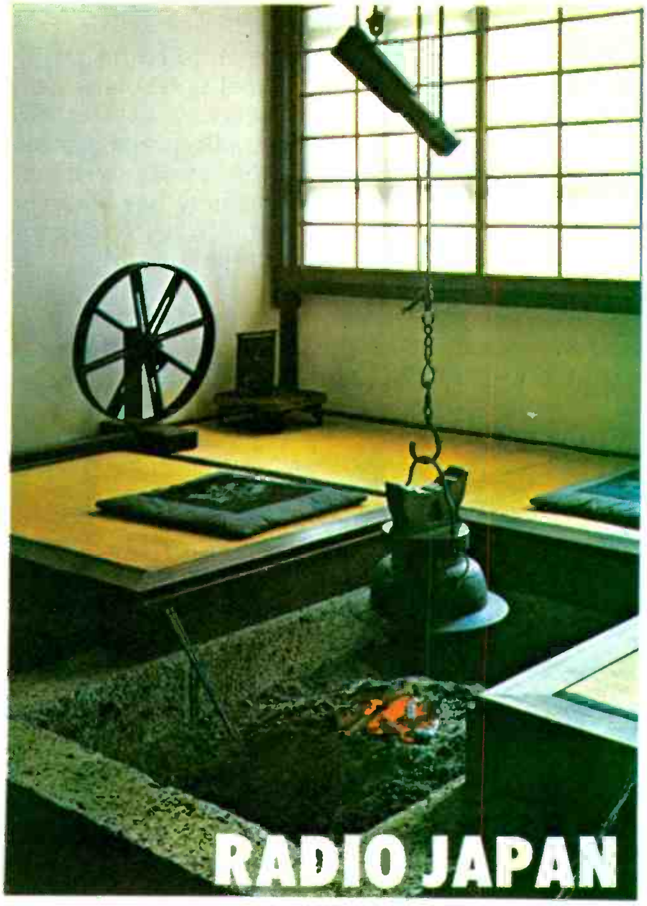
Discerning listeners can also gain clues as to the current status of relations between China and the United States or Soviet Union from Radio Peking's newscasts and commentaries. For those less interested in politics, Radio Peking offers both traditional Chinese music and modern revolutionary works. Tune for their English programs at 0000-0100 GMT (7:00-8:00 pm EST) on 15060 and 15520 kHz and again on 15060 kHz at 0200-0300 GMT (9:00-10:00 pm EST).

Some Radio Peking programs are relayed from Albania over the facilities of *Radio Tirana*, so be sure the transmission you hear actually came from China if you report for a QSL card. All the frequencies we have given are for broadcasts from China.

Peking is a friendly verifier, and usually sends numerous magazines and pamphlets along with their QSL card. Many listeners also have received gifts such as attractive calendars from Radio Peking. Send your reports to English Language Section, Radio Peking, Fu Hsin Men, Peking, Peoples Republic of China. Be careful to use the full name of the country, not just "China." Mail not using the full name will be returned unopened by the Chinese postal authorities! This advice applies equally to *all* Communist nations in Asia.

The other China

Radio Peking is not the only international broadcaster which claims to represent China. The other is the *Voice of Free China*, transmitting from the



Japan QSL card

China QSL card

island of Taiwan. Their English programs originate in the capital city of Taipei and can be heard on 15425 kHz at 0100-0200 GMT. Be forewarned, however, that this station does not have the powerful signals of Radio Peking or Radio Japan. The summer months and early autumn is the best time to hear the Voice of Free China.

Besides the inevitable news and commentaries, the Voice of Free China features much Chinese music and Chinese language lessons in a program called "Let's Learn Chinese." To enroll in the course, or report reception for a QSL card, write the Voice of Free China, 53 Jen Ai Road, Section 3, Taipei, Taiwan, Republic of China.

Countries divided and united

SWLs who have the chance listen to North Korea and South Korea take verbal potshots at each other through their shortwave services. Back in 1972 the two nations agreed to cease radio propaganda against each other as the first step toward eventual reunification of Korea. That agreement has been largely forgotten since then, and it is fascinating to compare the two nations' interpretation of the same news event.

South Korea's international service is known as *Radio Korea,* and it's on the air in English on 9640 kHz at 1000-1030 GMT and also on 9655 kHz at 1130-1200 GMT. Listeners along the West Coast may also be able to hear them on 9720 kHz at 1800-1830 GMT (10:00-10:30 am PST). Programming features many programs on Korean culture and history, with much Korean music, along with news and commentaries. You can send for their QSL card by writing to Radio Korea, 1-Yoido-Dong, Youngdungpo-Gu, Seoul, Republic of Korea.

There's one way to know for certian if you've tuned in North Korea's *Radio Pyongyang*—listen for the name Kim Il-Sung every other sentence! Sung is the leader of North Korea, and is the object of a cult

Japan QSL pennant

(complete with endless praises and quotations from his "thoughts") that may be more intense than the one of Chairman Mao in China. You can hear Radio Pyongyang on 9977 and 11535 kHz at 2300-0050 GMT in English.

It's often difficult to tell where their news broadcasts end and their political commentaries start, although there is much interesting music, especially the newer revolutionary works. Radio Pyongyang will send QSL reports, and a package of propaganda

North Korea QSL card

as well. Address your reports to Radio Pyongyang, Korean Central Broadcasting Committee, Pyongyang, Democratic People's Republic of Korea.

Vietnam no longer occupies the daily newspapers as it once did years ago. Formerly home to numerous pro-and anti-Communist radio stations, all broadcasting today is conducted by the *Voice of Vietnam* (not Radio Hanoi as often reported in the American press).

English is scheduled on 10040 kHz at 1000-1030 GMT and again at 2030-2130 GMT. Besides news and commentaries, the station carries many programs on life in Vietnam after the war and plays traditional Vietnamese folk music.

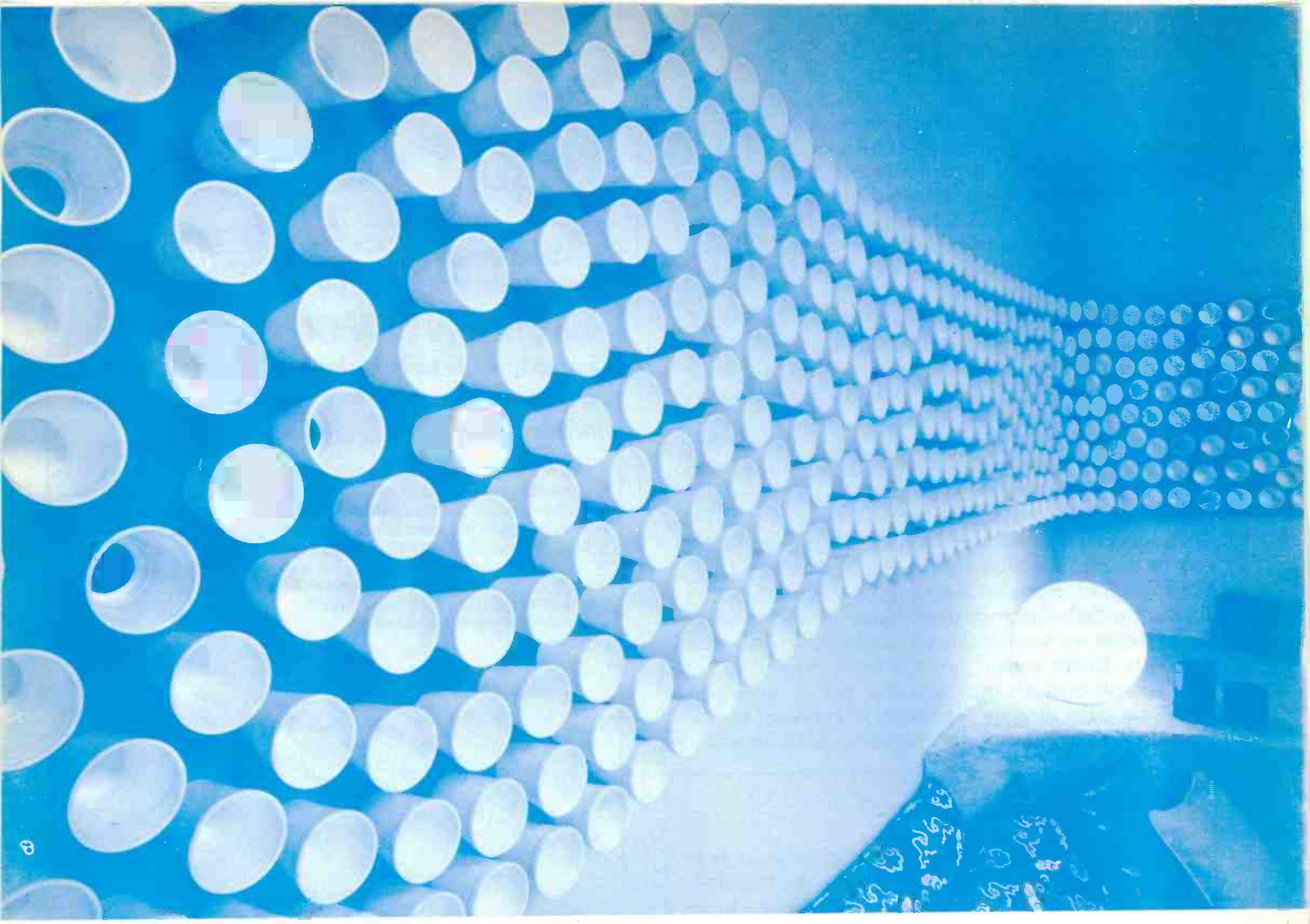
The Voice of Vietnam deserves particular attention from the politically aware SWL during periods when it is engaged in border clashes with neighboring Cambodia and ideological disputes with China. They have recently started verifying reports again, which can be sent to the Voice of Vietnam, 58 Quan Su Street, Hanoi, Socialist Republic of Vietnam.

Despite their distance from North America, all of the stations we've mentioned can be heard on simple receivers. Exotic music, news directly from the source, and insights into how the rest of the world lives—brought directly into your home from far away. That's what *shortwave listening* is all about! ■

How good a DXer are you?

A "DXer" is a special type of SWL who seeks out difficult, rarely-heard stations. All the stations in our article are audible throughout North America on even simple equipment. Yet not all shortwave stations in Asia can be heard so easily. Most nations have shortwave outlets intended for their home audiences, and these operate with lower powers than their international services. All of the following stations have been heard in North America, but it takes good equipment, tuning skill, patience, and even a little luck to catch them. If you think you're equal to the challenge of this DX, here they are:

Frequency (kHz)	*Station*
2510	Taegu, South Korea. Korean talks and music around 1445 GMT.
2850	Pyongyang, North Korea. Male and female talks and martial music at 1315 GMT.
3230	Taipei, Taiwan. Talks and Oriental music at 1415 GMT.
3260	Guizhou, China. Talks and instrumental music at 1400 GMT.
4915	Nanning, China. English lessons for Chinese students at 1345 GMT.
6840	Nei Menggu, China. Chinese dramatic program 1330 GMT.
7512	Tay Nguyen, Vietnam. Newscast in Vietnamese 1300 GMT.



Sound room
customize your den for stereo

How to change your average size living room or bedroom into a top-notch listening environment.

If you have a good ear and a room that's shaped like a wind tunnel, you can change the listening and recording quality of the room. Or, if you have an average-sized living or bedroom and want to make it a better listening environment you can do it yourself with ordinary tools and readily accessible supplies.

First, let's limit the possibilities by considering only practical "do-it yourself" construction, as opposed to a professionally designed and built room.

Generally speaking, an ordinary room has three sets of parallel surfaces: the floor/ceiling and two opposing walls. An adequately designed *listening room* can be developed from this room by using a wide variety of materials, limited, really, only by your imagination.

Basically, the materials used should be soft and multi-surfaced. The softness will help "soak up" the sound, the exposed surfaces will "break up" the reverberation. The efficiency of this process, therefore, is dependent on the degree of softness and number of surfaces exposed.

In the case of the ordinary room where three sets of parallel surfaces exist, you should try to break up these surfaces by covering all or parts of one of the opposing surfaces.

Floor vs. ceiling

For obvious reasons, most people treat the floor instead of the ceiling. However, you could carpet the ceiling and get the same acoustical effect as carpeting the floor. Acoustical tile is commonly used. Sound experts at 3M Company recommend rugs and carpet, rather than tile. The quality of the tile is a major consideration and, once the tile is painted, it loses much of its sound absorption properties.

