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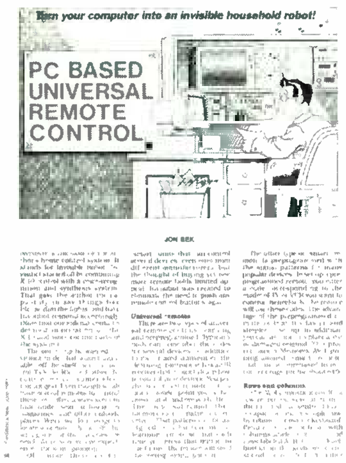
CIRCLE 121 ON FREE INFORMATION CARD

June 1993

Electronics NOW®
Vol. 64 No. 6

ON THE COVER

Music's in the air at **Electronics Now** this month! To get the beat going strong, we have the ThumbDrum on page 33. The electronic drum set turns finger-tapping into real drum sounds that you can output as either MIDI or audio signals. The Wireless Guitar Transmitter, on page 40, lets you move freely around, without tripping over a mess of cords. The transmitter plugs into your guitar's output jack and plays through your FM stereo tuner or a portable FM receiver, with no cables or separate power sources. Finally, our Musician's Friend, the Perfect Pitch, helps you hone your musical skills. The microprocessor-based device combines an instrument tuner, a headphone amplifier, and a metronome. Musicians can put it to good use in practice sessions, and everyone else can use Perfect Pitch to get the most out of other audio-based projects. Turn to page 47 for details.



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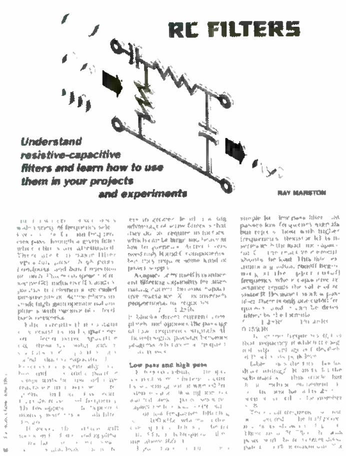

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Freq.MHz,DC to	1000	2000	2000	1000	2000	2000	1000	1000
Gain, dB at 100MHz	18.5	12.5	12.5	8.3	20	13.5	32.5	12.7
Output Pwr. +dBm	1.5	4.5	10.0	12.5	2.0	5.5	12.5	17.5
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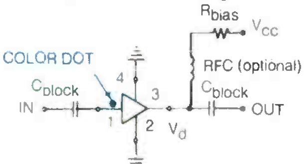

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CIRCLE 193 ON FREE INFORMATION CARD

F155 REV. A

A review of the latest happenings in electronics.

Interactive program guide

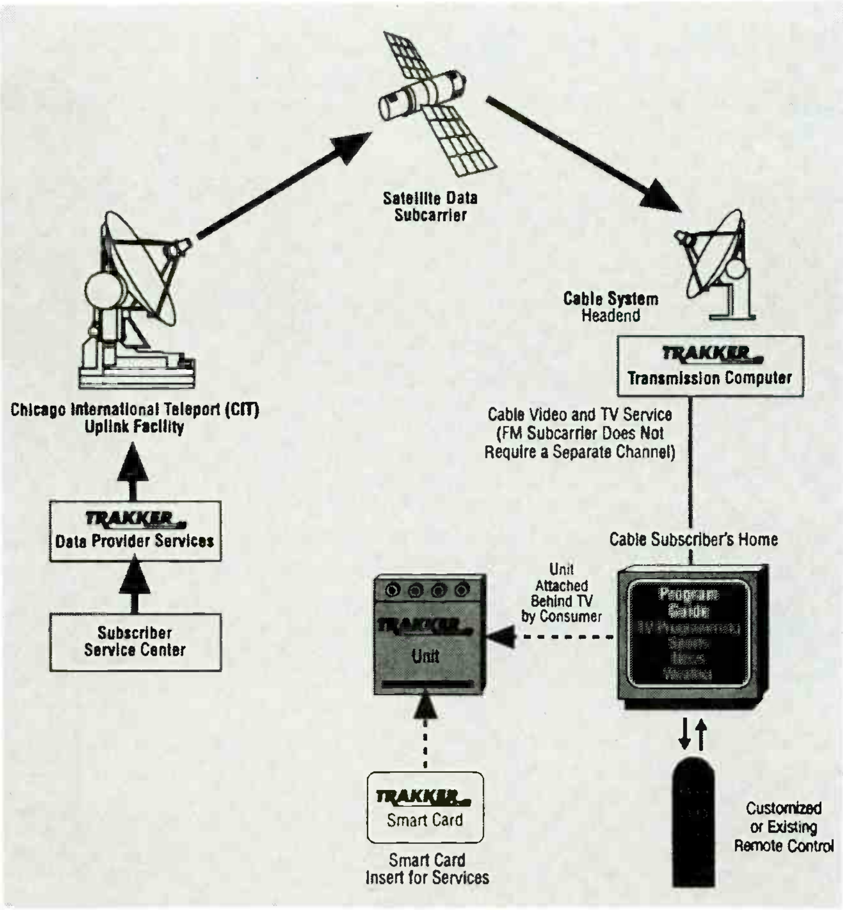
An interactive electronic program guide in selected markets is now available from Trakker Interactive Services (Tulsa, OK). The service is delivered to the homes of cable subscribers by an FM subcarrier.

The homeowner installs a "sidecar" box on the back of his television set, and his remote control can access the service. Information is presented in colorful on-screen windows. It includes eight hours of varied programing.

The Trakker system is designed to be upgraded easily to other interactive services by inserting a "smart card" circuit board into the box. The card authorizes the reception of TV Trakker and forthcoming services. Those services are expected to include news, entertainment, weather, business, and the latest sports information.

TV Trakker is developing an advanced version that will offer point-and-shoot VCR programming with a remote control to make recording TV programs off-the-air easier.

The first full-scale commercial roll-out of the system began in November 1992 on the Cox Cable system in Omaha, Nebraska. The service costs less than $30 a year. TV Trakker is affiliated with Prevue Networks, Inc, a supplier of electronic programming information to the cable industry, and United Video Satellite Group.



THE TRAKKER TV SYSTEM TRANSMITS DATA BY SATELLITE to a computer at the cable system front end. An FM subcarrier transmits the data to a small Trakker receiver unit on the viewer's TV set. Once installed, viewers can access the programming guide and other services with subscription "smart cards" that activate the services.

Cable company to build digital data system

An 8000-mile fiberoptic "electronic superhighway" that could provide digital data services (DDS) to homes in the metropolitan New York region has been proposed by Long Island-based Cablevision. In addition to initial coverage in Nassau and Suffolk counties, Bronx, and parts of Brooklyn could be served.

The network could deliver video on demand, home shopping and banking, interactive games, and "telecommuting" for those employees who work out of their own homes.

Fiberoptic cables made up of bundles of hair-thin glass fibers will carry pulses of laser light. Capable of transmitting far more messages than much larger copper cables, the system will convert digital signals from various sources into to light pulses at one end and will then reconvert them back to digital data at the other end without the need for a modem.

Cablevision expects to compress the data to provide as many as 1100 channels initially. The fiberoptic optic cables will be run to within 1000 feet of each home being served, and each cable will serve a cluster of only 750 homes. Because the cables will be underground, the system will be less susceptible to outages and interference than cable strung on telephone poles.

Under the plan, conventional coaxial cable will carry the signals from the fiberoptic cable terminal into each home. Over short distances, the coaxial cable is capable of meeting the needs of each home.

Cablevision plans to start with only 77 channels and use the extra

continued on page 80

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VIDEO NEWS

What's new in the fast-changing video industry.

DAVID LACHENBRUCH

• HDTV "grand alliance." Negotiations are under way among proponents of the four digital HDTV systems on the possibility of getting together and developing a single system combining the best features of all four. As of our deadline, "serious talks" were under way, but there appear to be plenty of snags in the path to any such alliance.

The prime mover in the push toward a single compromise system is Richard Wiley, chairman of the FCC's Advanced TV Advisory Committee (ATAC). One report indicates that all proponents except the Advanced TV Research Consortium (ATRC), composed of Philips, Thomson, NBC, and others, have agreed in principle on the idea. The other three systems could combine to present a united front against ATRC. Of course, many hurdles remain. For example, how does one compromise between interlaced and progressive scan?

Because the tests have shown no digital system markedly superior to any other digital or analog system, ATAC has decided on a new round of tests, which will be conducted if the idea for a grand alliance fails. That will delay the choice of a system—once scheduled for February 1993—until this fall. After the preliminary choice, on the basis of lab tests, one or all of the systems could go into field testing. If there should be an alliance and only one system remains, there would be a 30–45-day development period, followed by six months to build the combined system.

• Compulsory HDTV tuning? The All-Channel Act, passed by Congress many years ago to help provide an audience for UHF TV stations, should be applied to HDTV as well, according to a proposal made to the FCC by a broadcast group. The Association for Maximum Service Television has urged that the Commission use its authority under the All-Channel Act to require that all television sets made after a certain date be able to tune HDTV as well as standard NTSC channels. The group argues that since the FCC will make HDTV broadcasting mandatory, it should also mandate that sets be required to receive the broadcasts (but not necessarily in high definition). It proposes that HDTV reception become mandatory no later than six years after an HDTV standard is adopted.

That's ridiculous, replied Zenith in comments to the FCC. Zenith said that studies have indicated "a retail price premium in the area of $500 per set [for] receiving, demodulating, and decompressing digital [HDTV] signals in a non-HDTV receiver." Zenith added, "It is clear that a $500 premium would put millions of Americans out of the market for new TV receivers," in view of the fact that 70% of all TV sets are purchased for less than $350 each.

• Video disc recorder. While Japanese manufacturers discuss standards for a new generation of home digital high-definition videocassette recorders (*Electronics Now*, May 1993), a major Korean manufacturer is proposing that the next home video recorder use a disc rather than tape, foreshadowing a video battle comparable to the current digital audio recording contest between the Mini Disc and the Digital Compact Cassette.

Samsung, Korea's largest electronics company, announced that it will introduce a digital videodisc recorder (D-VDR) in 1995. Samsung has developed a green laser for both recording and playback of a magneto-optical disc, providing 55 minutes of digital recording on a 4.75-inch disc. When the product is commercialized, Samsung says that it will record for 120 minutes per disc.

Samsung says that it developed the system in a three-year project at a cost of more than $25 million, "working with various Russian technology institutes." According to Samsung, a disc-based camcorder would have portability advantages over tape, and "the video-rental industry would benefit from the compact size and durability of the disc." The D-VDR, said Samsung, will have two to three times more storage capacity than "the next generation of magneto-optical disc."

• Big tubes grow. The largest picture tubes in general consumer use became increasingly popular last year, according to figures from the Electronic Industries Association. As prices gradually came down and interest in home-theater installations increased, sales of color TV sets with 35-inch picture tubes increased by 52% over 1991. Compared with total color-TV sales of 22.4 million sets, the 35-inch number was relatively small. Nevertheless, some 244,000 sets with 35-inch tubes were sold last year. Sets with tubes 30 inches and larger totaled 787,000 in 1992, and if projection TV is included, the total came to 1.2 million—the first time the 30-inch-and-over category totaled more than a million sets.

Sales of projection TV's totaled a record 404,300 units last year. United States Precision Lens Co. (USPL), which makes plastic lenses for most projection TV sets, forecasts that about 445,000 will be sold this year. The trend to larger screen sizes will continue, the company says, predicting that 41% of the total will be in the 50–54-inch size, with 9% of them 55 inches and larger.

Despite some inroads by liquid crystal device (LCD) projection systems, USPL says that for the next few years the cathode-ray tube will continue to be the primary picture source for projection TV. Ω

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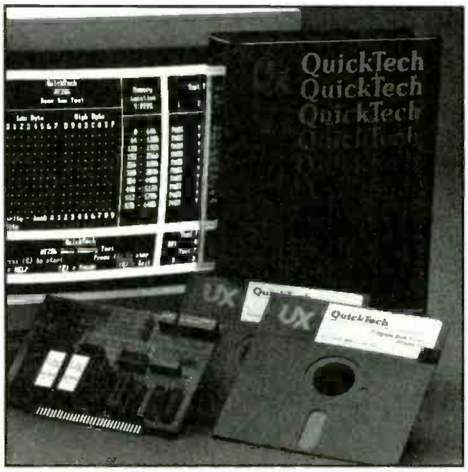

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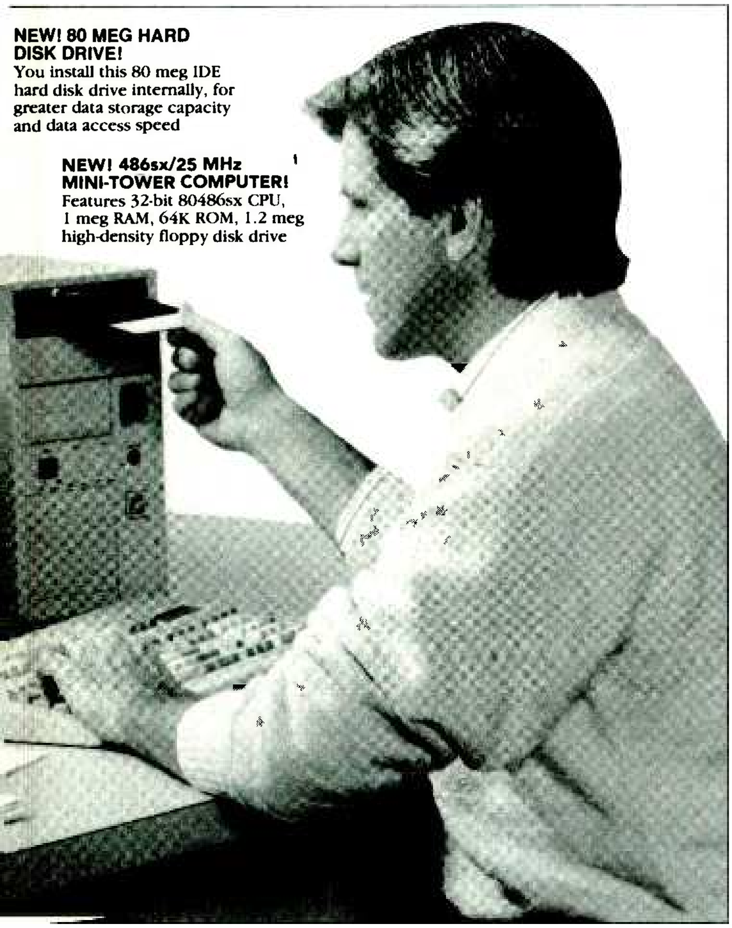

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COMPUTER LANGUAGE

I was a bit late getting interested computers, but I got a PC last year. I'm now interested in learning about programming. I've been studying BASIC but I'm wondering whether I ought to spend my time getting familiar with some of the other computer languages such as assembly language or C. Is any one of them better to know or more powerful than any of the others, or are they all equally useful?—G. Benjer, Faffel, IN

Learning how to program is the best way I know to take the mystery out of computers. Picking the language to use, however, is far from being a clear-cut issue. The decision ultimately has to be based on what you want to do with the software you write, how much time you want to spend on it, and, most important, how much you already know about the inner workings of computers in general.

All languages are designed to give specific instructions to the microprocessor and other hardware that make up your computer. It usually takes a lot of these individual instructions to get a task done. A good example of that is getting a character typed on the keyboard to appear on the screen. A simple GET statement in BASIC has to read the keyboard, transfer the typed character that's found in the keyboard buffer to the appropriate location in video memory, and then put that character on the screen location of the cursor.

High-level languages have statements that can do a lot of work for you and, as a result, program development is usually a lot faster and easier. Things are easier because high-level language statements are often English-like and intuitive. When a language like BASIC executes a program, it takes each of the program statements (such as PRINT, INPUT, and so on), and runs a series of low-level instructions that implement the statements. The tradeoff made for ease of programming is a loss of control over how things are done—it's a "Take the bus and leave the driving to us" kind of situation.

The lower the level of language, the more control you have over how things happen, but the more work you have to do when you're writing a program. In general, the approach to low-level programming is to create subroutines that do common tasks (such as putting stuff on the screen), and then calling them as they're needed. In a certain sense you try to structure things as if you were dealing with a high-level language in the first place.

There is no computer language that's best suited for all jobs and all programmers, and choosing the language to use is as important a decision as deciding what the program is going to do. You always have to weigh the requirements of the job against the time you can spend to make it happen. If you're programming for your own amusement, you can pick any language you want. But if you have a client breathing down your neck to get the job done, the choice of language can mean the difference between getting paid for a job well done and getting sued.

TWO SWITCHES, ONE LIGHT

I'm having a problem rewiring the lights in my house. In some of the rooms I want to be able to control a single light from two different switches. In rooms with two entrances, I want to be able to turn the lights on from switches at both doors. I know this is a simple problem but I haven't been able to figure out a solution. Can you show me a schematic for this?—F. Stone, Albany, NY

Wiring a single light so that it can be controlled by two switches is a common practice. A trip to your local hardware store will show you that there are switches and dimmers designed specifically for this purpose. The only difference between these specially designed devices and their single-control cousins is that the single ones are two-wire switches and the others are three-wire switches.

Simple switches are single-pole, single-throw devices, and the more complex ones are single-pole, double-throw switches. Working out the wire layout so a single light can be controlled by two separate switches is an interesting exercise in logic but, to save you the trouble, the schematic for the circuit is shown in Fig. 1.

As you can see, when the light is off, it can be turned on with either switch, and when the light is on, it can be turned off with either switch. Switches and dimmers designed for this application have three wires connected to them, and the center pole is identified with a different color. When you wire them, make sure you use cable that has three wires as well as the ground wire. All three wires have the ability to carry current so make sure you don't use the bare ground wire for this purpose.

Tell the person behind the hardware counter exactly what you want to do, and they'll tell you which switches and cable are the right ones for the job. When you're playing around with house wiring, the most intelligent course to follow is to make sure you know exactly what you have to do before you start doing it.

Most localities require that all electrical work be done by licensed electricians and that it be inspected afterward. There's a reason for that: miswiring electrical switches can be catastrophic.

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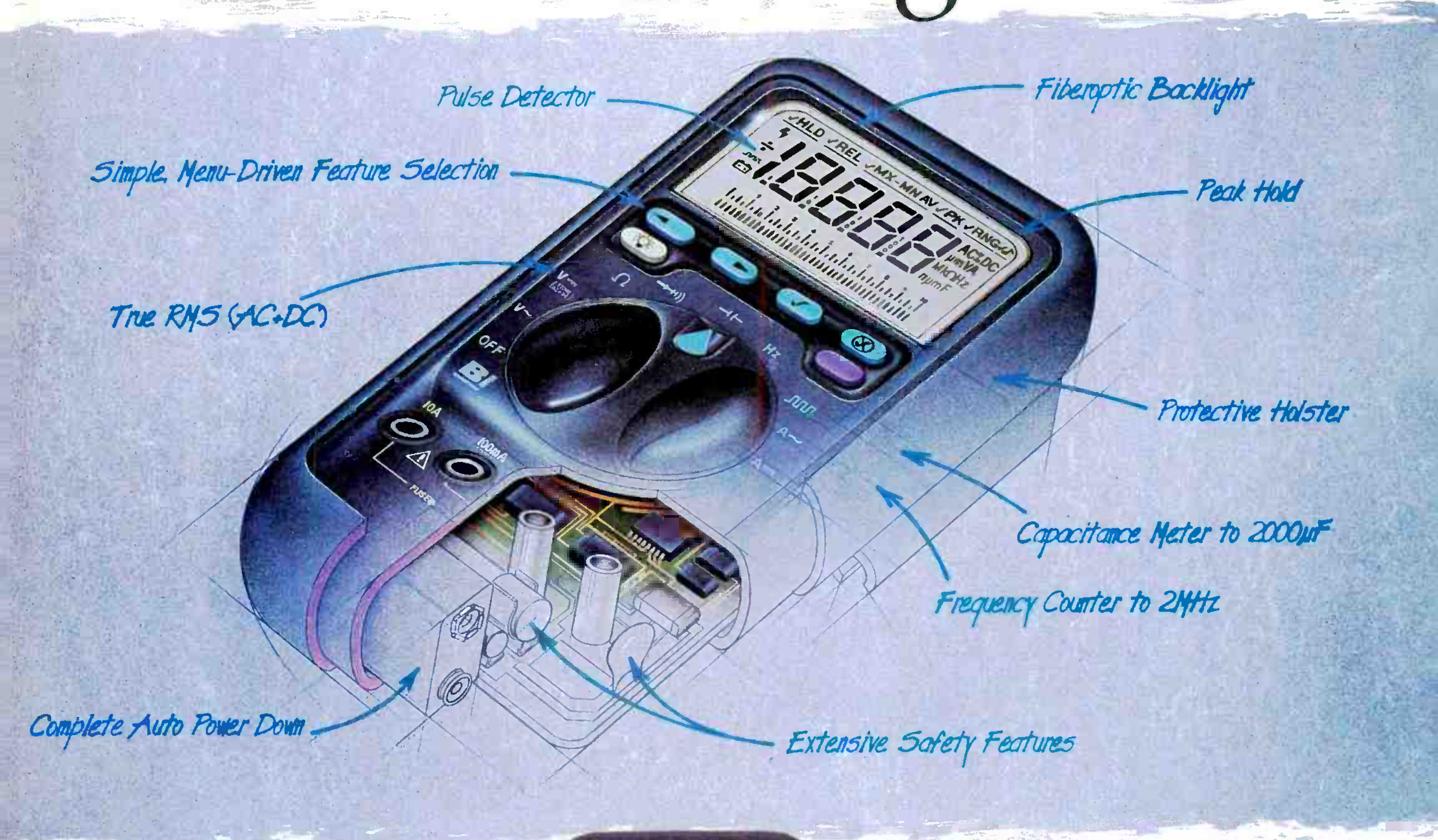

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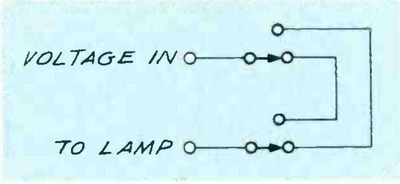

FIG. 1—TYPICAL TWO-WAY switch wiring. When the light is off, it can be turned on with either switch, and when it's on, it can be turned off with either switch.

MAKING WAVES

I do a lot of amplifier testing on my job and it would help a lot if I had a small device to generate sine waves. I don't need to vary the frequency continuously because I'm interested only in measuring the distortion at several frequencies in the audio range. A small battery-powered device that I could carry with me in my toolkit would be ideal.—M. Bill, San Diego, CA

There are lots of commercially manufactured pieces of equipment that will do this job for you, but if you're looking for a circuit that's easy to assemble, cheap to build, and small enough to fit in a match box, the circuit in Fig. 2 is exactly what you need.

The quality of the sine waves produced by this circuit will depend on how closely you match the components in the twin-T network in the op-amp's feedback loop. You'll never be able to get the kind of sine wave purity produced by a good bench generator but, then again, you can't put together equipment like that for under five bucks either.

There are ways to make the 741 operate with a single-sided supply, but this is one of those times when it's a good idea to stick with a bipolar supply—a 741 operating with a single-sided supply just can't produce good sine waves. The circuit can be assembled with any technique from wire wrap to PC board.

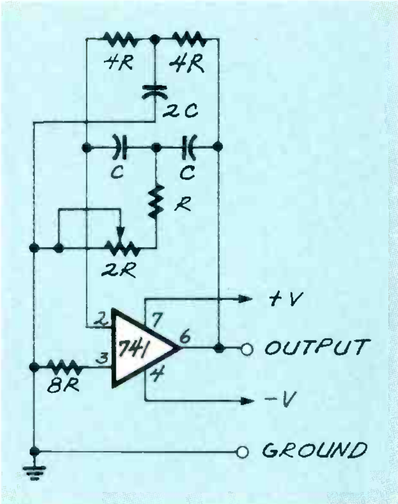

FIG. 2—BATTERY-POWERED sine-wave generator. The quality of the sine wave depends on how closely you match the components in the twin-T network in the op-amp's feedback loop.

Once you have it working, you can experiment with the component values to find out how much flexibility you have in producing sine-waves.

The output frequency of the circuit is determined by the values of the components and follows the simple formula:

$$f = 1/2\pi RC$$

You can vary the frequency a bit with the potentiometer, but it's a good idea to use a small trimmer, tune the circuit to a particular frequency, and lock the trimmer in place with a drop of nail polish. You can make one for each frequency you need. Ω

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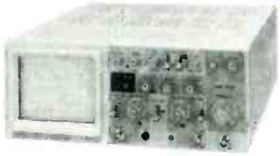

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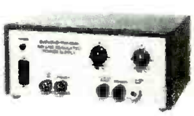

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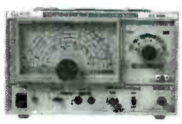

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AUDIO UPDATE OPPOSITION

As an electrical engineer and a devoted enthusiast who builds, designs, and listens to high-end audio equipment, I have to give a vote of "no confidence" to Larry Klein. In his zeal to represent our hobby as a sordid enclave of knaves, fools, and reprobate hucksters, he has allowed himself to spout a mixture of "factoids" and opinion that have no place in a reputable publication for electronic hobbyists.

To put it more bluntly, some equipment for reproducing recorded music just sounds better—in other words, it reproduces music more accurately as perceived by the extremely sensitive but inherently *subjective* human ear—than some other gear.

Some of that difference can be explained by measuring such parameters as frequency response, power, bandwidth, slew rate, total harmonic distortion, intermodulation distortion, and several other tests that are industry standards. However, as much as Mr. Klein and others might not like to hear it, some of that difference simply cannot be explained by such tests.

That doesn't make the concept of measuring performance objectively invalid. Nor does it make the current battery of tests useless. And it doesn't mean that there is anything supernatural or inexplicable about why amplifier Y and preamplifier X and CD player V driving Z speakers makes a string quartet sound far superior in my living room to some other set of components (each of which might make better measurements in one parameter or another than its equivalent).

It does mean that Mr. Klein might not be able to hear—or comprehend that he is hearing—or even admit to himself or anyone else that he can hear any difference between sound systems. He simply is not justified in saying, on scientific grounds, that such differences can't be heard.

It is obvious that Larry Klein doesn't listen to the music I listen to and he doesn't listen for the same things in that music. Moreover, he doesn't listen in my living room—and most important of all he doesn't listen to it with the audio receptors that are in the space between my ears.

Because, in the final analysis, I can't listen to music through Mr. Klein's ears, I am not calling him a liar. I am certain that he cannot perceive any difference between a $799 shopping-mall rack system and a *Stereophile* "Recommended Class A" system correctly matched and set up—but I can.

Come to think of it, I might even prefer the rack system, although that's very unlikely, but I'm quite confident that there would be a big difference.

I don't own class-A-rated units. My system consists of speakers from a reputable up-scale manufacturer (purchased used for a reasonable price), a pair of power amplifiers I built on a discarded public-address amplifier chassis with surplus and flea market parts, and a preamplifier made by an upstate New York manufacturer *not* considered to be a favorite of the sound experts.

I have replaced every resistor and capacitor with surplus parts; I use speaker wires and interconnects that I bought from commercial electrical supply shops for less than a dollar a foot. Each of these choices was made after many hours of listening and testing. If I couldn't hear any difference, it would have wasted my time and money, wouldn't it?

Finally, what I find most galling is Mr. Klein's shameless plug for one audio magazine. I regularly read or peruse *Stereophile, The Absolute Sound, The Sensible Sound, Audio Amateur, Glass Audio, and Sound Practices*. I also study the schematics in the Japanese *MJ Audio Technology* because the text is in Japanese and I do not read that language. Although I don't agree completely with the views expressed in any of those publications, each has provided me with some useful information so I will continue to read them.

JOHN BERGLUND
Quincy, IL

ANOTHER VIEW

I'm writing in response to the anonymous reader whose letter attacking Larry Klein's methods of evaluating audio equipment appeared in the March issue of *Electronics Now*. I'd like to establish my credentials: I've been in the audio industry many years, and in the early 1970's I manufactured what were then state-of-the-art "home speaker systems."

At that time, a typical "Faber System" cost about $800 for two satellites and a subwoofer. That might sound like a lot for the 70's, but at that time such a system did not exist until I introduced it at the 1972 Consumer Electronics Show in Las Vegas.

The design of those systems was the result of many years of work. Simply put, I agree with the letter-writer about the ability of the drivers and crossover network to affect the solid-state amplifiers being made today. Even the choice of speaker cable affects the overall sound.

But I think that most audiophiles who have become accustomed to the smooth sound of tube-type amplifiers with audio-output transformers and speakers matched to the system are bothered by the new solid-state equipment. They seem to be annoyed by direct-coupled amplifiers that connect directly to a speaker system capable of reproducing even the most complex audio waveforms.

That setup generally results in a technically correct musical output, but it does not allow for the fact that most instruments are "close miked" when in a recording session. Because we do not normally listen to instruments with our ears pressed against them, an extremely sharp grating feeling is created by long exposure to a musical score played on those exacting systems.

The mass of air between the listener and the instrument is missing. The air acts like a massive spring and modifies the sound, slightly, rounding off the "sharp edges." In normal operation tubes with transformer output amplifiers provided that effect. Therefore, although not technically correct, they did give the "correct" sound to simulate the proper distance from the instruments to the listener.

For a short time, MacIntosh manufactured a solid-state stereo amplifier with massive output transformers. I hauled one of those amplifiers and the speakers I designed from recording studios to upscale audio equipment retailers all over California. After listening through their switching systems, I determined that nothing could touch the correctness of the output. However, we could see the technical differences with an oscilloscope. In other words, both Mr. Klein and his unnamed critic are correct to a degree. It depends on how you define "correct audio" to the listener.

I believe that in our quest for technical perfection we have lost sight of objective—pleasing the listener. Some people enjoy ultra-sharp highs and the harmonics associated with them. They turn their volume controls "full on" to create clipping and extreme driver overloads. Personally, I enjoy music that sounds as if I were in an auditorium with an audience listening to a superb performance that doesn't rupture my ears from excessively high decibels.

I still have one of my original Faber System II's, my old MacIntosh amplifier, and a compact disc player. And yes, Mr. Unknown, CD's do sound better than records for more reasons than Mr. Klein mentioned in his article. (It would take a book to explain them all.) A properly tuned system that includes a compact disc makes every other recording medium seem like the difference between a Chevrolet and a Cadillac automobile. Both will get you there in the same time, with the same kinds or engines and wheels, but the difference is in the grace and style of the Cadillac as your mode of transportation.

I'd like to see more solid-state, high-quality amplifiers driving output transformers between them and the speaker system. The hysteresis of the transformer coupling would put the missing factor of distance back into the loop and satisfy those of us who enjoy music for the sheer pleasure of it—not just those who want to brag about the specifications of their systems.

Incidentally, from input to driver output, my system delivers ±1.5 dB from 150–20 kHz if I want a totally flat output. But that's impractical because most listening rooms need compensation.

LELAND R. RABER, C.E.T. 269
Elk Grove, CA

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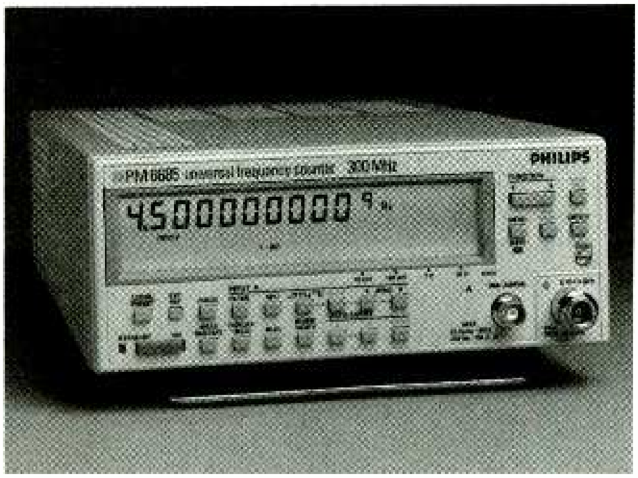

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The fully-programmable frequency counter supports IEEE-488.2 and SCPI standards. It can measure non-repetitive events, television signals, pulse trains, and amplitude-modulated waveforms. Its standard pulse width and duty-factor functions also lets you analyze pulse-train signals.

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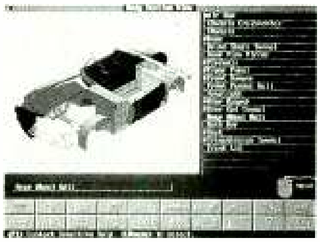

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On-board rechargeable batteries, an RS-232-C interface and 3-year warranty are included. Tektronix offers a wide range of accessories from printers and current probes to computer software. And each scope is UL and CSA certified — for the ultimate in quality and safety. To order, contact your authorized Tektronix representative or distributor.

	224	222PS	222A
Useful Storage BW Single Shot Repetitive	 1 MHz 60 MHz	 1 MHz 10 MHz	 1 MHz 10 MHz
Channels	2	2	2
Sensitivity Range	50 mV – 500 V/div	50 mV – 500 V/div	5 mV – 50 V/div
Max. Sampling Speed	10 MS/sec	10 MS/sec	10 MS/sec
Record Length	512 bytes	512 bytes	512 bytes
Vertical Resolution	8 bits	8 bits	8 bits
Timebase Range	20 sec – 50 ns	20 sec – 50 ns	20 sec – 50 ns
Horizontal Magnifier	X10	X10	X10
Glitch Capture	100 ns	100 ns	100 ns
Custom Triggers	video	motor	N/A
Maximum Safe Input Voltage	+850 V dc + peak ac 600 VAC, 6 kV peak surge	+850 V dc + peak ac 600 VAC, 6 kV peak surge	+400 V dc + peak ac
Price	$2750	$2950	$2450

Tektronix

40W-283-444

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or above, VGA or EGA display, 3.5 megabytes of available hard disk, and either a 1.2 megabyte 5¼-inch or 720 kilobyte 3½-inch floppy drive. A mouse will be a handy accessory.

The program also includes electric cars, diesel engines, four-wheel drives, and on-board car computers. It offers useful advice on how car owners can reduce air pollution, and history of the automobile and its impact on society. Utilities for printing, searching for parts locations, and exporting graphics to PCX files are included.

Auto Insight is priced at $79.95.—**Informative Graphics**, 706 East Bell Road, Suite 207, Phoenix, AZ 85022; Phone: 602-971-6061; Fax: 602-971-1714.

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ESD WORKSTATION MONITOR/TESTER. *Pilgrim Electric's Model GAM-7* ESD monitor/tester is test instrument for maintaining the effectiveness of electrostatic discharge (ESD) protective tools, accessories, and facilities. It can measure the resistance of shoe ground straps, conductive shoes, work surfaces, antistatic smocks, toteboxes, grounded tools, and packaging and shipping materials.

The line-powered monitor/tester can verify the polarity of an AC outlet to which it is connected. It can also determine the integrity of the ground straps and other grounded tools and appliances at ESD-protected workstations to assure that they comply with OSHA's regulations for operator safety.

The wriststrap monitoring circuitry allows the instrument to measure all conventional operator grounding wriststraps with coiled cords, operator capacitance, and 60-Hz AC fields. High- and low-resistance limits verify the presence of the wriststrap's current-limiting resistor necessary to protect the wearer against shock.

The *GAM-7* has a common point ground, two pairs of red and green LED's, an audible alarm and continuity tester, a resistance-test button, a six-second disconnect delay, and a six-foot line cord.

The price of the *GAM-7* ESD monitor/tester is $169.—**Pilgrim Electric Company**, 76 Summit Avenue, Sea Cliff, NY 11579; Phone: 516-674-3649.

GLOBAL POSITIONING SOFTWARE. *DeLorme Mapping* is offering its *GPS MapKit SV*, software that permits personal computer users to link Global Positioning System (GPS) satellites to maps. Data from one of the many popular-priced GPS satellite receivers is processed so that it can place a blinking symbol on a computer-generated map to represent the location of the receiver.

A standard laptop computer linked to a CD-ROM drive and a GPS receiver will permit users to display their locations anywhere in the United States on detailed maps. The *GPS MapKit SC* includes a map database of all roads,

CIRCLE 20 ON FREE INFORMATION CARD

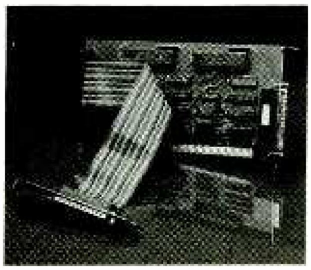
streams, and lakes in the United States, even in rural areas. In major metropolitan areas, street addresses can be located.

A GPS receiver is connected to one serial port of an IBM-compatible portable computer with Windows 3.0 or higher (2 megabytes of RAM, 4 megabytes of hard-disk drive with VGA graphics) the second serial port is connected to a portable CD-ROM drive. The map database is contained on a single CD-ROM disk.

The system can be used in a moving verhicle or airplane. By monitoring the moving symbol on the map, the system can display such information as speed, direction, and altitude.