Drapes on two of the opposing walls are effective. Burlap "wallpaper" works well. Some rooms feature strips of carpeting on the walls with good results.

One effective acoustical wall treatment can be made with foam cups adhered to plywood shapes. The shapes are cut from a 4x7 hardboard panel. They are then affixed to one wall.

Another treatment along the same line is to affix painted egg cartons on a panel or wall. In both cases—foam cups or egg cartons—the idea is to break up the wall surface to soften the sound.

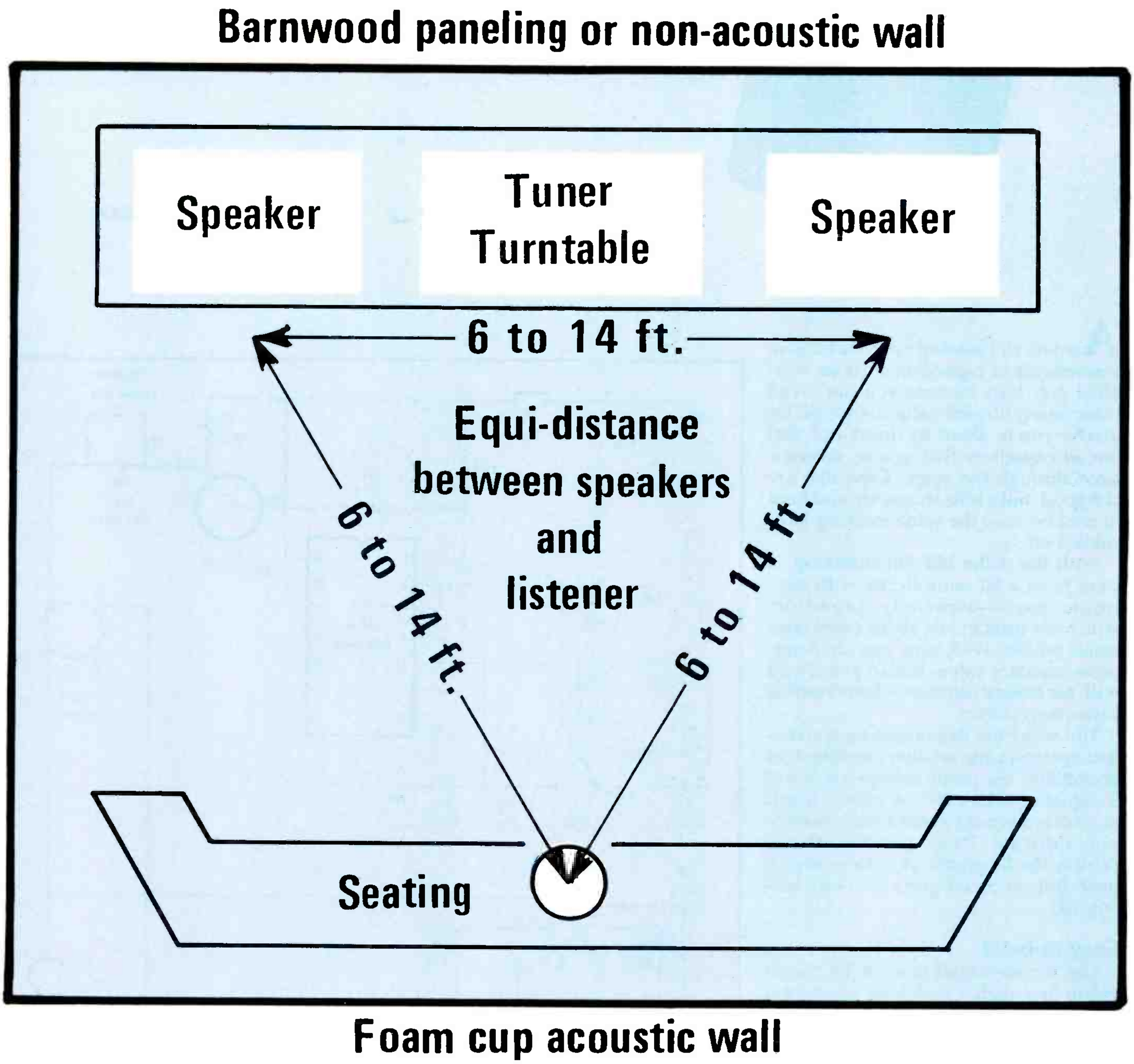
The extent of the surface treatment does not have to be 100 percent. Only 75 to 80 percent coverage should provide adequate acoustical control. Therefore, you can use scatter rugs in place of wall-to-wall carpeting. The walls can be covered in strips of material, soft velvetized wallpaper, drapes, even a Polar bear hide if you desire.

Tweed, not vinyl

Again, generally, a highly fibrous material is better than a smooth, slick one. Tweed would be better than vinyl, for instance. The end result should be a room with "controlled" reverberation. A completely *dead* room is undesirable, because the sound would be unnatural. Remember, on most recordings, a slight echo is added to give the sound a natural tone.

One of the big problems with "listening rooms" in an apartment building, for instance, is the unwanted noise entering from the doors and windows. Therefore, these should be treated with sound absorbing material to keep unwanted noise out as well as containing the music within the room, so it does not distract your neighbors. Ordinarily, most windows are the double pane variety, which helps considerably. Doors should be sealed as tightly as possible around the edges.

Good recordings and good listening can be yours—if you build your own sound room and use name-brand tapes and equipment. —*Dick Ziff*



Plans for Modern Electronics' huge foam-cup graphic and listening-environment conditioner. Three four-foot by eight-foot by ⅛th inch Masonite panels are needed.

Build this easy capacitor meter

If you've got a junk box full of unmarked capacitors, you'll want this easy to build, direct-reading meter.

by Charles Green

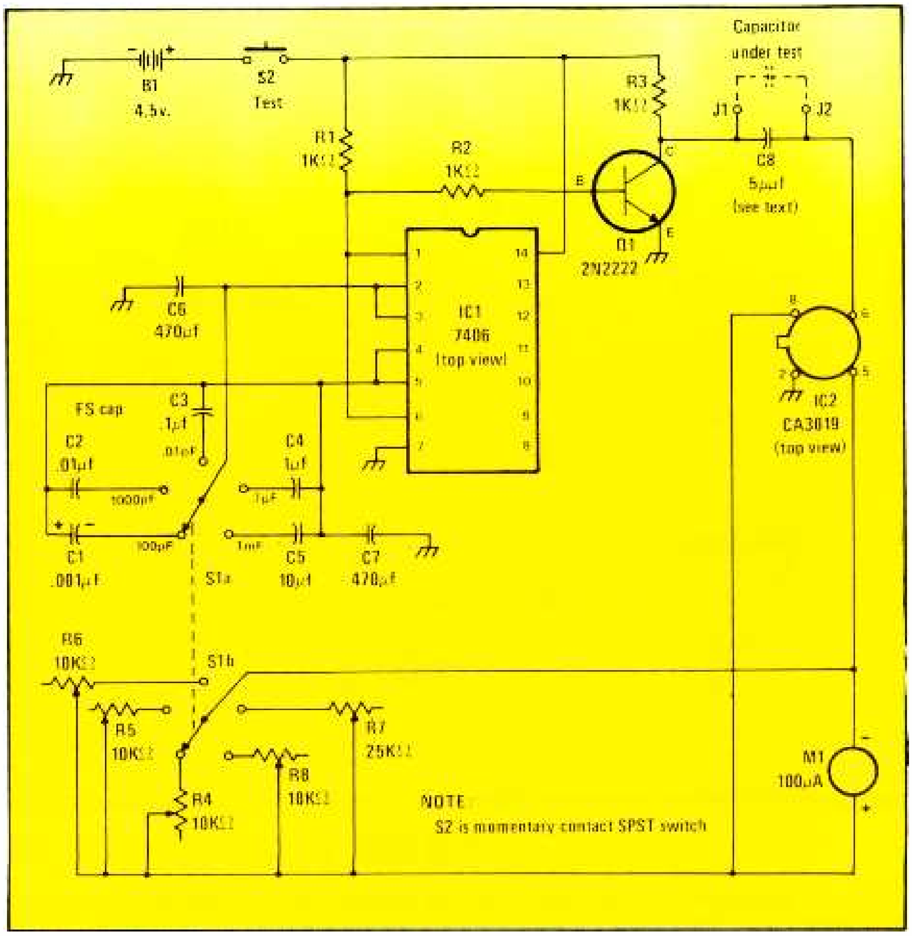
Are you still passing up those bargain assortments of capacitors in those well-filled poly bags because you can't read those nearly illegible value markings? Or maybe you're about to throw out that box of capacitors that you've accumulated through the years. Caps that are still good, but a little shopworn and hard to read because the value marking have rubbed off.

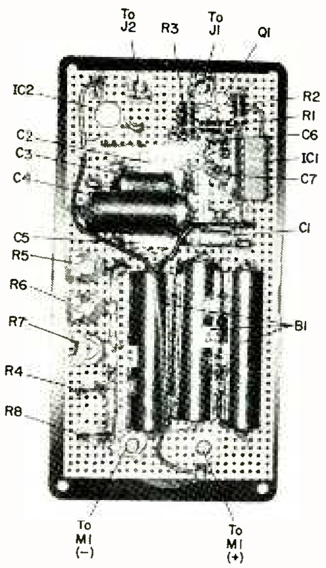
With the dollar bill still shrinking, it pays to be a bit more thrifty with electronic parts—especially capacitors which are used in just about every electronic project. Well, now you can determine capacitor values from 5 pf to 1 mfd with the *Modern Electronics* direct reading capacitance meter.

The meter has five ranges for convenient operation and is battery operated for portability. The circuit uses two IC's and a transistor with a 100 uA meter, which doesn't require any special scales to indicate capacity. Three penlite-batteries furnish the dc power. A battery saving push-button circuit gives you long battery life.

Easy to build

Our model is built in a 6 X 3 X 2-inch plastic box with a matching plastic top panel. The exact size is not important, and can be any convenient size or shape. A larger meter can be used, and you can substitute a metal cabinet in place of the plastic box.





For best results, follow the component layout shown in the photos. Keep the components in the same general orientation for the shortest wiring lengths. Most of the components are mounted on a 5 X 2 ½-inch perfboard section. The controls are installed on the top panel with the meter.

Start construction by cutting out the perfboard section. The perfboard in our model is supported on one end by the meter terminal screws, and on the other end by two solder lugs connected to solder lugs on the front panel terminals. Components are held on the board by soldering to Circuit-Stik conductors made from adhesive copper foil. But, you can use push-in clip terminals as well.

Layout and mount the top panel components M1, S1, S2, J1 and J2. Make sure that you install shakeproof washers on S1 to prevent it from accidental movement. Install solder lugs on J1 and J2.

Temporarily position the perfboard section in back of the top panel and locate the M1 terminals. Then drill holes in the board to fit the terminal screws. Drill two more holes at the other end of the board and mount two solder lugs so that they will be able to mate with the solder lugs on J1-J2.

Install the components on the perfboard section and wire them as shown in the schematic and photos. IC-1 is installed in a DIP socket that fits the 0.1 hole spacing of the board used in our model, but small holes can be drilled as required to fit the particular board you're using.

The three penlite cells that make up B1 are soldered to push-in clips that hold them mechanically secure to the board. Make sure that the polarity of the batteries is correct before wiring them in series.

Mount the components on the board with short leads to prevent movement of the parts. After you complete wiring the perfboard, lay the board alongside the top panel. Then complete wiring the meter with the necessary connections to S1A-B, and S2.

Carefully mount the board on the M1 terminals and complete the connections to the meter circuit. Solder the two lugs to their matching lugs on J1 and J2. Check the perfboard for mechanical stability and for any wiring shorts or opens.

Press the push-button switch S2 and rotate S1 through its range positions. There should be only a very small movement, less than ¼ division, of the meter pointer at the bottom end of the 100 pf range. There should be no meter movement on the other ranges. Recheck the wiring if there is.

A 5 pf capacitor, C8, was added in our model to make the lowest capacity range linear. This may not be necessary in your model.

Before calibrating the meter, mark the top panel with rub-on lettering or with cemented typed paper strips. Install a knob on S1 and make sure that the knob has a pointer or mark to identify the range setting.

Part number	Description	Radio Shack Part number
B1	3 AA cells in series (4.5 V)	—
C1	100 pf ceramic capacitor	272-123
C2	.01 mfd ceramic capacitor	272-131
C3	0.1 mfd ceramic capacitor	272-135
C4	1 mfd capacitor	272-1055
C5	10 mfd @ 16 V tantalum	272-1411
C6, 7	470 pf ceramic capacitor	272-125
IC-1	7406 hex buffer IC	276-1821
IC-2	RCA CA-3019 diode array	—
J1, 2	Insulated binding posts	274-662
M1	100 uA microammeter	—
Q1	2N2222 NPN transistor	—
R1-3	1K, ¼ watt resistor	—
R4-6, 8	10K trimpot	271-218
R7	25Ktrimpot *can be made by connecting a 33K resistor across a 271-220 100K trimpot	*
S1	2-pole, 5-position rotary switch	—
S2	SPST momentary contact switch	275-1547

You'll also need perfboard—.02-inch holes on a 0.1-inch spacing such as Vectorboard pattern P is recommended—a pointer knob for S1, a 14-pin DIP socket for IC-1, and miscellaneous hardware and wire. The prototype was built in an all-plastic box, but you can use just about any enclosure you'd like. A Radio Shack 270-626 should work well.

How it works

An SN7406N TTL hex inverter buffer/driver is used as IC-1. Three of the buffer/drivers are unused. The other three are connected into a free-running multivibrator circuit with the frequency of operation selected by capacitors switched into the circuit by S1A. The larger the capacitor, the lower the frequency of operation. The approximate frequencies are 23 Hz with 10 mfd, 330 Hz with 1 mfd, 3 kHz with 0.1 mfd, 30 kHz with 0.01 mfd, and 250 kHz with 1000 pf.

The square wave output of IC-1 is coupled through a buffer stage, transistor Q1, and through J1 to the capacitor being measured. The IC-1 signal is fed through the unknown capacitor to the full-wave bridge circuit of the diode array CA3019 (IC-2). The rectified output of IC-2 is fed to the 100 uA meter M1. S1B selects the meter shunt, R4 to R8, that controls the sensitivity of M1.

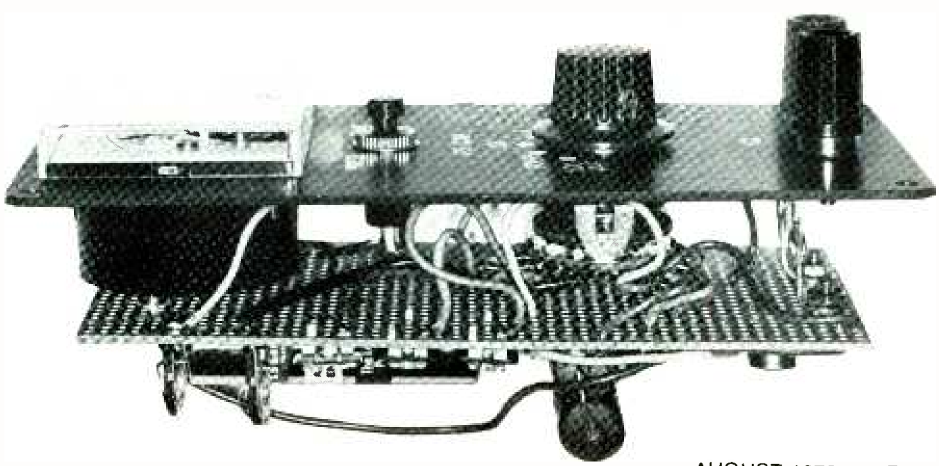
The amount of signal current rectified by IC-1 is dependent upon the value of the unknown capacitor and the frequency of the signal. The meter integrates these values and indicates the value of the unknown capacitor.

If your particular meter has an easily removed bezel, you can cement on a typed "Capacitance pf-uf" marking as in our model. The actual meter scale markings, 0 to 100, don't have to be changed.

Allow a few hours for the meter components to cool to normal room temperature before calibration. Then connect a known value capacitor to J1-J2. While depressing S2, calibrate each range by adjusting the appropriate trimmer potentiometer for a current meter indication.

Operation of the capacitor meter is straightforward. Start at a much higher range than you think necessary for measurement. While depressing S2, rotate S1 downward to the lower ranges until you get a meter indication. This will prevent the meter pointer from pinning at the high end of the scale.

The battery should be checked periodically to prevent damage to the circuit from a leaking, spent battery. Aging of components may require an occasional re-calibration of the meter circuits. A shorted capacitor is indicated by full scale pointer on all ranges.



How automatic gain control works in your radio

AGC: a little-understood but very important part of your shortwave, ham, CB or music radio receiver. It makes listening easy but can seem a mystery in operation. Read this quick explanation and you'll know how the unique system works to keep sound levels smooth. And you'll know how it works when you fire up your test equipment to check out a radio on the bench this weekend.

by George McCarthy, W6SUN

How would you like to be hit right between the ears with something one million times stronger than what you were expecting? In fact, let's make that right "in the ears" for we are talking about radio signals. That's exactly what could happen if you were listening to a signal on your radio that was coming in clearly at an S-3 on your signal strength meter and a local signal at 30 db over S-9 came on frequency.

That's a differential in power level of 60 db, which just happens to be a factor of one million times! And that's not even an extreme, for many signals will "peg your meter" at full scale. Yet, on the other end of the range of power levels it is perfectly normal to be able to get good "Q-5" copy on a signal that is barely wiggling the needle on your S meter.

We are talking about a "dynamic" range of over 80 db on the typical shortwave receiver. From the weakest signal that you can copy—depending on interference levels and the sensitivity and signal-to-noise ratio or your receiver—to the strongest signal that will pin your meter the variation can be as much as one hundred million times!

Signal differential

A rapid change of CB channels or a spin of the dial on a ham receiver will easily bring in just those levels of signal differential. It would seem that such violent changes in signal strength would almost blow your radio out of the water. But there's a device in all radios that prevents that from happening. It's called AGC for automatic gain control. It used to be called AVC for automatic volume control in the earlier days of its use. They both mean the same thing, so don't worry if you see "AVC" on some old radio—it is AGC.

Let's examine how it works and how it got started. In the early days of radio, when the vacuum tube replaced the crystal as a means of detecting radio signals, the amplification of the signal depended on how many stages were used, each one adding to the signal level, or to the audio level if it took place after detection.

Although the audio volume could be controlled by a potentiometer which limited the signal going into the audio amplifying stages, there were times when a very strong local signal would "overwhelm" the radio and cause severe distortion.

To remedy this condition, another control was added to the receiver called the "rf gain" control. This was also usually a potentiometer. It was used to control the "bias" on one or more of the very first tubes that handled the signal from the antenna.

Changing the bias changed the amplification factor of the tube. It could be made far less sensitive to signal levels, thus the rf gain was used to reduce the "sensitivity" of the receiver. This solved the overload problem to a degree.

Blast of sound

But there was clearly a deficiency in operation. If the rf gain were "full on" in order to pick up a fairly weak signal and the dial was changed to pick up a strong signal it could "blast" the speaker or earphones before the listener had time to even reach for the gain control.

Something was needed to make the needed adjustments to receiver sensitivity automatically—fast enough to respond to very rapid changes in signal level. Designers reached for a principle which has been used with increasing frequency in modern technology, the *feedback loop*.

In order to understand how AGC works we must examine "feedback."

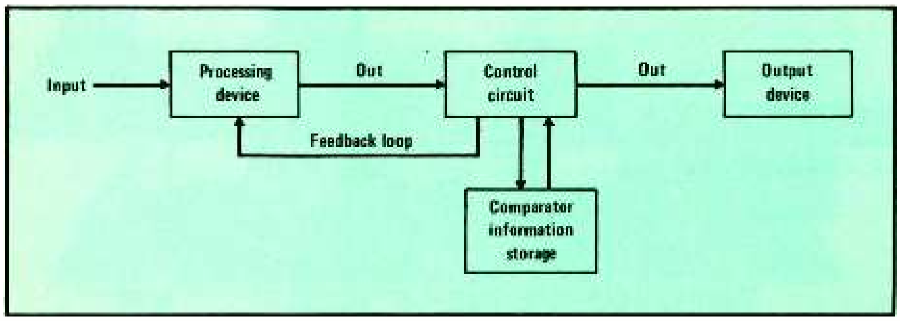


Figure 1 **The basic feedback loop. Information from the processor is used to compare with a standard and signals are sent back to modify the processing function.**

The word has lately made its way into our everyday language in a number of contexts. Now we hear about "biofeedback" in which the body can react to and control some of its own functions.

Or we read about feedback as a device in personal encounter groups, in which people are, hopefully, trained to heighten their ability to be senstive to what another person is trying to communicate and to respond in an appropriate fashion. For those who have ever held a microphone too close to a speaker system and generated an awfull "squealing" sound the feedback was obvious and immediate.

One of the first uses of the feedback principle was in the regenerative detector, which vastly increased the sensitivity of the vacuum tube by taking a little of the voltage from the output circuit and "feeding it back" into the input circuit; it brought the tube to the point of oscillation or beyond.

Feedback loop

In our modern industry the feedback loop is used in the computer, communication and manufacturing industry on a very wide scale. Feedback consists, basically, in taking a sample from a later stage in some consecutive process and using it to generate a control which will be sent back to some prior stage to modify the way in which it is functioning. It's that simple!

In order to have an effective feedback loop we must have a circuit that will react to changes in a specified time limit and generate a control signal which can be used to change the operating parameters.

Devices called "transducers" are widely used in the process industry to convert certain mechanical, physical, chemical or electrical inputs to an electrical output which can be transmitted rapidly to a device which can analyse this input, usually against some standard, and return any corrective electronic signals which may be required.

Other transducers then convert these correcting signals into physical or chemical actions. The oil refining, cement processsing, power distributing, paper mill, steel mill, and many other industries base their controls on such feedback systems, using computers and stored programs to react to any changes in time periods as short as millionths of a second—infinitely faster than any human could possibly respond. See figure 1 for the basic feedback loop.

From the foregoing discussion you can see that "time" is an essential factor in how any feedback loop will work, depending on the exact requirements of the circuit involved. In our immediate concern, the AGC system of a receiver, the time element is controlled by two parts, a capacitor and a resistor.

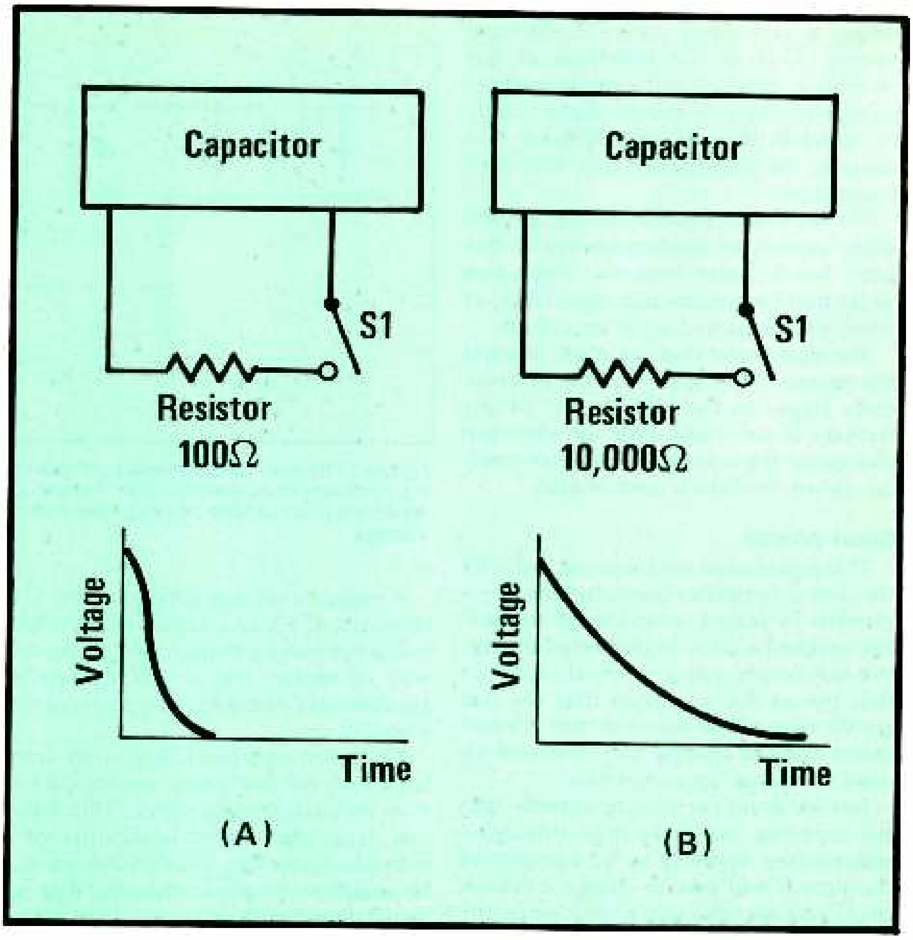


Figure 2 **In "A" when the switch SW-1 is closed, the capacitor will discharge through the 100-ohm resistor very quickly as shown in the decay-rate chart. In "B" when the switch is thrown, the rate of decay will be much slower, as shown on the chart. The values of the capacitor and resistor determine the time constant of the circuit.**

A capacitor has the ability, among other things, of "storing" an electrical charge—much like a battery. The amount of charge that it will store is directly dependent on its capacity measured in microfarads.