The *GPS MapKit SV* is priced at $795.—**DeLorme Mapping**, Lower Main Street, P.O. Box 298, Freeport, ME 04032; Phone: 207-865-1234.

COUNTER–TIMER BOARDS. *Analogic's CTRTM Series* of counter–timer boards for IBM PC/AT-compatible computers offers either 5- or 10-channel general purpose 16-event counters. They are intended for event counting, frequency synthesis, coincidence alarms, or complex pulse generation.



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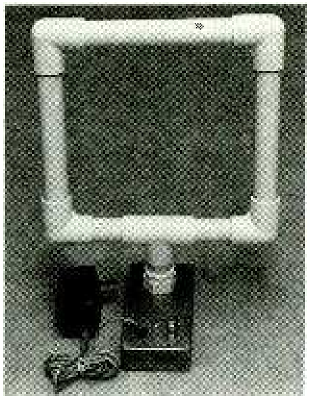
The boards are both compatible with industry standards for registers and connectors. They offer 1- or 5-MHz internal clocks for application flexibility. Many different internal frequency sources and outputs can be selected as inputs for individual counters. Each counter can be gated by hardware or under software control. They can be programmed to count up or down in either binary or BCD. The counters can also be connected together by computer software to form 32-, 48-, or 80-bit counters.

The five-channel *CTRTM-05* is priced at $255, and the 10-channel *CTRTM-10* is priced at $390.—**Analogic Corporation**, 360 Audubon Road, Wakefield, MA 01880; Phone: 508-977-3000; ext. 2089; Fax: 617-245-1274.

AM BROADCAST LOOP ANTENNA. The *Electron Processing's BCL-1* indoor loop antenna can improve your reception of distant radio stations in the crowded AM broadcast band. It is said to have excellent directional and low-noise characteristics, making it suitable for receiving weak signals.

The *BCL-1* is a compact 8 × 8-inch square unshielded loop that brings in standard broadcast band stations from 530 to 2000 kHz without picking up excessive noise. An internal 30-dB signal intensifier preamplifier boosts incoming signals. The antenna is powered from the 120-volt AC line by means of an adapter. A jumper cable for connecting the antenna to your receiver is included and its end connector can be specified.



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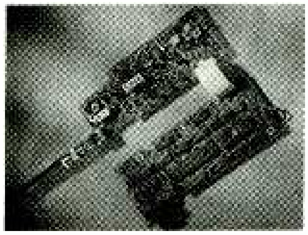
The price of the *BCL-1* loop antenna is $125 plus $5 for shipping and handling.—**Electron Processing, Inc.**, P.O. Box 68, Cedar, MI 49621; Phone: 616-228-7020.

OEM RADIO MODEM BOARD. *Monicor Electronic's System 200* is a radio modem board set that allows computer and peripheral manufacturers to eliminate the interconnecting cables in their systems. It consists of a set of two boards that can communicate any RS232C port and it allows computer systems to be mobile.



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One of the boards is a digital transmitter/receiver and the other is a modem. The two are linked by flexible cable that carries only low-frequency signals and direct current. The system's power requirement is 7.5 volts DC, 250 milliamperes, maximum, supplied by the RS-232C connector or rechargeable nickel-cadmium batteries on the modem board.

The system is sold with Monicor's TurboLink 2.0 operating system that accommodates up to 48 terminal nodes. It resides in an EEPROM on the modem board. However, users can install their own operating systems. The output level can be set from 1 milliwatt for connectivity of ten feet to 2 watts for two miles or more.

The *System 200* is priced at $465 per set in quantities of 1000.—**Monicor Electronic Corporation**, 2964 NW 60th Street, Fort Lauderdale, FL 33309; Phone: 305-979-1907; Fax: 305-979-2611.

WIRE-TRACING SYSTEM. The*Amprobe AT-2000* wire-tracing system will locate opens, ground faults, and shorts in wiring and cable systems (including LAN's), metal piping, and metal-shielded fiberoptic cable. The modular system is available in four different configurations with components that are interchangeable to permit the user to upgrade a basic system to meet future needs.

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The *AT-2000* includes three handheld primary components: receiver, signal generator, and transmitter. The receiver has a 20-foot range, high noise immunity, and a display that can be read easily in bright sunlight. The signal generator is suitable for making tests on any circuit that carries between 9 and 600 volts AC or DC.

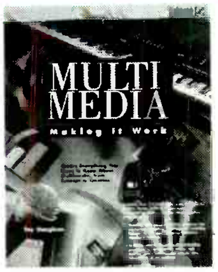
According to the manufacturer, the power to any circuit being traced need not be interrupted, so the tracing not cause any system downtime. The wire tracing equipment does not generate RF so the instrumentation will not affect sensitive electronics. The transmitter and its clamp-on accessory can induce a signal on any line, whether or not it is energized.

The basic *AT-2000* kit is priced at $439.85, but the complete *AT-2004* system (pictured here) is priced at $699.85.—**Amprobe Instrument**, 630 Merrick Road, P.O. Box 329, Lynbrook, NY 11563; Phone: 516-593-5600; Fax: 516-593-5682. Ω

NEW LIT

Use The Free Information Card for fast response.

Multimedia: Making It Work; by Tay Vaughan. Osborne McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710; Phone: 800-227-0900; $27.95, including 3½-inch diskette.



CIRCLE 40 ON FREE INFORMATION CARD

This book with its included diskette gives you information you need to make decisions on how to set up a multimedia system and use it to create professional multimedia presentations. Multimedia is the hottest trend in computers today, and it is fast becoming an integral part of the computing environment.

However, those who want to combine text, animation, sound, graphics, and video elements face an overwhelming array of choices. There are dozens of multimedia hardware products on the market, and hundreds of titles on CD-ROM.

Vaughan's handbook explains hardware requirements, how to design and build multimedia projects from scratch, and how to find and select the right text, sound, graphic, and video elements for a unique presentation. It also explains how to perfect your original concept.

The disk, a special edition from Mathematica, includes two programs: TEMPRA GIF, an image-editing program, allows you to capture, paint, edit, and print images in popular industry-standard formats, and TEMPRA SHOW is a multimedia authoring program for integrating audio, full-motion video, graphics, text, animation, and special effects into all of your interactive presentations.

Software Engineering Tools Catalog No. 6; from BSOFT Software, Inc., 444 Colton Road, Columbus, OH 43207; Phone: 614-491-0832; Fax: 614-497-9971; free.

This engineering software and hardware tool catalog for personal computers and IBM compatibles offers professional, low-cost, stand-alone engineering programs and hardware designed for engineers, technicians, and hobbyists.

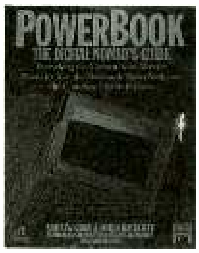
CIRCLE 39 ON FREE INFORMATION CARD

Programs are offered for drawing schematics, simulating logic-control circuits, FFT analysis, and circuit analysis. CAD programs for structural analysis, circuit design, and PC-board layout are also offered, along with new PC bus board products for control and data acquisition applications.

PowerBook: The Digital Nomad's Guide; by Andrew Gore and Mitch Ratcliffe. Random House Electronic Publishing, 201 East 50th Street, New York, NY 10022; Phone: 800-733-3000; $24.00, including diskette.

This combination book and disk package explains how to turn the MacIntosh PowerBook laptop into a total mobile office. Written by two *MacWeek* editors, the book applies to all the latest models, including the 160, 180, and PowerBook Duo models.

The wide range of topics



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covered include networking, optimizing battery life, computing in foreign countries, on-line tips and tricks, faxing, memory expansion, and attaching color displays.

The 3½-inch disk contains the Roadside Assistance Kit, powerful laptop utilities software worth more than $325 including:

- Applicon 2.2 lets you set up applications files loaded into memory anywhere on the screen.
- Dynodex 2.0.1, an electronic Rolodex and address book.
- QuickKeys for Nomads that lets you toggle backlighting ON and OFF, spin down the hard drive, shut down or put the PowerBook to sleep, and locate the cursor instantly.
- SuperClock! 3.9.1, a utility that displays a clock in the menubar.
- Synchro, a file sorting utility.
- A demonstration version of AgentDA 2.1.2, a personal calendar/appointment book program.
- Spiral 1.0, a RAM-resident notetaker that works like a word processor but also allows you to add tabbed sections with tables of contents linked to specific passages in a designated section.

Low Profile Amateur Radio: Operating a Ham Station from Almost Anywhere; by Jim Kearman, KR1S. The American Radio Relay League, 225 Main Street, Newington, CT 06111; $8.00.

This book provides ideas and guidance for amateur radio operators who want to operate their gear without attracting attention. If you are a ham operator who lives in an apartment, condo, or dormitory, setting up a traditional ham shack might not be possible. Moreover a standard setup is not feasible if you want to get on the air from your car or while you are on a camping trip.

Kearman's book begins with an historical review of spies who have managed for decades to keep a low profile while operating a transmitter. The book goes on to show you how to set up an operate an amateur station in an apartment, condo, or campesite without attracting unwanted attention or annoying others.

The author recommends low-power operation, but

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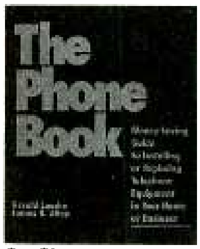
this is not another QRP CW book. He discusses the problems you will encounter in operating the digital modes with low power and hidden antennas. He also describes techniques for low-power voice, CW, RTTY, AMTOR, packet-radio, and VHF/UHF radio operation.

You'll find out how to obtain a good RF ground in a tall building, and how to install a rig in a compact car. The book also describes small HF and VHF antennas for apartment dwellers, and explains how to solve interference problems presented to or originating from your ham station. Because many low-profile stations depend on indoor antennas, the complete guidelines of the ARRL Bioeffects Committee are included.

The Phone Book; by Gerald Luecke and James B. Allen. Prompt Publications, Howard W. Sams & Company, 2647 Waterfront Parkway East Drive, Indianapolis, IN 46214-2012; Phone: 317-298-5710; Fax: 317-298-5604; $16.95.



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This book explains the basic principles of telephones and how they work. It also provides guidelines to help you evaluate existing phone systems.

According to Luecke and Allen, a telephone installed in your home by the phone company, or a complete phone system installed in your office by a private contractor can be expensive and involve long waiting periods for service.

This book will help you avoid those problems. It includes instructions and extensive illustrations on how to install a single phone or complex, multi-line systems. Detailed information is also given on modular installations, wiring new systems, installing business, private home, and apartment installations as well as modem operation. A separate chapter covers troubleshooting and system checks. Ω

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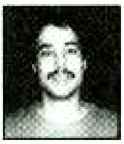

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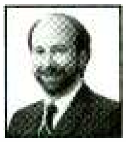

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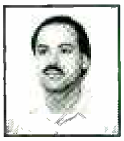
Analog Devices, Inc.



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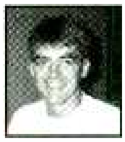

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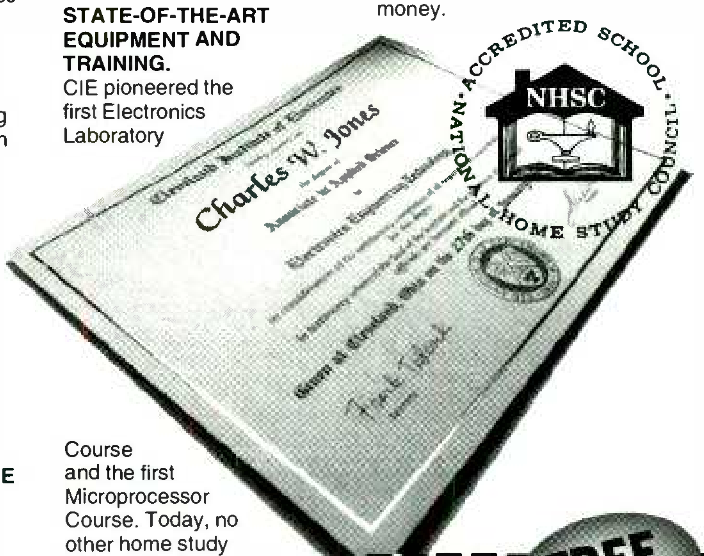

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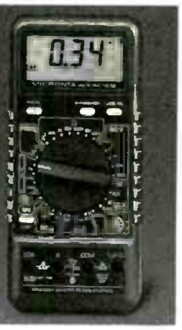

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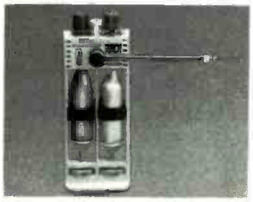

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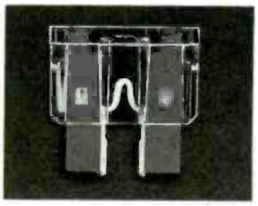

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ThumbDrum

Let your fingers do the tapping with the ThumbDrum.

JOHN SIMONTON and KENT CLARK

PLAYING THE DRUMS MAY LOOK easy, but if you've ever picked up a pair of sticks and tried to play real drums, you probably realize that it takes a little practice to sound like Buddy Rich—or even Ringo Starr. On the other hand, you probably sound great when you finger-drum on a table top. That's the idea behind the ThumbDrum, a controller that converts finger drumming into real drum sounds.

MIDI (Musical Instrument Digital Interface) users will want to build the ThumbDrum's computer board, which turns taps on the ThumbDrum's foam percussion pads into MIDI NOTE-ON, NOTE-OFF, and VELOCITY data which can control sounds from MIDI keyboards, sound modules, and many MPC (Multimedia Personal Computer) computers.

Would-be drummers who are not interested in MIDI will want to build the ThumbDrum tone board, which contains analog circuitry for creating a drum kit with bass, tom-tom, snare, conga, wood-block, clave, and synth drum sounds. The tone board uses ringing oscillators, a noise source, and diode "tricks" to get a classic—or at least retro—set of electronic drums that can plug right into guitar amplifiers or hi-fi equipment.

Sensor board

The sensor board is common to both MIDI and analog versions. It converts the force of a finger striking a pad into voltage pulses with peak amplitudes that are proportional to how hard the pad is hit. The schematic is shown in Fig. 1. Because the same basic circuit is repeated eight times, we'll look at only the circuitry around IC1-d in detail.

Underneath each rubber thumb pad is a piezoelectric transducer, or sensor, which is normally used as a buzzer. These piezoelectric discs deform or distort when a voltage is placed across them. More important for our purposes, they produce a voltage when they are physically deformed by a mechanical force.

The output of sensor PZ1 is wired to trimmer R2, which controls the sensor's output level. The trimmer can compensate for differences in individual sensor outputs or differences in finger strength.

After attenuation, the piezoelectric output is processed by a simple peak-detector consisting of D5, C3, and R3. That con-

verts the transient signal from the transducer into a more predictable pulse with an almost instantaneous attack and a slightly slower decay. The peak level of the pulse is proportional to the force of the strike, which makes the pads touch-sensitive. The signal is then buffered by IC1-d and becomes the trigger output for that channel. The arrangement of R4, where the output is taken from within the feedback loop, permits individual outputs to be wire-ORed together to drive a single output. One reason for that arrangement is because it's easier to do drum rolls on two pads than one

A light-emitting diode, LED1, serves two functions: it acts as a power indicator and also provides a simple way to calibrate the sensitivity of the sensors without test equipment. The voltage dropped across the diodes D1–D3 causes the junction of D3 and D4 to be at about 3 volts with respect to ground. When the output of IC1-d reaches a voltage slightly less than 4 volts, D6 is forward biased and begins to add current to the current already flowing into LED1 through D1–D3. As a result the LED glows more brightly. The increase in brightness becomes noticeable when the output of IC1-d begins to approach its maximum allowable output of slightly less than 5 volts.

Because the sensor board is required for both analog and MIDI versions, the power supply is located there. Power from a 12-volt DC wall-mounted adapter is switched by S1, filtered by C1, and becomes the unregulated +V supply for the op-amps. The 7805 5-volt regulator, IC3, provides power for the MIDI computer or is used as an internal audio ground for the tone board. The individual sensor outputs and power are routed to a 14-pin DIP header, J1, which serves as the connector to the MIDI or tone boards.

MIDI computer

A schematic for the MIDI computer is shown in Fig. 2. The circuitry is a traditional application of the 8031 microcontroller. The 12-MHz crystal XTAL1 is the timing source for the microcontroller's (IC3) clock, and R1 and C3 provide power-on reset.

A 74HC373 octal latch, IC2, under control of the ADDRESS LATCH ENABLE output (pin 30) of the 8031, demultiplexes the address and data lines and provides the lower eight address bits to the 2764 EPROM (IC4) and optional RAM (IC5). A 74HC138 1-of-8 decoder (IC8) changes the states of the address lines A12–A14 into one of eight ENABLE lines.

Two NAND gates (IC10-c and IC10-d) combine one of the ENABLE lines (IC8 pin 15) with the processor's read ($\overline{RD}$) and write ($\overline{WR}$) lines (pins 17 and 16, respectively) to select and control IC11, an ADC0809 eight-input analog-to-digital converter (ADC). Address lines A0–A2 select the ADC's input to be converted. The remaining two NAND gates (IC10-a and IC10-b), along with R11, R12, and C13, form the 500-kHz clock that is required by the ADC.

Serial MIDI data streams are handled by a UART (universal asynchronous receiver/transmitter) that is built into the 8031. MIDI data coming from the processor's TXD output is buffered by IC6-a and IC6-b, two of the six inverters in the 74HC04 package. A third inverter (IC6-c) drives the SEND ACTIVE indicator LED1, which is a convenient means for seeing that data is actually being output.

On the MIDI input side, ground isolation required MIDI is provided by an H11A1 optoisolator, IC7. The output of IC7 is routed to the 8031's UART input, RXD. There are provisions on the circuit board for a second MIDI input (J4, IC9, etc.), but these are not used in this application—and are shown in the schematic to be consistent with the circuit board artwork. Similarly, the general-purpose indicator LED2 is not used.

The eight inputs to the ADC, which are the outputs from the sensors, as well as the 5 volts needed to power the processor, are fed from the sensor board to the computer board through 14-pin DIP connector J5. Expansion connector J1 provides access to the processor's control, address, and data lines. The connector isn't used in this project, but is provided for future expansion.

The software for the computer board is contained in IC4, a 2764 EPROM. The computer's biggest job is monitoring the eight peak-detector outputs for rising and falling voltages that indicate that a sensor has been hit. The outputs are monitored on a scanning basis, so that no pulses are ignored while another input is processed; each input gets checked about every 2 milliseconds.

To find the maximum value of the sensor-board outputs, which is used to calculate velocity, the firmware looks at the last two readings from the ADC. If a reading is larger than the previous one, the old value is thrown away and the new one is saved. When the software sees two consecutive readings that are smaller than the largest reading, the pulse is assumed to be decaying, and the largest ADC value is saved.

Since the ADC is an eight-bit

SENSOR BOARD PARTS LIST

All resistors are ¼-watt, 10%.

R1—1500 ohms
R2, R5, R8, R11, R14, R17, R20, R23—100,000 ohms, trimmer potentiometer
R3, R6, R9, R12, R15, R18, R21, R24—1 megohm
R4, R7, R10, R13, R16, R19, R22, R25—1000 ohms

Capacitors

C1, C2—100 µF, 15 volts, Electrolytic
C3–C10—0.01 µF, ceramic disc

Semiconductors

IC1, IC2—LM324 quad op-amp
IC3—7805 5-volt regulator
D1–D3, D5—1N914 diode
D4—not used
LED1—red light-emitting diode

Other components

S1—SPST slide switch
T1—12-volt DC wall transformer
PZ1–PZ8—piezoelectric disc transdcuer
J1—14-pin DIP socket

Miscellaneous: PC board, foam-rubber pads, double-sided tape, wire-wrap wire, ribbon cable, project case, hardware, solder

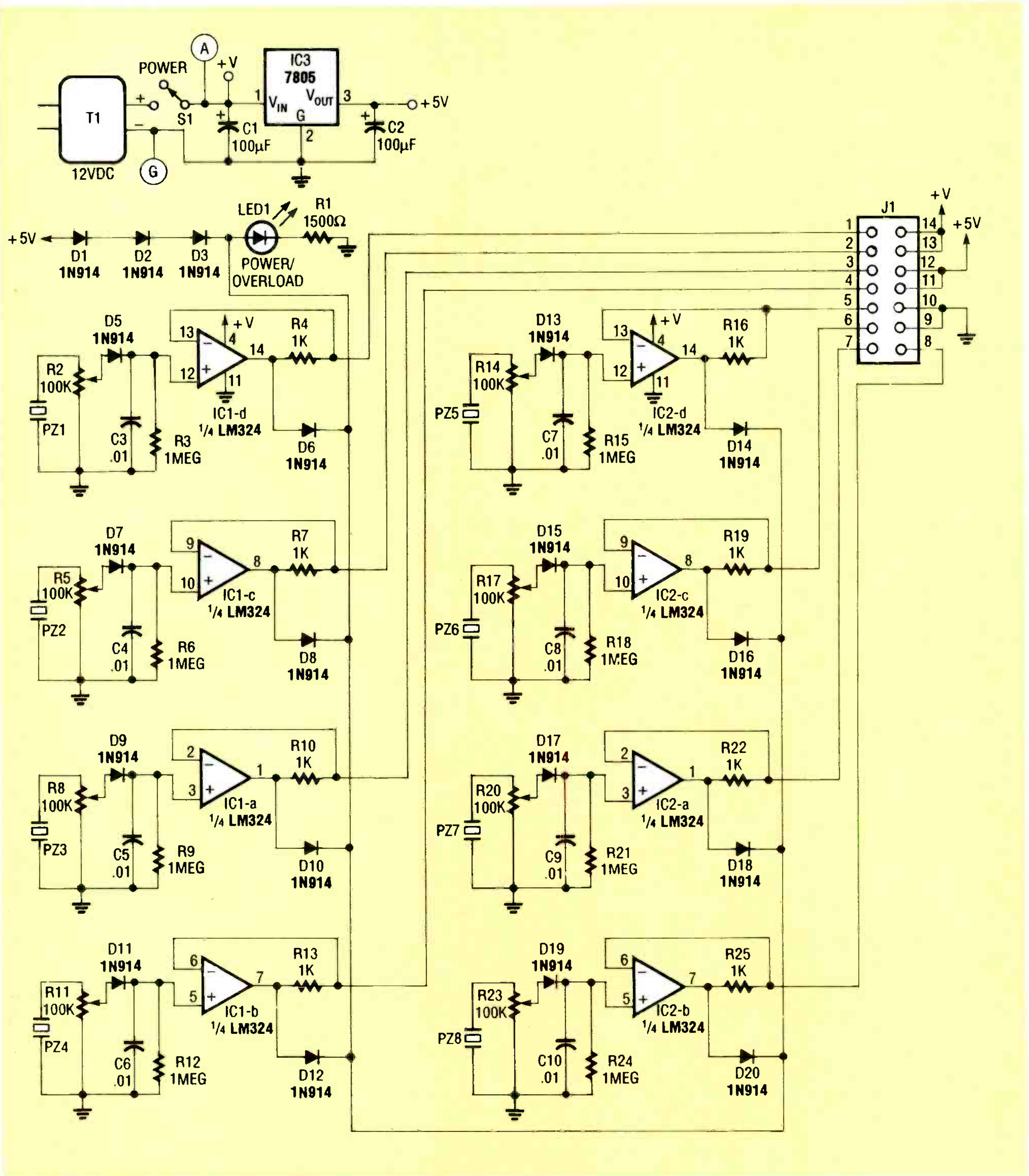
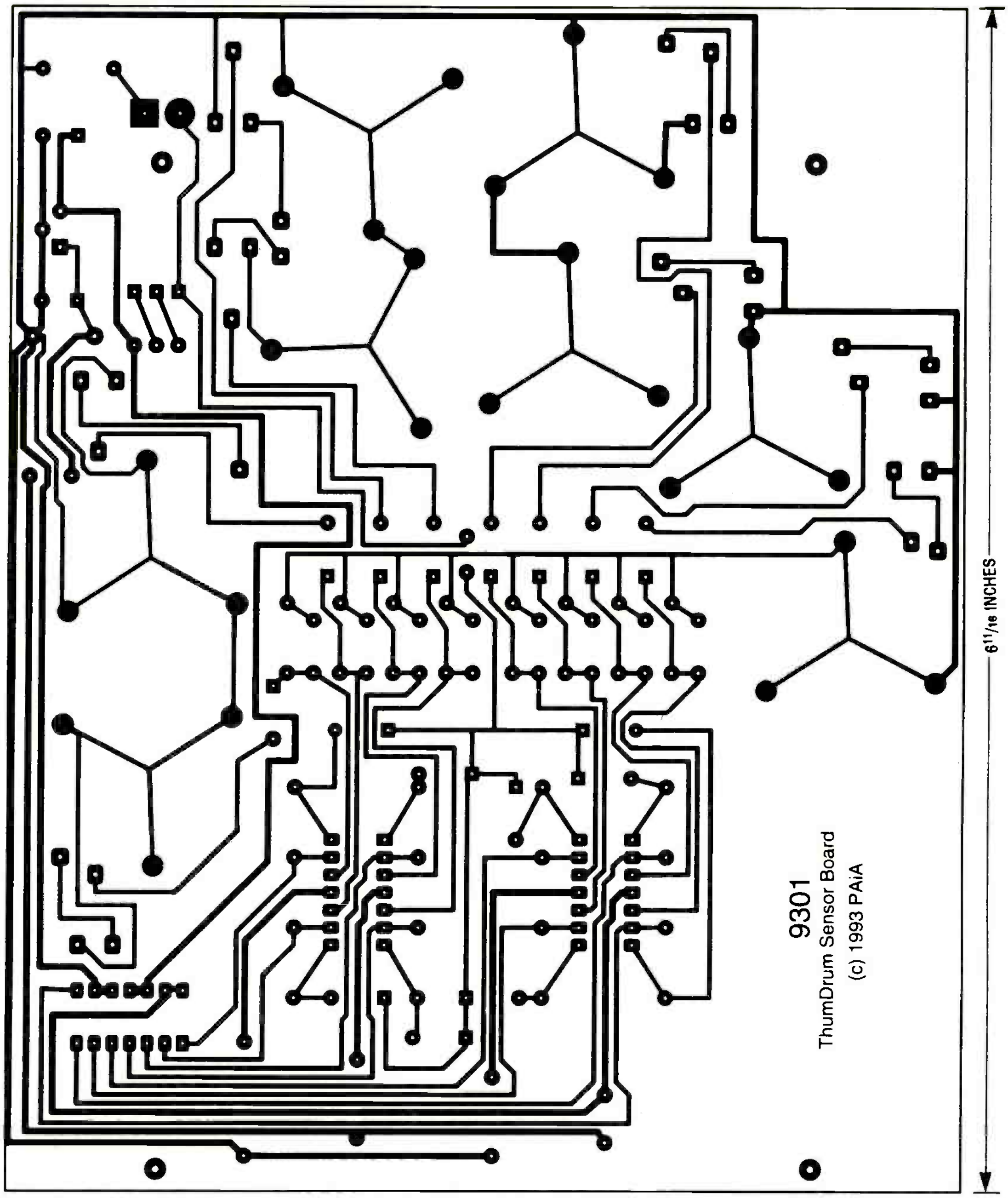


FIG. 1—THE SENSOR BOARD converts the force of a finger striking a pad into voltage pulses with peak amplitudes proportional to how hard the pad is hit.

device and the MIDI data word for velocity is only seven bits, the least-significant bit (LSB) of the ADC output is discarded. The second least-significant bit is also ignored so that the value is well above the "noise floor" of the sensors. The rest of the bits are saved to determine the velocity.

As the input pulse decays, the firmware sends a MIDI NOTE-ON message; the MIDI channel number is determined by the four DIP switches connected to lines P14–P17 of IC3. The firmware next fetches the MIDI note number assigned to the sensor in the map (selected by the DIP switches connected to lines P11, P12, and P13 of IC3) and sends it. Finally, the velocity data is fetched and either sent directly or used as a pointer to a logarithmic value in a look-up table depending on the lin/log option selected by the last DIP switch (connected to line P10 of IC3). After about ⅓ second, the firmware sends a NOTE-OFF



SENSOR BOARD foil pattern.

message to cancel the NOTE-ON.

The firmware checks for additional RAM and sets remapping capabilities accordingly. It also merges the NOTE ON/OFF messages generated by sensor activity with MIDI data appearing on MIDI In Port 1. We'll see why merging and remapping are important when we talk about using the system.

Tone board

In the days before digital sampling, most electronic percussion instruments generated drum sounds with the "ringing oscillator" approach that is used here. When sampling instruments were first introduced, the realistic sounds resulting from playing what is essentially a recording of a drum made electronic sounds unfashionable. But, what goes around comes around, and now the electronic units are regaining popularity because they don't sound exactly like drums. Go figure!

Acoustically, the biggest difference is that, while real drums (and all "natural" instruments) generate a complex spectrum of subtle overtones, electronic drum circuits generate a fairly pure tone. They sound like drums because they capture what is the essence of all percussion instruments, an envelope that rises rapidly to some peak when the instrument is first struck (the definition of "percussion") and then logarithmically decays back to 0.

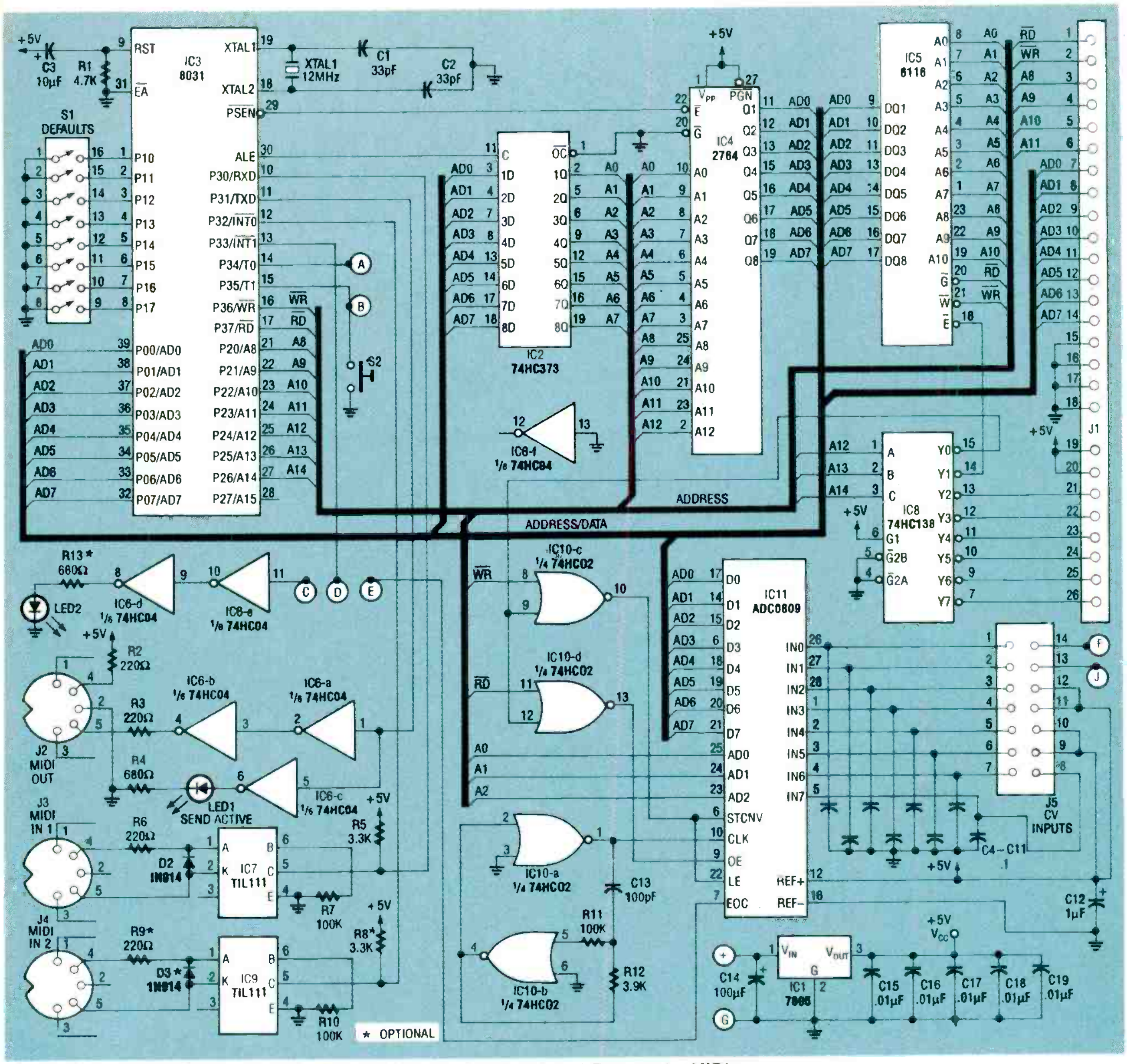


FIG. 2—THE MIDI COMPUTER BOARD is used if you want the ThumbDrum to be MIDI-compatible.

Although the schematic for the drum circuits shown in Fig. 3 might seem imposing at first, notice that it's primarily one circuit duplicated six times. That basic building block is typified by the circuit built around IC1-a, one of four LM324 op-amps within IC1.

This circuit, which is designed to sound like a wood block, is basically a "twin-T" notch filter (R3, C2, and R4 makes up one "T" and C3, R5, and C4 make up the other) in the inverting feedback loop of an amplifier. DC gain of the stage is set by R6 and R7. When the gain is high, it overcomes the losses in the filter section, and the circuit oscillates at the frequency set by the filter components. As gain is reduced, the circuit will stop oscillating, and it acts as a resonant bandbass filter—but not a very good bandpass filter because of its transient response. If the filter is hit with a pulse input, it temporarily breaks into oscillation and rings like crazy. However, what's not good for a bandpass filter is great for producing drum sounds. Input pulses are coupled into the circuit by C1 and R1.

The snare drum sound starts with a burst of white noise to simulate the rattle of the snares when the drum is hit. The noise source is an avalanching base-emitter junction of NPN transistor Q1. The low-level noise from the transistor is amplified by op-amp IC2-b.

High-level noise is then gated on by IC2-c by the simple expedient of having the trigger pulse bias the op-amp out of saturation into a linear operating range. Components C25 and R44 stretch the relatively short pulse from the drum sensor to hold the noise burst on a little longer than the sensor pulse alone would.