Once a capacitor has been "charged" it will retain the electric potential until some path is provided to "discharge" it. We discharge a battery by causing it to do work, such as lighting a flashlight bulb, or running a pocket calculator.

The time that it takes to discharge a battery or a capacitor is a direct function of the amount of current that we pull out of it to do some job. And that depends directly on the resistance of any circuit placed across the capacitor.

If a very low resistance is placed across the terminals of a charged capacitor it will act almost like a short circuit and discharge the capacitor almost immediately. See figure 2. If, however, a high resistance is placed across the terminals the energy in the capacitor will slowly "bleed" out until there is no longer any charge left. This will be done by the current flowing through the resistor.

What we have shown is that the values of the capacitor and resistor can be chosen to give us a particular "time constant" in which the "discharge rate" of the capacitor is regulated by the value of the resistance of the circuit into which it is going to send its energy, "decaying" more slowly with the larger resistance.

Charge time

One other factor involved in the control circuit is the "charge" time of the capacitor—how long it takes before a voltage going into the capacitor will have it in a fully charged condition.

When we consider the time constants of control circuits using capacitor and resistance we are concerned with their "attack" time (how long to charge fully) and their "release" time (how long to discharge). For it will be these times that will determine how long it will take for our feedback loop to perform the function we want it to do.

Bear in mind that the time element is one of the most important parts of any feedback loop, for each requirement needs a specific time factor—there is such a thing as reacting too quickly as well as too slowly, as we shall show.

Now that we've got an understanding of the feedback principle and how the time factor is developed and controlled, let's apply the knowledge directly to our receiver to see what happens. See figure 3.

Radio signals coming in from the antenna are usually in the micro or millvolt range, a very small value of electrical energy. One of the functions of our receiver is to select and amplify a signal so that it can be processed to eventually be heard as the audio modulation that contains the intelligence that had been transmitted.

We will not concern ourselves with other aspects of receiver theory at this time. We do know from our discussion so far that the variation in signal level of what will be picked up is enormous.

We also know that we could control the sensitivity or gain of some of those early stages in the "front end" of our receiver if we could alter the electrical charge on the transistor's base or emitter, or on the tube's control grid.

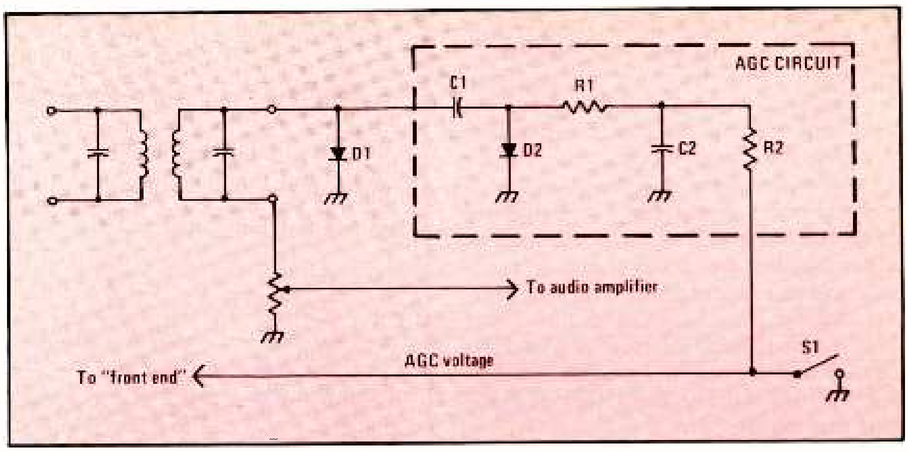


Figure 3 **The AGC circuit takes a sample of the voltage from the detector and feeds it back to the front end to control the gain. Some radios even control the gain of the if stages too. The feedback is in the form of a negative voltage. The stronger the signal, the more negative the voltage.**

Steal power

This is just what we are going to do. By the time a signal has been amplified by a number of stages operating in series it has reached a fairly high level of power. We are simply going to "steal" some of that power for a sample that we will rectify with a little diode to turn it into a direct current charge (dc) that will be used to charge up a capacitor.

But we don't run that dc directly into the capacitor, we make it go through a resistor (see figure 4) so we can control the time it will take to charge it (attack time) and we also use a resistor in the discharge (release time) part of the circuit to control the time it will take to develop the voltage we need for our control.

Now, by selecting the proper value of capacitor and resistors we can use our "sample" to generate a control voltage that will be in exact conformance with the amount of signal that is coming in to that part of the circuit. And the time that it will take to send the sample back to the start of the amplifying circuits is also controlled.

Negative voltage

By using the correct polarity of the diode in the AGC circuit we can store a negative voltage—that is, negative with respect to the ground potential of our receiver.

A negative voltage applied to the right elements of a transistor or vacuum tube will act to reduce its gain. That's another way of saying that it will reduce the sensitivity of that stage to signals coming into it.

The more negative voltage that is run back into the beginning stages the less they will amplify the signal. This action can take place in thousandths of a second—faster than sudden changes can be manifest in audio changes that we could detect with our ear.

It's all done automatically. The AGC circuit simply reacts to any signal level that has reached its place in the chain of amplification and sends a control voltage back up to the front end of the receiver which acts to keep the signal at a given level. That's why you rarely hear any static or other background noises in the presence of a strong signal.

The signal has caused the AGC circuit to generate enough feedback voltage to cut the gain or sensitivity of the front end down to the point where it will not even "hear" signals of lesser intensity than the radio signal.

On the other hand, when there are no strong signals to cause AGC action, you can literally hear the front end of your receiver as it becomes "wide open" to its maximum sensitivity. Then you will hear static and even receiver internal noise. In this state your receiver is very susceptible to any sudden signal.

Often you will hear the extreme of a sideband from a signal that is 5 or 10 kHz away, as a "rasping" sound as the voice hits occasional peaks. Splatter from an overmodulated signal will cause all kinds of "hash and trash" when your receiver is in the wide open mode.

Carrier level

Perhaps a question or two may have occurred to you at this point, such as, if the AGC is going to react so darn quickly to changes in signal level—how come it doesn't keep the modulation in an am (amplitude modulated) signal constant, when we know that the signal level is going up and down in strength right along with the speech being transmitted?

Well, if we made the circuit too fast it would do just that, but we choose the components so that they will react to changes in the carrier level, but not so fast as to distort the modulation.

Fine, you say, but what about single sideband signals which don't even have a carrier to sample? Right. Without a carrier the AGC circuit must look elsewhere for its controlling voltage to be developed.

There are two basic systems used to do this. In one the voltage that is needed to develop AGC action is taken from before the signal is even detected and turned into audio. In the other, the audio is sampled on an averaging basis and the control voltage developed that way. Both work quite well.

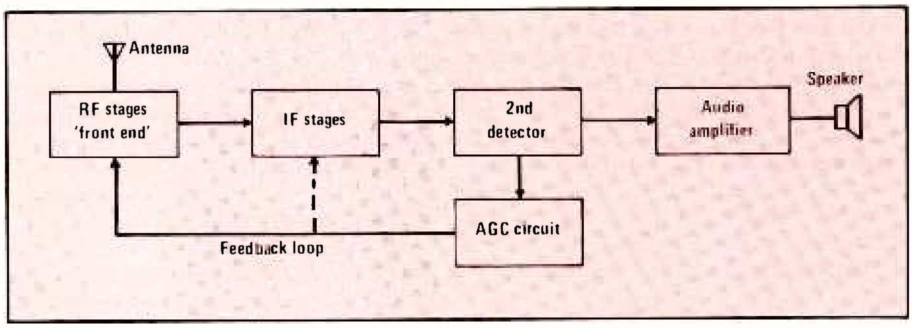


Figure 4 **A typical AGC system. The signal is taken from the if stage through capacitor C-1 and rectified by diode D-2. The voltage is fed to capacitor C-2 through resistor R-1, which determines the charge rate. AGC voltage is sent to the front end through R-2 which determines the discharge rate. Additional resistors will be used for each circuit controlled by the AGC voltage. If switch S-1 is grounded, the AGC will be cut off.**

Time constants

You should know, however, that am and ssb use different time constants for AGC action and CW normally doesn't use any, though it can be copied with AGC on. You see, with ssb the signal is varying over much wider limits than with am.

There is no carrier without modulation, so the "swings" between no modulation and peak modulation are much more extreme and the AGC action must be slowed so that it doesn't act to "clip off" the peak modulation and cause distortion. Many of the better communication receivers (and transceivers) have a switch for "fast AGC", "slow AGC" and AGC off.

If you watch the S meter on a receiver and have the ability to switch from "fast" to "slow" AGC you can see just what is happening. With fast AGC the meter will deflect over a wide scale and the audio will have kind of a "pumping" sound as it will be unnaturally loud on some peaks. As soon as you switch to slow AGC the needle will tend to "hang up" for longer periods as the circuit "averages" the signal. If you take the AGC out entirely the needle will make wild fluctuations as it attempts, unsuccessfully, to follow every consonant and vowel.

There can, in fact, be no better demonstration of just what the AGC is doing than that described above. You should be aware, however, that even with the tremendous dynamic range of a well-designed AGC circuit, there will be some signals that will simply overwhelm the control capability. In these instances an rf gain control is very handy.

Any really good communications grade receiver (or transceiver) should be equipped with an rf gain control for this reason. Those of you who have parked right next to another CBer who was on the same channel, or those who found the Ham next door on the same band know full well what I am talking about.

Compression

There are many other circuits in the radio field that use the feedback loop principle to perform some special function. The ALC circuit in a transmitter is designed to prevent voice peaks from overmodulating by sending back a sample signal to cut the gain of the microphone amplifying circuit. The circuit that "compresses" your modulation in a speech processor also uses feedback voltages to do its job.

Even the smallest and cheapest pocket transistor radio uses an AGC circuit. Some of the very expensive radios use an "amplified AGC" circuit to effect a wider range of control, but the principle and action are the same as for a simple circuit.

So, AGC or AVC or whatever you want to call it does a very important job in our receiver. It not only can keep a wide variety of signals at a fairly constant audio level and save our ears from a blasting, but it also can work on signals that are fading in and out in strength and keep them at a constant readable level. For a diode and capacitor and a couple of resistors it's one of the most valuable circuits in your receiver. ■

Stereo

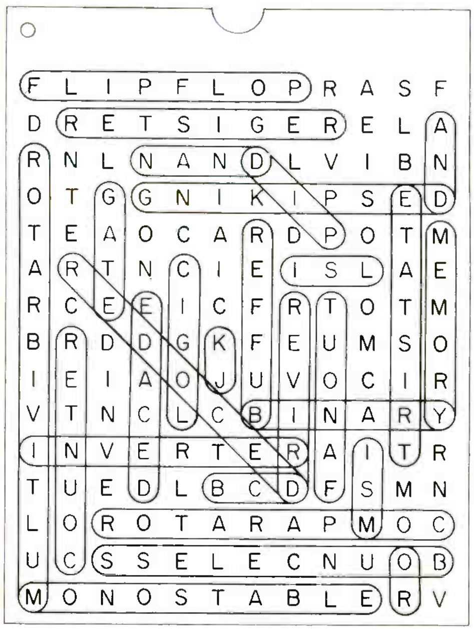
continued from page 19

equalizers has prompted some manufacturers to incorporate them into their regular receivers and amplifiers. Many of the JVC's recievers, for example have a built-in 5-band equalizer, as does Harman/Kardon's Citation 17 preamp ($575). The Marantz Model 3600 ($500) has a self-contained 3-band equalizer while JVC's JP-S7 preamp features a full 10-band octave equalizer for $700.