Be aware that this technique is not universally applicable to switching audio because the change in DC level at the output

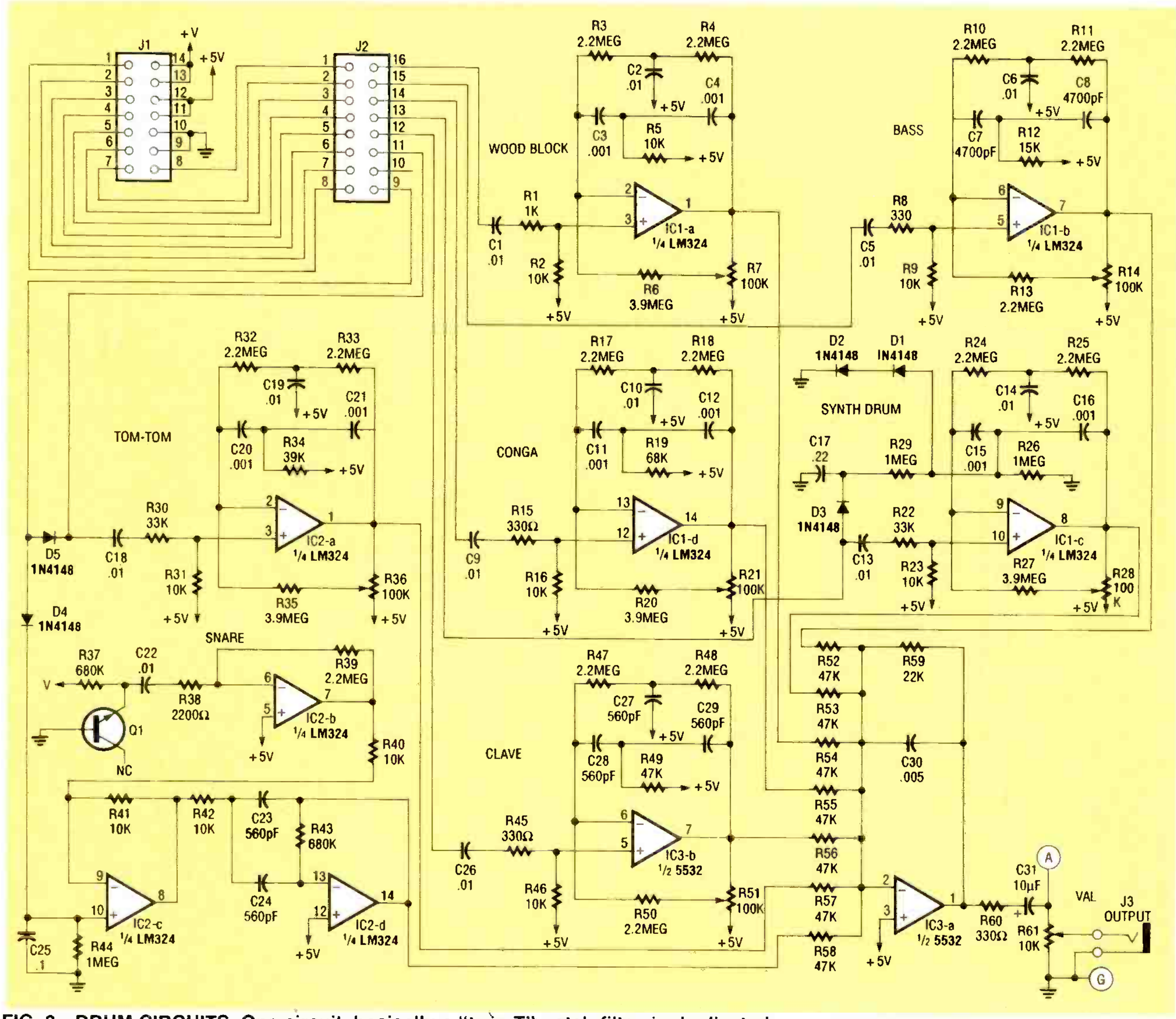
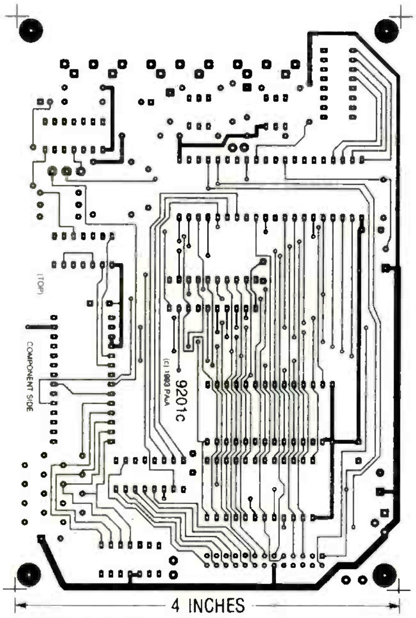


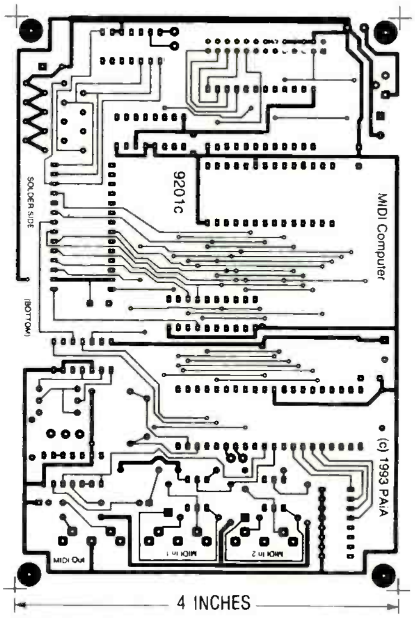
FIG. 3—DRUM CIRCUITS. One circuit, basically a "twin-T" notch filter, is duplicated six times.

of the stage, as it goes into its linear range, generates a large pop. We can get away with it here, though, for two reasons: the first is that the output of the gate drives a high-pass voicing filter (IC2-d, C23, C24, R42, and R43) that has the primary function of brightening the noise to stimulate more closely the sound of snares but also dissipates much of the energy in the level shift. Second, what little "pop" that might get through the filter is acoustically masked by the noise being gated on in the first place.

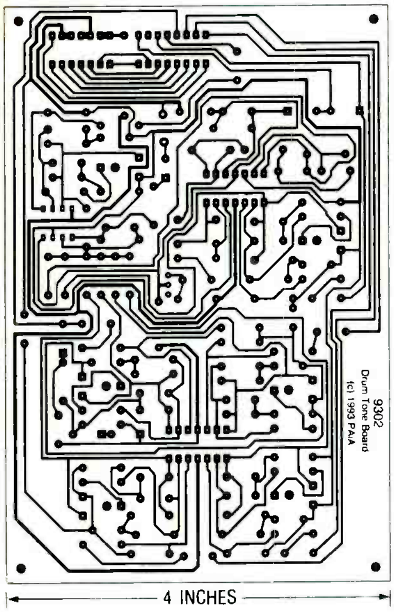
Just the noise burst alone would do a credible job of simulating a snare sound, but because we already have a tomtom sound built around IC2-a



MIDI BOARD component side.



MIDI BOARD solder side.



TONE BOARD foil pattern.

(and a snare drum is nothing but a tom-tom with snares), diode D5 couples the tom-tom oscillator to the snare trigger so that it rings when the snare pad is hit. Diode D5 also prevents the snare from sounding when only the tom-tom trigger is hit.

Whereas all the other drum circuits operate at a constant pitch, the SynthDrum built around IC1-c is a little different. It slides down in pitch as it decays. The circuit is a ringing oscillator like the others, but here the frequency can be adjusted by varying the current flow through diodes D1 and D2. It's not typical to see diodes used that way, but as current flow through a diode increases, its equivalent impedance goes down. Diodes D1 and D2 are "controlled" by the current flow through R29, which is a trigger pulse stretched by D3 and C1. The "control" is done by the notch frequency of the filter network (R24–R26, and C14–C16). A pulse raises the frequency which then glides down as the charge on C1 drains away.

While the input triggering pulse coupled by C13 and R22 knocks the circuit into oscillation and provides the percussive edge, the circuit would oscillate spontaneously just because of the change in impedance of the diodes. The result is that this drum is capable of much longer "sustains" than the others because as the trigger decays it effectively turns the tone off.

Finally, the audio outputs of all the drum circuits are mixed by the summing amplifier built from IC3-a and R52–R59, AC-coupled by C31 to the level potentiometer R61, and appear at the audio-output jack J3. The 5532 dual low-noise amplifier can directly drive high-efficiency headphones.

That's all we have room for. Next month we'll finish up. Ω

Note: The following items are available from PAiA Electronics, Inc., 3200 Teakwood Lane, Edmond, OK 73013, Phone (405) 340-6300, Fax (405) 430-6378:
- **Sensor PC board only (item # 9301pc)—$16.50**
- **MIDI PC board only (item # 9201pc)—$27.25**
- **Tone PC board only (item # 9302pc)—$19.25**
- **Sensor board kit (item # 9301k, includes PC board and parts)—$54.25**
- **MIDI computer kit (item # 9201k, includes PC board, DIN jacks, and PROM with firmware)—$89.50**
- **Tone board kit (item # 9302k, includes PC board and parts)—$34.75**
- **Complete MIDI ThumbDrum kit (item # 9300m, includes case, PC board, all parts, and firmware in PROM)—$165.00**
- **Complete audio ThumbDrum kit (item # 9300a, includes case, PC board, and all parts)—$99.00**
- **Case only (item # 9300c, includes wood side panels)—$28.50**

TONE BOARD PARTS LIST

All resistors are ¼-watt, 10%.
R1—1000 ohms
R2, R5, R9, R16, R23, R31—10,000 ohms
R3, R4, R10, R11, R13, R17, R18, R24, R25, R32, R33, R39, R47, R6, R20, R27, R35—3.9 megohms
R7, R14, R21, R28, R36, R51—100,000 ohms, trimmer potentiometers
R8, R15, R45, R60—330 ohms
R12—15,000 ohms
R19—68,000 ohms
R22, R30—33,000 ohms
R26, R29, R44—1 megohm
R34—39,000 ohms
R37, R43—680,000 ohms
R38—2200 ohms
R40–R42, R46, R48, R50—2.2 megohms
R49, R52–R57—47,000 ohms
R58, R59—22,000 ohms
R61—10,000 ohms, potentiometer
Capacitors
C1, C13, C18, C26, C9—0.01 µF, ceramic disc
C2, C6, C10, C14, C19, C22—0.01 µF, Mylar
C5—0.05 µF, Ceramic
C7, C8—4700 pF, Mylar
C3, C4, C11, C12, C15, C16, C20, C21—0.001 µF, Mylar
C17—0.22 µF, Mylar
C23, C24, C27–C29—560 pF, Mylar
C25—0.1 µF, Mylar
C30—0.005 µF, Ceramic
C31—10 µF, 15 volts, electrolytic
Semiconductors
IC1, IC2—LM324 quad op-amp
IC3—5532 dual low-noise op-amp
D1–D5—1N914 diode
Q1—NPN silicon transistor (selected for noise, see text)
Other components
J1—14-pin input connector
J2—16-pin DIP socket
J3—¼-inch phone jack
Miscellaneous: PC board, ribbon cable, solder

MIDI COMPUTER PARTS LIST

All resistors are ¼-watt, 10%.
R1—4700 ohms R2, R3, R6, R9—220 ohms
R4, R13—680 ohms
R5, R8—3300 ohms
R7, R10, R11—100,000 ohms
R12—3900 ohms
Capacitors
C1, C2—33 pF, ceramic disc
C3—10 µF, electrolytic
C4–C11—0.1 µF, Mylar
C12—1 µF, electrolytic
C13—100 pF, ceramic disc
C14—100 µF, electrolytic
C15–C19—0.01 µF, ceramic disc
Semiconductors
IC1—7805 5-volt regulator
IC2—74HC373 octal latch
IC3—8031 8-bit microcontroller
IC4—2764 EPROM
IC5—6116 static RAM
IC6—74HC04 hex inverter
IC7, IC9—TIL111 optoisolator
IC8—74HC138 1-of-8 decoder
IC10—74HC02 quad NAND gate
IC11—ADC0809 8-input ADC
D1—not used
D2,D3—1N914 diode
LED1, LED2—red light-emitting diode
Other components
J1—optional expansion header
J2–J4—5-pin DIN (MIDI) socket
S1—8-position DIP switch
S2—normally open pushbutton switch
XTAL1—12 MHz chrystal
Miscellaneous: PC board, ribbon cable, solder

DINESH BHATIA

WIRELESS GUITAR TRANSMIT

TRANSMIT YOUR GUITAR CHORDS through the air to a nearby FM receiver, and get rid of those cords on the floor. Your FM receiver can feed one or more amplifiers if you really want to boost the sound and fill the room with music. Simply plug this transmitter into your guitar's output jack, make a few adjustments, and start playing "wireless" through your FM stereo tuner or a portable FM receiver.

With this Guitar Transmitter, you won't have to plug in cables, hook up guitar-effects pedals, and turn on a lot of different power sources. Moreover, you can build your own transmitter for a lot less money than you would pay for a factory-built unit—and you'll end up with a better product. The parts for the Guitar Transmitter described here cost less than $40. This transmitter has a built-in distortion effects unit, so you won't have to fumble with an effects pedals every time you play your guitar.

Today many professional guitar players have their own wireless guitar transmitters. Why doesnt't every guitar player have one? Probably because of price. Until now it has just been a lot less expensive to plug your guitar into your amplifier with a patch cord.

Commercial wireless guitar transmitters have available since the late 1960's, but those early units were either too noisy or too expensive for most amateurs. It seemed that only rock stars could afford them. However, integrated circuitry cut the cost of transmitters and led to significant improvements in signal-to-noise (S/N) ratio over the earlier models.

However, recent "affordable" IC-based transmitters have usually included some form of *companding* to reduce background noise. Companding is a technique for compressing the signal's dynamic range at the transmitter and then expanding it back to its original range at the receiver. Dynamic range is the difference in volume between the lowest and highest audio levels.

Companding usually works well as a noise-reduction technique, but it has drawbacks: the most common of these is a response known as "breathing—" the background noise gets softer and louder as

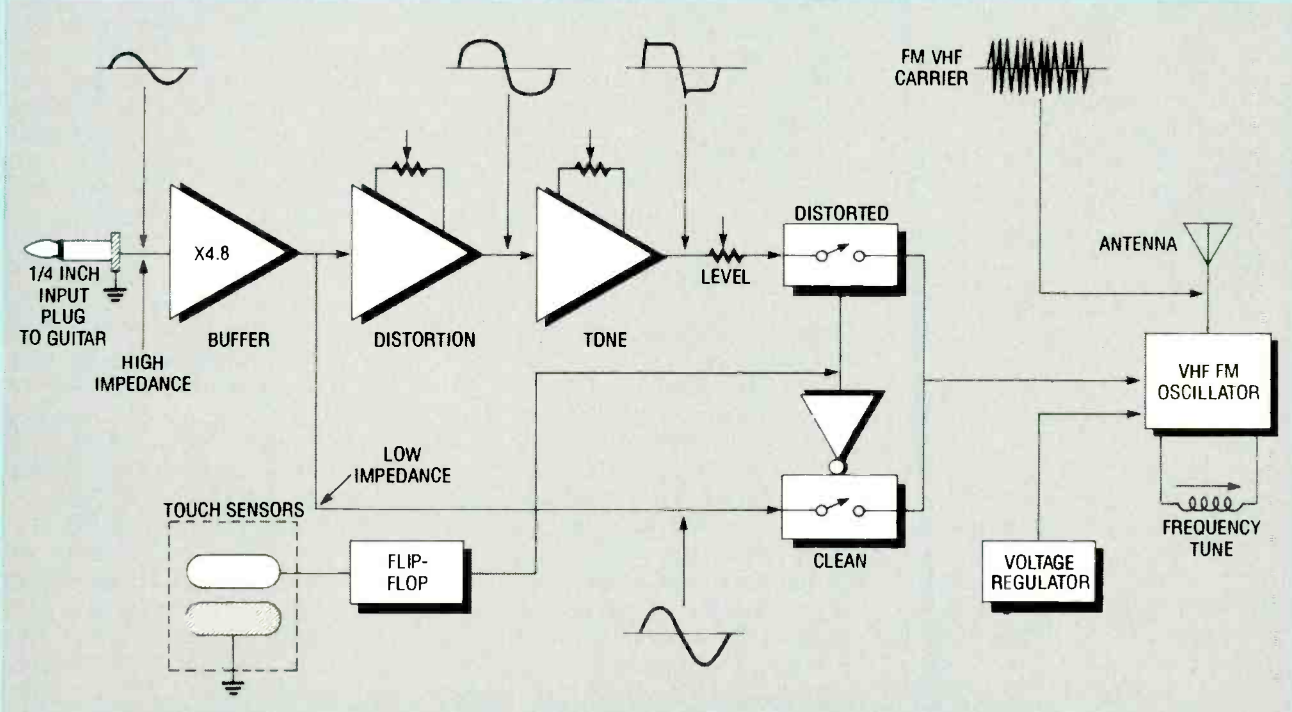


FIG. 1—BLOCK DIAGRAM OF THE WIRELESS GUITAR TRANSMITTER showing the separate channels for the distorted and clean sound and the VHF FM oscillator.

Build a wireless FM guitar transmitter that is better than what you can purchase —and save money.

TER

the guitar is played. The latest commercial wireless guitar transmitters include modifications of companding that reduce background noise and suppress "breathing," but that improvement has increased their price.

A transmitter must have a high signal-to-noise ratio (S/N) if it is to be used with a distortion-effect unit because it is essentially a high-gain audio amplifier. Therefore, if the distortion effect is inserted after the receiver (as in typical wireless guitar transmitters), *all* sound including background noise will be amplified. The result is a lower overall S/N ratio.

Typical S/N ratios for wireless transmitters rarely exceed 70 dB unless some form of companding is present. However, if you assume that a commercial wireless transmission system has an S/N of 100 dB and a distortion effects unit is inserted between the receiver and amplifier, the overall S/N will drop to about 54 dB. This is based on the assumption that voltage gain is 200, therefore:
S/N reduction = 20 log (200) = 46 dB

The Guitar Transmitter differs from the latest commercial products because it has a distortion-effects unit which precedes its transmitter. As a result, the effects unit amplifies *only* the pure guitar signal and not the background transmission noise. Therefore, noise is reduced, component cost is lower because no companding circuity is required, and you can expect a consistent 60-dB overall S/N.

Figure 1 is a block diagram of the Guitar Transmitter with typical waveforms shown at various stages of signal processing. Notice that the complete transmitter has three functional circuits: distortion, touch switch, and VHF FM voltage-controlled oscillator (VCO).

How it works

Figure 2 is the schematic diagram for the Guitar Transmitter. The plus and minus signs on the schematic near the potentiometer symbols indicate that clockwise rotation is from the minus sign towards the plus sign.

This circuit will produce both undistorted and distorted audio output. The undistorted output is produced by non-inverting amplifier IC1-*d* with a gain of:
R4/R5 + 1 = 68K/18K + 1 = 4.8.

Capacitor C1 blocks the DC components of the input signal, and resistors R2 and R3 form a voltage divider to bias the input of an LM324 operational amplifier IC1 at about half of its supply voltage of 9 volts. Resistor R1 sets the input impedance of the circuit to 1 megohm.

Capacitor C2 attenuates unwanted ultrasonic frequencies, while capacitor C3 lowers the impedance of the bias voltage at audio frequencies to yield a cleaner bias-voltage supply. Capacitor C4 performs the same function on the supply voltage for IC1.

The clean signal is then routed to IC2, a CD4066 CMOS quad bilateral switch, and is also amplified from 1 to 214 times by IC1-*a*, depending on the setting of DISTORTION control potentiometer R7. Resistor R6 and capacitor C5 establish a low-frequency roll-off (i.e., attenuation of low frequencies) of approximately 160 Hz.

To produce a distorted signal from IC1-*a*, three 1N4148 diodes, D1, D2, and D3 clip the amplified voltage at asymmetric levels of about Ø.7 volt and -1.4 volts, producing a distortion similar to that obtained with an overdriven vacuum-tube amplifier.

The distorted signal is then sent to the tone-control section centered around IC1-*b* where frequencies above about 1KHz are attenuated when TONE control potentiometer R10 is set full counter-clockwise (i.e., the wiper is at the non-inverting input of IC1-*b*. This stage amplifies frequencies above 1KHz when R10 is fully clockwise.

Resistor R8 and capacitor C6 form a low-pass filter that attenuates the high-frequency components of the clipped

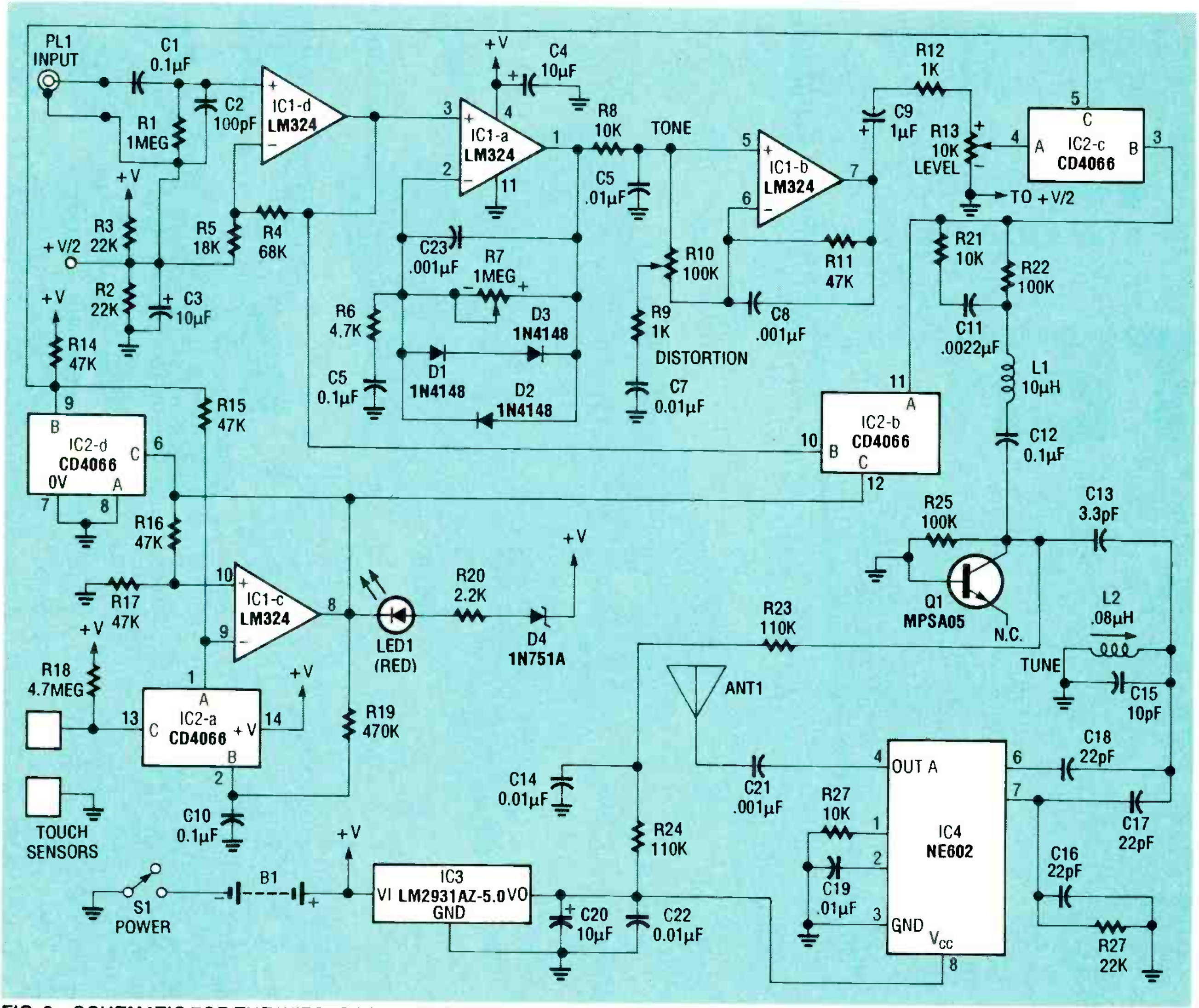


FIG. 2—SCHEMATIC FOR THE WIRELESS GUITAR TRANSMITTER. The touch sensors permit fingertip control of the sound.

waveform produced by IC-*a*. High-frequency roll-off for IC1-*b* is set by C8 and R11. The AC voltage gain is determined by resistors R9, R10 and R11.

The output level from IC1*b* is controlled by LEVEL control potentiometer R13. Capacitor C9 AC-couples R13 from the output of IC-*b*. Resistor R12 limits the maximum output voltage to prevent overmodulation of the transmitted carrier.

Touch control:

Two sections of IC2 switch between the clean and distorted signals. Sections *a* and *b* of IC2 are operated as complementary switches by the touch-control section of the transmitter. Operational amplifier IC1-*c* forms a voltage comparator with hysteresis produced by positive feedback resistor R16. The reference for this voltage comparator is set slightly higher than half the supply voltage by R16 and R17.

The entire comparator circuit performs a flip-flop function by combining an inverter IC2-*d* and R14 with low-pass filter R19 and C10. That filter has a time constant of 47 milliseconds to prevent false triggering and high- frequency oscillations.

To understand the operation of this flip-flop, assume that C10 is initially discharged, IC2-*a* is open, and IC1-*c* is in its true state (the voltage at the inverting input is less than at the non-inverting input; thus its output is at supply-voltage level. Capacitor C10 charges through R19 to a value higher than the reference voltage.

Now, if IC2-*a* were closed momentarily (pins 1 and 2 shorted), IC1-*c* would change state (i.e., output drops to zero volts). Resistor R15 provides the inverse of the output level of IC1-*c* from IC2-*d*, keeping IC1-*c* in static equilibrium. Then C10 discharges through R19 and once discharged, IC2-*a* closes momentarily, causing IC1-*c* to change state again.

This process causes a "push-pull" action, thus forming a "touch-on/touch-off" switch. In practice, the touch sensors will be shorted by a finger tip, causing control input pin 13 of IC2-*a* to be grounded, opening the switch.

The EFFECT/BATTERY LED1 lights only when the distorted sound channel is selected. Zener diode D4, resistor R20, and LED1 form a measuring circuit to indicate when battery voltage falls below about 7 volts. Replace the 9-volt battery if the *effect/battery* LED dims when the distorted sound channel is selected.

VHF FM oscillator:
The clean or distorted audio signal is fed into the VHF FM oscillator section of the transmitter. Resistors R21 and R22 and capacitor C11 form a pre-emphasis network to complement the de-emphasis network found in most FM receivers. The values chosen for this network attenuate frequencies below about 700 Hz to produce a "brighter" sound with a lot of "edge."

Low-power VHF mixer/oscillator forms an oscillator with an operating frequency of about 100 MHz, a frequency that can be adjusted across most of the FM broadcast band of 88 to 108 MHz by tuning variable coil L2. *Caution: It is unlawful to broadcast above or below the FM band with this transmitter.* The oscillator is frequency modulated by using transistor Q1 as a varactor diode. The transistor's collector-to-base junction capacitance varies directly with the applied audio voltage.

The output of voltage regulator IC3 powers IC4 and supplies a stable DC bias for transistor Q1 through resistors R23, R24, and R25. Capacitor C14 and resistors R23 and R24 form a low-pass filter that prevents unwanted RF from affecting the DC bias supply. Capacitor C13 limits the capacitance change of transistor Q1 as seen by the inductor-capacitor tank tuning section made up of variable coil inductor L2 and capacitor C15.

The tank limits the frequency deviation of the FM carrier to a maximum of ± 75 kHz in accordance with the Canadian Department of Communications (DOC) and the U.S. Federal Communication Commission (FCC) regulations. The VHF FM sinewave is generated by the inductive-capacitive tank section, and amplified and buffered by IC4. This signal is then AC coupled to the antenna by capacitor C21, which also helps to minimize antenna loading effects on IC4.

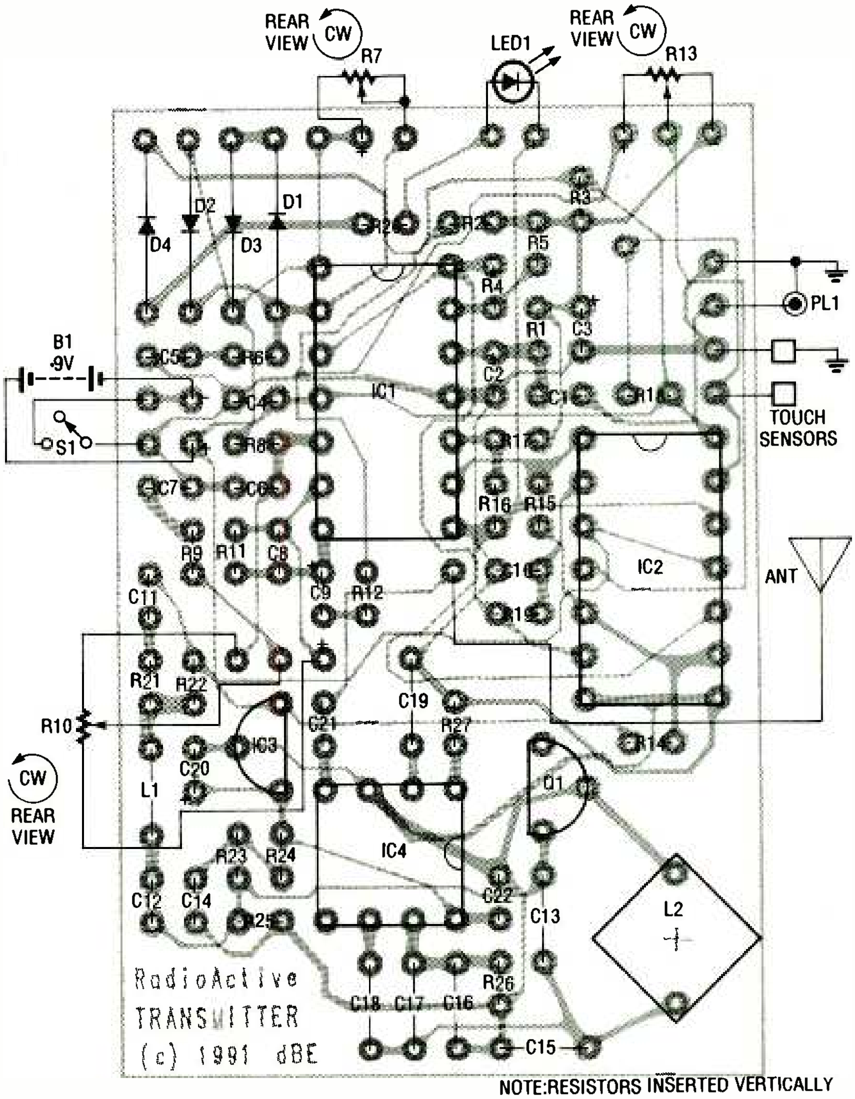
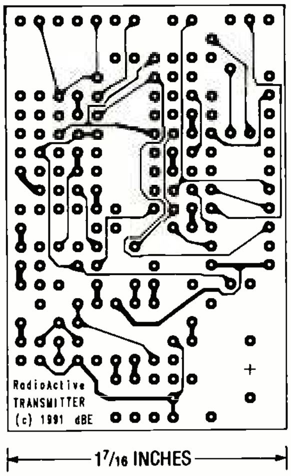
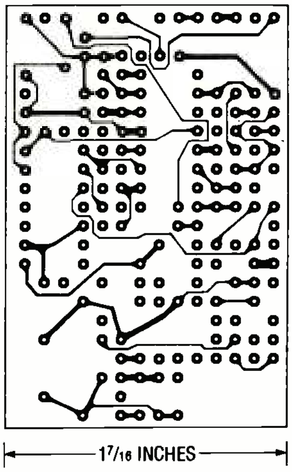


FIG. 3—PARTS PLACEMENT DIAGRAM for the wireless guitar transmitter. Three control potentiometers, the LED, and touch sensors are located on the case cover.

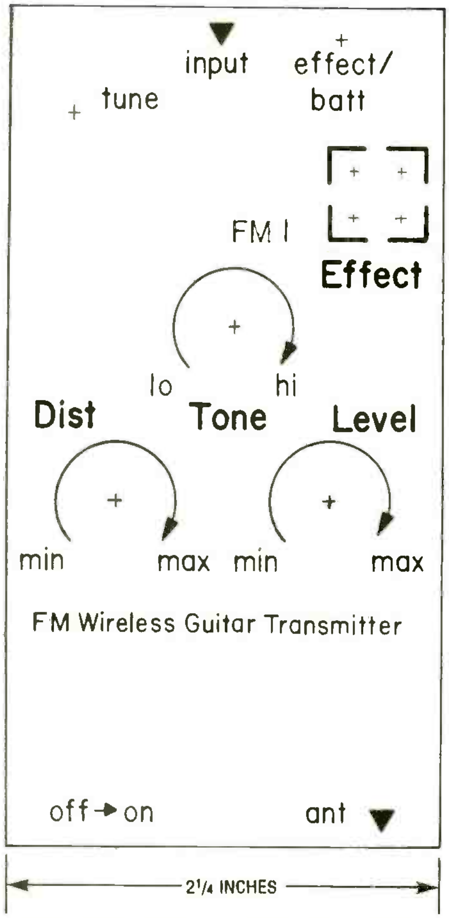


COMPONENT-SIDE FOIL PATTERN for the two-sided circuit board of the guitar transmitter.



SOLDER-SIDE FOIL PATTERN for the two-sided circuit board of the guitar transmitter.

Building the transmitter
Most of the components in the Guitar Transmitter are stan-



DRILLING TEMPLATE FOR THE COVER of the wireless guitar transmitter. Holes must also be made in the case for the input plug and the switch.

dard, off-the-shelf parts available from electronics retail stores and mail-order distributors. Although not surface-mount, the components were selected to conserve PC board space and miniaturize the circuitry.

All resistors are specified as ⅛-watt, metal-film units because they generally produce less noise in audio circuits than carbon-composition or carbon-film resistors, and they are smaller. Radial-leaded monolithic ceramic capacitors were selected because of their small size, and dipped solid tantalum capacitors were specified in place of aluminum electrolytics for 1-microfarad and 10-microfarad values to save space. Moreover, tantalum capacitors retain their rated capacitance values at higher frequencies better than aluminum electrolytics, and they do a better job of filtering out stray radio frequency (RF) noise from the power supply.

Board assembly: The Guitar Transmitter will perform better if it is built on the double-sided printed-circuit board designed for it. Both component- and solder-side foils are included in this article if you want to make your own boards. Notice, however, that plated-through holes are recommended so that you do not have

PARTS LIST

All resistors are ⅛-watt, 5%, unless otherwise specified.

R1—1 megohm
R2, R3, R26—22,000 ohms
R4—68,000 ohms
R5—18,000 ohms
R6—4,700 ohms
R7—1 megohm miniature potentiometer
R8—10,000 ohms
R9—1000 ohms
R10—100,000 ohms miniature potentiometer
R11, R14, R15, R16, R17—47,000 ohms
R13—10,000 ohms miniature potentiometer
R12—1000 ohms
R18—4.7 megohms
R19—470,000
R20—2,200
R21, R27—10,000 ohms
R22, R25—100,000 ohms
R23, R24—110,000 ohms

Semiconductors

IC1—LM324N quad low-power operational amplifiers, Motorola or equivalent
IC2—CD4066BCMOS quad bilateral switch, Harris or equivalent
IC3—LM2931Z-5.0 low-dropout voltage regulator, 5-volt, Motorola or equivalent
IC4—NE602Nlow-power VHF mixer/oscillator, Signetics or equivalent
Q1—MPSA05 NPN transistor National or equivalent
D1, D2, D3—1N4148 fast-switching diode
D4—1N751A Zener diode, 5.1-volt, 500 mW
LED1—light-emitting diode, general purpose, T1 case size, red,

Capacitors

C1, C5, C10, C12—0.1 µF ceramic monolithic , radial-leaded, 10%
C2—100 pF, ceramic disc, 10%
C3, C4, C20—10 µF, tantalum, solid dip, 10%, 10 volts
C6, C7, C14, C19, C22—0.01 µF ceramic monolithic, 10%,
C8, C21, C23—0.001 µF ceramic monolithic, radial leaded, 10%
C9—1 µF tantalum, solid dip, 10%, 10 volts
C11—0.0022 µF, polyester film, 5%
C13—3.3 pF ceramic Philips 09338 or equivalent
C15—10 pf ceramic, Philips 10109 or equivalent
C16, C17, C18—10 pF ceramic, Philips 10229 or eqivalent

Inductors

L1—10 µH, fixed, 5% Toko FL-4 or equivalent
L2—0.08 µH variable molded, Q = 130 @ 100 MHz, Toko MC-120 or equivalent

Other components

B1—battery, 9-volt, alkaline transistor
tr- S1—switch, subminiature slide, SPDT
PL1—input plug, ¼-inch, mono phone

Miscellaneous: double-sided printed circuit board, 9-volt battery clip, plastic project case with cover with inside dimensions of 4 ¼ × 2⅛ × ¹¹⁄₁₆-inch deep, three miniature black knobs, 28 AWG stranded, black-insulated hookup wire, multicolored ribbon cable, plastic coil alignment tool, solder, epoxy cement, RTV silicone adhesive.

Note:The following parts are available from RadioActive Transmissions, P.O. Box 6714, Station "A", Simcoe St., Toronto, Ontario, M5W 1X5 Canada (519) 974-0163, Fax (519) 974-0165.

- **Kit 1—complete kit of all parts including double-sided PC board, plastic coil alignment tool, and screened predrilled case —$39.95 plus $5.00 shipping and handling.**

- **Kit 2—silk-screened and pre-drilled case with cover and three knobs—$10.00 plus $2.50 shipping and handling.**

- **Assembled and tested unit $54.95 plus $5.00 shipping and handling. Please send U.S. money order only. Canadian residents please call for prices. Other countries add additional $5.00 for shipping.**

to solder leads on both sides of the board to assure a sound solder joint. If you do not want to make the board yourself you can purchase a finished circuit board from the source listed in the Parts List or build the circuit on perforated board.

You can obtain the full performance capabilities of the circuit with perforated board if you are aware of the possible pitfalls in building an RF circuit on that substrate—and take extra care in placing components and dressing wires. Nevertheless, the use of perforated circuit board stock is not recommended.

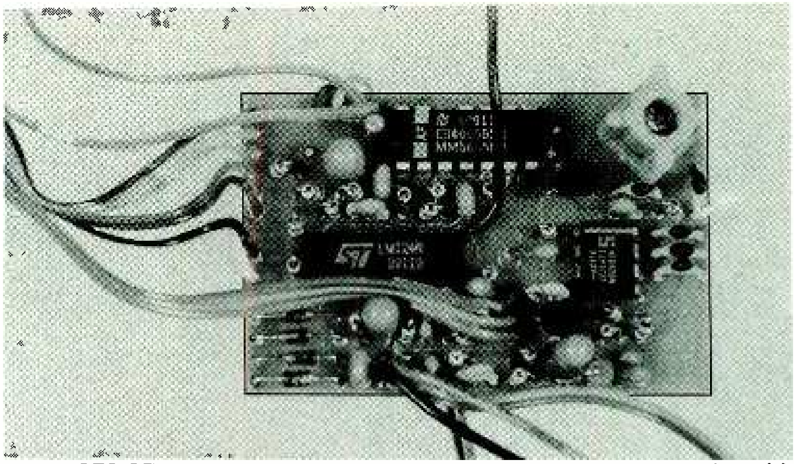


FIG. 4—PHOTO OF THE COMPLETED guitar transmitter circuit board showing wiring to off-board components. Note the star-shaped tuner body.