SAE favors the parametric-type equalizer and put one of them in their Model 2100 preamp, which sells for $750. Incidentally, the figures given here are official list prices which a) are subject to frequent change, and b) often are discounted by local dealers.

Just within the last few months, there has been so much interest in equalizers that makers of car stereo amplifiers now incorporate them in some of the fancier under-dash models. Nobody expects you to fiddle with all those controls while you're driving. The idea is to adjust them to get optimum sound balance in the particular acoustics of your car and then leave them set. Clarion, Jandy Car-Fi, Pyramid Industries and Laser Acoustics are among the firms now offering automotive equalizers. If you have a top-quality car cassette player and some multi-element wide-range car speakers, you may find that this latest wrinkle in on-the-go sound helps bring out the best in the components you already own. ■

Answer to PUZZLE appearing in the June issue.



Computer languages

continued from page 60

guage such as Basic, and translates it into a complete machine language program which is then performed by the computer. The important characteristic to notice is that the compiler translates the entire program before trying to perform it.

An interpreter, on the other hand, never really does a complete translation. It may translate just one instruction at a time into some other language, not even necessarily the machine language, and then immediately perform that instruction.

Partial translation in this way may be easier than going all the way into machine language, and it may also require less computer memory. Moreover, interpreting a program is often more foolproof, since the translator can catch errors in the program as soon as a single instruction has been translated and prevent further translation before any harm is done, while a compiler may not realize that an instruction has errors which will show up some time later when the translated version is finally performed.

In terms of simplicity, then, the interpreter has many advantages over a compiler. But it has one very important fault; it is much slower for programs which have *loops*.

A loop is a part of a program which is repeated over and over. A compiler will translate the instructions in the loop only once, and each repetition of the loop will then require no more translation.

On the other hand, an interpreter will do a completely new translation each time the loop is repeated, because it does only one instruction at a time. Since translating a program from a higher level language into machine language and running it can take considerable time, this places the interpreter far behind the compiler on some programs.

We can see this better by using some typical numbers. Suppose a small portion of a program is to be run 1000 times in a loop. If the instructions in that loop take 1 second to translate, but only 0.001 second to perform once translated, and these are fairly typical numbers, then the compiler will take 1 second to translate and another to run, for a total of 2 seconds.

But an interpreter will take 1000 seconds to translate and 1 second to run, for a total of 1001 seconds. This makes the compiler 500 times faster. In real life, the difference may not be as great. Since the compiler has to do a more thorough job because it has a harder time catching mistakes, it generally takes more time for translating.

Moreover, the interpreter requires less computer memory and so it can often run in a small computer without having to be interrupted, whereas a compiler running in the same computer might require additional time to read additional instructions from external memory devices such as rotating disks or tapes, or might even require continual swapping of memory contents back and forth between main memory and external devices. So the difference in running times may not be obvious except for really large programs.

With all their advantages, higher-level languages must have some weak points, and there are a few. Given a particular program to write, most programmers will require more time to do the job in machine or assembly language than in a higher level language.

But the higher level language will require a larger computer, with enough memory so that it can run a translator program, and will also require more computer time. Not only is more time needed because of the need to translate from the higher level language, but programs translated by computer tend to be less efficient than those written by a good programmer. They require more memory and more instructions, and so take longer to run.

Moreover, most higher level languages, with just one or two exceptions, are intended for specific kinds of programs. Basic and Fortran, for example, are designed for mathematical problems, while Cobol is designed for business.

Although each of these languages can be used for other kinds of programs, it may not always be convenient or easy. It's like trying to drive a nail with a pair of pliers—it can be done, but not as fast as with a hammer.

Difficult tasks

There are some kinds of tasks which are very difficult or even impossible to do with a higher level language like Basic, whereas they might be relatively easy to do in machine or assembly language.

This is why, earlier in this article, we said that anything that a computer can do can be programmed in machine or assembly languge; this is not always true of high level languages. Nevertheless, their ease and speed of use, especially for beginning programmers, makes them still the best bet for most programs.

Very often the translator program is much bigger than the program being translated. If all you need is a small computer for some particular application, then it may not pay to buy a larger one just so it can be used for translating as well. It might be much cheaper to do the translating on some other computer, and just bring the translated program, in machine language, from one computer to the other and feed it into the small one.

If the same type of computer is used both for the translation as well as for the eventual running of the program, then a standard translator can be used, either an assembler or a compiler. An interpreter would not be useful here, because the interpreter both translates and runs, and so only one computer is involved. But there is no reasony why the two computers must be the same.

It is entirely possible to translate a program intended for a small Intel microprocessor on a large IBM computer. The IBM computer need not be able to *run* the program it is translating; all that is necessary is that it be able to run the translator.

In the same way, if you want a book translated from French into German, you need not hire a German to do it. A Russian could do the translation assuming he was sufficiently intelligent and had a good enough dictionary. An assember or compiler intended to translate for foreign computers is then called a *cross*-assembler or cross-compiler.

Many such translators exist, but they are generally used only by professionals, rather than by hobbyists, because the larger computers on which they are used tend to be expensive to use.

Cross-translators have another important use when a computer is first being built. Even before the prototype of a computer comes out of the laboratory, the manufacturer will already know exactly what its machine language will be like. He can therefore write a cross-assembler on an existing computer, and use it to work on programs for the new computer even before it exists.

This gives the programming people a head start with developing important programs for the new computer. In fact, it is possible to write a *simulator* program which will teach an existing computer how to understand a machine language not its own. In this way the programmers can even test programs for a new computer before the computer comes off the production line.

This overview of programming languages is really just that—an introduction. There are many variations on the ideas we have gone over, but many of them are either not important to the user, or else become clearer when the time comes to use them.

How do you learn more about programming and home computers? Programming is as much an art as it is a science. Some of it can be learned by reading books and magazines, or watching other people program, but much of it will even then remain mysterious.

In many ways, learning to program a computer is like learning to drive a car. Even after reading all the books on it, you still cannot pass a driver's license test until you get behind the steering wheel and spend a good amount of time practicing. All of a sudden, all those difficult jobs you never thought you could do will seem easy and you will wonder why others think it hard.

Radio

continued from page 6

cluding what we called the smallest handheld vhf fm transceiver for amateur radio operaters (see *Gear*, page 37, February 1978), the Mark II handheld portable by Wilson Electronics Corp., 4288 South Polaris, Las Vegas, NV 89103.

In the six months since we reported the Mark II, a couple of interesting things have happened: we've had several letters from readers asking for more info. And I've had a chance for hands-on experience with the radio. Here's what I found:

First, it is the smallest on the market at this time. Palomar Electronics and Standard Communications, both well-known California names in radio communications, were showing tiny two-meter handhelds at the Dayton, Ohio, Hamvention this year. But the rigs are not yet available. When they do become available, they apparently will be comparable in size to the Mark II. With Wilson's solid reputation among hams, the newcomers will have a race on their hands when they do enter the marketplace.

How small is the Mark II? It'll fit inside the back pocket of your jeans with only the control knobs and rubber-ducky antenna sticking out the top. It's a chunky little package in the palm of your hand, roughly two-thirds the size of earlier models. It's about the size of a U.S. greenback—or, rather a stack of silver certificates.

Belt clip

It's a lightweight so you feel like carrying it around in your pocket. Or you can sling it from your belt with an optional leather case to keep the rain drops off. And a belt clip, expected soon from Wilson, can be attached firmly to the back of the Mark II.

Inside, there's no radical change. Just carefully planned shrinkage. Wilson has built upon their years of experience with the larger 1402, 1405 and other handheld models in packaging necessary electronics and battery pack in a smaller size. The circuitry is conventional and reliable. No cheap tricks have been used to cut size. Yet it works the same as older models.

The transmitter is rated at 2.5 watts output. An identical model, the Mark IV, expected soon, will deliver four watts.

The receiver has the same sensitivity as larger models. It's ability to reject stations on nearby channels is as good as the selectivity of its big brothers.

I gave a Mark II the New York City road test. In the metro area, two-meter repeaters are spaced 15 kHz apart in the radio spectrum. For instance, it's possible to hear a repeater on 147.150 MHz, 147.165 MHz, 147.180 MHz, etc. Each frequency is 15 kHz from its neighbor.

To test selectivity, I drove to a point geographically located roughly halfway between a repeater transmitter on 147.15 MHz and another transmitting on 147.165 MHz. I listened for chatter on both channels. As *QSOs* (ham lingo for conversations) were underway on both machines, I switched back and forth looking for *bleed over*, as CBers refer to poor selectivity. None was heard. The radio lived up to performance promised by Wilson.

By the way, to make the case as thin as possible, Wilson eliminated sockets for channel crystals. You seat the crystals in small holes in the radio's circuit board and solder them in place. It's a delicate maneuver risking damage from overheating to other components on the printed-circuit board. I would recommend having your dealer or Wilson install the crystals in the radio. It will hold up to six sets of transmit and receive crystals.

The transmitter put out a healthy 3.1 watts, considerably above the minimum 2.5 watts needed to pass muster.

To see if the radio was sensitive in our field user evaluation, I left the repeater channels and used the Mark II for simplex contacts in the city and outside.

Direct communication from the Mark II to a model 1402, both equipped with rubber-ducky antennas, resulted in good copy up to one-quarter mile in the city, and one mile in open countryside.

From the Mark II portable to a mobile station in a car with antenna on a trunk-lip mount, range was doubled. And a base station with a beam antenna was contacted five miles away.

Within the two-meter ham band, repeaters are operated between 144.5-145.5 MHz and 146-148 MHz. Of course the band extends from 144-148 MHz so there are lots of other channels available for simplex contacts. In fact, all 800 channels are available for use in the Mark II. Since it holds crystals only for six channels at a time, many hams program it for four repeater frequencies and two simplex frequencies.

The Mark II starts at about $219. Add to that the special tiny $20 NiCad rechargeable battery pack, which drops into a compartment in the back of the radio, and a wall charger and you are over $250. With a Touch Tone pad for making autopatch telephone calls the price is just over $300. Not bad for a pocketable portable which can talk 100 miles.

Of course, the rig has squelch so you can monitor a silent radio until someone speaks up on the frequency you are listening to.

About the only thing it needs is a built in *frequency synthesizer* so you can work all of the 800 channels without changing crystals. Oh yes, and a scanner on the rig will tune up and down the band looking for somebody interesting to talk to. How about it Wilson?

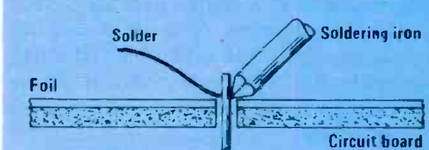
Six steps for successful PC soldering

There's no question about it, using a printed circuit board makes circuit construction much, much easier than old-fashioned point to point wiring. But, if you're not careful, you'll find printed circuits also make it a lot easier to create *short* circuits. That's because it's so easy accidentally to leave a solder bridge between two adjacent foil strips.

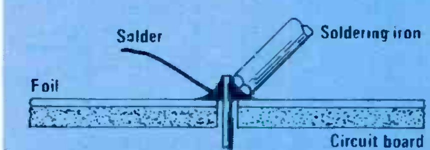
Another problem you might encounter using printed circuit boards is a false connection—a solder joint that looks good, but is in fact no connection at all. This happens when only the component lead is heated. The solder forms a blob on the lead, which becomes insulated from the copper foil by rosin from the solder's core.

The trick to using printed circuit boards is to do a good job of soldering the component leads to the copper foil. It's really easy to do, if you'll follow these tips and take your time.

- Use a soldering iron designed for use on printed circuits. These are usually rated at 25 watts and have relatively small tips—perhaps a chisel point about 1/8th-inch wide.
- Use a top-quality electronic solder, which must be of the rosin core variety. Use the smallest diameter solder you can obtain.



- Place the soldering iron tip on the copper foil and against the lead to be soldered. Apply the solder to the junction of the foil and lead on the side opposite the soldering iron.



- When the foil and lead have been heated to the proper temperature by the soldering iron, the solder will *flow* onto the foil and lead like a drop of light oil.
- Remove the solder and iron. As the solder cools and hardens, it should appear smooth and it will shine.
- As you remove the soldering iron from the foil, *lift* it away. If you drag it away, you risk making a solder bridge across the gap to the adjacent foil strip.