When building the transmitter, refer to schematic Fig. 2 and Parts Placement diagram Fig. 3. Follow standard practice in inserting the components and soldering them in place. Use a grounded, 15- to 30-watt, pencil-type soldering iron, especially for soldering the semiconductor devices to avoid damaging or destroying the devices with excess heat or electrostatic discharge (ESD).

There is a choice of three different values for capacitor C15 because the tuning coil L2 for this transmitter has a high Q (130 at 100 MHz). The letter Q stands for quality factor—a reference to the ability of the circuit to present a well defined oscillator frequency. The higher the resolution, the smaller the tuning range if the range of the tuning slug is limited to the length of the coil body.

Variable coil L2 specified in the Parts List has a tunable frequency limit of about 15 MHz. Because the FM broadcast band spectrum is 20 MHz wide (from 88 to 108 MHz), select one of three standard values for C15:

- 10 picofarads gives a tuning range 15 MHz wide centered at approximately 98 MHz. (The ends of the FM broadcast band can be obtained with slightly higher or lower values for C15.)
- 12 picofarads permits tuning in the lower end of the band.
- 8.2 picofarads permits tuning in the upper end.

The exact tuning range obtained will vary with each transmitter because of the parasitic capacitance and inductance introduced by the interconnecting wires.

Do not use IC sockets for any of the ICs because all lead lengths must be kept as short as possible. The components can be inserted and soldered in any order, but it is a good idea to check off each part on the Parts List after you insert and solder it.

Observe all polarities shown on the schematic for the diodes and tantalum capacitors. Mount all resistors vertically, and mount all capacitors flush against the circuit board. After soldering, trim all lead lengths as short as possible to reduce stray noise pick-up in the audio-frequency section of the transmitter.

Antenna length

Cut a 38.2 centimeter (15.3-inch) length of black stranded 28 AWG insulated hookup wire for the antenna. Trim one end and solder that end in position as shown in Fig. 3. The Guitar Transmitter operates at 98.00 MHz, so one wavelength equals 3.0612 meters.

Transmitted signal strength is generally proportional to antenna length up to one wavelength, but if its length is more than 76 centimeters (30 inches) the transmitted carrier will exceed the maximum allowable signal strength level specified by the DOC and FCC regulations. That's why the 38.2 centimeter antenna length was selected for this transmitter.

Mechanical assembly

After all of the components are inserted and soldered on the PC board, refer to exploded assembly drawing Fig. 4 as well as the Parts Placement diagram Fig. 3 for the location and orientation of off-board components. If you purchase the case and cover from the source given in the Parts list, all holes will be drilled.

If you elect to provide your own case, use the cover template provided to drill:

- Three control potentiometer mounting holes.
- Four 3⁄32-inch holes for the touch sensor.
- One 1⁄16-inch hole for access to tuner L2.
- One 3⁄32-inch hole for LED1.

Then drill a 0.39-inch diameter hole centered in the end wall of the case for plug PL1, taking care that the plug fits snugly. (The plug will be the sole support for the completed transmitter when it is plugged into the guitar, so it is important that it be rigidly mounted.)

Finally, cut a slot in the opposite end wall of the case for switch S1, and drill one or two holes beside the slot, as necessary, for fastening the switch to the case. With a hacksaw, cut a slot about 1⁄16-inch deep in the end wall of the case near the switch slot for the antenna wire to permit it to pass under the cover without interference when the cover is closed.

Assemble the touch sensor from four 1/4 inch, No. 4-40 Phillips-head screws with match-

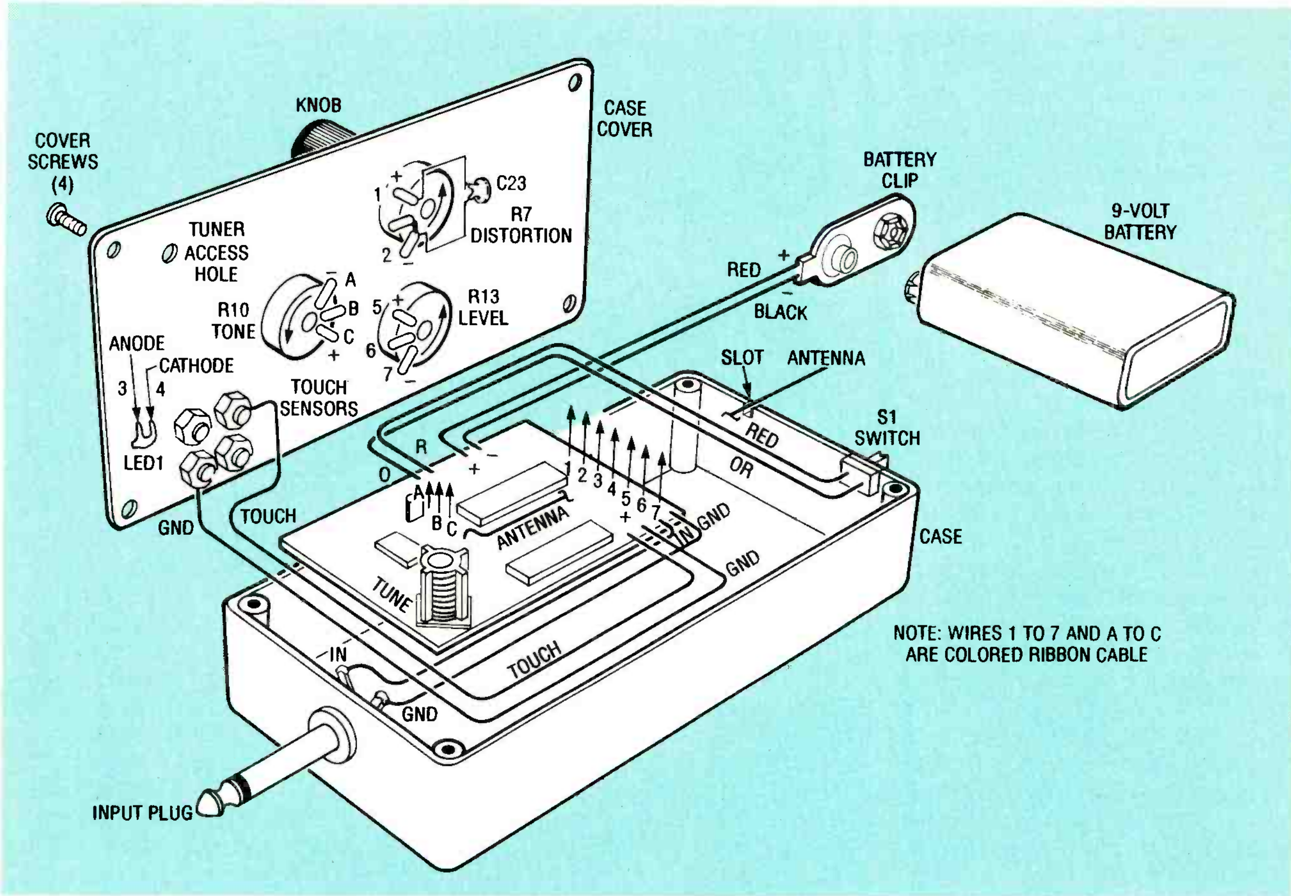


FIG. 5—EXPLODED VIEW OF THE TRANSMITTER showing the locations of the off-board components and wiring. The input plug attaches the transmitter to the guitar.

ing nuts. (Two of the four nut-bolt combinations will be non-functional.) However, be sure that the two to be wired as active sensor elements are electrically isolated.

Assemble the three miniature control potentiometers R7, R10 and R13 to the underside of the cover with the ring nuts provided, orient their terminals as shown as shown in Fig. 4, and tighten the nuts. Insert plug PL1 and secure it in position with its nut. Insert switch S1 in the case and fasten it with one or two rivets or self-tapping screws.

Off-board wiring

Cut 6- to 7-inch lengths of standard multicolored ribbon cable (28 AWG 7×36 stranded tinned copper), strip about 1/16-inch of insulation from the ends, and insert one set of wires in the board and solder them in position. (As many as ten wires can remain bonded together for most of their length if they are separated only near top and bottom to permit making the connections.) Then crimp the bared ends of the off-board wires around the lugs of the potentiometers, and the leads of the LED and plug before soldering:

- The terminal lugs of potentiometers R7, R10, and R13 (as shown in Figs. 3 and 4): 8 wires.
- Light-emitting diode (LED1): 2 wires.
- Input plug PL1: 2 wires.

Insert capacitor C23 between the terminals of potentiometer R7. (It reduces the possibility of audible feedback in the high-gain distortion stage.) Solder all wires to the potentiometer lugs and the leads of LED1.

Loosen two of the touch -sensor nut-bolt combinations, and wind one turn of the bare end of the "ground" wire around one of the screws and one turn of the bare end of the "touch" wire around the other screw. Then tighten both nuts to clamp the wire ends securely in place.

Cut, and strip the ends of about 3-inch lengths of the red and black battery-clip wires, and solder them to the PC board. Bend the leads of LED1 90°, insert the LED in the drilled hole in the cover, and cement it in position with epoxy cement. Carefully check all wiring to be sure that you have made no mistakes, and make any corrections necessary.

Position the circuit board as shown in Fig. 4, being certain that the top of inductor L2 is aligned under the access hole drilled in the cover. Apply one drop of RTV silicone (or other appropriate adhesive) to each of the four corners of the circuit board on the solder side, and position the board correctly in the bottom of the case. Also place a drop of adhesive in the slot for the antenna wire cut in the edge of the case, and position the wire in the slot to keep it in position. Allow time for all adhesives to set.

Snap a fresh 9-volt alkaline transistor battery to the battery clip. Check to see that the EFFECT/BATTERY LED lights when you bridge the screw

continued on page 87

Hone your musical skills with Perfect Pitch, the microprocessor-based instrument tuner, headphone amplifier, and metronome.

MUSICIAN'S FRIEND

FRED EADY

THERE ARE FOUR VERY IMPORTANT things that anyone who wants to be a good musician must do: practice, practice, practice, and play in tune. Perfect Pitch will help you do all four! Perfect Pitch, which is based on the 8751H microprocessor, is an inexpensive and easy-to-build instrument tuner/frequency counter with a built-in headphone amplifier and a visual metronome. Perfect Pitch converts the audio signal from your instrument to a digital signal, and displays the musical note you are playing and its frequency in real time on a 16-character liquid-crystal display. It also has an auxiliary audio input for radio, tape, or CD players so you can tune up and play along with your favorite artists.

The not-so-musically inclined can use the Perfect Pitch's 60-kHz frequency counter/period measurement system to get the most from other audio-based projects. Perfect Pitch not only processes audio signals; any TTL-compatible digital signal up to 60 kHz can also be measured. Building Perfect Pitch will demonstrate the concepts behind driving liquid-crystal displays (LCD's), performing mathematical calculations, sensing and reacting to switch closures, and digitally processing audio signals.

Operation

As previously stated, Perfect Pitch is based on the popular 8751-series microcontroller. The circuitry is not particularly complex when divided into five major areas: processor, LCD, signal processing/conditioning, audio amplifier, and power. Let's start by examining the 8751 and its directly associated components.

The 8751H

The 8751H is an 8-bit microcontroller that contains four 8-bit ports with 32 bidirectional and individually addressable I/O lines, 4 kilobytes of on-chip EPROM, 128 bytes of on-chip data RAM, two 16-bit timer/counters, and extensive Boolean processing (single-bit logic) capability. Its maximum clock speed is 12 MHz, with a corresponding instruction-cycle time of 1 microsecond. Figure 1 shows the 8751's block diagram.

Note that we're more interested in the processing power of the 8751H than the abundant I/O capabilities it contains. The complexity of the design is reduced because the 8751H instruction set and internal hardware structure is very efficient and powerful. Take a look at the Perfect Pitch schematic in Fig. 2.

Port 1 of the 8751H provides the ASCII display data used by the LCD, with bit 7 doing double-duty as an LCD BUSY input. Only five bits of Port 3 are in service as common I/O. Bits 5, 6, and 7 of Port 3 supply binary control sequences for LCD read/write operations. Bits 0 and 1 of Port 3 monitor the multipurpose switch, S1, which is used for scrolling through the menu selections as well as for pacing the visual metronome when the metronome function is invoked. The processor's external clock is connected to pins 18 and 19, and the processor-reset circuit, consisting of R1 and C3, is attached to pin 9 of IC1. A reset switch is not necessary, but if you think you might need one, place a normally open momentary switch across C3.

Port 3 can be configured as a bidirectional I/O port, or its pins, under software control,

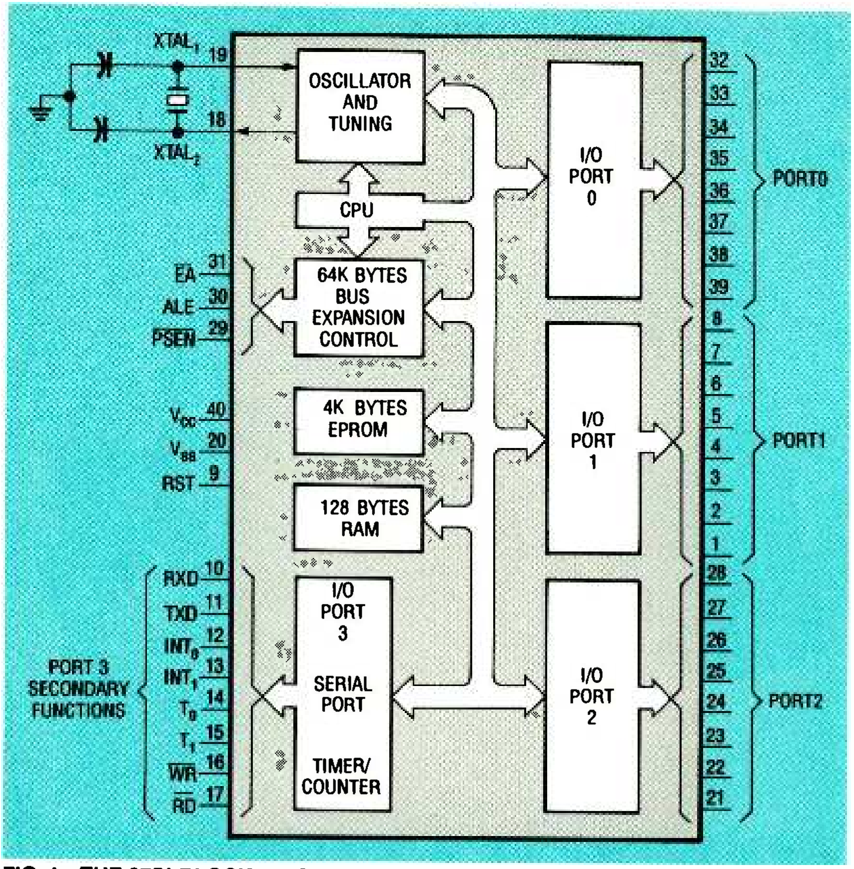


FIG. 1—THE 8751 BLOCK DIAGRAM: The 8-bit microcontroller contains four 8-bit I/O ports, 4K bytes of EPROM, 128 bytes of RAM, two 16-bit timer/counters, and Boolean processing.

can be used for timer/counter inputs and gates, serial communications, or control of external memory access. Perfect Pitch takes advantage of the timer/counter functions provided by bits 2 and 4 of Port 3. Bit 2 of Port 3 (INT_0) is organized by software to provide the gating function for timer/counter 0 for period measurement. which is used for tuning. Bit 4 of Port 3 (T_0) is the input for the frequency-counting function.

Period measurements are made while a TTL high state is present at INT_0. The program loads a bit pattern into the 8751H TMOD (Timer/Counter Mode Control) register to enable or gate Timer 0 when a high condition is detected on INT_0. (Both source code and executable code is available from the *Electronics Now BBS*, 516-293-2283, 1200/2400, 8N1, as a self-extracting compressed file called PERFECT.EXE. A preprogrammed microcontroller is available from the source mentioned in the Parts List.)

The resolution of Timer 0 is 1 microsecond. Thus, if 1000 microseconds were counted in Timer 0 during one complete cycle of a sampled signal, the frequency of the measured signal would be computed by Perfect Pitch to be 1 kHz. The frequency would be computed using the formula $f = 1/T$, where f is frequency in hertz and T is one cycle time in seconds (the period). This is a very fast and accurate way to determine the frequency of a signal that varies in amplitude over time, as guitar signals do. Perfect Pitch requires only 1 cycle of the incoming signal at proper amplitude to determine its frequency.

For frequency counting, the T_0 counter input detects 1-to-0 transitions of an incoming TTL signal on a timebase of 1 second. Those transistions provide the logical trigger that increments Timer/Counter 0 on each transition. Since the timer/counter registers are 16 bits wide, the maximum count is limited to 65.535 kHz maximum, with the usable resolution of our circuitry ending at just below 62 kHz. The 1-second timebase is implemented in software, which allows easy customization or fine tuning if it's necessary for your particular application.

The LCD

The Perfect Pitch display is a 16-character × 1-line dot-matrix LCD module that is based on the HD44780 controller and driver chip. The 8751H (IC1) provides ASCII data and associated control sequences to the HD44780, which controls the display of alphanumeric characters on the LCD. Contrast control is provided by potentiometer R2.

There are several advantages to using an LCD instead of LED's. For one, they are easier to interface to a microcontroller. They also have alphanumeric output capability, and are low in power consumption.

Processing/conditioning

If you were to take a snapshot of an electric-guitar signal on an oscilloscope, you would see that the base or fundamental frequency exhibits the maximum peak-to-peak amplitude, and all of its harmonics would be distributed around its center line at reduced amplitudes. To get an accurate frequency determination, only the fundamental frequency should be measured. And to get the most accurate readings, it is necessary to measure the desired signal peaks as many times as possible during the life of the signal.

Perfect Pitch begins at the first cycle and measures and displays the frequency of a signal until the amplified signal amplitude is too low to drive the input of IC4-d. If there is no signal, or if the amplified signal negative peaks cannot reach the 0.8-volt threshold of IC4-d, the software embedded in the 8751H provides an auto-zero function that automatically zeros the display. That allows multiple repetitive readings without manual intervention. The software also suppresses the display of leading zeros.

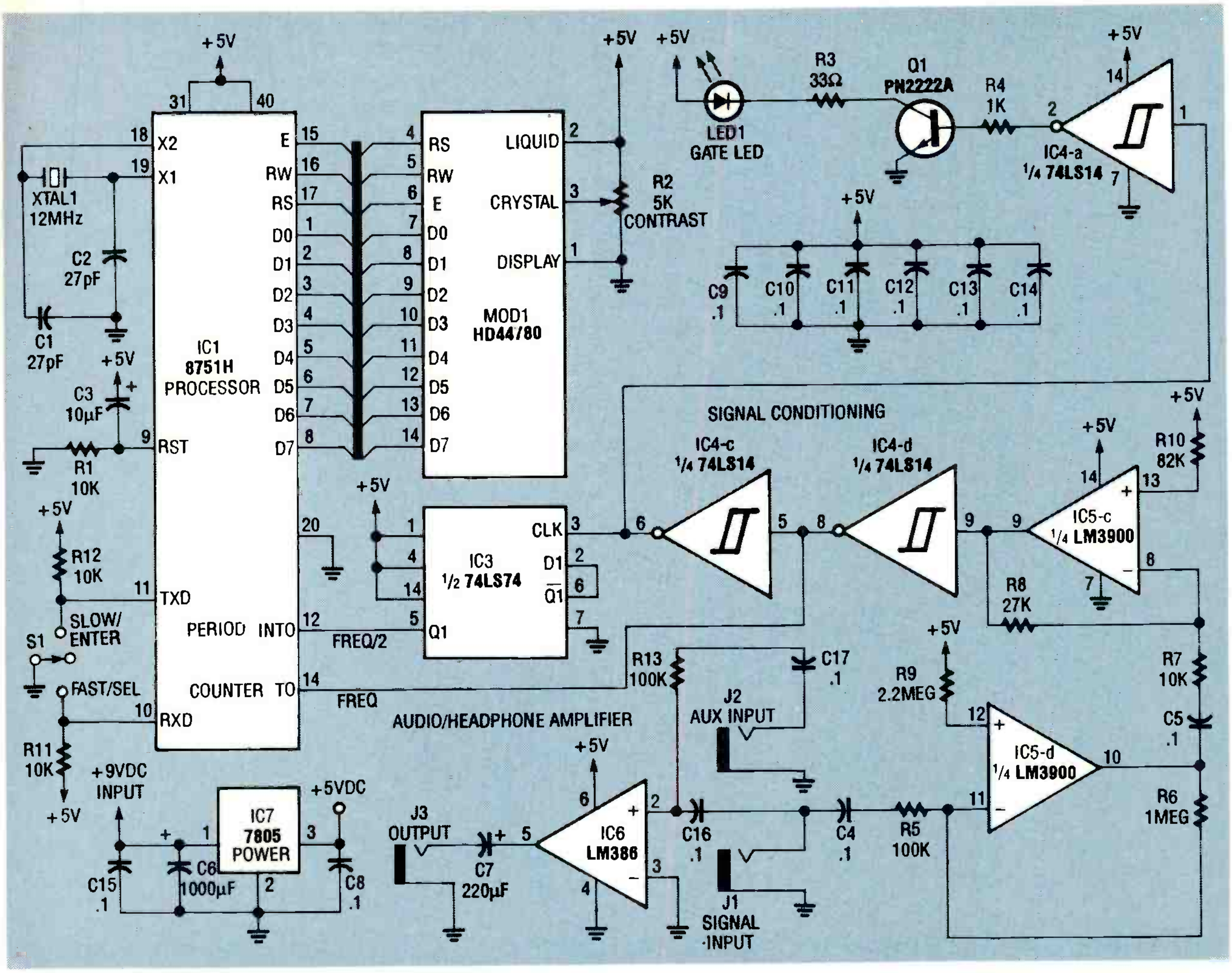


FIG. 2—PERFECT PITCH SCHEMATIC: The complexity of the design is reduced because the 8751H instruction set and internal hardware structure is efficient and powerful.

Most electronic instruments and microphones emit audio signals in the millivolt range. An average electric guitar produces a 65- to 100-millivolt signal into a high-impedance input. That is plenty of amplitude to drive an audio amplifier preamp circuit, but far below the level needed to drive a TTL gate (in our case, IC4-d, a Schmitt trigger). The incoming signal must be amplified so that it can be converted to a TTL-compatible waveform that the 8751H can interpret. A voltage gain of around 25 is the minimum required.

An LM3900 quad Norton amplifier (IC5) is configured as a two-stage audio amplifier with an overall voltage gain of 27. Given a sinewave with an amplitude of 65 millivolts or greater, an amplifier with a gain of 27, and the Schmitt trigger, you can produce clean TTL-compatible square waves that will be suitable as input to the 8751H processor.

Because musical instruments can generate many harmonics that will also be amplified, and possibly converted and analyzed, you have to get rid of the harmonics. "Filtering" is the first thing that comes to mind, but in this case that would be complicated and require additional circuitry. Amplifying the input signal enough to force signal clipping would be another solution, but that generates even more unwanted harmonics. You can solve the harmonic problem easily by using a feature inherent to the Schmitt trigger: hysteresis. As shown in Fig. 3, in effect, you will force the harmonics to reside in a "dead zone" where they cannot trigger IC4-d. Only the fundamental frequency will have enough amplitude to toggle the output of IC4-d. That enables you to use signal peaks as timing markers to calculate your results.

For the 74LS14 Schmitt trigger, the dead zone is nominally 0.8 volts wide with a minimum positive-going threshold of +1.6 volts and a minimum negative-going threshold of +0.8 volts. Audio amplifiers are normally designed to allow the output signal to swing symmetrically around a DC value of one half of the power-supply voltage. But since you want to convert your signal to a digital pulse with a Schmitt trigger, you can waive the symmetrical output rule.

Ideally the center line should be set at or above the +1.6-volt DC level because that will produce a TTL high level at the in-

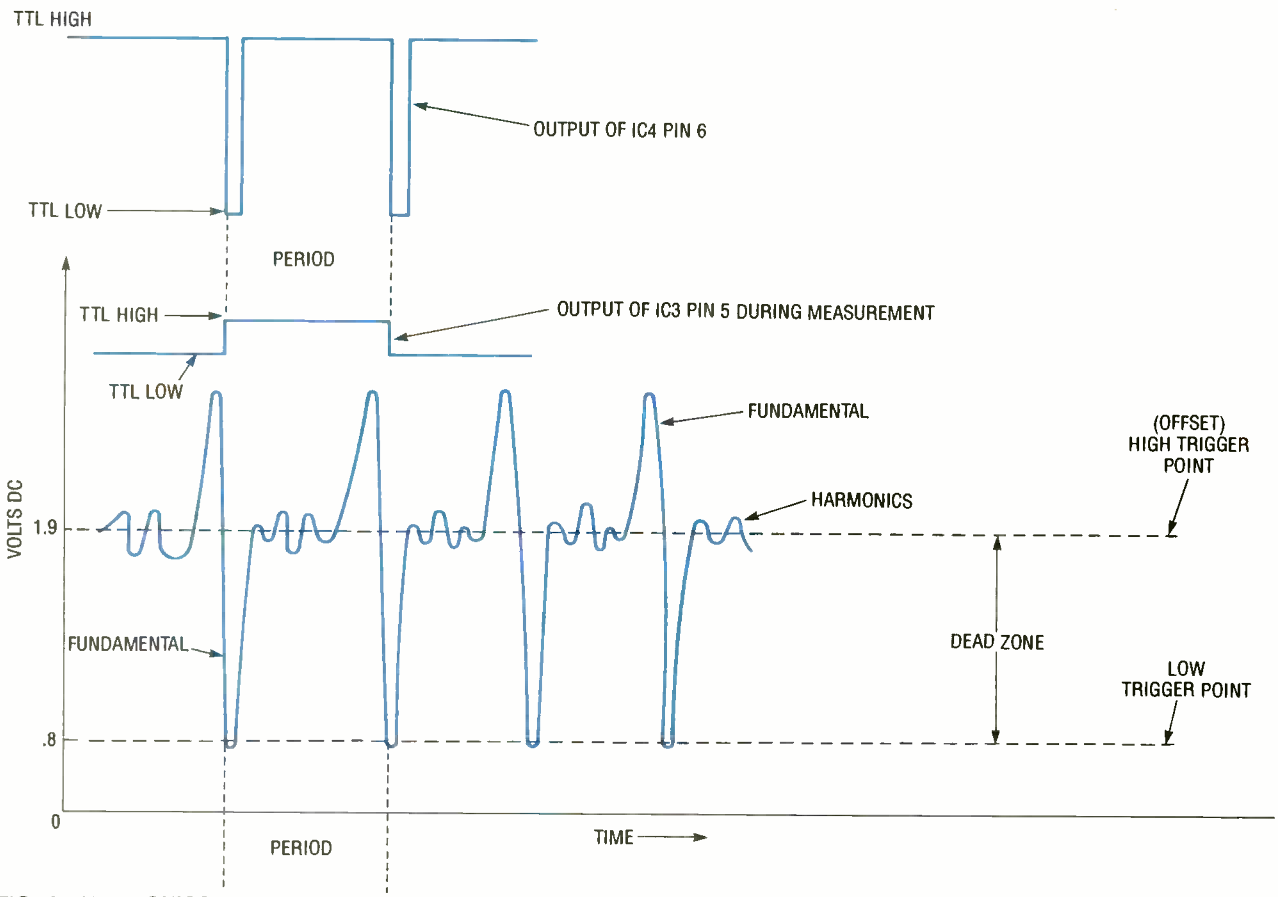


FIG. 3—HARMONICS ARE FORCED to reside in a "dead zone" so that only the fundamental frequency will have enough amplitude to cause the output of IC4-d to toggle.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted
R1—10,000 ohms
R2—5000 ohms, trimmer potentiometer
R3—33 ohms
R4—1000 ohms
R5, R13—100,000 ohms
R6—1 megohm
R7, R11, R12—10,000 ohms
R8—27,000 ohms
R9—2200 ohms
R10—82,000 ohms
Capacitors
C1, C2—27 pF
C3—10 µF, 16 volts, Tantalum
C4, C5, C8–C17—0.1 µF
C6—1000 µF, 16 volts, electrolytic
C7—220 µF, 16 volts, electrolytic
Semiconductors
IC1—8751H microcontroller (must be programmed)
IC2—not used
IC3—74LS74 D flip-flop
IC4—74LS14 Schmitt trigger
IC5—LM3900 quad op-amp
IC6—LM386 audio amplifier
IC7—7805 5-volt regulator
LED1—light-emitting diode, any color
Q1—PN2222A NPN transistor
Other components
MOD1—Hitachi H2570 16-character × 1-line LCD module (uses HD44780 controller chip)
XTAL1—12-MHz crystal
S1—SPDT center-off momentary rocker switch
J1–J3—audio jacks and plugs of your choice
Miscellaneous: PC board, project case, ribbon cable, 9-volt DC power supply (500 mA), hardware, IC sockets, solder
Note: The following items are available from Fred Eady, PO Box 541222, Merritt Island, FL 32954:
• Kit of parts with a programmed microcontroller and PC board (does not include batteries/power supply, case, plugs and jacks, ribbon cable, or rocker switch)—$59.00 + $5.00 S&H
• Programmed 8751H microcontroller—$25.00 + $2.50 S&H
• Blank 8751H microcontroller—$18.00 + $2.50 S&H
• PC board only—$20.00 + 2.50 S&H
• 8751H source code on 5.25-inch diskette—$5.00 postpaid
• 8751H modification plans for 874X programmer (includes source code, terminal program, and schematic)—$10.00 postpaid
• 874X programmer kit and 8751H modification plans—$59.95 + $5.00 S&H

Please send check or money order only
For technical assistance call (407) 454-9905

put of Schmitt trigger IC4-d. You can set that center line by adjusting the value of output offset resistor R10, which sets the output of IC5-c. The data sheet for the 74LS14 states that the minimum positive-going threshold value is +1.6 volts, and the maximum positive-going threshold value is +1.9 volts. To compensate for devices that toggle at the +1.9 volt value, the output of IC5-c is set at +1.9 volts. Note also that a TTL high threshold for most TTL devices is +2 volts DC, and the low threshold is +0.7 volts DC.

When referring to TTL levels in this discussion, we are speaking specifically about the 74LS14 Schmitt trigger, unless otherwise stated. With the output center line of IC5-c set at TTL high (+1.9 volts DC in our case), you will trigger and subsequently toggle the Schmitt-trigger chain when the output of IC5-c swings negative about the +1.9-volt DC line to +0.8 volts. Approximately 80 millivolts of incoming audio signal at IC5-d would be the minimum required to initiate a measurement when using the +1.9-volt reference.

When alternating high and low thresholds are reached at the input of IC4-d, its output is a clean TTL square wave that provides the input for the T_0 frequency counter. Schmitt trigger IC4-d also triggers IC4-c, which in turn triggers IC4-a. Schmitt trigger IC4-c also drives the clock input of IC3, a 74LS74 D flip-flop, which is configured to divide by two. The division is required because a period is the time required to complete one cycle. Also, the 8751H Timer 0 measures time only when INT_0 is presented with a TTL high.

Because one complete cycle consists of a high and low state of varying duty cycle that is not always 50%, the 8751H will measure time only for some fraction of a period that depends on a high percentage for the duty cycle. By dividing the incoming signal with a flip-flop, you produce a TTL signal with a 50% duty cycle that doubles the input signal's period. Since we measure time only at the TTL high level, and the TTL high level is one time period, the 8751H will log the period of the incoming signal. Note that the divide-by-two output of IC3 (pin 5) feeds the INT_0, or period input (pin 12) of IC1.

Once the period (T) has been measured, the algorithm contained in the 8751H EPROM performs the math necessary to solve the equation $f = 1/T$. The result of that equation (f) is then formatted and converted to ASCII and displayed for the user. A lookup table is used to determine the musical note associated with the frequency that has been calculated by perfect pitch.

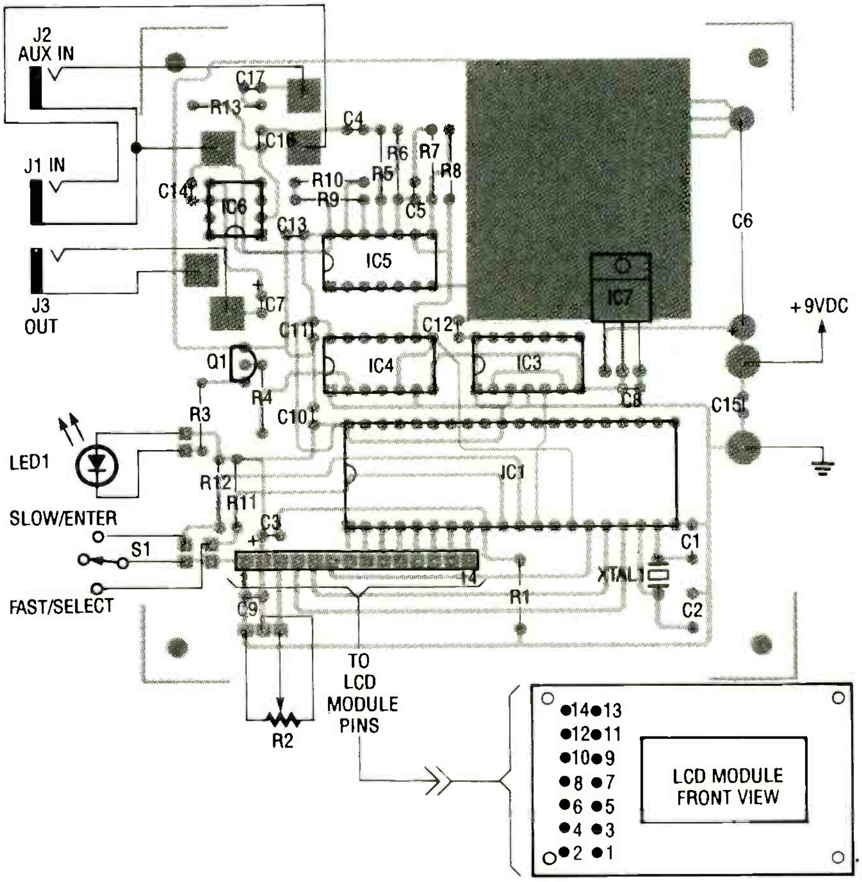


FIG. 4—PARTS-PLACEMENT DIAGRAM. The main board connects to the LCD module with a length of ribbon cable.