How to use IC timers

Some of the best fun you'll have experimenting in electronics will come when you work with timers. Building clocks, triggering gadgets, pulsing your test gear, however you use them, you need to know just exactly how timers work. Here's the a complete explanation of the latest integrated-circuit timers you'll want to try on your own home workbench.

by Joseph J. Carr

Timer circuits using bipolar or unijunction transistors tend to be very sensitive to problems such as changing supply voltage, temperature, and so forth. Certain *integrated circuit* timers, on the other hand, eliminate these problems and are a lot easier to tame when designing circuits. The IC timers include the 555, 2240, 2250, and 2260 devices.

The 555

Figure 1 shows the insides of a 555 integrated circuit timer. This low cost IC has become one of the most popular on the market. It is widely available from both industrial sources and mail order and local supply houses that serve amateur and electronic hobby markets.

The main reason for the popularity of the 555 is its flexibility. It is neither TTL nor CMOS, but *is* of bipolar design, meaning that it contains ordinary NPN and PNP transistors. One difference between the 555 and typical TTL chips, which also are bipolar devices, is that the 555 can be used with a wide range of power supply voltages.

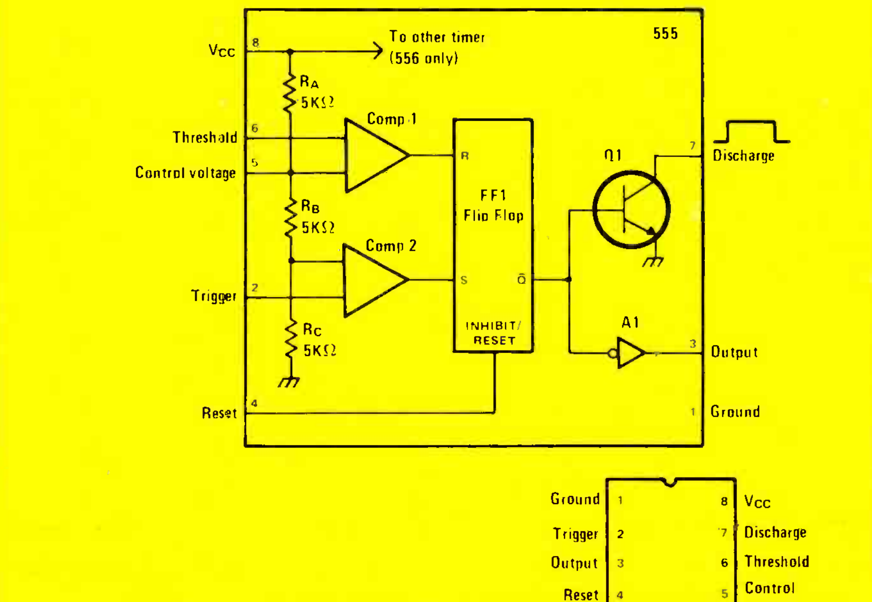


Figure 1 Internal block diagram and pinouts for 555 timer.

TTL requires exactly 4.75 to 5.25 volts. The 555, on the other hand, operates over a range of 4.5 volts to 18 volts, with something in the nieghborhood of 9 to 12 being considered optimum.

When the output terminal of a 555 is in a *low* state it can *sink* up to 200 milliamperes of current. Alternatively, when the output terminal is *high* it will source up to 200 milliamperes. The wide range of operating voltages and the ability to restrain or pass so much current allows the 555 to be used in lots of circuits without external components, and even more applications with external components. The range of possible applicatons is limited mostly by the imagination and cleverness of the designer.

In the *astable* mode of operation the 555 will become a source of squarewaves with the frequency and cycle controlled by an R-C network. In the *monostable*, or "one-shot" mode the 555 will operate as a single pulse source, timer, or signal delay line. The 555 timer is one IC where an understanding of the internal workings is essential to making *you* a clever designer.

Most presentations draw the circuit diagrams as they would appear in a schematic. But, in our approach, we will use the block diagram of figure 1 in each

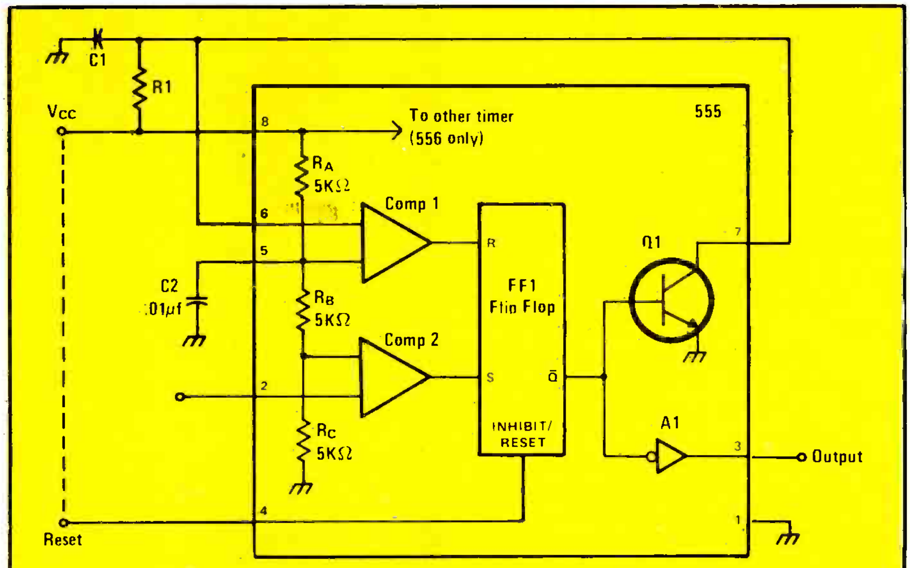


Figure 2A Monostable multivibrator built around 555 timer IC.

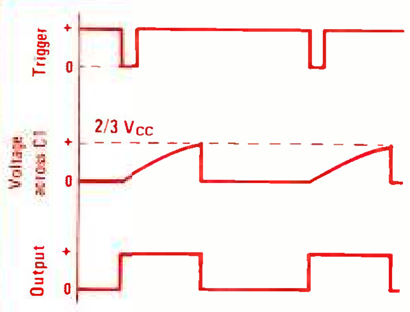


Figure 2B Waveforms for 555 timer circuit.

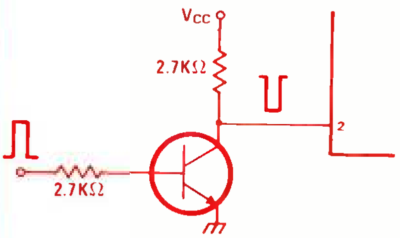


Figure 2C Transistor inverter for triggering 555 timer.

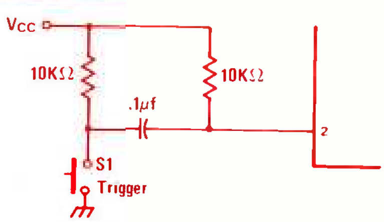


Figure 2D Manual triggering circuit for 555 timer.

circuit presentation. This will allow you to analyze each circuit in terms of the internal block diagram.

Monstable mode

A monostable *multivibrator*, or "one shot" as it is often called, remains off (output in *low* state) until it is triggered by an external pulse. After is is triggered, the one-shot will produce a *single*, constant amplitude output pulse of *fixed* duration. This means that the output terminal will snap *high*, and will remain high for specified time, after which it drops low again.

The low state in the 555 is considered the *stable* state. The output terminal will normally remain low, but snaps high when a *trigger pulse* is received. The high state is an unstable state, so the output remains high for only a fixed time period, and then drops back to the low stable state. Since only one of the two possible states of the 555 are stable, we call it a *monostable multivibrator*.

Figure 2 shows the 555 connected in its monostable circuit. The heart of the 555 is an R-S flip-flop (FF1) that is controlled by a pair of voltage comparators. An R-S flip-flop is a *bistable* circuit. That is to say, it has *two* stable states. In its initial state, following power turn-on, the Q output is low and the not-Q (Q) is high. If a pulse is applied to the flip-flop's SET (i.e. "S") input the situation will reverse itself, and the not-Q output drops low and Q output goes high.

Under the initial conditions the not-Q output of the flip-flop is high and this turns transistor Q1 on hard, placing its collector (IC pin no. 7) effectively at ground potential. This keeps the external capacitor (C1) discharged. Amplifier A1 is an inverter, so a high on its input (also from the not-Q of the flip-flop) causes its output to be low. The output of A1 is also the output of the 555, and comes out on IC pin no. 3.

Voltage comparator

A *voltage comparator* is basically an operational amplifier with no feedback resistor, so its gain is very high. As long as the voltages applied to the two inputs are equal, then there is no output, but if the voltages are different either a positive or negative output occurs. In this case only positive outputs are possible.

Resistors Ra, Rb, and Rc are inside of the integrated circuit, and are of equal value, nominally 5000 ohms. These form a voltage divider that biases the inverting (—) inputs of the voltage comparators.

The inverting input of comparator no. 1 is biased to a potential of ⅔-Vcc, if you want to prove that apply the voltage divider equation. This means that the output of comparator no. 1 will reset the flip-flop when the voltage applied to the threshold terminal (pin no. 6) reaches ⅔-Vcc.

The same voltage divider applies a potential of ⅓-Vcc to the inverted input of comparator no. 2. The flip-flop in the 555 is set when the voltage on the trigger input (pin no. 2) drops to ⅓-Vcc.

Negative-going pulse

The *control voltage* in this circuit is the potential across capacitor C2, which charges through resistor Ra and will reach the ⅔-Vcc level in less than one millisecond after power is applied.

If a short, negative-going, pulse is applied to the trigger input, then the comparator will set as soon as the pulse amplitude drops to a level of ⅓-Vcc. This places the flip-flop in the set condition, with the not-Q output low, and the Q output high.

If the not-Q of the flip-flop goes low, two things will occur simultaneously. One is that the discharge transistor Q1 1s turned off, so capacitor C1 will begin to charge through resistor R1. Secondly, the output terminal, which is driven by amplifier A1, snaps high. The voltage across capacitor C1 is applied to the noninverting input of comparator no. 1.

When the C1 voltage reaches ⅔-Vcc (see figure 2B) the comparator will reset the flip-flop, returning it to its initial condition, with not-Q high. This condition turns on Q1, discharging C1, and causes the output to go low.

The length of time which the output will remain high is given by T = 1.1 X R1 X C1 (where T is in seconds, R1 in ohms, and C1 in *farads*). The time relationship between the trigger pulse, output pulse, and the potential across capacitor C1 is given in figure 2b.

The *reset* terminal is used to reset the flip-flop (hence also the 555 output) to its initial condition. If a negative-going pulse is applied to the reset input and the trigger input simultaneously, then the output pulse will terminate, causing the

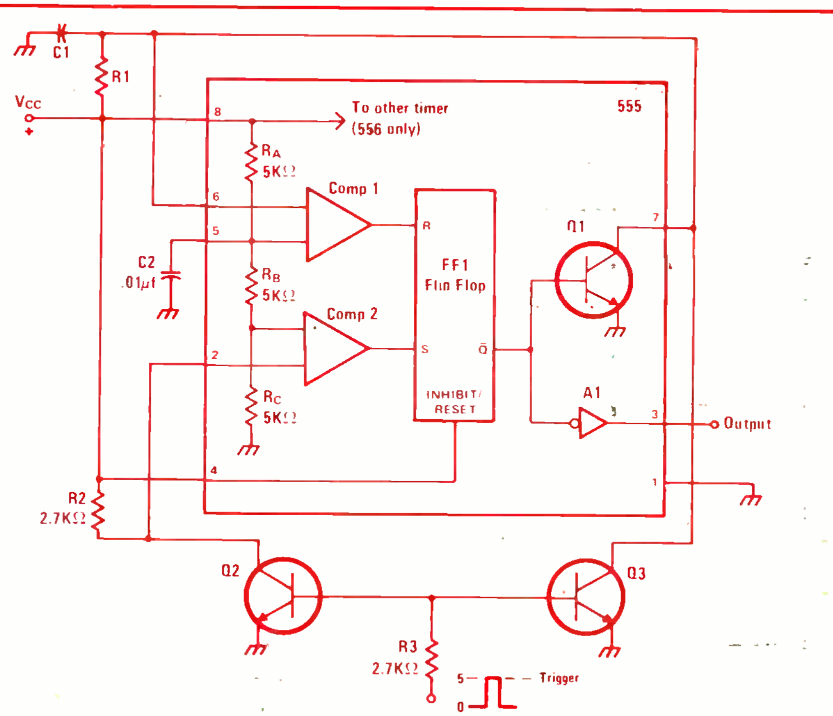


Figure 3A Retriggerable one-shot built around 555 timer IC.

flip-flop to return to its stable state. If the reset terminal is not used it should be permanently tied to Vcc so that noise pulses will not interfere with the operation of the 555.