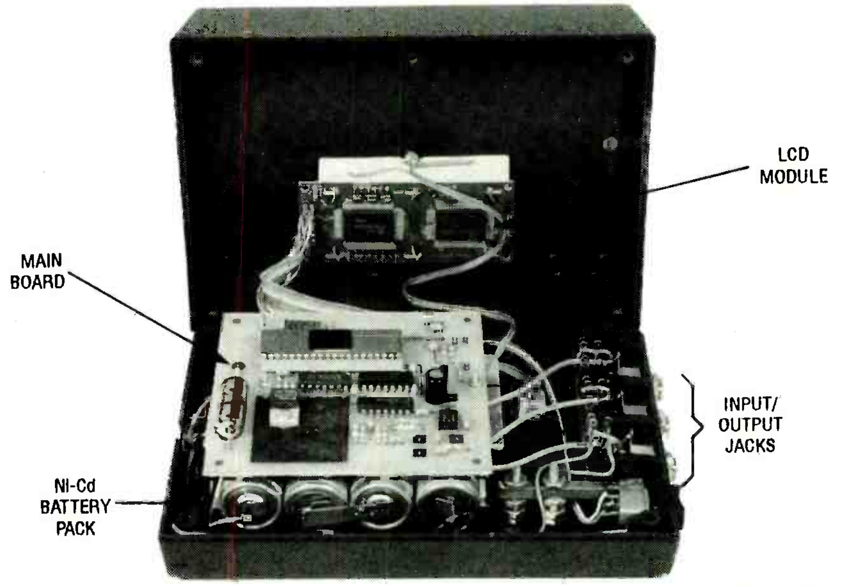
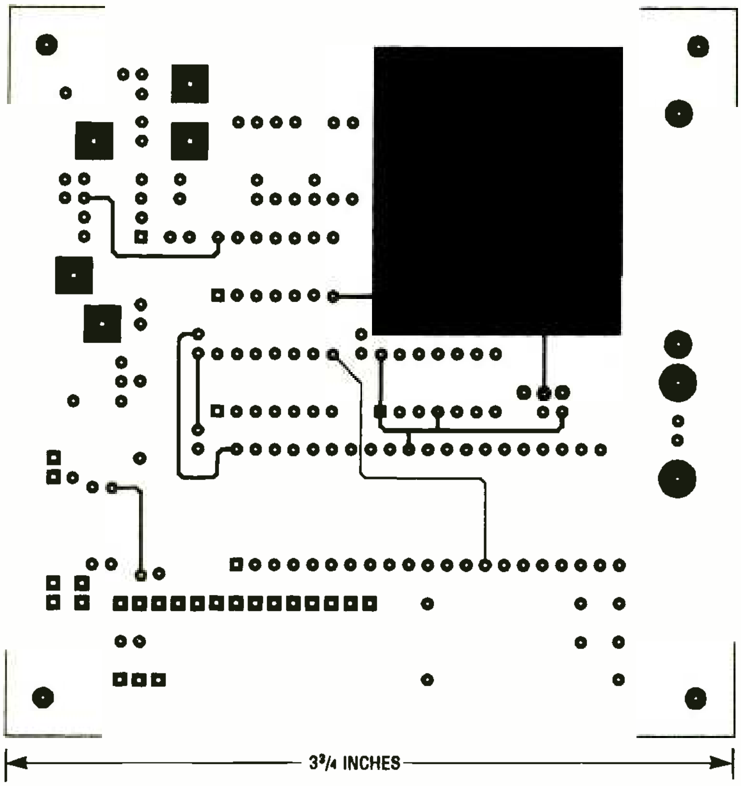
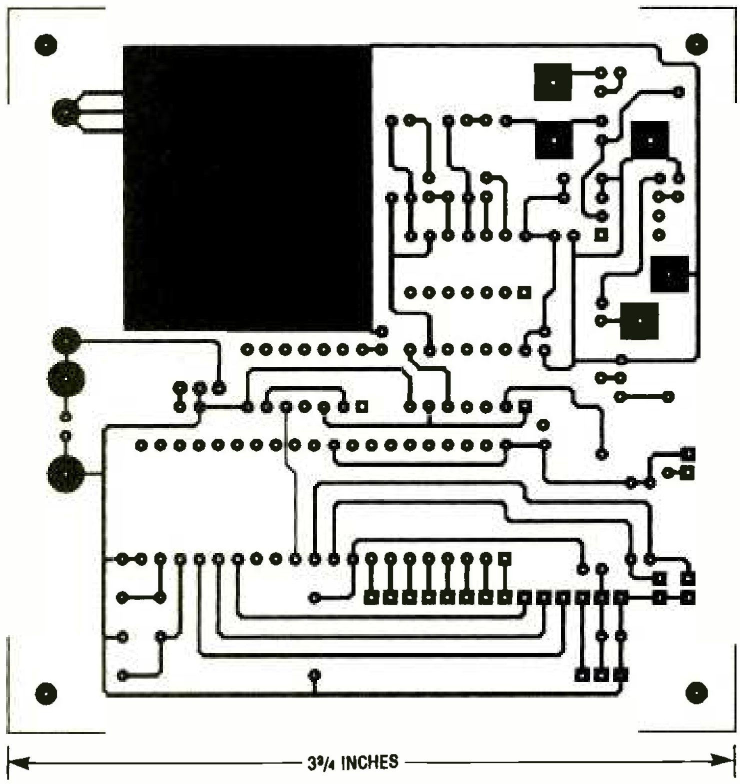


FIG. 5—INSTALL PERFECT PITCH in an enclosure of your choice. This is the author's completed prototype.



COMPONENT-SIDE foil pattern for Perfect Pitch.



SOLDER-SIDE foil pattern for Perfect Pitch.

Schmitt trigger IC4-a drives the base of transistor Q1 which provides a path to ground for LED1, the gate indicator; LED1 is illuminated when the amplified audio signal has sufficient amplitude to cross IC4-d's +0.8-volt threshold on negative peaks. Keep in mind that period and count measurements are made only when LED1 is illuminated.

Audio amplifier

So far we have discussed the signal-processing circuitry containing IC5, an LM3900 quad Norton amplifier, IC3, a 74LS74 D flip-flop, and IC4, a 74LS14 Schmitt trigger. Although Perfect Pitch displays the musical note and its frequency, the user still has to be able to hear the note. Therefore, headphone amplifier IC6 is included in the circuit. The amplifier also allows external audio to be mixed in at its noninverting input.

Note the absence of volume and tone controls. Most electronic instruments have their own volume and tone controls, so why not use them? The same goes for the auxiliary input: mix with the controls provided on the auxiliary device. If you require a volume control, put a 1K potentiometer in series with the output of IC6 pin 5.

Power

The Perfect Pitch prototype is battery powered, but any stable 9-volt DC source will work. A 7805 regulator, IC7, outputs 5-volts DC from the 9-volt input. Capacitors C8 and C15 perform bypass functions, while C6 provides some additional stability, and C9–C14 are standard TTL bypass capacitors.

The battery pack used in the prototype is composed of eight 1200-milliampere/hour sub-C rechargeable nickel-cadmium (Ni-Cd) cells. Perfect Pitch draws about 200 milliamps and battery life averages 4 to 5 hours. You can use smaller Ni-Cd cells but battery life will decrease accordingly.

Construction

Because we are combining audio and digital circuitry in close proximity, parts layout is critical. PC board construction is recommended. You can fabricate your own PC board or purchase a factory-made version from the source mentioned in the Parts List. If you decide to breadboard or wirewrap, the audio sections will be more susceptible to digital noise from the processor and the LCD. Use short lead lengths and shielded cable. Regardless of the method you choose, you can mount all components in a case of your choice.

Figure 4 shows the Parts Placement diagram. Begin construction by installing the power components IC7, C6, C8 and C15. Mount IC7 with the metal heatsink tab against the heatsink pad on the PC board. Use No. 6-32 nuts and bolts to secure IC7 to the heatsink pad. Be careful with C6's polarity. Temporarily attach a 9-volt DC supply, and verify +5-volts DC at the output of IC7 (pin 3). Next, install all resistors and recheck your 5-volts DC. Install all capacitors, being careful to note the polarities of C3 and C7. Install Q1 and XTAL1, and again recheck the 5-volt DC line.

Install the IC sockets and verify that 5-volts DC is present at all pin locations shown in Fig. 2. Once you are sure the power distribution is correct, connect an appropriate length of 14-conductor ribbon cable between the LCD display module and PC board using the pin-connection information given in Fig. 4. Use a 3-conductor ribbon cable to connect contrast-potentiometer R2. If you expect to adjust the contrast often, mount R2 so it is accessible without having to open the enclosure. The lengths of the ribbon cable should not be excessive, but should allow for easy access to the PC board when you open the enclosure.

Install IC1, the 8751H, and apply power. "PERFECT PITCH" should appear on the display for a few seconds and then "TUNER" should appear and remain on the display.

Use a three-conductor ribbon cable to connect S1 to the PC board. Apply power and wait for "TUNER" display to appear. Center-off switch S1 will let you toggle through the menu selections "TUNER," "COUNTER," and "METRONOME," in one direction and select the displayed function in the other. If you select the Tuner function, expect to see "00000 Hz T" on the display. The same legend appears for the counter function except that "T" is replaced by "C." Selecting the Metronome function should reveal a pulsating display that can be made to oscillate faster or slower with "FASTER" and "SLOWER" appearing as you toggle and hold S1. If all is well at this point, remove power and install LED1 with an appropriate length of two-conductor ribbon cable.

Using shielded cable and the audio jacks and plugs of your choice, connect the input and headphone jacks to the PC board as shown. The prototype has standard ¼-inch phone jacks. The prototype has an input jack (J1) that contains a DPDT switch which applies power to Perfect Pitch when a ¼-inch phone plug is inserted. A recharge jack that disconnects power to Perfect Pitch when the charger is plugged in is also incorporated in the prototype.

Install IC6, the LM386 audio power amplifier. Plug a set of headphones into headphone-jack J3 and apply power. Touch the ungrounded input conductor of J1; you should hear a buzz or pop that corresponds to your touch. If not, recheck the work done in the audio-amplifier section. Install a jack for the auxiliary input (J2), and perform the touch test on it.

Install IC3, IC4, and IC5. Connect a signal source to J1 and headphones to J3 (the signal source can be a guitar, electronic keyboard, etc.) Apply power and select the Tuner function. When notes are struck, strummed, or keyed, you should see the gate LED illuminate and hear the audio in your headphones. The LCD should show a reading other than "00000" and possibly a note will appear at the far left of the LCD. If so, everything is OK and you can mount Perfect Pitch in a permanent enclosure. Figure 5 shows the inside of the author's completed prototype.

Using Perfect Pitch

Perfect Pitch is as easy to use as it is to build. There are only one switch, two inputs, and one output to deal with. The contrast adjustment is usually made once and forgotten. Use your own judgement with regard to contrast.

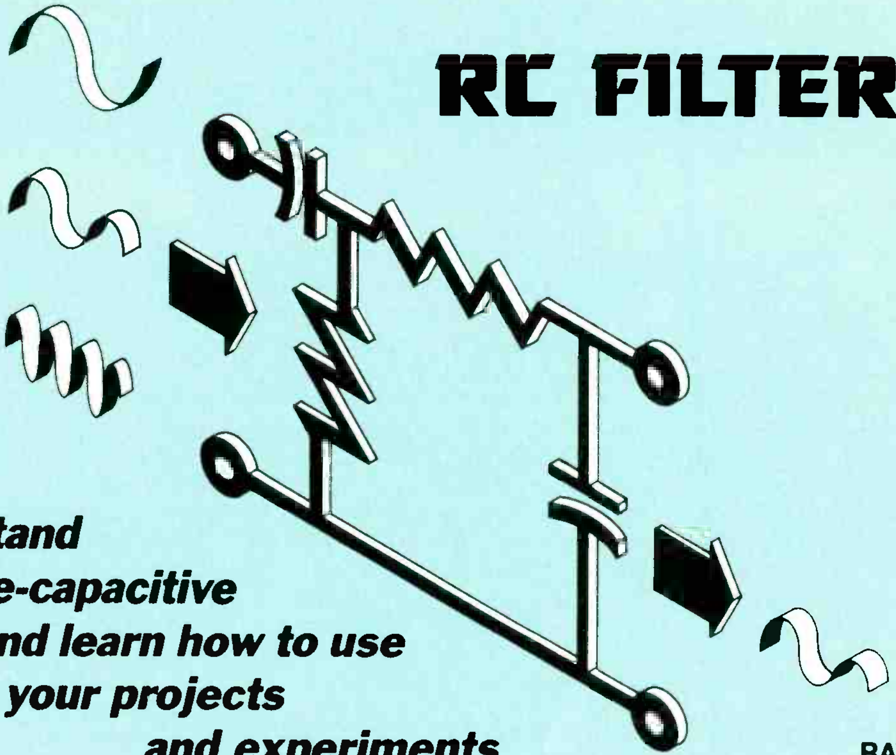
When you turn on Perfect Pitch, the "PERFECT PITCH" banner is displayed, followed by the first menu selection, "TUNER." At this point you can scroll through the remaining two menu items (Counter and Metronome) or select any of the three when displayed using S1. As pointed out earlier in the construction section, "00000 Hz T" or "00000 Hz C" appears when the Tuner and Counter mode are selected, respectively. Connect the audio source and select Tuner or Counter and proceed. Only the Tuner mode will display notes on the musical scale along with frequencies. An added feature places a "+" or "−" immediately following the note to designate one cycle above (+) or below (−) the musical note shown in the display. For example, "A− 439 Hz T" denotes a signal that's one cycle below the universal A 440 Hz. Conversely, the display "A+ 441 Hz T" denotes 1 cycle above A 440 Hz. The Tuner mode's musical-note identification function spans from C 32 Hz to C 1046 Hz, or five musical octaves. Above a frequency of 1046 Hz, only frequency is displayed.

In the Counter mode, Perfect Pitch is a frequency counter. You can also bypass IC5 completely and feed TTL signals directly into pin 9 of IC4-d. You can also use the Tuner function if you bypass IC5 in favor of TTL inputs. Be sure to remove IC5 if you choose to run TTL only.

The Metronome function, which alternately turns on the left and right sides of the LCD, and is the only function that you can control in real time; S1 selects either "FASTER" or "SLOWER" while the function is invoked. A visual metronome allows you to keep time without having an audible tone or click mixed into the headphones with your music.

The auxiliary input (J2) is exclusively for mixing in headphone output from a radio, CD player, or tape player. Inputs at J2 will not reliably trigger the counting circuitry. By adding another output jack to the existing output jack, you and a friend can practice as a duet. Ω

RC FILTERS



Understand resistive-capacitive filters and learn how to use them in your projects and experiments

RAY MARSTON

THE TERM FILTER DESCRIBES A wide variety of frequency-selective circuits. Certain frequencies pass through a given filter while others are attenuated. There are four basic filter types: *low-pass*, *high-pass*, *bandpass*, and *band rejection* or *notch*. Filters composed of resistive (R), inductive (L), and capacitive (C) elements are called *passive filters*. *Active filters* include high-gain operational amplifiers with passive filter feedback networks.

Filter circuits that contain only resistors and capacitors are called resistive-capacitive (RC); those that contain only inductors and capacitors are called inductive-capacitive (LC). Filter circuits generally combine inductive and capacitive components because inductive reactance increases with frequency, and capacitive reactance decreases with frequency. The two opposing effects permit many possibilities in all filter design.

However, this article will focus on RC filters and applications. Later articles will review LC filters and look at active filters in greater detail. The big advantage of active filters is that they do not require inductors, which can be large and heavy at low frequencies. Active filters need only R and C components, but they require some kind of power supply.

A capacitor by itself has inherent filtering capability for alternating current because capacitive reactance, X_C, is inversely proportional to frequency

$$f_c = 1/2\pi RC$$

It blocks direct current completely and opposes the passage of low-frequency signals although signal passage becomes progressively easier as frequency increases.

Low-pass and high-pass

Filters contribute to the operation of many different circuits by screening out unwanted frequencies and allowing only the wanted ones to pass. Resistive-capacitive filters are better suited for low-frequency filtering (up to 100 kHz), whereas inductive-capacitive filters are better suited for high-frequency filtering (above 100 kHz).

Figure 1-*a* is the circuit of a simple RC, low-pass filter that passes low-frequency signals but rejects those with higher frequencies. Resistor R1 is in series with the load, and capacitor C1, the reactive element, shunts the load. This filter exhibits a gradual rolloff beginning at the upper cutoff frequency where capacitive reactance equals the value of resistor R. Because it is a low-pass filter, there is only one cutoff frequency, and it can be determined by the formula:

$$f_c = 1/2\pi RC = 1/6.28RC = 0.159/RC$$

The cutoff frequency (f_c) is that frequency at which the signal output voltage is 6 decibels (dB) below its peak level.

Table 1 lists the formulas for determining f_c, R, and C for the schematics in this article that do not include component values. In these formulas 2π has been converted to the number 6.28.

The cutoff-frequency can also be measured at the *half-power points* as shown in Fig. 1-*b*. These are at 70.7% of the peak power with the real power dissipated at 50% of maximum. The half-power point is the upper cutoff frequency of a low-pass filter.

High-pass filter

The high-pass filter passes high frequencies and opposes or blocks the passage of low frequencies. As shown in Fig. 2*a*, the simplest high-pass filter consists a single capacitor in series with the load and a resistor that shunts the load. Capacitor C1 opposes current flow that varies inversely with frequency. The higher the frequency, the smaller the opposition, measured in ohms. The filter completely or partially blocks signals at low frequencies, but permits their passage as frequency increases.

Figure 2-*b* shows the positive slope at the high-frequency end of the frequency vs. gain response curve for a high-pass filter. The ***pass band*** is defined as the area under the curve and the ***stop band*** is the area to the left of the curve.

The high-pass filter cuts off or blocks all frequencies below the cutoff frequency, f_c, permiting all those above that frequency to pass. The half-power (-3dB) point of a high-pass filter is the lower cutoff frequency. Both high-pass and low-pass filters have just one cutoff point, but as will be explained later, both *bandpass* and *band-reject (or notch)* filters have two cutoff frequencies.

Both of the filter circuits shown in Figs. 1-*a* and 2-*a* have a single RC stage and are known as a *first-order* filters. If a number (n) of these filters are cascaded, they will form what is known as an *nth-order* filter.

Phase-shift oscillator

Filters can be effectively cascaded by including them in the feedback networks of operational amplifiers. Figure 3 is a circuit for a third-order, high-pass filter that converts an op-amp into a phase-shift oscillator. The filter is inserted between the output and the input of the inverting (180° phase-shift) amplifier.

The filter will provide this phase shift at a frequency of about 1⁄14 of the product of R and C. Thus the complete circuit has a loop shift of 360°, and it will oscillate at this frequency if the op-amp has sufficient gain. An op-amp with a gain of about ×29 will compensate for filter losses and yield a loop gain greater than one.

Figure 4 is a schematic for an 800-Hz phase-shift oscillator. Potentiometer R4 must be adjusted to give a clean output sinewave and potentiometer R6 will vary the output gain.

Bandpass filter

A bandpass filter passes a specified frequency band while rejecting adjacent frequencies above and below that passband. A bandpass filter can be made by combining (or cascading) a high-pass filter with a low-pass filter as shown in Fig. 5-*a* so that a band of frequencies not stopped by either filter is passed.

A typical bandpass filter response curve, as shown in Fig. 5-*b*, has a generally trapezoidal shape with a positive slope on the low-frequency (left) end indicating the limit of the high-pass stopband and a negative slope on the high-frequency (right) end defining the low-pass stopband. The flat top of the curve (0 dB) indicates constant signal gain.

The bandwidth of the filter is the frequency difference between the half-power, or −3dB points. These are the points where the filter response is 3 dB down from the maximum point on the curve. The bandwidth is between f_c1 (high pass and f_c2

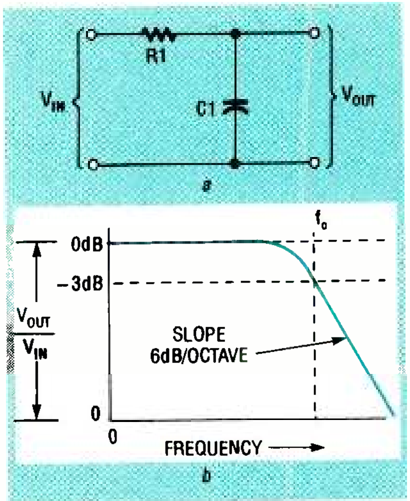


FIG. 1—LOW-PASS RC FILTER circuit (*a*), and frequency response curve (*b*).

TABLE 1
FORMULAS FOR DETERMINING FILTER COMPONENT VALUES

High- and Low-Pass Filter	(Figs. 1 to 5)
Balanced Wien Tone Filter	(Figs. 6 to 10)
Twin-T Notch Filter	(Figs. 11, 14, and 15)

$$f_c = \frac{1}{6.28\,RC} \qquad R = \frac{1}{6.28 f_c C} \qquad C = \frac{1}{6.28\, f_c R}$$

f_c = kHz, R = kilohms, C = microfarads

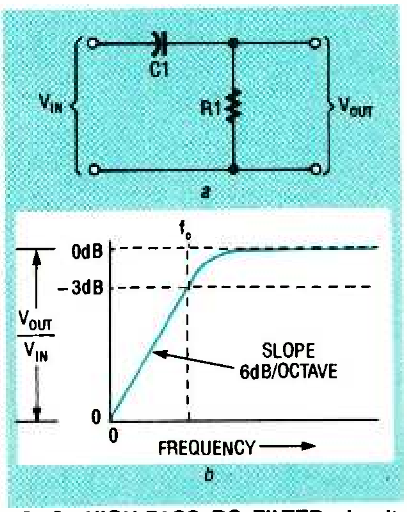


FIG. 2—HIGH-PASS RC FILTER circuit (*a*), and frequency response curve (*b*).

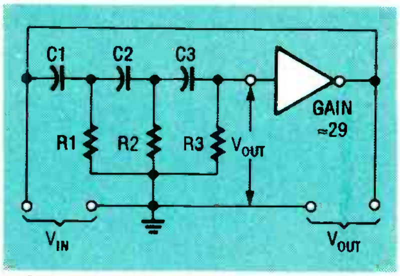


FIG. 3—THIRD-ORDER HIGH-PASS filter as a component in a phase-shift oscillator.

(low pass). The formula for bandwidth is:

Bandwidth in herz = $f_c2 - f_c1$

The *passband* of a filter is the range of frequencies that pass through the filter. *Insertion loss* is the loss of signal strength experienced by the frequencies in the passband passing through the filter. If the filter were absent, and the source and load were connected directly to each other, the output signal would increase by the amount of the insertion loss.

Figure 6-*a* is a special bandpass filter called the Wien-tone filter made by cascading a low-pass and a high-pass filter with the same cutoff frequencies. This permits the filter to select tones with minimum attenuation at a single frequency.

Resistors R1 and R2 have the same values and they are equal to the capacitive reactances of C1 and C2 at the desired cutoff frequency. The Wien-tone filter is called a *balanced* filter, a term that always means with respect to ground.

Figure 6-*b* is the frequency-response curve of the balanced Wien-tone filter with an attenuation factor of 3 (-9.5 dB) at f_c. The circuit's principal feature is its ability to shift input signal phase +90° and −90°, and set it precisely at the f_c of 0° as shown in the phase-shift curve Fig. 6-*c*.

This filter can be combined with an operational amplifier to become a sinewave oscillator as shown in Fig. 7. The outout of the non-inverting amplifier with a gain of about ×3 is fed back to its input through R1 and C1 to give a unity loop gain.

Band-reject filter

A *band-reject* or *notch* filter has a function that is the inverse of the passband filter. It is able to reject one specific frequency, the *stopband*, but pass all others. Figure 8-*a* shows a band-reject filter that is a modification of the circuit shown in Fig. 7.

In this circuit resistors R2 and R4 divide the voltage with a nominal attenuation factor of 3. As a result, the voltage divider and Wien filter outputs are identical at f_c, and the output, which equals the difference between the two signals, becomes zero.

The Wien-bridge band-reject filter network can close a loop around a high-gain operational amplifier to form an oscillator as shown in Fig. 9-*a*. It might appear that the Wien filter's output is fed to the input of the high-gain amplifier that has its out-

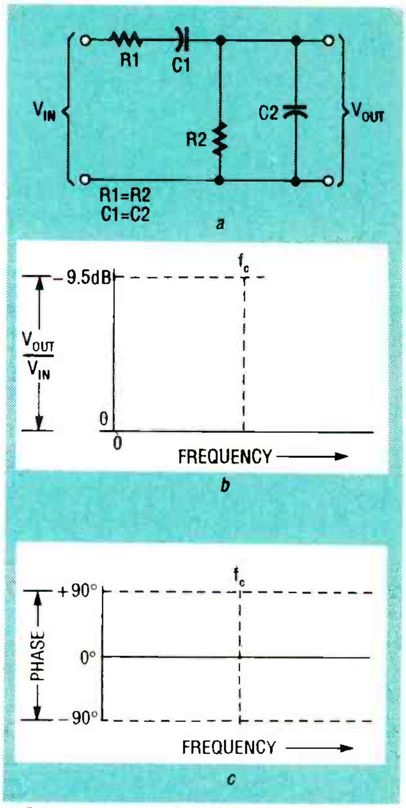


FIG. 6—BALANCED WIEN-TONE FILTER (*a*), frequency-response curve (*b*), and phase-shift curve (*c*).

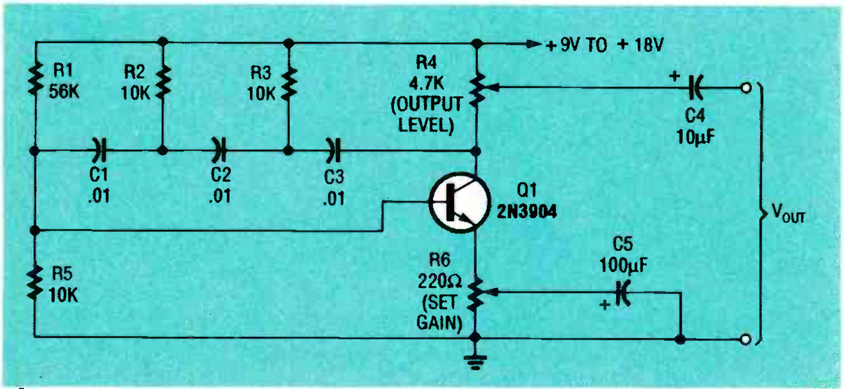


FIG. 4—PHASE-SHIFT OSCILLATOR produces 800Hz sinewaves.

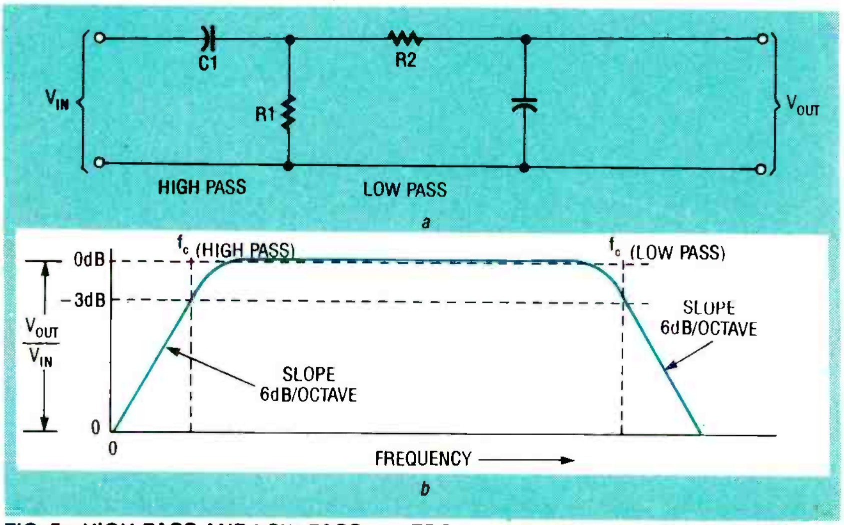


FIG. 5—HIGH-PASS AND LOW-PASS FILTERS cascaded to make a bandpass filter (*a*), and frequency response curve (*b*).

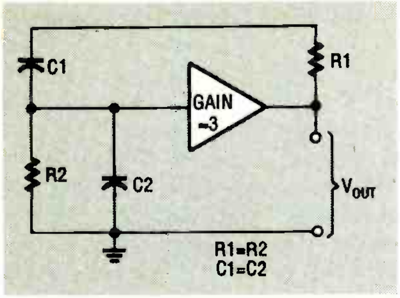


FIG. 7—BASIC WIEN-FILTER-BASED oscillator.

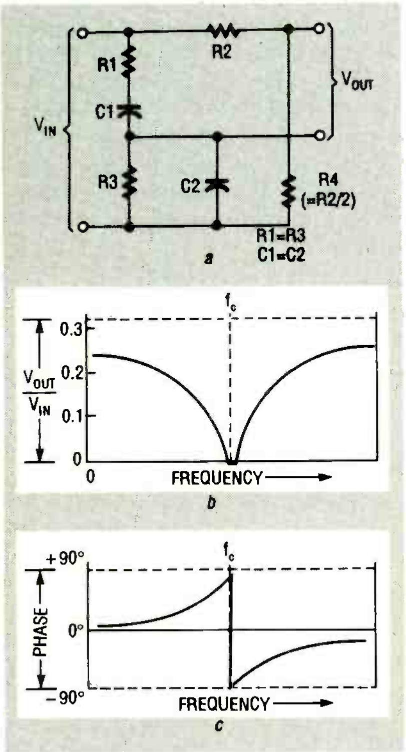


FIG. 8—WIEN-BRIDGE NOTCH FILTER (*a*), frequency- response curve (*b*), and phase-shift curve.

put fed back to the Wien filter's input to complete a positive feedback loop.

However, if the circuit is redrawn as in Fig. 9-*b*, it is clear that the op-amp actually functions as a ×3 non-inverting amplifier, and that the circuit is similar to that shown in Fig. 7. Some form of automatic gain control will be needed if high-quality sinewaves are to be generated from this circuit.

The tuned frequency of the Wien-bridge network can be changed by simultaneously altering its two resistor or capacitor values. Figure 10 is the schematic for a wideband (15 Hz to 15 kHz) variable-notch filter. Ganged potentiometer R3 and ganged switch S1 permit fine tuning and decade switching and trimmer potentiometer R6 performs null trimming.

Twin-T filter

Figure 11-*a* is a schematic for a *twin-T* notch filter. A prime advantage of the filter is that its input and output signals share a common-ground connection, and its off-frequency attenuation is less than that of the Wien-bridge filter. However, it also has a drawback: To work effectively, the values of all three resistors (and the capacitive reactances at a specified frequency) must be varied simulta-

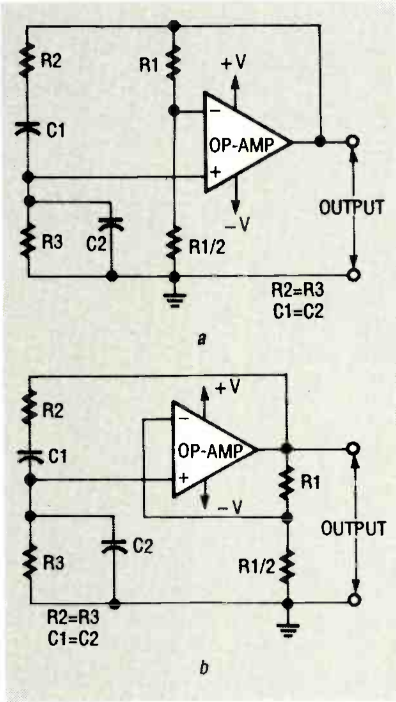


FIG. 9—THE WIEN-BRIDGE OSCILLATOR (*a*) is the equivalent of the oscillator shown at (*b*).

neously. This filter is *balanced* when its components have the precise ratios shown in Fig. 11-*a*. For perfect nulling, the R1/2 resistor value must be carefully adjusted.

The distinctive notched frequency-response curve for the balanced twin-T filter is shown in Fig. 11-*b*. Notice that at f_c the notch has a value of zero. The abrupt phase shift curve is shown in Fig. 11-*c*. The filter has zero phase shift at f_c, but that phase shift changes sharply to +90° or −90° for slight variations above and below f_c.

Both the balanced twin-T and the Wien-bridge filter have very low effective Q's. The value Q is calculated by dividing the value of f_c by the bandwidth between the filter's two −3 dB points. A typical value for a twin-T filter is 0.24. The filter attenuates the second harmonic of f_c, 9 dB. By contrast, an ideal notch filter would not attenuate the input signal.

This shortcoming of the twin-T filter can be overcome by "bootstrapping" the common terminal of the filter, as shown in simplified block diagram Fig. 12. High effective Q values can be obtained with this circuit, and attenuation of the second harmonic of f_c will be negligible.

An explanation of how a balanced twin-T filter works can be quite complicated, so the equivalent diagram Fig. 13 is presented here to simplify that explanation. The filter has been resolved into a parallel-driven, low-pass filter (f_c/2) and a high-pass filter ($2f_c$) whose outputs are connected to an RC voltage divider (f_c). This output divider loads the two filters and affects their phase shifts.

As a result, the signals at points A and B are identical in amplitude, but have phase shifts of −45° and +45° respec-

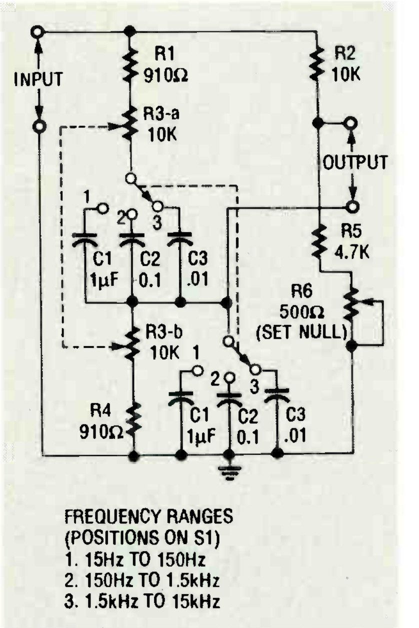


FIG. 10—VARIABLE-FREQUENCY, Wien-bridge notch filter (15 Hz to 15 kHz).

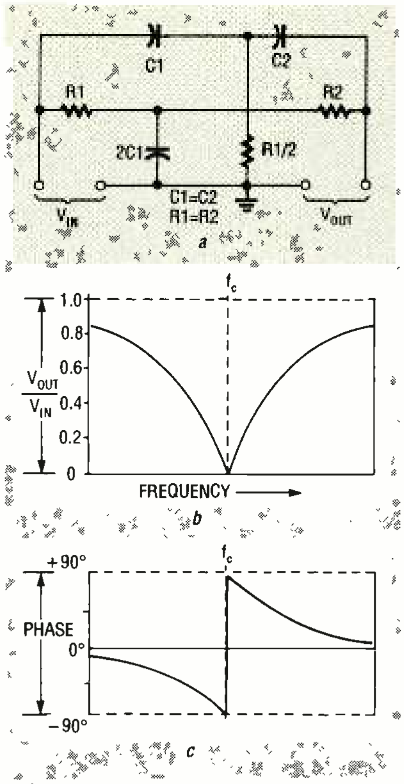


FIG. 11—BALANCED TWIN-T NOTCH FILTER (*a*), frequency-response curve (*b*), and phase shift curve (*c*).

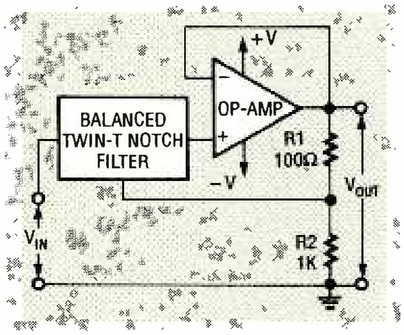


FIG. 12—BOOTSTRAPPED HIGH-Q notch filter.

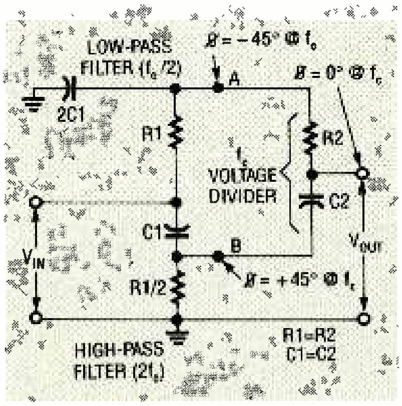


FIG. 13—EQUIVALENT CIRCUIT DIAGRAM of the balanced twin-T filter.

tively at f_c. At the same time, the impedances of the R and C sections of the output divider are equal and introduce a 45° phase shift at f_c. Thus the divider effectively cancels the two phase differences and gives a precise output of zero, the phase-cancelled difference in amplitudes between the two signals.

Therefore, a perfectly balanced twin-T filter has a zero output and zero phase shift at f_c. As shown in Fig. 11-*c*, if the frequency is slightly below f_c, the output is dominated by the response of its low-pass filter, and is shifted in phase by −90°; at frequencies above f_c, the output is dominated by the response of its high-pass filter, and is shifted in phase by +90°.

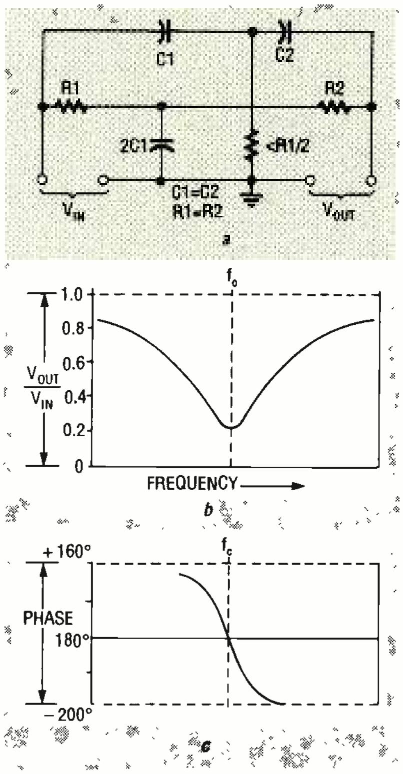


FIG. 14—NEGATIVELY UNBALANCED TWIN-T FILTER provides a 180° phase shift at f_c (*a*), its frequency-response curve (*b*), and phase-shift diagram (*c*).

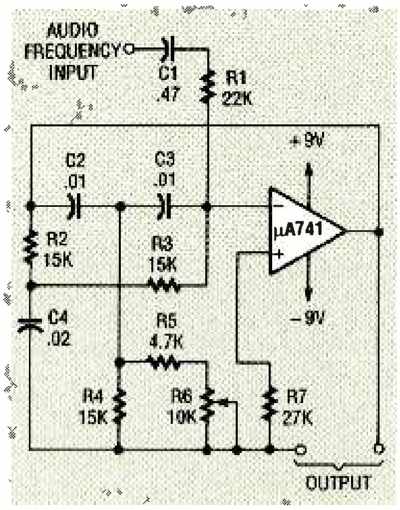


FIG. 15—A 1 KILOHERTZ OSCILLATOR/ACCEPTANCE FILTER based on a negatively unbalanced twin-T network.

An *unbalanced* version of the twin-T filter can be made by changing the value of the R1/2 resistor to one that is not ideal. If this resistor has a value greater than R1/2, the circuit will be *positively unbalanced*. It will act the same way as was just described, but its notch will have limited depth (it will not reach zero). However, it still offers a zero phase shift at f_c.

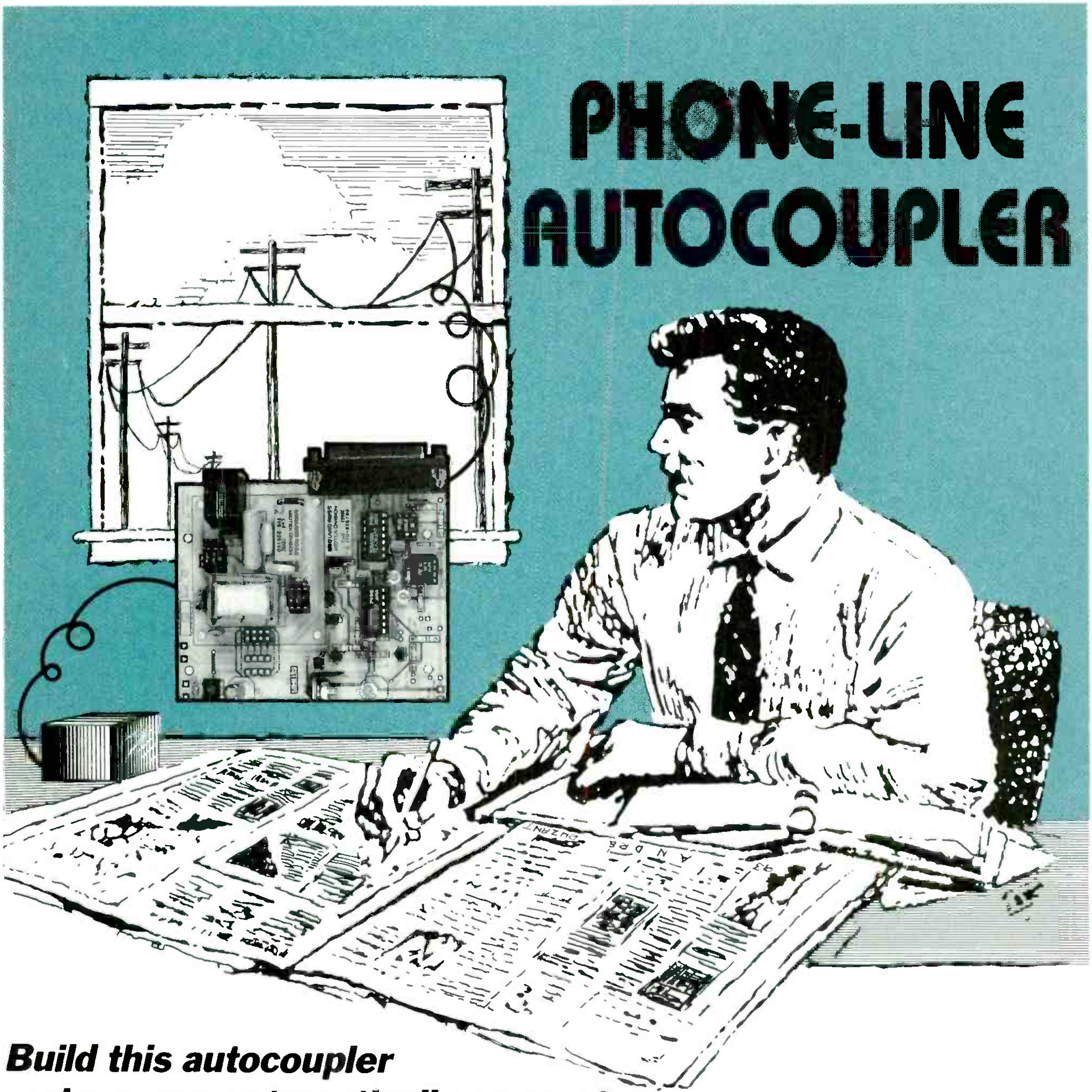
If, by contrast, the resistor has a value less of than R1/2, the circuit, as shown in Fig. 14-*a*, will be *negatively unbalanced*. It will also give a notch of limited depth, as shown in Fig. 14-*b*, but it has the useful characteristic of being able to produce a phase-inverted output. There will be a 180° phase shift at f_c, as shown in Fig. 14-*c*.

Figure 15 is a schematic of a negatively unbalanced twin-T notch filter that can be a component in either a 1 kHz oscillator or a tuned acceptance filter. The twin-T filter is connected between the input and output of the high-gain inverting amplifier so that an overall shift of 360° occurs at f_c.

The circuit will oscillate if potentiometer R6 is adjusted so that the twin-T notch gives enough output so the system has an overall gain greater than unity.

To convert the circuit to a tone filter, adjust trimmer potentiometer R6 to give a loop gain that is less than unity, and feed an audio input signal through C1 and R1. Under this condition, R1 and the twin-T filter interact to form a frequency-sensitive circuit that gives high negative feedback and low gain to all frequencies except f_c. The circuit gives little negative feedback and high gain at f_c. Trimmer potentiometer R6 can vary the sharpness of the tuning. Ω

PHONE-LINE AUTOCOUPLER



Build this autocoupler and you can automatically connect your telephone line to a variety of projects.

MIKE HAGANS and KYLE MAGRILL

LAST MONTH WE DESCRIBED THE MPC-2 telephone interface. The MPC-2 provides ring detection, line-current detection, a caller-ID compatible audio path, and all the isolation, audio limiting, and protective elements to make it—and anything connected to it—comply with the FCC's Part 68 rules. This month we'll discuss and build an auto-answer/auto-disconnect telephone coupler that incorporates an entire MPC-2 circuit.

The autocoupler's logic monitors the RING DETECT and LINE-CURRENT DETECT lines from the MPC-2 circuit and causes it to "pick up," or go off-hook, after detecting an incoming ring. When the line-current detector signals that the calling party has hung up, the autocoupler forces the MPC-2 to release the line to be ready for the next call.

The autocoupler contains an isolated relay that can signal the beginning of a call, or that can stay latched for the duration of the call to control external equipment. Remote pick-up and hang-up switches can be connected to the autocoupler, and LED's can indicate ring and on-line conditions.

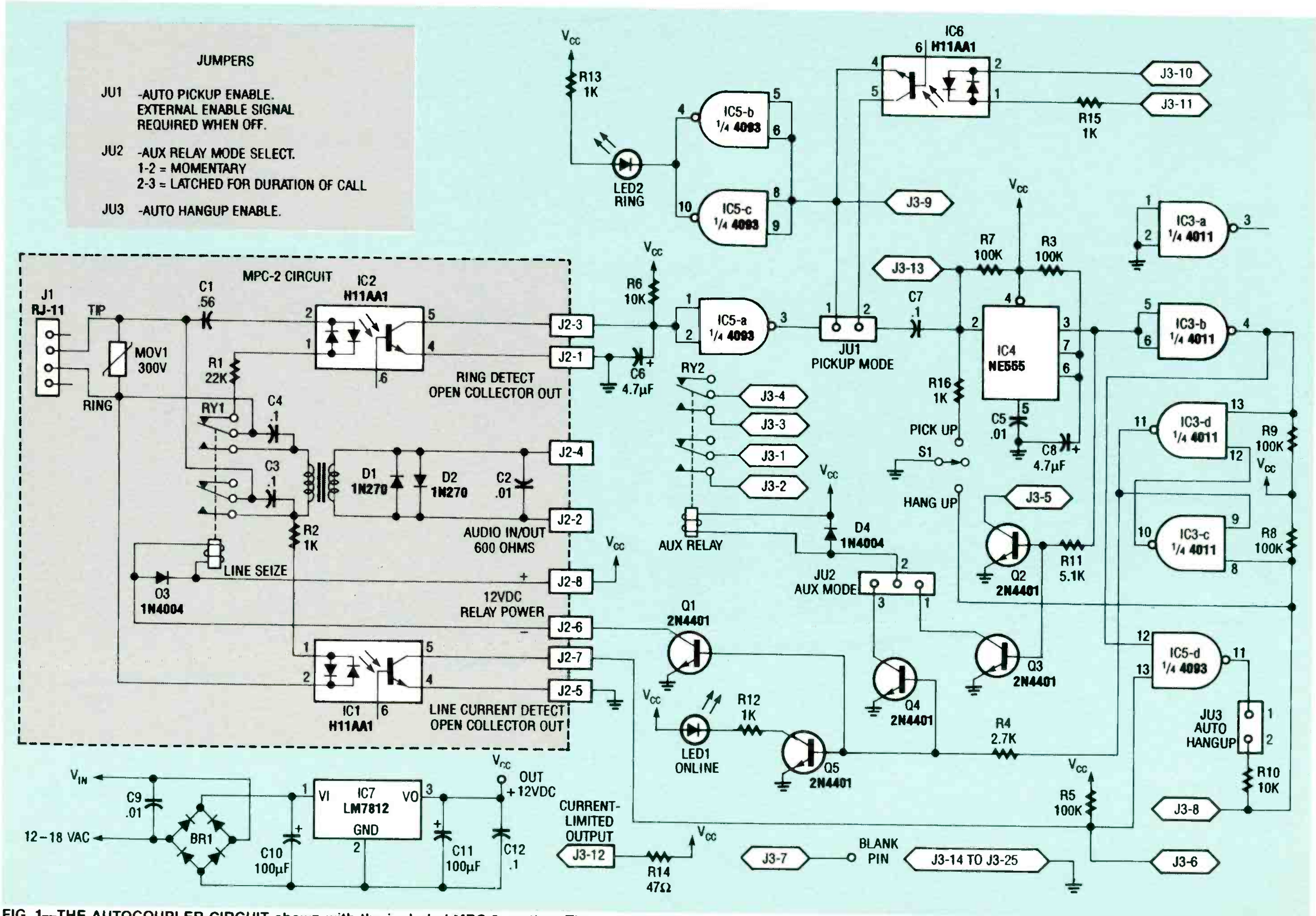


FIG. 1—THE AUTOCOUPLER CIRCUIT shown with the included MPC-2 section. The MPC-2 interface meets all technical requirements in the FCC rules, Part 68.

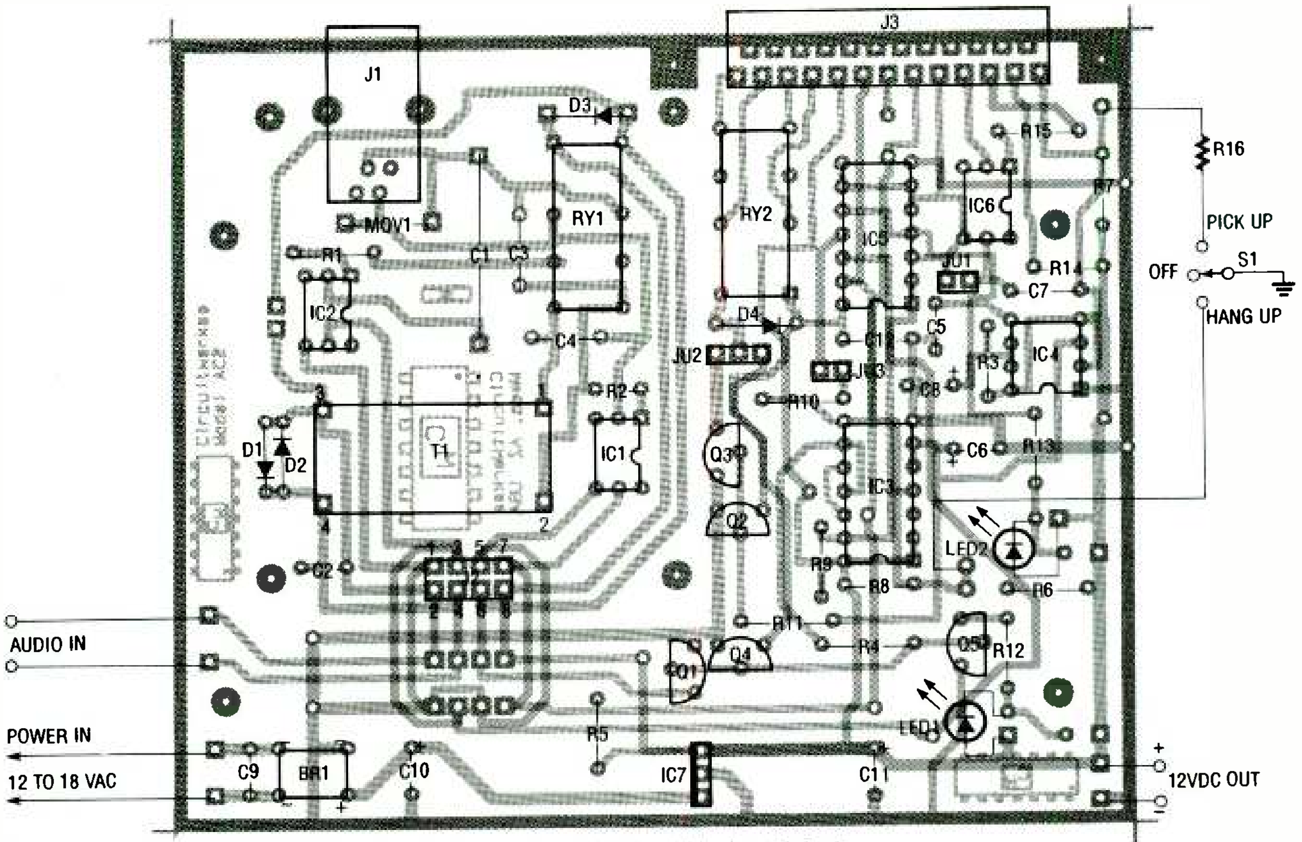


FIG. 2—PARTS-PLACEMENT DIAGRAM. Voltage-regulator IC7 should be heatsinked. Note that the MPC-2 section must be built exactly as described to be type-approvable.

Circuitry

A stand-alone MPC-2 board can be connected to the autocoupler board with an 8-wire ribbon cable or the parts for the MPC-2 section can be installed directly on the autocoupler board. Figure 1 shows the autocoupler along with the MPC-2 circuit.

The RING-DETECT output of the MPC-2 interface is pulled up by resistor R6 and conditioned by capacitor C6 and IC5-a, a 4093 Schmitt-trigger NAND gate configured as an inverter. The hysteresis action of the 4093 significantly cleans up the RING DETECT signal, presenting a square wave (high during the incoming ring signal) to one side of capacitor C7. That capacitor is normally charged through the 100K pull-up resistor (R7) while the output of IC5-a is low. When the output of IC5-a goes high, C7 discharges. When IC5-a's output goes low again at the end of the ring, C7 momentarily loads down R7 (as it charges). The momentary low triggers the input of the 555 timer (IC4), which is set up in monostable (one-shot) mode.

The cleaned-up ring-detect signal from IC5-a also feeds the ring-detect LED circuit consisting of IC5-b and IC5-c in parallel. The inputs of those two gates are pulled high during a ring, causing their outputs to go low. When that happens, ring indicator LED2 turns on. When manual-pickup switch S1 (a momentary SPDT switch with center-off) is activated, pin 2 of the 555 gets pulled low as if a ring had occurred. The 1K resistor (R16) connected to S1 limits C7's instantaneous current flow when the switch is activated, protecting IC5-a.

Jumper JU1 is located between pin 3 of IC5-a and C7. If JU1 is left open, optocoupler IC6 provides the pickup-enable signal. The two inputs to the optocoupler (pins 1 and 2) are connected to pins 10 and 11 of the DB-25 connector J3. An external AC or DC voltage from 5 to 30 volts will turn on IC6, enabling the ring signal to trigger the 555.

The duration of the 555 timer's high output is controlled by C8 and R3, and lasts for about half a second. The 555's output turns on two transistors; Q2 is the open-collector momentary output that appears on J3 pin 3; Q3 is one of two transistors (selectable via jumper JU2) that can operate the auxiliary output relay. The 555 also feeds NAND gate IC3-b, which is set up as an inverter.

A set-reset latch is formed by NAND gates IC3-c and -d. One input of each gate is tied to the output of the other, and the remaining two inputs (one on each gate) are pulled high by resistors R8 and R9. Before a ring occurs, the latch's output (pin 11 of IC3-d) is low, and stays that way because it holds one input of IC3-c (pin 9) low, which causes IC3-c's output to be high. That output keeps pin 12 of IC3-d high, and the circuit is in stasis until triggered by the previous stage (IC3-b) after an incoming ring.

Pulling the SET input of the latch (IC3-d pin 13) low causes IC3-d's output to go high. That causes IC3-c's output, and the other input of IC3-d, to go low.

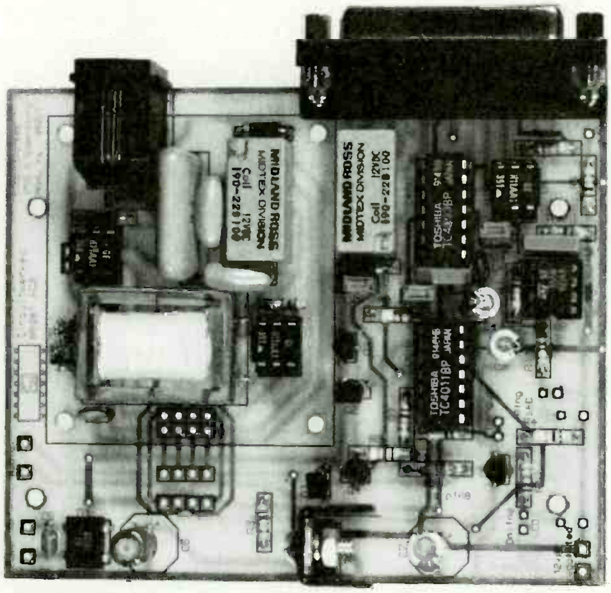


FIG. 3—AN ASSEMBLED, type-approved autocoupler board. You can purchase an assembled one from the source in the Parts List.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—22,000 ohms
R2, R12, R13, R15, R16—1000 ohms
R3, R5, R7, R8, R9—100,000 ohms
R4—2700 ohms
R6, R10—10,000 ohms
R11—5100 ohms
R14—47 ohms

Capacitors
C1—0.56 µF, 250-volts, Mylar
C2, C5, C9—0.01 µF, 50-volts, ceramic disc
C3, C4—0.1 µF, 250-volts, Mylar
C6, C8—4.7 µF, radial electrolytic
C7, C12—0.1 µF, metal-film
C10, C11—100 µF, 35 volts, radial electrolytic

Semiconductors
IC1, IC2, IC6—H11AA1 AC-input optoisolator (GE)
IC3—4011 CMOS quad NAND gate
IC4—555 timer
IC5—4093 CMOS quad Schmitt-trigger NAND gate
IC7—LM7812T 12-volt regulator
D1, D2—1N270 germanium diode
D3, D4—1N4001 diode
Q1–Q5—2N4401 NPN transistor
BR1—DT102 DIP bridge rectifier (1A, 100V)
LED1, LED2—light-emitting diode, any color

Other components
J1—RJ-11c right-angle, PC-mount telephone jack (must be 50 micro-inch gold-plated)
J2—8-pin male header, 2 × 4, matching female IDC connector, and ribbon cable (optional, see text)
J3—short-style right-angle PC-mount DB-25 connector
JU1, JU3—1 × 2 jumper block
JU2—1 × 3 jumper block
T1—Telco line-isolation transformer (Dale TA-40-01)
MOV1—300-volt axial metal-oxide varistor
RY1, RY2—12-volt DPDT relay (Midland Ross 190-22B100)

Miscellaneous: PC board, three 6-pin DIP sockets, one 8-pin DIP socket, two 14-pin DIP sockets, T0-220-type stand-up heatsink (for IC7), three shorting blocks (0.1" jumpers for JU1–JU3)

Note: The following items are available from CircuitWerkes, 6212 SW 8th Pl, Gainesville, Fl 32607 (904) 331-5999:
- **Double-sided, silkscreened autocoupler PC board only—$14.95**
- **Autocoupler PC board with pre-built Part-68 registered MPC-2 section—$39.95**
- **Complete autocoupler kit with pre-built Part-68 registered MPC-2 section (no enclosure)—$69.95**
- **Fully assembled and tested, Part-68 registered autocoupler (no enclosure)—$99.95**
- **Screen-printed black plastic enclosure with machined end panels for the autocoupler—$26.00**

Include $3.50 for shipping and handling. Add $4.50 for COD (cash or certified funds only). Arizona and Florida residents must include appropriate sales tax.

The circuit remains in that condition until the RESET input (IC3-c pin 8) goes low, toggling the latch back to its original state. This takes us back to inverter IC3-b whose output does two things: It triggers the SET input of the latch, and it holds pin 12 of IC5-d low, preventing the latch from resetting for the duration of the 555's pulse. After about a quarter of a second, the line-current detector (IC1) prevents the latch's RESET line from going low by holding pin 13 of IC5-d low while telephone line current is established again.

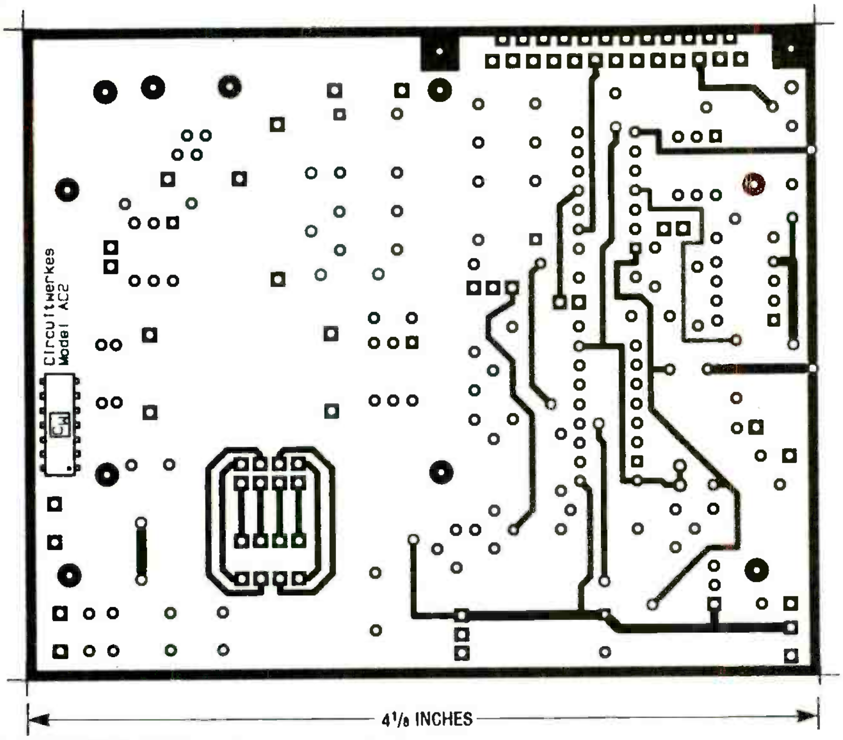
When the coupler is on-line, the only time the latch's RESET line should go low (and cause a reset) is when both inputs of IC5-d are high. That happens only when the 555's output is low and the output of the line-current detector (IC1) is off, or high, as happens briefly when the telephone company's central office signals that the calling party has hung up.

The output of the latch, when set, turns on transistors Q1, Q4, and Q5. Transistor Q1 supplies ground for the line-seize relay RY1, Q4 can turn on the auxiliary-output relay RY2 (if selected by jumper JU2), and Q5 turns on the on-line indicator LED1 through current-limiting resistor R12.

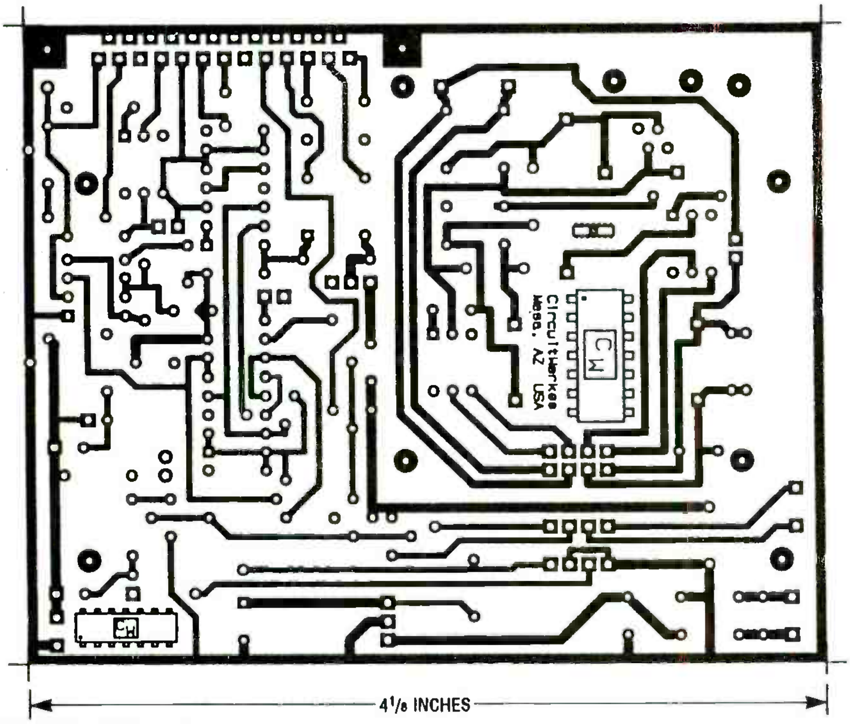
Construction

You can make your own double-sided PC board using the foil patterns we've provided, or purchase one from the source mentioned in the Parts List. Kits are available from the same source.

Note that two 2 × 4-pin headers with mating IDC connectors



COMPONENT SIDE for the autocoupler board.



SOLDER SIDE for the autocoupler board.

and a piece of 8-conductor ribbon cable can be used to attach a stand-alone MPC-2 board (see **Electronics Now**, May 1993) to the autocoupler board, and then you would just leave out the MPC-2 parts on the autocoupler board. An 8-pin header can also be used to mount the MPC-2 board as a daughter board on top of the autocoupler board. Otherwise, you can mount all of the parts on the autocoupler board.

Solder the components on the board following the Parts-Placement diagram in Fig. 2.

Voltage-regulator IC7 should have a heat sink attached to it. Be sure to apply heat-sink compound on the back of the regulator before attaching the heat sink. The indicator LED's can either be board-mounted or panel-mounted and connected with wire jumpers. When the board is finished, insert the IC's into their respective sockets. Figure 3 shows a completed unit.

Initial testing

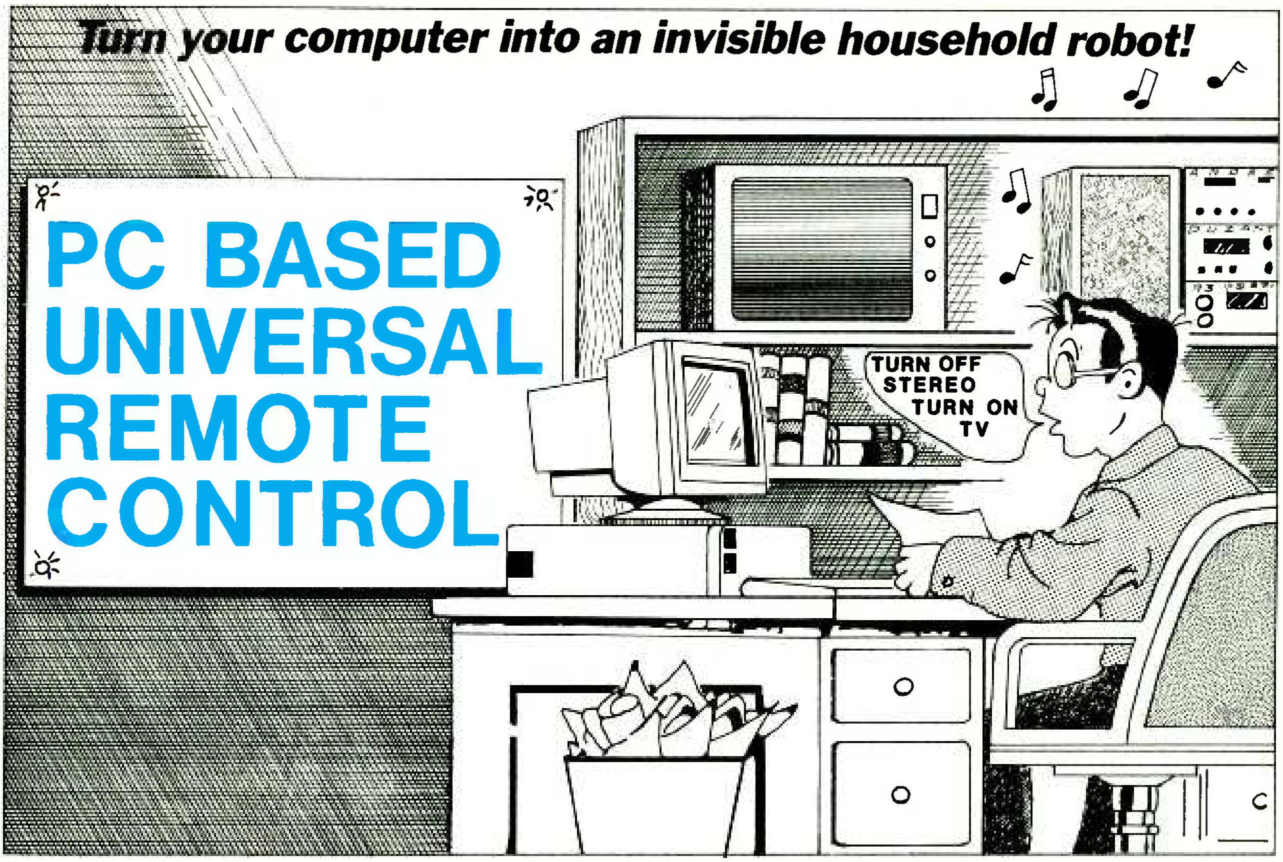
Verify that all IC's are properly installed and that polarity-sensitive devices are oriented properly before connecting power, audio, or a phone line to the autocoupler. Then, you can connect 12 to 18 volts (AC or DC) to the board's power-input pads. When power is applied, the two relays will energize for about a half second, and then drop out. That indicates the initial operation of the one-shot and latch circuits. If the unit is connected to a phone line when powered up, it will seize the line and hold it until a line current zero-crossing occurs, at which point the unit will drop the line.

Almost every modern central office in this country generates a zero-crossing in the telephone-line battery voltage less than a minute after dial tone is applied to the line—if no activity is detected in that period of time. That also occurs after the calling party hangs up. If your local central office is one of the rare systems that does not support that signaling, you might have to include a preset timer or, preferably, a dial-tone detector that will hang up your autocoupler automatically.

If the initial power-up occurs as has been described, you are ready to test the device on the phone line. Remember that the phone line carries voltages that are high enough to give you a nasty shock if you happen to be touching the tip and ring conductors on the bottom of the MPC-2 coupler section during a ring.

Connect the RJ-11 jack to your phone line with a standard modular cord, and have someone call your line. As soon as the phone starts ringing, you should see LED2 light up. The coupler should answer at the end of the first ring; when it

continued on page 72



JON BEK

INVISIBOT IS THE NAME OF THE AUthor's home-control system. It stands for Invisible Robot. Invisibot started off by combining X-10 control with a voice-recognition and synthesis system. That gave the author the capability to say things like *Please dim the lights,* and have Invisibot respond accordingly. (Note that our sidebar contains detailed information on the X-10 and voice-control parts of the system.)

The one thing he wanted Invisibot to do that wasn't available "off-the-shelf" was to control TV's, VCR's, and other IR-controlled consumer-electronics gear. Even though we all have several remotes to control these toys, they always seem to hide under seat cushions, in magazines, and other unlikely places. When we do manage to locate a remote, it's usually the wrong one, or the batteries are dead. We're sure you've experienced the same problem.

Of course, there are the "smart" units that can control several devices, even ones from different manufacturers, but the thought of buying yet one more remote holds limited appeal. Invisibot was created to eliminate the need to push any remote-control buttons again.

Universal remotes

There are two types of universal remote controls: learning and preprogrammed. Typically both can remember the codes for several devices. In addition to its infrared transmitter, the "learning" control also has an IR receiver that it uses to learn how to control your devices. You put the universal remote into a "learn" mode, point your other remote at it, and press a button. The universal remote then memorizes the pattern it receives. That pattern can be assigned to a button on the learning remote so that each time you press that button in the future, the remote will send the corresponding pattern.

The other type of "smart" remote is preprogrammed with the signal patterns for many popular devices. To set up a preprogrammed remote, you enter a code corresponding to the model of TV or VCR you want to control; henceforth, the remote will use those codes. The advantage of the preprogrammed remote is that it's faster and simpler to set up; in addition, you can use one to replace a lost or damaged original. This project uses a Memorex AV-4 preprogrammed "smart" remote, that can be purchased from a corner drugstore for about $40.

Rows and columns

The AV-4 consists of one IC, a few resistors, several diodes, the infrared transmitter LED's, a capacitor, and a simple row-by-column, or matrix keyboard. Picture a tic-tac-toe board with columns labeled 1, 2, 3, . . . and rows labeled A, B, C, ... Each button on the keyboard corresponds to one letter/number pair. The goal was to devise a circuit that would connect to an existing PC simply and inexpensively, and activate the rows and columns of the keyboard matrix under software control.

A standard parallel port provides a suitable interface. All signals run at five volts, so connecting to the remote is straightforward. In addition, the printer port is directly addressable, even in BASIC, so programming wouldn't be a challenge. The only problem was how to control a 5-by-8 switch matrix using only the eight bits that comprise a standard parallel port. Five CMOS 4051 8-channel analog multiplexers make the job easy.

The 4051's, shown in Fig. 1, have three address inputs (A0, A1, and A2), eight channel inputs (0–7), and an input/output (I/O) pin. Each 4051 internally connects one of its eight channel lines to its I/O pin. The channel selected depends on the combination of signals applied to the input-select lines.

The address inputs are weighted in a binary fashion (A0 = 1, A1 = 2, A2 = 4). You select the desired channel by applying "highs" to the appropriate address inputs. For example, to select input channel 5, you would apply +5 volts to the A0 and A2 address inputs. The three address inputs provide a total of 2^3, or eight combinations, ranging from 0 to 7.

The 4051 has one other input, chip enable, or $\overline{EN}$ for short. When $\overline{EN}$ is brought high, the IC prevents any connection between I/O and the input channels, regardless of the states of the address inputs.

Circuit details

The complete circuit, shown in Fig. 2, consists of five 4051's, some pull-up resistors, and a connector. Note that the eight columns from the remote's keyboard form a "bus" to which the eight channel lines of all five 4051's are connected in parallel. Also note that each of the remote's five rows connects to the I/O line of a different 4051. Thus, all the channel lines will be selected simultaneously, but with only a single I/O line.

The computer's parallel port connects to J1. Of the eight lines, three form a bus that drives the address inputs, and each of the other five lines drives a separate $\overline{EN}$ input on the 4051's. That arrangement presents the same binary input combination to all five 4051's, but as long as the software drives only one of the five $\overline{EN}$ lines high, only a single row-column connection can be made at any one time.

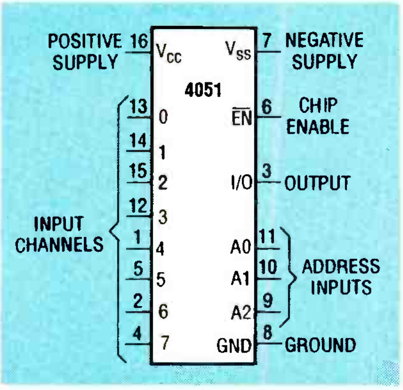


FIG. 1—THE 4051's have three address inputs, eight channel inputs, and an I/O pin. One of the eight channels is connected to I/O pin.

To understand how the circuit works, let's go through an example. Assume first that the PC has set all the $\overline{EN}$ lines high, so all the 4051's are off, and no row-column connections exist. Now assume that we want the computer to "press" the key corresponding to intersection A1 in the matrix. That corresponds to a binary value of 001 at the address inputs. By driving A0 high and the other two (A1 and A2) low, we obtain 001.

With the 4051's still disabled, the PC drives the $\overline{EN}$ line of IC1 low, which turns the device on. That makes the connection between row A and column 1, just as if we'd physically pressed that key.

MY FRIEND, INVISIBOT

I've always been fascinated by robots. Since the first time I saw "Forbidden Planet" as a child, I was certain that someday one of those electronic servants would cater to my every whim. I still don't have anything that looks like Robby the Robot, but I do control many of the lights and appliances in my house with spoken commands—and my invisible robot responds verbally as well!

The primary elements of "Invisibot" came as two off-the-shelf accessories for my PC: the X-10 CP290 computer interface, and the Covox Voice Master Key system.

The X-10 product has been around for years; it consists of a master control unit and one module for each appliance you want to control. The modules can be installed in place of normal light switches in the wall, or plugged in between the AC power outlet and the device being controlled.