Figures 2c and 2d show methods for triggering the 555. In figure 2c an NPN transistor is used as an inverter stage. When its input is held low, the transistor is turned off, so its collector is essentially at Vcc; holding the trigger input high.

When a positive-going pulse is applied to the base of the transistor it will turn on briefly, causing the collector voltage to drop suddenly. When the collector voltage drops to ⅓-Vcc the 555 output will go high.

Finger the trigger

Figure 2d shows the use of a pushbutton switch to manually trigger the 555. When the switch is open the capacitor is not charged, and the trigger terminal of the 555 (pin no. 2) is held high.

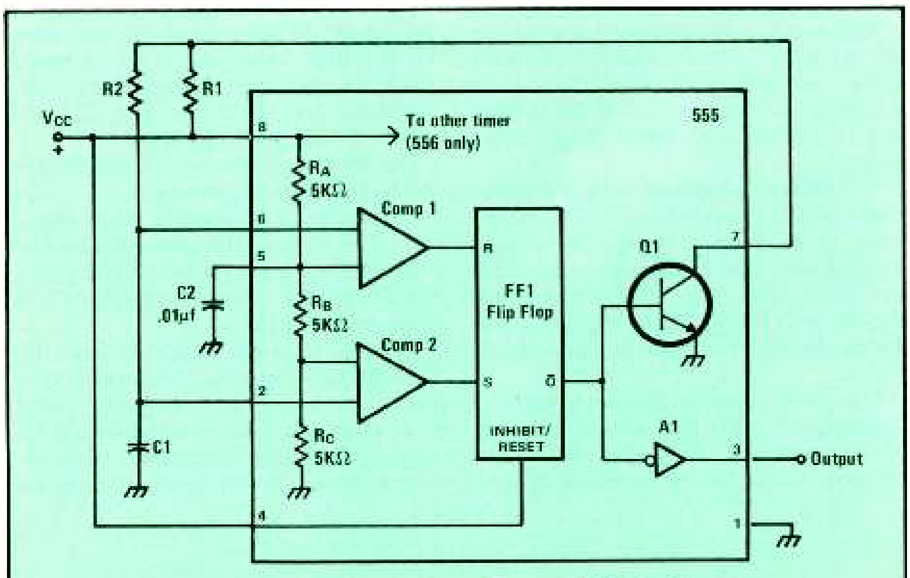


Figure 4 Astable multivibrator built around 555 timer IC.

When the switch is closed, however, one end of the capacitor is grounded, while the other end is still attached to the trigger input. For a brief instant set by the R-C time constant the voltage will drop, as the capacitor charges. When it drops to ⅔-Vcc the 555 will trigger.

To summarize operation of the 555 in the monostable multivibrator mode, in the stable condition the control voltage (pin 5) is at ⅔-Vcc and the trigger input is at ⅓-Vcc. The R-S flip-flop is in the reset condition with its not-Q output high. This places the output terminal of the 555 (pin 3) in a low condition, and turns on transistor Q1, which keeps capacitor C1 discharged.

When a short negative-going pulse is applied to the trigger input (pin 2) voltage comparator no. 2 sets the flip-flop, forcing the not-Q low. This turns off Q1, allowing C1 to charge through resistor R1, and causes the output terminal (pin 3) to go high. The trigger pulse must drop to a level of ⅓-Vcc before the comparator will set.

The voltage across capacitor C1 is applied to the threshhold input of the 555 (pin 6). When this voltage reaches a level of ⅔-Vcc the flip-flop will be reset by voltage comparator no. 1. In this condition the flip-flop not-Q output goes high again, causing the output (pin 3) to drop low, and turning on Q1. When transistor Q1 is turned on the voltage across C1 is dropped suddenly to ground potential.

The time required for the voltage across C1 to reach the ⅔-Vcc level that turns off the output is approximately 1.1R1C1, and this time is the duration of the output pulse appearing at pin no. 3 of the 555.

The monostable multivibrator will trigger when a pulse is received at its input, causing the output to go high for a specified duration. Subsequent trigger pulses that arrive while the output is high, prior to the expiration of the one-shot's period, are ignored. A *retriggerable one-shot*, on the other hand, will accept those subsequent trigger pulses and extend the output pulse by one period. The total time the one-shot remains high is the expired portion of the first period and one additional period.

The 555 is not normally considered a retriggerable one-shot. The circuit of figure 3a, designed by engineer C.E. McCullough, operator of amateur radio station WB4DVR, allows such operation of the 555. The timing waveforms for this circuit are shown in figure 3b. When a trigger pulse is received at time t_0 the 555 output will snap high.

Normally, the output would remain high until its period expires at time t_2, and would then drop low. But in this case a second trigger pulse is received at time t_1 and this extends the "up" time for

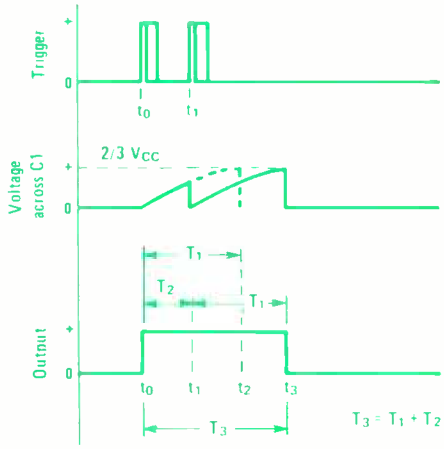


Figure 3B Waveforms for 555 retriggerable one-shot.

one complete period from t_1 to t_3.

The total time that pin 3 is high will be one complete period (i.e. 1.1R1C1) from t_1 to t_3 *plus* the portion of the first period (t_0 to t_1) that had expired when the second trigger pulse occurred.

Figure 3a shows the modified 555 one-shot circuit that allows retriggerable operation (transistors Q2 and Q3 are added). Transistor Q2 serves as an inverter for the trigger input (as in figure 2c), while transistor Q3 is connected in parallel across Q1 and C1. When this transistor is turned on, C1 will be discharged.

When the first trigger pulse is received at time t_0 (figure 3b) the collector voltage on Q2 drops to ground. When it has dropped as far as ⅓-Vcc the 555 will trigger on in the manner normal for monostable operation. The collector of Q3 would also go to ground at this time, except that Q1 had already discharged C1 in the initial condition following power turn-on.

Astable multivibrator mode

As soon as the trigger pulse is finished the capacitor will begin to charge, and both Q2 and Q3 are turned off. At time t_1 a second trigger pulse is received. Transistor Q3 is turned on and this discharges capacitor C1, but since the flip-flop is still in the set condition, the capacitor will begin to charge again immediately after the trigger pulse is finished, and the period begins again.

An astable multivibrator circuit is, in many respects, very much like the

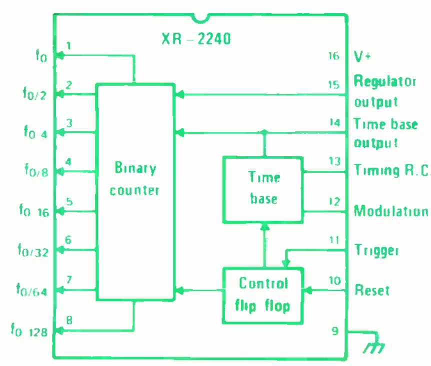


Figure 5A Block diagram of the XR – 2240.

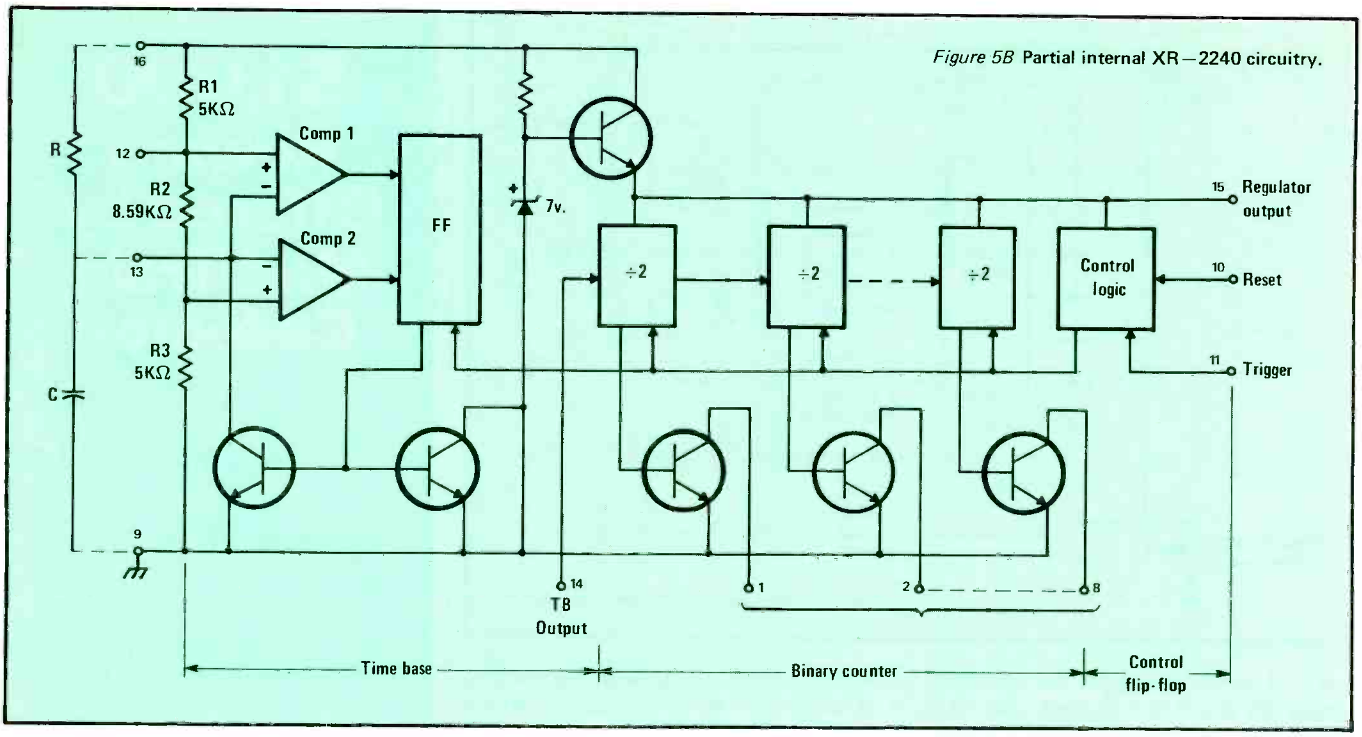


Figure 5B Partial internal XR—2240 circuitry.

monostable, except that it is self-triggering. The astable multivibrator, then, has *no* stable states, so will gyrate back and forth between the two possible unstable states; output high and output low. This action produces a wavetrain of squarewave pulses.

An example of a 555 astable multivibrator is shown in figure 4. As in the previous cases the inverting input of comparator no. 1 is biased to ⅔-Vcc and the inverting input of comparator no. 2 is biased to ⅓-Vcc through the action of the internal voltage divider, Ra - Rc. The remaining inputs to the two comparators are strapped together, and are held at a voltage determined by the time constant C1(R1 + R2).

Under initial conditions the not-Q output of the R-S flip-flop is high. This turns on transistor Q1, keeping the junction of resistors R1 and R2 at ground potential. Capacitor C1 has been charged, but when Q1 is turned on it will discharge through resistor R2. When the voltage across capacitor C1 reaches a level of ⅔-Vcc, the flip-flop will be reset.

This action turns on transistor Q1, and allows C1 to discharge to a level of ⅓-Vcc, at which point the trigger input will set the flip-flop. Capacitor C1, then, alternately charges to ⅔-Vcc and then discharges to ⅓-Vcc.

The time that the output terminal (pin 3) is high is determined by 0.693 X C1 X (R1 + R2) because the capacitor charges through *both* resistors. The low time is given by 0.693 X C1 X R2 because the capacitor discharges only through resistor R2. The *total* period of the waveform is the sum of high time and low time, so is given by 0.693 X C1 X (R1 + 2R2).

In an electrical circuit, or any physical system for that matter, the frequency of an oscillation is the reciprocal of its period. In this case, then the frequency of oscillation is given by F_{Hz} = 1/0.693(R1 + 2R2)C1 = 1.44/(R1 + 2R2)C1.