The X-10 system communicates commands to the control modules by taking advantage of the fact that higher frequencies can piggyback on top of lower frequencies. The power service in your home is low-frequency 60-Hz alternating current. The X-10 system injects high-frequency signals via the power outlet on the 60 Hz. The information encoded in those high-frequency signals then travels over your existing house wiring to the control modules, which decode and act on it.

Each module must normally be set to a unique address; the control module sends one command at a time to a unique address.

Modules vary in price and functionality, but their average cost is about $12. You can purchase compatible modules from Radio Shack, Sears, and Stanley hardware dealers.

The CP290 controller attaches directly to the serial port of your PC, and is sold with software that allows you to start controlling your home immediately. The CP290 typically sells for about $40; you can purchase one from Egghead Software or Radio Shack. I was fortunate enough to be able to purchase mine some time ago for $19 on a close-out sale.

The other major component of the Invisibot consists of a Covox Voice Master Key, which provides both speech recognition and synthesis. The Master Key plugs into a standard PC bus; it can record and play back speech or other sounds, and includes an excellent speech-recognition package.

A memory-resident software module allows you to store a set of commands, each of which can be sent to DOS when the board recognizes a given phrase. For example, when I speak the command, "Oh butler, brighten the den," the system sends the proper commands to DOS to: 1) Play back a prerecorded voice file containing the words, "Yes sir! Right away sir!" and 2) Run the X-10 control program with the proper parameters to increase brightness in the den to 100%.

Not being content to control things through X-10 modules, I then designed the universal remote control project described here. Ω

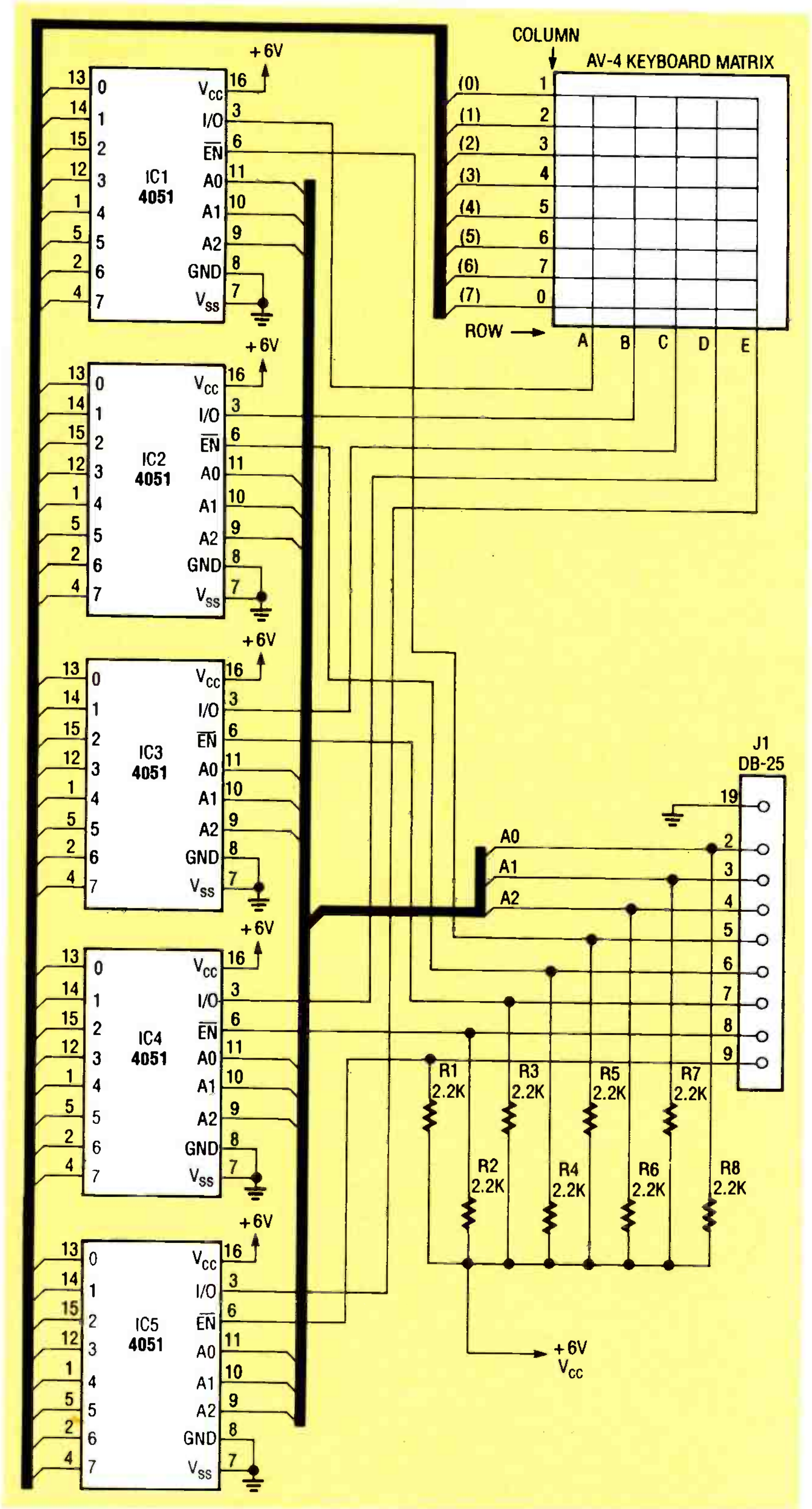


FIG. 2—INVISIBOT DRIVES A UNIVERSAL REMOTE CONTROLLER with five 4051 1-of-8 multiplexors.

Remember that until $\overline{\text{EN}}$ goes high again, the remote control will act as if the key remains pressed. Hence the software must reassert $\overline{\text{EN}}$.

Construction

Because of the simplicity of the circuit, the prototype was built using wire-wrap and point-to-point techniques. No PC board patterns are provided. The following are instructions for disassembling the remote control, mounting its PC board on a piece of perforated board, wiring the 4051's, making the remainder of the connections, and installing the device in a suitable enclosure.

First, remove the PC board from the AV-4 and clip off the metal battery contacts, leaving long power leads. Next, identify the row and column locations of the keyboard matrix. Then, using a hobby knife, carefully scrape a small patch of insulating paint from each trace of the matrix, leaving its shiny copper surface exposed.

Carefully solder connecting wires to the exposed traces of the AV-4 board. Cleaning them with a new rubber eraser or alcohol swab will help make a better solder connection. Tinning the wire and the traces before soldering will also help.

Mount the components on the perforated construction board, leaving enough space for the AV-4, as shown in Fig. 3. Mount five 16-pin DIP sockets for the 4051's, and a sixth to be used as a socket for the eight pull-up resistors. Then make all connections, using Fig. 2 as a wiring guide. Remember to connect pin 16 of each IC to V_{CC}, and pins 7 and 8 to ground.

Connect the power leads of the circuit and the AV-4 to the wall-mount transformer, *carefully observing polarity*. Bend the resistor leads to fit cleanly into the DIP socket, remove excess lead length, and insert the resistors. Now insert the 4051's,

PARTS LIST

R1–R8—2200 ohms, ¼-watt
IC1–IC5—4051 CMOS 1-of-8 decoder
J1—25-pin female DB-25 connector
6-volt DC, 300 mA, wall-mount transformer
Six 16-pin DIP sockets
Perforated construction board
Universal remote control (Memorex AV-4 or equivalent)
6-foot male-to-male DB-25 ribbon cable
Metal project case large enough to accommodate construction board and remote control
PC-board standoffs and mounting hardware

observing normal rules for handling electrostatic discharge-sensitive devices. Now we're ready to test the controller.

Important: Always apply power to the interface before attaching it to the PC, and disconnect it from the PC before turning off the controller. Because the interface draws very little power, you might want to leave it on all the time.

Use a nibbling tool (or a drill and a file) to make openings in the project enclosure for the DB-25 connector (J1), the power cable, and the AV-4's infrared LED's. Mount the board in the enclosure using four stand-offs, and the interface is complete.

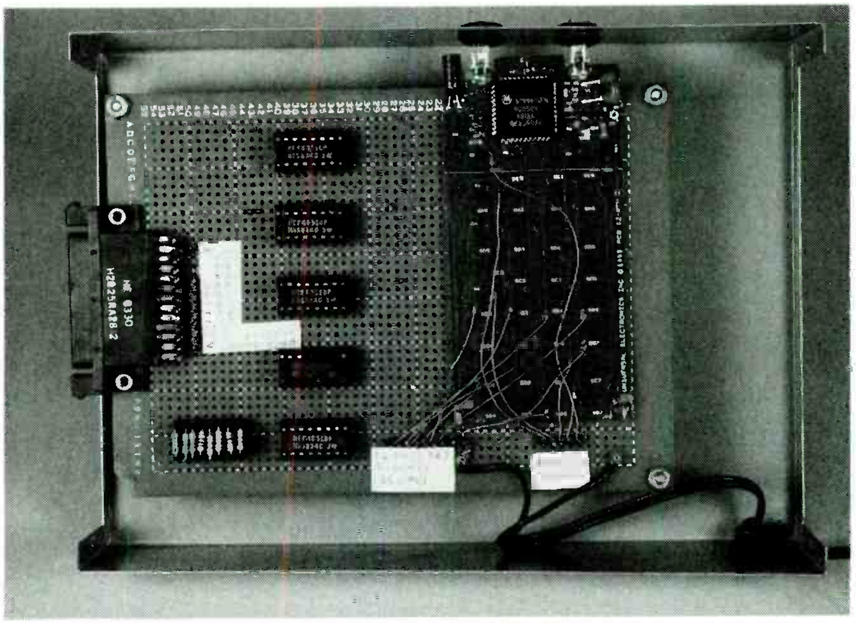


FIG. 3—MOUNT THE CONTROLLER AND CIRCUIT BOARD in the case as shown here.

Programming considerations

We don't have enough space to present a complete listing of the entire program. Moreover, if you don't use an AV-4 and a Sony TV, the commands won't work for you anyway. However, we present enough information so that you can test the unit and modify the command structure to suit your needs. In addition, the code will be posted on the *Electronics Now BBS* (516-293-2283, 1200/2400, 8N1) as a file called NVISIBOT.BAS. All code was developed in Microsoft QuickBASIC.

The interface uses only the data lines of the port, and ignores the control lines, so the software does not use the familiar LPRINT command. Instead, it uses the OUT instruction, which sends a byte of data directly to the specified port.

Listing 1 shows a set of constants that makes it easy to specify different rows and columns in the software. The first group (Chip1–Chip5) provides the values to enable each 4051; the second group shows the values to enable each row of the matrix; and the third group shows the values to enable each column. Enabling a particular position in the matrix is simply a matter of executing an OUT statement. (*Editor's Note: Determining the address of your LPT port can be tricky; more on that below. For now, assume use of LPT1 at an address of 0378 hex, or 888 decimal.*) To enable position A1 in the matrix, execute the command:

OUT 888, ROWA + COL1

Next execute a short delay, and then disable all rows and columns. Listing 2 shows a subroutine that delays processing after "pressing" a key, followed by a "release" of all keys.

Listing 3 shows a demonstration routine that selects the TV mode of the AV-4, turns on the TV, ramps up the volume, changes the channel, and turns the TV off again. Unless you use an AV-4 and a Sony TV, these commands probably won't work for you.

Listing 4 shows a diagnostic routine that enables each row and column of the matrix, requesting that you press Enter after each position. The routine will be useful for verifying that

LISTING 1—INVISIBOT CONSTANTS

```
REM ********************************
REM * INVISIBOT INTERFACE CONTROL *
REM ********************************
REM
REM lpt 1 port = 378h = 888 decimal
REM data lines: A = 1, B = 2, C = 4
REM chip inhibit lines: chip 1 = 8,
REM chip 2 = 16, chip 3 = 32,
REM chip 4 = 64, chip 5 = 128

REM ****** chip ENABLES table *****
chip1 = 255 - 8 - 7
chip2 = 255 - 16 - 7
chip3 = 255 - 32 - 7
chip4 = 255 - 64 - 7
chip5 = 255 - 128 - 7

REM ****** data channel table *****
data0 = 1
data1 = 2
data2 = 3
data3 = 4
data4 = 5
data5 = 6
data6 = 7
data7 = 0

REM ****** chip correspondence ****
REM | chip# | URC Row |
REM     1        A
REM     2        B
REM     3        C
REM     4        D
REM     5        E

rowa = chip1
rowb = chip2
rowc = chip3
rowd = chip4
rowe = chip5

REM ****** data correspondence ****
REM |  ABC  | URC Column |
REM    000        1
REM    001        2
REM    010        3
REM    011        4
REM    100        5
REM    101        6
REM    110        7
REM    111        0
```

LISTING 2—STALL ROUTINE

```
REM ******************************
REM *        STALL ROUTINE        *
REM *                             *
REM * make a URC keypress long    *
REM * enough to ensure command    *
REM * gets sent, then clear the   *
REM * keypress and allow circuit *
REM * to settle                   *
REM ******************************
stall:
REM hold the button down
REM for a time ...
FOR i = 1 TO 1500
NEXT i

REM let all buttons up and wait
REM for a time ...
OUT 888, 255
REM FOR i = 1 TO 5
REM NEXT i

RETURN
REM ******************************
```

LISTING 3—EXERCISE FUNCTIONS

```
REM ****************************
REM the following code exercises
REM some basic command functions

REM select the tv
REM as the device to control
PRINT "sending tv: a5"
OUT 888, rowa + col5
GOSUB stall
INPUT x

REM turn on the tv
PRINT "sending POWER: e6"
OUT 888, rowe + col6
GOSUB stall
INPUT x

REM crank up the volume
FOR k = 1 TO 20
PRINT "sending VOLUME UP: b6"
OUT 888, rowb + col6
GOSUB stall
INPUT x
NEXT k

REM change the tv channel
PRINT "sending CHANNEL DOWN: c6"
OUT 888, rowe + col6
GOSUB stall
INPUT x

REM turn off the tv
PRINT "sending POWER: e6"
OUT 888, rowe + col6
GOSUB stall

END
```

LISTING 4—SONY TEST COMMANDS

```
REM the next piece of code
REM initializes the URC for
REM a SONY TV (000)
REM the "INPUT x" statements
REM aren't necessary, they're
REM just here so you can
REM observe each command.
REM The AV-4 has a surface-
REM mounted LED that blinks
REM once as each command is
REM received, and multiple
REM times when a valid device
REM code has been
REM successfully programmed.
REM **************************
PRINT "sending A: e5"
OUT 888, rowe + col5
GOSUB stall

INPUT x

PRINT "sending V: e3"
OUT 888, rowe + col3
GOSUB stall

INPUT x

PRINT "sending 4: e1"
OUT 888, rowe + col1
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x

PRINT "sending #0: b2"
OUT 888, rowb + col2
GOSUB stall

INPUT x
REM ************ end URC init
```

the circuit is wired properly. You should see a change in the state of each line as it is tested.

To determine which LPT port to use, run the program shown in Listing 5. It will display the decimal and hexadecimal addresses of those parallel ports that are installed on your machine.

LISTING 5—LPT ADDRESSING

```
REM display addresses of lpt ports
REM jkh 2/21/93
DEF SEG = &H40
lpt1 = &H8: lpt2 = &HA: lpt3 = &HC
a = PEEK(lpt1) + 256 * PEEK(lpt1 + 1)
b = PEEK(lpt2) + 256 * PEEK(lpt2 + 1)
c = PEEK(lpt3) + 256 * PEEK(lpt3 + 1)
PRINT "Decimal", "Hex"
PRINT "LPT1:"; a, HEX$(a)
IF b > 0 THEN PRINT "LPT2:"; b, HEX$(b)
IF c > 0 THEN PRINT "LPT3:"; c, HEX$(c)
```

Adapting for other devices

When writing your own control program, keep the following in mind: Because the interface does not include a backup battery, the control program should send the proper setup commands for your particular device when you first start the program. Because the PC can "press" the remote control's buttons much faster than a human being, you could even program it to send keystrokes on-the-fly, each time you send a command. Doing so would allow you to overcome the four-device limit typical of inexpensive remotes, allowing you unlimited control over TV's, VCR's, CD players, video-disc players, and other IR-controlled devices.

The circuit described here is not specific to the Memorex AV-4; it could be attached to almost any device with a 5×8 or smaller keyboard matrix.

With only slight modifications, it could control much larger layouts. One way to increase the capacity of the interface while still using only eight data lines would be to add more 4051's. With additional decoding, the five control lines could control $2^5 = 32$ different 4051's. That's a 32×8 matrix, or a whopping 256 keys! Ω

AUTOCOUPLER

continued from page 67

does, LED1 will light up. Connect an audio source to the audio leads and try sending some audio down the line. Your calling party should hear it loud and clear. Next, connect an amplifier and speaker, to the audio port and listen to the calling party. Shortly after the caller hangs up, the coupler should automatically drop the line. With your amplifier still connected, pick up an extension phone; you should hear the dial tone through your off-line coupler. That confirms the audio pass-through from the MPC-2 section that makes the coupler caller-ID compatible.

The remote connections can be tested with a VOM. When the coupler first picks up, pin 5 of the DB-25 connector will go low for a moment. Depending on which way you set jumper JU2, the contacts of relay RY2 (available at J3, the DB-25 connector, pins 1–4) will close either momentarily or will latch as the unit picks up. A ring signal will produce a high output at pin 9 of J3.

You should be able to force the coupler to pick up by momentarily grounding pin 13 of J3 via switch S1. Be sure you don't ground pin 13 directly (R16 must be in place) or you might damage IC5. You can force the coupler to hang up by grounding pin 8 of J3 via S1. Test the external inhibit by connecting pins 11 and 12 of J3 together. Then remove JU1 and have someone call the coupler; it should not answer. Next, connect pin 10 of J3 to ground; the coupler should answer.

Conclusion

The couplers can send or receive audio signals and they have been used as outgoing message centers, listen lines, and remote-control interfaces, just to mention a few. You'll find that it is an excellent and versatile telephone-line interface suitable for automatically connecting your telephone line to a variety of projects. Ω

HARDWARE HACKER

Communication trade journals, micropower oscillators, thermodynamic basics, steam calliope sources, and avoiding energy scams.

DON LANCASTER

Electronics cannot stand on its own. It has been built on the underlying foundations of math, physics, chemistry, and engineering disciplines.

This month, I figured I'd take a back-to-the-basics tack over a topic that has been causing more than its share of helpline grief lately. In short, we are long past overdue in taking a close look at the...

Fundamentals of thermodynamics

As Fig. 1 shows, a *heat engine* is some device or machine that accepts thermal energy at a high input temperature T_H, performs some useful mechanical work, and finally loses its remaining thermal energy to a sink at a lower temperature T_L.

Nearly all auto and airplane power sources are heat engines, as are most electrical generators. Variations on the heat-engine theme lead us to heat pumps, ice makers, vacuum systems, refrigerators, and compressors. And, for that matter, to life itself.

The study of heat processes is known as *thermodynamics*. While it is more of a mechanical engineering topic than an electrical one, electrical-engineering students are usually required to take at least one thermodynamic course. That's because nearly all modern heat engines need lots of support electronics, and many home-power and new energy-recovery schemes are actually heat engines in disguise. Knowing the fundamentals of thermodynamics lets you instantly sort out the perpetual-motion rip-offs and the outrageous pipe dreams from the realities of physics and real-world economics.

We should note up front that more people have spent more time hacking heat-engine ideas than on *any* other engineering topic. The field has been studied to death, and there are *tons* of readily available literature out there.

Unless you can bring something truly new to the table, the chances are that your "new" heat-engine concept has been thoroughly trashed decades ago. Or even centuries before.

For instance, I got this model heat engine in the mail. It was a clever example of how crucially important *reversibility* is in preventing you from getting useful economic benefits. Reversibility is a very sticky thermodynamic problem that was first solved in a brilliant analytic breakthrough by James Watt in 1784.

Thermodynamic laws

Any study of thermodynamics starts off with the laws of thermodynamics. To the best of my knowledge, nobody has *ever* been able to find *any* exception to these laws. At least not on a practical scale.

Countless individuals have blown incredible amounts of their time and money trying to crack those thermodynamic laws. And all of them have failed miserably. Without any exception.

The laws are pretty fundamental, and they range well beyond heat engines. For instance, cell biology, the very life process itself, photosynthesis, all chemical reactions, and solar power all must rigorously obey these laws.

NEED HELP?

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Heat energy always travels from higher temperatures to lower ones. Systems always move toward their most chaotic and lowest energy-level states. Energy can neither be created nor destroyed in any thermodynamic process.

If you do build a heat engine, *only a small fraction of the total energy can ever be recovered as useful work; the rest is irretrievably lost as waste heat.*

Ah yes, that fraction. How big and just how much? Enter one of the most brilliant hardware hackers of all time, a French scientist named Sadi Carnot. Like most hardware hackers, Carnot did not have the foggiest idea what he was really doing. It took the establishment decades to understand how utterly profound and fundamental Carnot's discovery was.

Typical heat engines depend on a *working fluid.* The more important heat-engine fluids include air, steam, ammonia, freon, mercury, nitrogen, hydrogen, helium, and even liquid sodium. The working fluid goes through a number of individual steps or *processes* to trace out a *cycle*. A heat-engine cycle must close upon itself and return to initial conditions so that the engine can continue to produce useful work.

These thermodynamic cycles can usually be plotted in your choice of a *pressure-volume (p-v)* diagram or a *temperature-entropy (t-s)* diagram.

The *area* inside the cycle on either a pressure-volume or temperature-entropy diagram is related to the amount of useful work that can be extracted from your heat engine. The *efficiency* of any engine is the ratio of the useful work you extract compared to the energy that must be dumped as waste heat expressed as a percent.

Many different heat-engine cycles have been dreamed up. The

Otto cycle applies to gasoline engines, while the *Diesel* cycle obviously applies to diesel power plants. Electric-power turbines use a *Rankin* cycle. Or some multi-stage improvement on it. A lot of alternate-energy people get real excited over a *Stirling* cycle, since it is a kind of "external combustion" engine that can accept heat from diverse or low-grade sources.

Every few years or so, somebody reinvents the old Stirling engine, and then builds a bunch of prototypes that just barely miss. Then they will just barely go bankrupt. To date, the old Stirling cycle has largely proven to be both a sucker bet and an economic rathole. Except possibly for arcane cryogenic cooling applications.

Carnot asked two questions: What is the finest theoretical thermodynamic cycle you could possibly create, and what are the efficiency limits to that cycle?"

It was obvious that each part of a Carnot cycle had to be lossless. More precisely, all the processes involved had to be *reversible*. A heat engine must be able to undo anything it just did without losing any heat to friction or other losses. That means "no sudden moves" and "no rapid changes," with everything changing as incrementally and as slowly as possible. That also means zero friction, lossless seals, and perfect insulation. Figure 2 helps to explain the concept of reversibility.

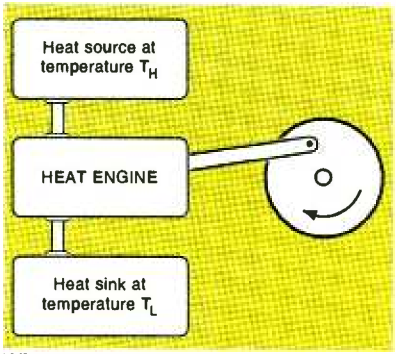


FIG. 1—A HEAT ENGINE accepts energy from a high-temperature source, does useful mechanical work, and then rejects a portion of that energy to a lower-temperature sink. Only a fraction of the available energy can ever be converted. Most electronic devices must also obey the same thermodynamic laws that govern heat engines.

Suppose you want to use a piston to compress the gas inside a non-insulated cylinder. Some work is needed to reduce the gas to a required volume. Any work above that is lost as waste or exhaust heat.

Let's say you build up your cylinder and throw an eight pound weight on it. You note that this particular piston happens to drop by a foot, doing work to compress the gas. In this case, eight foot pounds of work are expended, because the eight-pound weight dropped by one foot.

Is this the best you can do? If instead, you put a one-pound weight on the piston, waited until things settled down, added another one-pound weight, and so on, you now have the first pound pushing the piston a full foot and the final pound pushing the piston down only an eighth of a foot. Your total work is $\frac{8}{8} + \frac{7}{8} + \frac{6}{8} + \frac{5}{8} + \frac{4}{8} + \frac{3}{8} + \frac{2}{8} + \frac{1}{8} = 4.5$ foot-pounds.

Yet, in each case, you compressed the gas by the same amount, raising its energy state by the same value. The extra 3.5 foot-pounds of work has dropped through that irrecoverable low-grade heat rathole.

In both examples, you have an irreversible process. But your second one is clearly much better. As a third try, put a feather on the piston. Wait till things settle, and then put another feather on the piston. Repeat this until you have accumulated eight pounds of feathers, and you will also end up with the gas compressed by a foot. And only 4.0 foot-pounds of total work will be needed. This is a reversible process and the best you can do. And twice as efficient as your first attempt.

One more time: You must be able to undo what you just did. At all times, you do have to be willing and able to stuff the Genie *back* into the bottle. That's what reversibility is all about.

There are several important reversible processes. One of them is called an *isothermal* process, where everything takes place at a constant temperature. The heat-energy receiver must be at a temperature only a tad lower than the energy source. And the heat source must be so large that taking a small amount of energy out of that source does not significantly change its temperature.

A second one is an *adiabatic* process, in which heat energy is neither added nor removed. *For full reversibility, any compression or expansion of a working fluid should be adiabatic.*

At any rate, the Carnot cycle obeys fully reversible processes to trace out the best approximation of the theoretically ideal heat-engine cycles. Figure 3 shows some more Carnot cycle details. Once again, this is the best possible one you can ever build. Why? Because of the full eversibility. You just can't get better than this.

In the Carnot cycle, one starts with a working fluid at a low temperature. Then the gas is adiabatically compressed by doing work on it. Typically, the new external energy required can come from a flywheel or a second cylinder in the engine. Compressing the fluid raises its temperature and reduces its volume. *Extreme care is needed so that heat energy is neither added nor removed during compression.* The temperature rise has to result solely from the volume reduction.

Compression will continue until a temperature very slightly under that of the heat source is reached. After compression, an isothermal process transfers its heat energy into the fluid, expanding it, and increasing its pressure. The temperature, of course, stays the same. In the third step, the gas adiabatically expands while delivering useful output work. The fluid volume goes up and the temperature goes down. A final isothermal process dumps the remaining heat energy to the waste heat sink, reducing the volume and closing the cycle.

Once again, that *area* inside the curve on the pressure-volume diagram determines how much work is delivered.

Because every process is reversible, one can introduce heat energy at a high temperature to produce mechanical work output. Or, one can apply mechanical work to pump heat from the low side to the high side.

A gas engine runs "forward." A refrigerator runs "backward." And a heat pump can either heat or cool, by swapping the heat from the high-side to the low-side.

When you go through the math (the derivation takes a full lecture hour in any university physics course), this stunningly elegant and simple result pops out...

$$eta = (T_H - T_L)/T_H$$

Restated in English: *The very best possible efficiency that can be determined solely by the ratio of its source temperature to its sink temperature*—no matter what cycle, fluid, or engineering is used! And my key point: To get useful work out of any heat engine, lots more energy must be thrown away as irrecoverable waste heat.

For example, a modern auto engine has a theoretical efficiency of 55 percent, with something like 38 percent being a typical real-world value. That is at the engine's flywheel. The actual efficiency of the automobile as a transportation system is far lower.

Oh yeah. One minor gotcha. Absolute temperatures must be used for the Carnot formula to work. Absolute degrees Rankin are 460 degrees above Fahrenheit. Absolute degrees Kelvin are 273 degrees above Centigrade. And any efficiency is a hundred times the efficiency stated as a fraction from 0.0 to 1.0.

Down my street is an impressive artesian hot well that's spewing forth mightily at 125 degrees F. Could we get some electricity out of it?

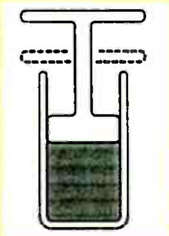
Assume the local average ground temperature is 75 degrees (The well sits in the Upper Sonoran life zone.) The best possible energy recovery efficiency here would be...

$$((125 + 460) - (75 + 460))/(125 + 460) = 0.085$$

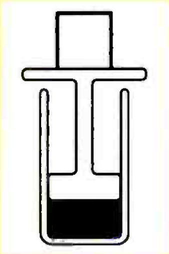
Or a mere 8.5 percent, under ideal conditions. That's assuming a perfect Carnot cycle. In the real world, you'd be lucky to get a tiny fraction of that—say three percent net. For every kilowatt hour generated, *thirty-two* are thrown away!

Sadly, it makes sense to ignore some $20,000 worth of electricity each year just by dumping it into the Gila River. Why? Because any practical recovery project of this size and temperature differential could *never* pay for the engineering, materials, operating costs, flood zone risks, and the time value of money needed to do the job properly.

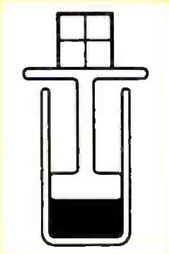
As one process in a heat engine cycle, assume you have a fluid you wish to compress by adding weight to the piston such that your piston drops by exactly one foot...



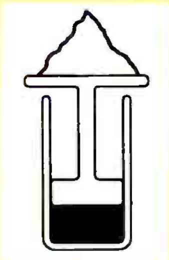
On your first try, you throw an eight pound brick on the piston and note that the piston does in fact drop by one foot. You have done 8.0 foot pounds of work. As we will shortly see, this is a useless and BADLY IRREVERSIBLE process, because one-half of your work will get lost as irrecoverable low grade heat...



On your second try, you place a one pound rock on the piston, wait till things settle, and then add another one pound rock. You will still need eight pounds of rocks, but this time, the work needed is only 8/8 + 7/8 + 6/8 + 5/8 + 4/8 + 3/8 + 2/8 + 1/8 = 4.5 foot pounds of work. This is a useful but MODERATELY IRREVERSIBLE process in which one-eighth of your work gets thrown away...



On your third try, you place a feather on the piston, wait till things settle, and add another feather. You still need eight pounds of feathers, but this time the work needed is only the tiniest amount above 4 foot pounds. This is a FULLY REVERSIBLE process in which virtually none of your work gets thrown away...



Any fully reversible scheme to compress or expand a fluid is also called an ADIABATIC process. Heat is neither added nor removed in any reversible adiabatic process.

FIG. 2—AN EFFICIENT HEAT ENGINE absolutely demands that all of its processes be fully reversible. Here are some good and bad examples of reversibility.

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Is there any way you can beat the thermodynamic laws? Generating electricity won't hack it, because you can always use your electricity to run a motor, which instantly gets you back to a heat engine which has to rigorously obey the laws.

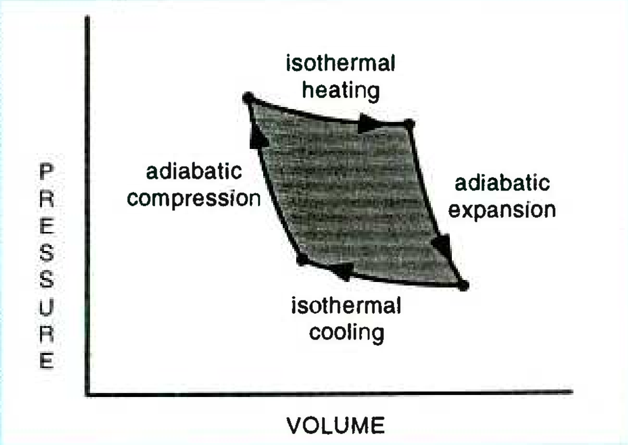
You can switch to a *binary* or even a *trinary* cycle which uses multiple stages and different fluids. But these often will only marginally improve the efficiency while doubling or even tripling the costs.

The only other way I know of is to do something useful with the rejected waste heat. Say by heating water, equalizing process temperatures, or starting your own catfish farm.

A solar panel that also heats water should have much better economics than one that solely generates electricity. Schemes such as these are sometimes called *cogeneration*, and they are now a very hot topic indeed. There's even a *World Cogeneration* trade journal.

A reality check

So, how do you separate the "real" heat engines from the scams and the wishful-thinking daydreams? First, calculate its Carnot efficiency and see what that reveals about the claims involved. Be especially suspect of statements



The **AREA** inside the Carnot cycle determines how much useful mechanical work is output.

The **EFFICIENCY** of a Carnot cycle is determined solely by this elegantly simple formula:

$$\eta = (T_H - T_L)/T_H = \Delta T/T_H$$

You can multiply this 0-1 value by 100 to get the percentage efficiency. Note that an **ABSOLUTE** temperature scale must be used such as Kelvin (Centigrade + 270) or Rankin (Farenheit + 460).

Note that the best possible efficiency of any heat engine depends **ONLY** upon the highside/lowside temperature differential and nothing else!

FIG. 3—THE MOST EFFICIENT HEAT ENGINE you can possibly build conforms to the Carnot Cycle. All four processes are fully reversible. Even the best Carnot cycles must dump a lot of non-recoverable energy as waste heat.

like "this is not a heat engine," or "the thermodynamic laws do not apply to me."

Then carefully look at the *p-v* or *t-s* diagrams (these will *always* be very obvious on any legitimate device). Then check carefully for anything that is obviously non-reversible. Any sudden changes or the need to add coolant to close a cycle are both dead giveaways that all is not well. Always ask "Can each and every process be run backward just as well as forward?"

Then throw in some economic analysis. This could be your time to break even. That's the length of time needed for generated power to pay for the materials, the design, and time value of the money needed to create the device. Assume that 17.58 watts is a heating rate of one BTU per minute, and that it raises one pound of water by one degree F. And that a nickel per kilowatt-hour is a sensible ballpark cost for electricity that you can avoid. And that a gallon of water weighs eight pounds. And that the time value of money normally triples the cost of a project.

Note that the time to break even can easily be infinite! If you produce less revenue from electrical generation per year than the interest on the construction financing, the longer you run, the more you will lose.

Finally, be extremely wary of the word "Stirling." When and where it happens to occur.

My favorite popular thermodynamic book is *Heat Engines* by Sanford. It is found in the Doubleday Science Series. Beyond that one, pick up any of the dozens of college-level course texts. Important thermodynamic resources include the *SAE Library* from the *Society of Automotive Engineers*, and the *EPRI Publications* from the *Electric Power Research Institute*.

Of the many trade publications,

Power Engineering is typical; it targets large-scale electrical generation. And, of course, virtually any and all thermodynamic papers ever published are instantly available through *Dialog*.

Communications resources

Where can you go to get a crystal for a pager? Or to find out more on fiber-optic communication? Or information on wireless modems? Or phone testing? Or computer local area networks? As always, your first and foremost source of insider information in any field is in the trade journals.

As our resource sidebar for this month, I have gathered together a bunch of the more obscure and more fragmented communications trade journals for you. I have a hunch I might have missed a few here, so be sure to let me know if you have any other favorites.

Crystal oscillator

Hacking a crystal oscillator is no big deal these days. You just bias any old CMOS gate into its active region and hang a crystal in the feedback path. But things get tricky fast if you try to run at ultra-low supply currents or want to start oscillation reliably at unusually low voltages.

Most hackers have discovered that typical CMOS transistors run out of gain at ultra-low currents. And they ultimately find that the best route to micropower oscillators is to use bipolar transistors instead of CMOS gates.

Harris Semiconductor has just introduced a cheap and very simple HA7210 all-CMOS crystal-oscillator chip. It costs under a dollar and free samples are available. As Fig. 4 shows, you simply hang a crystal on the chip, and away you go. The current consumed by this oscillator is a mere five microamps at 32 kilohertz.

Pin 6 is an enable; keep it high to run and make it low to disable the chip. Pins 7 and 8 can program the operating current. Make them both high for low frequencies (10–100 kHz) and both low for high frequencies (5–10 MHz). The supply-voltage range for the chip is 2.0 to 7.0 volts.

New tech lit

There are some new integrated circuits for this month: The SSI 67F687 is a new engine interface peripheral offered by *Silicon Systems*. It receives gasoline-engine crank and cam input signals for use as timing and pollution management.

From *Trident*, a new *Video View* video-processing chip set offers scalable, full-motion video windows and frame capture for VGA systems. From *Hitachi*, there's a new HD49049FS picture-in-picture controller chip, also intended for video-insertion applications. The *Grass Valley Group* has a fine video *Dictionary of Technical Terms* newly available. A good bookstore for navigation texts and GPS satellite secrets is the *Navitech Book & Software Store*.