The duty cycle, or duty factor, of the output waveform is the percentage of the total period that the output is high. This is set by manipulation of the values of resistors R1 and R2, and is given by R2/(R1 + R2).

The XR-2240

Another useful IC timer, which is also useful as an eight bit counter, is the EXar EX-2240, which is also available from Intersil as their type 8240. Figure 5a shows the internal block diagram of the XR-2240 circuitry.

The XR-2240 will operate over the same +4.5 to +18 volt range as the 555. The time base section, in fact, is very similar to the circuitry of the 555, see figure 5b. One main point of difference, however, is that the internal comparators in the XR-2240 uses difference reference levels. Recall that the comparators in the 555 were biased at ⅔-Vcc and ⅓-Vcc because the resistors in the bias divider were all equal valued.

In the XR-2240 the resistors are not all equal, so the reference levels for comparators 1 and 2 are 0.73-Vcc and 0.27-Vcc, respectively. One result of this modification of the basic circuit is that the period is given by a simpler equation, namely R1 x C1 instead of 1.1R1C1.

The binary counter section consists of a chain of J-K flip-flops connected in the configuration where each functions as a divide-by-two counter. The binary counter chain is connected to the output of the time base section through an NPN open collector transistor, which is also connected to pin no. 14 (*time base out*) so that a 20k ohm pull-up resistor can be connected to the collector from the output of the internal regulated power supply (pin no. 15).

The digital outputs from the counter are, in the usual fashion, given as voltage levels at a set of pins on the IC. Each output bit is delivered to a specific terminal on the IC package. Each output is through an open collector transistor, and requires a 10k ohm pull-up resistor. Alternatively, all eight outputs may be wired together through a single pull-up resistor. As long as one output is low, the total output is low. The outputs are weighted in the binary fashion 1, 2, 4, . . . 128.

Figure 6a shows the basic operating circuit for the XR-2240 IC timer. Interestingly enough, the sole difference between the circuits for astable and monostable operation is the 51k ohm feedback resistor (R4) linking the reset terminal (pin 10) to the wired-OR output terminals.

The timer is set into operation by the application of a positively going pulse to pin no. 11 (trigger). This turns on the time base, and begins the counting sequence. The process will continue until a positive-going pulse is received at the reset terminal (pin no. 10), or the timer times out.

Each output terminal has a weight between 1 and 128 in binary. If all terminals are wired together to a single pull-up resistor, as shown in figure 6a, then the output will remain low for 256R1C1. But other delays are possible by connecting only those output terminals that will sum to the desired period.

For example, let us make a 57 second timer. In binary weighted notation decimal 57 is a expressed as the sum 32 + 16

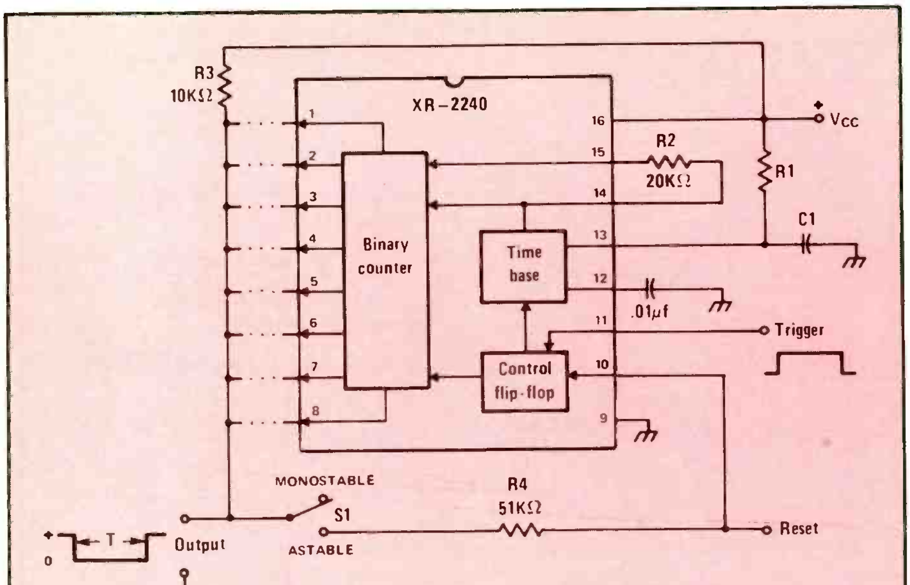


Figure 6A Basic XR–2240 operating circuits.

+ 8 + 1 = 57. If we set the timebase period (R1 X C1) to 1 second, and wire together the pins on the XR-2240 corresponding to these weights, our 57 second timer will be realized. The base diagram for the XR-2240 shows that the correct pins are 1, 4, 5, and 6. If we short together these pins, and set the time base to 1 second, the output will remain low for a total of 57 seconds following each trigger pulse.

Each output of the XR-2240 must be wired to Vcc through a separate pull-up resistor, unless the wired-OR configuration is used; in which case a single pull-up resistor serves all outputs that are used together. Current through any given output terminal must be limited to 5 milliamperes, or less, so select pull-up resistor values that take this limit into account.

The amplitude of the trigger pulse must be at least equal to two pn voltage drops, or 1.4 volts (i.e. 2 X 0.7 volts). In most cases it is wise to use at least standard TTL levels (i.e. 5 volts).

If it is desired to synchronize the internal time base to an external reference source, then connect a series R-C network (see figure 6b) consisting of a 0.1-uF capacitor and a 5.1k ohm resistor between the external reference source and pin no. 12 of the XR-2240. This forms a pulse at the time base which should have an amplitude of at least 3 volts, and a period that is between 0.3T and 0.8T. Another way to control the time base with an external reference oscillator is to go directly into the *time base out* terminal (pin no. 14).

2250 and 2260

The 2250 integrated circuit timer is similar to the 2240, except that the internal counter is designed to produce a binary coded decimal (BCD) output instead of straight weighted binary. Instead of having a 1, 2, 4, . . . 128 sequency for pins 1 - 8 the sequency is 1, 2, 4, 8 for pins 1 - 4, and 10, 20, 40, 80 for pins 5 - 8. The output times, then, are 1R1C1 to 99R1C1.

The XR-2260 is similar to the XR-2250, except that the counter is modified for use as a seconds, minutes, and hours counter. The low order pins (i.e. 1 - 4) count in the regular BCD 1, 2, 4, 8 sequence, but the high order pins (i.e. 5 - 8) only respond to a maximum count of 50. The times that can be programmed, then, are 1R1C1 to 59R1C1, which will become *seconds* if R1C1 = 1 second.

Intersil second sources these timers under their part numbers 8240 for the XR-2240, 8250 for the XR-2250, and 8260 for the XR-2260.

One difference between the XR-2240 on the one hand, and the two BCD output timers on the other is in the overflow function. Pin no. 15 on the XR-2240 is the internal regulator output terminal, while on the XR-2250 and XR-2260 it is an overflow carry to the next stage. This feature allows several timers to be used in cascade to produce long duration timers. ■

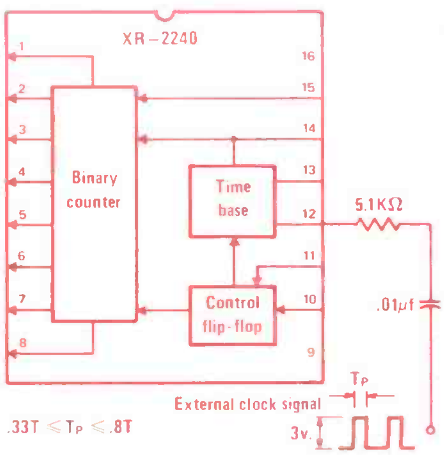


Figure 6B Synchronizing to external reference time base.


PERRY PEOPLE
BY HAROLD PERRY
OUR STORY UNFOLDS AS SPORTSCASTER, HOWDY COWSBELL, INTERVIEWS THE WORLD HEAVYWEIGHT CHAMPION, AHKMARRH MOHAMED ALIBABA!
IN THIS REPORTERS OPINION, THE LONGEVITY OF ALIBABA'S REIGN AS THE SUPREME MONARCH OF THE PUGILISTIC DOMAIN IS AN OVERPOWERING AND OBVIOUS STATEMENT OF THE PROCLIVITY OF....
GATES
CLAM UP HOWDY! NOW! WHAT I'M GONNA DO HERE TO CELEBRATE MAH 20TH ANNIVERSARY AS CHAMP IS TO GIVE SOME POOR UNKNOWN SCNOOK A CHANCE TO WIN THE TITLE. THE FIGHT WILL BE HELD TWO WEEKS FROM TONIGHT.
AND THAT 'POOR SCNOOK' IS AMATEUR BOXER STONEY BALONEY.
GEE WHIZ! GETTING A CHANCE TO FIGHT ALIBABA FOR THE TITLE IS A GREAT OPPORTUNITY, BUT, THERE'S JUST ONE THING!
WHAT'S THAT, KID?
MY JOB IS A FEMALE IMPERSONATOR AND UP TILL NOW I'VE ONLY FOUGHT GIRLS!
DON'T WORRY, I GOT A PLAN.
STONEY'S TRAINER, BARLEY MANDO, EXPLAINS HIS PLAN.
Y'GONNA GET ALIBABA A SEX CHANGE OPERATION?
NO! DUMMY! WE'RE GONNA USE THIS THING!
A TYPEWRITER WITH A TV ON TOP OF IT?
THIS IS A RADIO SHACK TRS-80 HOME COMPUTER.
Y'SEE STONEY, I'M GONNA FEED ALL THE PHYSICAL INFORMATION ABOUT THE CHAMP INTO THE COMPUTER; PLUS A BLOW BY BLOW DESCRIPTION OF EVERY BOUT HE'S HAD IN THE LAST TWO YEARS.
THEN THE COMPUTER WILL TELL US EXACTLY HOW THE CHAMP WILL HANDLE THE FIGHT, AND WHAT COUNTER MOVES THAT YOU GOTTA MAKE.
HEY THAT'S REALLY NEAT! NOW—CAN YOU GET LAVERNE AND SHIRLEY ON THAT THING??
DUH
WELL, THE BIG FIGHTS GONNA START IN A FEW MINUTES IF IT WASN'T FOR YOU, ANNABELLE, YOUR FAITH IN ME YOUR ENCOURAGEMENT YOUR LOVE FOR ME. IF IT WASN'T FOR DAT I COULDN'T OF MADE IT. HERE TONIGHT
JUST REMEMBER STONEY, WHEN YOU GET INTO THAT RING AND COME EYE TO EYE WITH THE CHAMP, I WANT YOU TO DO ONE THING FOR ME: TAKE A DIVE! BEFORE HE BEATS YOUR HEAD IN.
BONG
I WISH SHE COULD'VE REPHRASED THAT A LITTLE.
OK, STONEY, HERE Y'GO. NOW DON'T WORRY! WE HAVE THE COMPUTER HERE AT RINGSIDE. JUST DO WHAT THE COMPUTER SEZ TO, AND WE'LL WRAP THE TITLE UP


ROUND AFTER ROUND, ALIBABA & STONEY BATTLE FURIOUSLY LIKE TWO ANCIENT GLADIATORS, FIGHTING FOR THEIR LIVES.
THE CROWD GOES WILD! STONEY HAS STAYED IN THE RING WITH THE CHAMP LONGER THAN ANY OTHER CONTENDER.
THIS IS THE LAST ROUND, KID. THE COMPUTER SEZ THAT IN THIS ROUND YOU GOTTA — PSSST PSSST BUZZ BUZZ...
BARLY, I WISH YOU'D STOP PSSTING AND BUZZING IN MY EAR. PEOPLE WILL TALK.
STONEY FOLLOWS INSTRUCTIONS ...
WHAP
...SIIIIX...SEVEEEN...EEEIGHT...
I DID IT! I DID IT! I PUT AWAY THE OLD MAN!
WHAT'D YOU CALL ME, TURKEY?
GOBBLE?
HEY KID, THE COMPUTER SEZ THAT THE CHAMP HATES TO BE CALLED AN OLD MAN.
NOW HE TELLS ME. WELL I LOST THE FIGHT AND MY CHANCE AT THE BIG TIME. I HOPE I DIDN'T LOSE YOU TOO, ANNABELLE.
YOU'LL ALWAYS HAVE ME, STONEY. AND GUESS WHAT ELSE YOU HAVE? A JOB! RADIO SHACK CALLED AND THEY WANT YOU TO BE THEIR EAST COAST REP FOR THE TRS-80.
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