One source for Apple II repairs and supplies is *Rolf Taylor*. The best Apple II magazine is still *Resource*

NAMES AND NUMBERS

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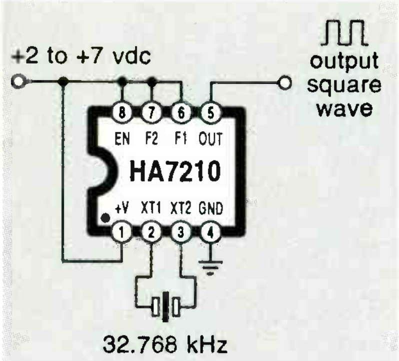


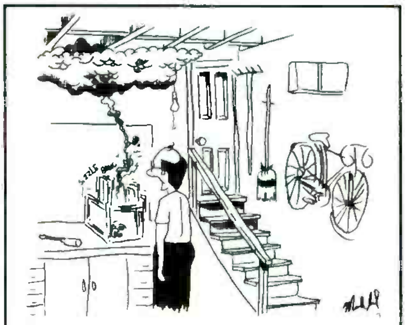
FIG. 4—THIS MICROPOWER CRYSTAL OSCILLATOR from Harris Semiconductor needs only five microamps of supply current from a source as low as two volts. It costs under a dollar. Free sample kits are available.

Central. And the *A2 GEnie* Round-Table has just seen its 20,000th library uploads. Yet another trade publication for this month is the *Industrial Laser Review*. A good source for steam calliopes is *Ragtime*. It offers a $5 catalog.

Free samples of *Volara*, *Volextra*, and *Minicel* foams are available from *Voltek*. Ask for their specifier kit.

A reminder here that I have autographed copies of my *Incredible Secret Money Machine II* here for you at my own *Synergetics*. This book is a must if you are starting up your own tech venture. Plus a reminder about my Hardware Hacker Round-Table on *GEnie* PSRT at (800) 638-9636. And our no-charge technical helpline is found at (602) 428-4073. Best calling times are 8–5 weekdays, Mountain Standard time.

Most of the items I've mentioned appear in our *Names & Numbers* or *Communications Trade Journals* sidebars. Be sure to check here first before calling our helpline. Let's hear from you. Ω



Fred then realized that he forgot to build in an off button.

WHAT'S NEWS

continued from page 4

capacity for two-way, interactive programming. Cablevision Chairman Charles Dolan will only generalize about the possible services at this time.

Among the possibilities mentioned are pay-per-view TV programming, video conferencing, and interactive long-distance educational programming. In addition, he said Prodigy has been talking to Cablevision about introducing its electronic banking and shopping services to the system.

Newsday, a Long Island regional newspaper, has discussed the possibility of providing on-line newspaper articles and information services. Another possibility is a "personal communications network" that could provide an alternative route for subscribers to reach long-distance telephone carriers, bypassing the local telephone company. The new telephone service has not been approved by the FCC. Wireless, pocket-sized telephones would be needed.

Under Cablevision's ambitious plan, 100,000 homes on Long Island could be connected by early 1994. The network is expected to reach the rest of Cablevision's 1.1 million customers in the tri-state area by the end of 1995. There are also plans to extend the service to subscribers in 16 other states.

Global positioning network

A nationwide network called Pinpoint will permit the determination of the positions of vehicles within a few feet of their true positions. Signals from U.S. Navstar Global Positioning System (GPS) satellites are being corrected to improve their accuracy before being retransmitted by local FM radio stations.

Most of the commercial GPS receivers now available for private yachts and commercial vessels can deterine a ship's position to an accuracy within about 300 feet. (For what it says are security reasons, the Department of Defense restricts the accuracy of the signals that civilian GPS receivers can receive directly from the satellites.) However, it is legal to correct those signals to permit more accurate "fixes" on land and at sea and retransmit them from ground-based stations.

Pinpoint, which went into operation in February in Los Angeles, can improve the GPS signal because it maintains a reference position that constantly monitors the satellites navigational signals. Because the coordinates of that reference station are precisely known, the station can measure any errors in each satellite's signal and calculate correction factors that are used to offset those errors.

Those correction factors are transmitted by local FM radio stations by radio data link to mobile GPS receivers, where the differential data is applied to the raw GPS data.

Pinpoint is operated as a joint venture between Magnavox Electronic Systems Co. (Torrance, CA) and Cue Network Corp.(Irvine, CA). The system is expected to be used by:

- Municipal traffic authorities to manage traffic flow more efficiently.
- Emergency vehicle dispatchers responding to 911 calls in directing fire trucks, police cars, ambulances and tow trucks.
- Commercial and utility vehicle dispatchers to keep track of the movements of buses, trucks, taxis, and delivery vans.

Radio data links of this kind have been difficult to organize because of the congestion in suitable radio frequency bands that are strictly regulated by the FCC. However, Pinpoint overcame this obstacle because the system is based on frequency allocations that are assigned to Cue, a large paging and message forwarding service.

Cue's satellite paging system transmits on subcarriers—unused bands within the assigned bandwiths of more than 300 commercial FM stations. It can reach 90% of the continental U.S.and Canada. The differential GPS data is "piggybacked" on the FM subcarriers along with Cue's paging signals. Pinpoint plans to expanded to as many as 50 North American cities this year, beginning with Houston and New Orleans. Ω

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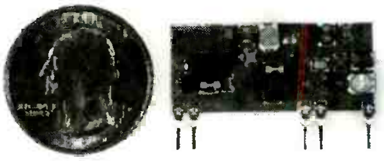

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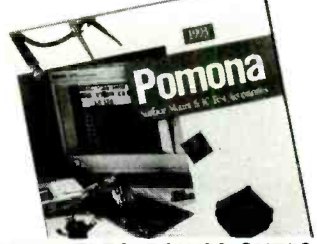

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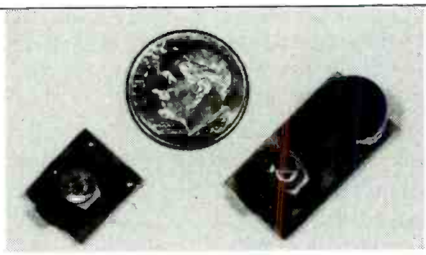

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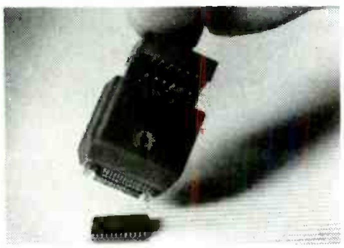

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Loudspeaker Power Ratings: What do they mean ... and how do you avoid problems?

LARRY KLEIN

Do you have a sense of impending disaster involving smoke and flame because your expensive speakers rated for 50 watts are being driven by a 100-watt amplifier? The salesperson who sold you the system claimed that you'd have no problem, but never explained why. You recently read that CD recordings of reed instruments such as clarinets and saxophones can produce enormous instantaneous signal peaks. Will those peaks drive your amplifier to speaker-damaging levels? In short, given your setup, is it possible to have absolutely safe sax?

Speaker power: min and max

Most speaker-system specification sheets expound at length about their computer-designed fourth-order Butterworth filters with phase-compensated 24-dB-per-octave slopes, and so forth. That kind of language might be meaningful to speaker designers, but it certainly doesn't mean much to the typical speaker buyer.

On the other hand, significant information such as a speaker's power rating usually gets short shrift in specifications with such brief cryptic notations as "Power rating: 10 watts minimum, 70 watts maximum." To that bare-bones specification some manufacturers add "RMS" or "Peak," as if that clarified anything.

Aside from the near impossibility of being able to buy an amplifier with a power rating as low as 10 watts, what have you been told? Not much—and here's why. A speaker system's maximum power rating necessarily includes amplitude, frequency, and time. In other words, it isn't just the strength of an incoming audio signal that can damage a speaker system, it is also the frequency of the signal and length of time it is applied.

The reasons become clear when you examine the the features of the drivers in a typical system. To tweet effectively at the upper end of the human hearing range, a high-frequency driver must have a small, low-mass radiating surface. The smaller a tweeter's diaphragm, the wider its dispersion. And the lower the mass of the device, the greater its efficiency.

Unfortunately, miniaturization resulting in such low mass implies both fragility and the speaker's inability to handle a lot of potentially destructive heat. Where does the heat come from? As in most powered products, heat results from inefficiency; it has been shown that typically more than than 95% of an amplifier's output fed to a speaker ends up doing nothing more than heating the drivers and crossover network.

Fortunately for tweeter designers, music energy is not distributed uniformly throughout the audio-frequency range. The spectral display of music viewed on a 10-band real-time analyzer (as found in many audiophile equalizers) shows that most musical energy is concentrated in the midrange of the audio spectrum. In addition, the display shows that the frequencies which normally reach the tweeter, except for a few high-level transients, are both low in amplitude and short in duration.

You can confirm that distribution for yourself by placing your ear close to the high-frequency driver in an operating three-way system. If the crossover to the tweeter is sufficiently high, very little sound will be heard compared to the sound at midrange.

Damaging circumstances

Because of the unequal power distribution to the drivers within a system. a tweeter designed to withstand 4 watts of power within its frequency range is considered to be a fairly heavy-duty unit suitable for use in, say, a system rated for 150 watts. But if that 4 watts were exceeded for a sustained period, damage is likely to occur. So although comparatively little energy reaches the tweeter with the normal playing of music, there are several circumstances that can effectively char-broil its voice coil.

For example, the same 10-band octave equalizer that shows how much audio energy is being fed to your tweeters can also blow them out if you use it to boost the upper octaves excessively on loud material. Pink noise can also cause damage if applied carelessly—as I discovered by blowing out a pair of very expensive beryllium-dome units during some acoustic tests. As I recall, the tweeters didn't seem to be producing very much sound before they suddenly weren't producing any sound at all!.

Marginally unstable amplifiers can be a mysterious source of tweeter blowout. When connected to a reactive speaker system, such killer amplifiers will, under certain signal conditions, oscillate ultrasonically and/or generate large high-frequency transients.

An underpowered amplifier driven into severe signal clipping is likely to be more dangerous to the health of their speaker systems than a high-powered unit with sufficient headroom to avoid clipping. An over-driven amplifier operating in the hard-clipping region produces far more high-frequency energy than can normally be found even in loud program material.

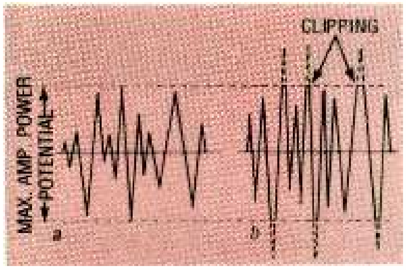

FIG. 1—LOUDNESS PEAKS of a musical waveform shown reaching an amplifier's maximum rated power level, (*a*). When the amplifier is driven harder to achieve greater loudness, the tops and bottoms of the peaks are clipped as shown. When viewed on an oscilloscope, clipped areas appear as bright spots on the trace, (*b*).

The high level of this spurious energy, combined with the high-frequency oscillations that frequently accompany hard clipping, is a common cause of tweeter failure. It is likely that more tweeters have been killed by overdriven 20-watt amplifiers than have been killed by being overdriven by oversized power amplifiers. (I once solved a tweeter-popping problem for a discotheque owner by recommending that he use higher power amplifiers.)

In short, tweeters are seldom destroyed by playing music too loudly. Some unusual circumstances such as those mentioned are usually involved. Incidentally, overstressed tweeters don't go out with a bang; they usually don't even whimper. They just quietly quit working. For that reason, days might pass before you notice that the highs are missing from a defunct tweeter in a three-way system.

The magnetic solution

On the subject of power handling, woofers and, to some extent, midranges have a large advantage over tweeters: Their cone movements pump air around their cylindrical wire voice coils and help carry off some of the heat that inevitably builds up. With tweeters, the diaphragm movements are so minute that there's no convection or forced air movement to provide cooling.

Conduction doesn't help either because there's only a pair of thin wires connecting the tweeter voice coil to the rest of the structure. About the only way that the voice coil can cool itself is by radiation of heat to the surrounding metal magnetic structure—an inefficient process at best. However, in 1977 the situation improved dramatically when ferrofluid was introduced to loudspeaker manufacturing. Today ferrofluids are at work in more than 200-million speakers.

Technically, the ferrofluid used in speakers can be described as a colloidal suspension of magnetite (Fe^3O^4) particles in a low-vapor-pressure carrier fluid. It was originally developed as a highly stable lubricant for aircraft turbines.

Ferrofluids consist of about 5% microscopic, coated, spherical submicron-sized magnetite (about 0.02 micrometer in diameter) suspended in synthetic lubricating oil. The coating on the magnetic particles controls clearances, preventing the particles from clumping together. Thus ferrofluids are rather like submicron ball bearings, each a permanent magnet floating in a vehicle of lubricating oil.

In practical applications, a measured drop of ferrofluid is deposited in the voice-coil gap where, responding to the tweeter's normal magnetic flux field, it instantly disperses uniformly throughout the gap where it is held in place magnetically. In brief, ferrofluid is a special magnetizable fluid that provides efficient heat transfer between the tweeter's voice coil and its surrounding metal structure.

Ferrofluids not only provide heat transfer without interfering with normal speaker performance, but they can also improve other variables. For example, their viscosity can be adjusted to provide a desired degree of voice-coil damping.

Ferrofluids also provide stability in voice coil centering. During speaker construction ferrofluid is injected into the voice-coil gap. The material stays there because of the intense magnetic field.

Recently manufacturers have begun using ferrofluids in woofers and sub-woofers. The latest fluids can withstand long-term operation at 200°C.

Next month we'll conclude our discussion of power ratings with a look at midrange and woofer power-handling capabilities, sources of distortion, and the meaning of minimum power ratings. Ω

DRAWING BOARD

Real-world considerations.

ROBERT GROSSBLATT

Before we close this subject (for the time being at least), you all should be aware that the SSAVI system is several years old and has undergone some changes. The basic principles are the same, and the circuitry we've developed is the way to go if you want to descramble it, but the chances of building our design, hooking it up to your TV, and seeing an unscrambled picture, are about the same as finding any intelligent life on Pluto.

The two most significant changes in the SSAVI system involve horizontal sync and picture inversion. The first is no problem, but getting around the second one is going to take a bit of brain activity on your part.

In the original SSAVI system, horizontal sync was never inverted during active video (when the picture was showing up on the TV), but that has changed. The video waveform in Fig. 1-*a* shows the state of the horizontal interval as of fifteen minutes ago (as of this writing) on my cable. I've drawn it with an unscrambled horizontal interval so you can see how the scrambled signal relates in time to the normal one in Fig. 1-*b*. A change has been made to the 4.7-microsecond position normally occupied by the horizontal sync signal. There are also two 1-microsecond spikes at the very beginning and end of the horizontal interval. If you watch a scrambled picture, you can see these at both ends of the interval as it weaves its way down the middle of your screen.

These spikes peak at 100 IRE units but since they're not really in the horizontal interval, they don't cause any problem. If I had to make a guess as to why the "woop-dee-doo" has been added to the horizontal interval, I'd say that it's to keep people from doing what we're doing—adding a single sync pulse to restore the signal.

When I was designing the section of the descrambler that put the horizontal sync pulse back in the interval, I had to modify the circuit slightly to make it work. Basically, all I did was add some gates to the output of the 4040 line counter to create a pulse that started 2 microseconds into the horizontal interval and had a width of 4 microseconds—the approximate length of the horizontal sync pulse. I used it to gate the incoming video, completely eliminate the change from the transmitted signal, and make sure that the only thing that appeared in that section of the line was the generated horizontal sync from the phase-locked loop.

During the vertical interval, of course, this entire activity was disabled to allow the transmitted sync (which is still being sent in the clear) to be passed through the descrambler.

The polarity indicator for the picture still works as I described, but the newer SSAVI systems (at least the one in my area) move it around between lines 20 and 22. This is actually a dangerous thing for cable companies to do, since line 22 is usually considered to be active video.

The information as to where it will be is probably buried in the subscriber codes, which are difficult to decode. The code format is usually as a series of 32-bit words with bits that are about 2-microseconds wide at a data rate of 504 kHz (which should be a somewhat familiar number).

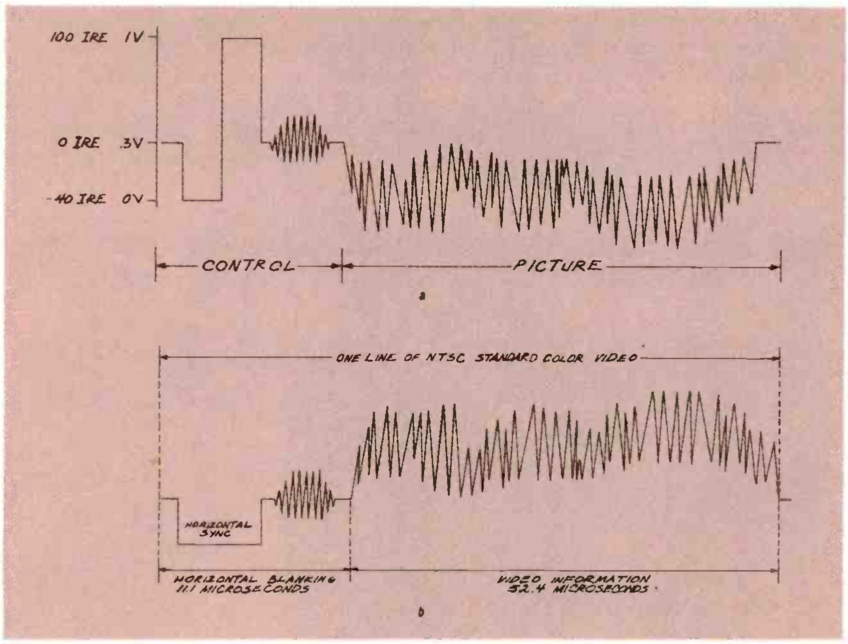

FIG. 1—This video waveform shows one variation on the SSAVI system. A change has been made to the 4.7-microsecond position normally occupied by the horizontal sync signal, and there are 1-microsecond spikes at the beginning and end of the horizontal interval.

How to handle this problem depends on the nature of the scrambled signal in your area. You can decode the marketing code and figure out which bits indicate the correct line to examine for determining the polarity of the following video frame, but that is an involved subject and there's just not enough room here to go into it. It's also not the best approach since there's nothing stopping the cable companies from putting the code somewhere else or, to make matters even worse, change the encoding algorithm.

A second way to deal with the problem is to examine the vertical interval on a scope, see where the polarity-indicating lines are, and work out some circuitry that examines them all. Remember that what has changed is the location of the line (it now moves around from place to place), and not the structure of the line. In essence, if there are three lines to examine, a high in the second half of any of them would indicate that the next video frame is inverted. That's the approach I took.

One interesting piece of information I can pass along to you is that, again in my area only, the video is *always* inverted. Check the signal in your area and see if that's true for you as well. If it is, the design of the descrambler is much simpler.

Before you get to work, however, some thought has to be given to the things that might be done in the future. Since the SSAVI system has changed over the years, there's no guarantee that the way you go about detecting inverted video today is going to hold up tomorrow. Put yourself in the shoes of a cable company executive and look at the problem from his point of view.

You're spending a lot of money for the cable boxes and, while the fundamental scrambling method can't change (it's built into the basic circuitry of the box), the hooks and signals that tell the box what to do can certainly be moved around the vertical interval. If I were designing their system, I'd put a bunch of alternate encoding methods in the EPROM. They would include the ability to store the inverted-video indicator directly in the marketing codes as well as being able to change the format of the codes themselves.

If you go through the trouble of building something to detect the state of video by looking at line 20, it can all be made useless if the cable company moves the information somewhere else. Restoring horizontal sync is pretty much locked in stone, but I can definitely think of a few ways that even that could be changed.

Remember that large-capacity EPROM's are cheap, and there's nothing stopping the cable company from putting several encoding techniques in the chip. To guarantee your work against obsolescence, the techniques you use to clear up inverted video have to depend on things that can't be easily changed by the cable company.

There's a much more interesting way to deal with the problem. I haven't worked out the circuitry yet, but I'll pass it along for all of you to kick around.

The vertical interval provides a lot of information. One thing we haven't talked much about is the white and black levels. I don't bother too much with these because the TV (or VCR) has excellent circuits to clamp the levels and condition the video signal before it reaches the sync separator. I've found that if I feed the video in at anywhere from 1.2 to 1.5 volts DC, the TV or VCR doesn't have any truble working out the levels for itself.

The black level (0 IRE) should be about 0.3 volt and the white level (100 IRE) should be about 1 volt. Super black is the bottom of sync (−40 IRE) and is at 0 volts. Even if you can't find the polarity line to get the white level, you can always get the black and super-black levels from the unscrambled transmitted sync that's sent in the vertical interval. You can even get the black level of the video signal in the horizontal intervals during active video from the 5-microsecond section containing the back porch.

Once you know the black level, you can integrate the picture part of the line to get the average DC voltage of the signal. That's the same sort of thing we had to do to isolate vertical sync from the composite

sync signal. If it's below the black level, you know that the line has been inverted, and if it's higher, then you know that the line was normal. You'll probably have to filter out the chroma and look at the luminance (DC level) of the line, or else the circuit might have a hard time telling the difference between a dark normal video line and a bright inverted line.

If you do that, one other clue that will help detect an inverted line is that the picture's DC level should never get below about −20 IRE. If it does, the TV's vertical sync detector might sense it and falsely trigger a vertical retrace. That's the sort of thing that frequently happens when you try to view a scrambled video signal—even if the transmitted signal isn't doing anything to the original vertical interval.

Since video is inverted (or not) by the cable companies on a frame-by-frame basis, it's safe to assume that finding an inverted line means that the next one will be inverted as well. Remember that the descrambler is completely reset during the vertical interval when vertical sync is detected.

There's no way that I can provide you with an absolute method to descramble the video in your area—there are just too many subtle variations that can be added to the basic SSAVI system. The ones I just described are only a few of the many possible twists that can be done to a video signal.

The approach and circuitry we developed over the last few months—as well as the theory—should give you a good head start for working out the details that have to be added to deal with the particular scrambling method used by your cable company.

Here's an offer. If you've been following this topic, have been designing a circuit that will work in your area, and are having a problem, drop me a note and I'll help you out. The more information you give me, the more help I'll be able to give you. At a minimum, what I want to see from you are schematics, block diagrams, concise descriptions of the problem you're having, and I'd like either scope photos or drawings of the video signal. Ω

GUITAR TRANSMITTER

continued from page 46

heads with your fingers and that it goes out when you remove your fingers and touch the sensors again. The operations should be "touch-on/touch-off."

If this happens, position the battery in the space provided in the case behind the circuit board, and carefully dress all wires to avoid stressing any wire terminations or interfering with cover closure. Close the cover, and fasten it with four screws. Position control knobs on the potentiometer shafts and secure them with setscrews.

Place an FM receiver near the transmitter and tune it to any station or blank location determined by your selection of C15. Then tune L2 with a plastic IF core alignment tool until the transmitted carrier cancels the FM station.

Plug the Guitar Transmitter into an electric guitar, pluck the strings, and listen for "clean" and "distorted" audio signals. Verify that the DISTORTION, TONE, and LEVEL controls are functioning properly. The DISTORTION should transition from clean to highly distorted sound when the EFFECT is on (i.e., EFFECT LED is lighted).

The TONE control will permit you to adjust the high-frequency response of your electric guitar, and the LEVEL control will permit you to adjust the output volume of your "distorted" sound only. When EFFECT is bypassed, only "clean" sound is transmitted.

Tuning the transmitter

During tune up, play your guitar through the clean channel, and then switch channels with the touch sensor so that you can adjust the level control to match the output volume of the distorted channel with that of the clean channel.

The volume of the clean channel has been set to a pre-determined level so that the guitar signal will remain undistorted when played vigorously. Ω

COMPUTER CONNECTIONS

A confluence of technologies

JEFF HOLTZMAN

Many believe that computer technology is the prime mover in the merging of publishing, telemommunications, consumer electronics, and entertainment, with computer technology, but it turns out that the real locomotive is digital technology. In last month's column the business side of the computer industry was discussed. At the end of that column it was suggested that you visualize a diagram of those five important economic activities with computers in the middle—as shown in Fig. 1—indicating some areas where they overlap. In effect it shows a *confluence* of five endeavors.

Confluence is defined as "a flowing together of two or more streams, or the point of juncture of such streams." That definition is taken from the latest in information interchange, *The American Heritage Dictionary,* Houghton Mifflin, 1987; Microsoft Bookshelf, 1992, a dictionary on a disk. The confluence of the business activities diagrammed in Fig. 1 is exerting a tremendous influence over the way we work, play, and learn. While the computer industry is central to this concept, some people believed that it was the only driver in the merger.

It has now become apparent, however, that digital technology is the true cause of these changes. What is digital technology and how does it relate to these changes?

Digital technology

Digital technology is the creation, capture, storage, transmission, and presentation of information in a binary format (text, graphics, sound, animation, or video), irrespective of the system on which it was created, captured, stored, transmitted or presented.

Figure 2 shows how this definition fits together. Viewed this way, the activities in Fig. 1 industries cut across the information-delivery process shown in Fig. 2. For example, the entertainment industry is primarily concerned with the capture and creation of information; telecommunications is primarily concerned with the transmission and, to a lesser extent storage of information on film and tape. Publishing traditionally has been focused at the ends of the process—creation and presentation of hard copy.

But changes in commerce and society are forcing the publishing industry to pay more attention to the transmission and storage of information in formats other than the printed page. Consumer electronics has been primarily concerned with presentation, but recent partnerships have moved it into the area of creation as well.

Those who earn a living in the computer industry tend to have a "computer-centric" view of the world, as shown in Fig. 1. But in reality, the computer industry is doing little more than supplying the hardware for the digital-technology-based changes sweeping society. The computer industry is responding to a need, not creating new styles for business and living, as some think.

Disktop publishing

The traditional publishing industry (including newspapers, books, and magazines) has resisted change unless it is forced on it. It did not embrace computer typesetting with enthusiasm, and accepted it only after it found that it could reduce staff (typesetters, printers, copy editors) and perhaps break the hold of entrenched unions.

Electronic publishing, on the other hand, is growing rapidly in popularity, accessibility, and utility. Look for big changes—as digital production, delivery, and presentation of information takes hold.

Early evidence of these changes is visible. One emerging area is called Disktop publishing; it involves extremely low-cost production and distribution of information with floppy disks and CD-ROM's as media. For example, a recently formed company called Allegro New Media has developed Turbo Books—electronic books intended to be read on-screen under Microsoft Windows. Initial titles include a business travel guide, science fiction books, computer reference works, books on Japan and college selection, and more. All are floppy-based; prices range from about $25 to $50.

Who wants to read books on-screen? Perhaps children, perhaps the visually impaired, perhaps the person forced to kill time in waiting rooms. A business traveler can now pack a travel guide in a laptop computer. A translation dictionary will help to interpret a foreign language, and can encourage and simplify the task of learning useful words and phrases for those who have no intention of studying another language formally. Electronic games can help the traveler pass "dead time" in airports or on trains.

There is a huge potential market here, but the user interface—the presentation aspect—needs a lot of work. And that's where Apple Computer and the Japanese consumer electronics inductry could succeed and the rest ot the worldwide computer industry fail.

In 1993 several more CD-ROM formats will be introduced, along with portable display/interaction devices. Sony has already introduced one; look for others from Apple, Toshiba, Sharp, Casio, and Tandy. Expect high prices, limited title availability, and total incompatibility with existing systems. If you think the VHS vs. Betamax war

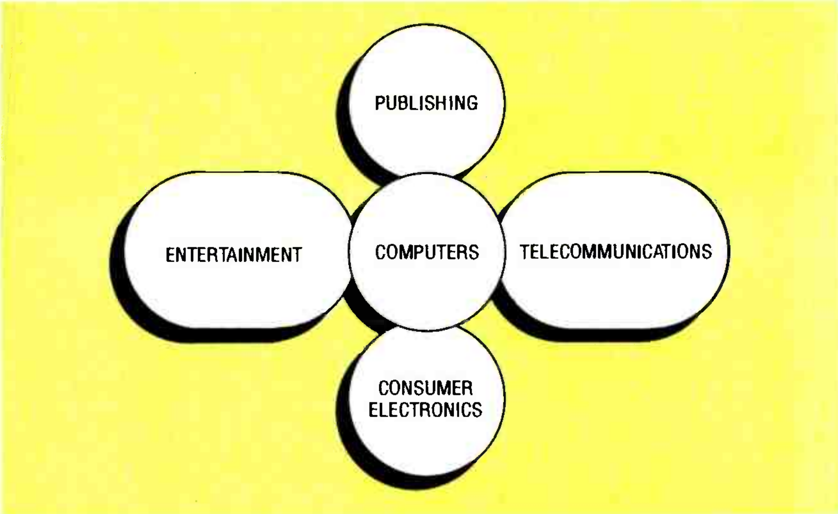

FIG. 1—LEADING ACTIVITIES ARE CONVERGING to meet increased demands for information.

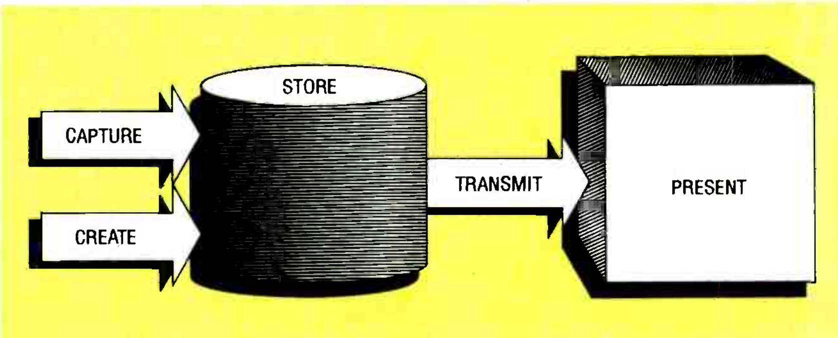

FIG. 2—HIGH-TECH INDUSTRY is merging as a result of a growing appetite for information. Entrepreneurs will make and losew fortunes controlling the major steps of the process.

was a disaster, get ready for the upcoming blood bath in consumer CD-ROM formats.

The many host-based services such as CompuServe, Prodigy, and America Online are other forms of electronic publishing. If you haven't subscribed to one of these services recently (or ever), you're cheating yourself. CompuServe offers an incredible variety of services including shareware files, "forums" or meeting "grounds" for discussions on subjects of mutual interest: computers, politics, human sexuality, art, literature, sports, language, news, stock quotes, etc.

The other services don't offer CompuServe's depth, but they cost less and are more user-friendly. In general, as with Disktop publishing, there is a huge potential market for on-line services.

Telecommunications

The transmission of information in digital form will grow astronomically in the next decade; entrepreneurs will probably make and lose fortunes in these ventures, but they could spin-off a lot of interesting new technical jobs.

The integration of telecommunications with the other digital-information technologies is about to explode on the scene. But it's not here yet. However, different branches of the telecommunications are engaged in a wide variety of experiments in storing and transmitting information. For example, there are about a half dozen experiments in interactive TV across the United States. In France a nationwide interactive system is already operational.

ISDN—Integrated Services Digital Network has not lived up to expectations because of the staggering technical, political, and cost impediments it must overcome. However, it now appears poised to take off. It is expected that ISDN will provide a digital conduit (comprising two 64-kilobit data channels and a 16-kilobit signaling channel) to every phone jack in the world.

That should pronounce the death knell on analog modems, presage more efficient data transfer, and pave the way for videophones, efficient access to host-based publishers, increased use of telecommuting, and even lead to electronic town meetings.

Some believe that ISDN suffers from the too-little-too-late syndrome. It simply cannot supply enough bandwidth to move the tremendous amounts of audio and video data required in a multimedia information environment. This has led to proposals for replacing the nation's wired telephone and cable-TV infrastructure with optical fiber, thereby providing gigahertz of bandwidth (vs. the kilohertz of basic ISDN). But the cost of such massive projects scares many who wonder if consumers will pick up the tab.

The Clinton administration has announced that it favors a "national data highway." Parts of that highway would certainly support gigahertz

RESOURCES

- Turbo Books, Allegro New Media, 387 Passaic Avenue, Fairfield, NJ 07004. (201) 808-1992.
CIRCLE 41 ON FREE INFORMATION CARD
- Derive 2.5 ($295), Derive XM ($375), Soft Warehouse, 3660 Waialae Avenue, Suite 304, Honolulu, HI 96816-3236. (808) 734-5801.
CIRCLE 42 ON FREE INFORMATION CARD
- Outside In 2.0 ($89), Systems Compatibility Corp., 401 N. Wabash, Suite 600, Chicago, IL 60611. (312) 329-0700.
CIRCLE 43 ON FREE INFORMATION CARD
- Microsoft Word for Windows & Bookshelf, Multimedia Edition ($595; academic and upgrade prices available), Microsoft Corporation, 16011 NE 36th Way, Box 97017, Redmond, WA 98073-9717. (206) 882-8080.
CIRCLE 44 ON FREE INFORMATION CARD
- Katron PE-300B ($225), Micro-lan Integration, Inc., 7400 Harwin Drive, Suite 120, Houston, TX 77036. (713) 266-3891.
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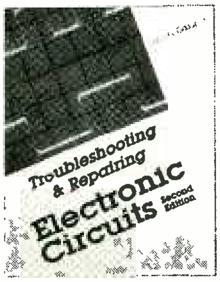
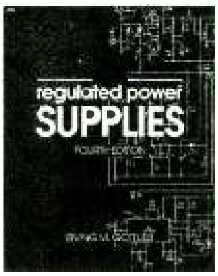
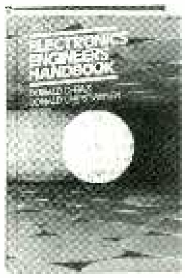


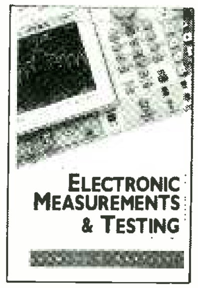
3258P **$19.95**
This book offers up-to-date instructions for troubleshooting and repairing all major brands of equipment, with hundreds of diagrams, specs, and schematics. Covers TVs, VCRs, CD players, and much more. 310 pp.
Softcover



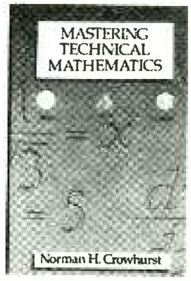
3991H **$39.95**
Engineers and technicians will find full coverage of standard power supply sources. Covers new frequency devices including insulated-gate bipolar transistors (IGBT) and mos-controlled thyristors (MCTs). 464 pp., 365 illus.



9255H-XXX **$105.50**
"Outstanding, extensive reference to current technology of electronics. Covers everything from principles to applications."
—Computer Book Review
2,528 pp., 1,800 illus.
Counts as 3



003961H **$40.00**
Here's your guide to basic electrical measurements, component measurements, system tests, and performance verification. Most of the methods and procedures you'll find here use available off-the-shelf test equipment.
224 pp., 180 illus.



3438H **$39.95**
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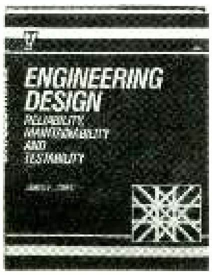
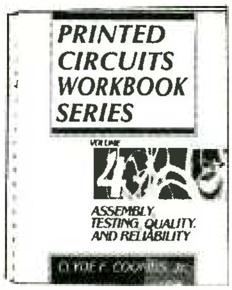
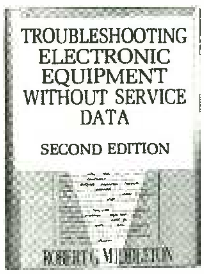


3151H-XX **$42.95**
In this comprehensive guide, management and logistics expert Jim Jones presents a total, field-tested plan that will help you keep your customers satisfied and increase your chances for success. 334 pp.
188 illus. *Counts as 2*



012739P-XX **$26.95**
From the design, layout, and specification guidelines to material properties, this convenient manual contains authoritative coverage of all aspects of printed circuits engineering.
256 pp., Illus. *Softcover*
Counts as 2



9290H-XX **$36.00**
This book provides the practical approaches and innovative, easy-to-perform troubleshooting techniques you need to pinpoint symptoms and effectively evaluate the cause of electronic malfunctions. 318 pp.
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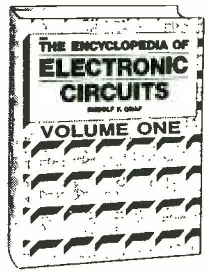
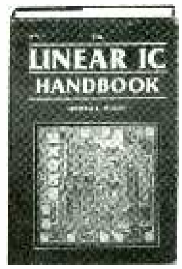
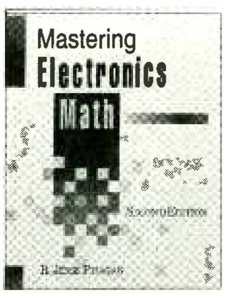


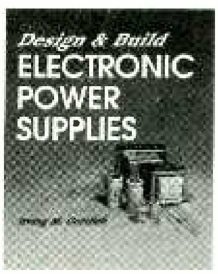
1938H-XX **$60.00**
For quick-reference and on-the-job use, this sourcebook puts over 1,300 state-of-the-art designs at your fingertips. From A (alarm circuits) to Z (zero crossing detector circuits) this compendium excels in content, scope, and design.
768 pp. *Counts as 2*



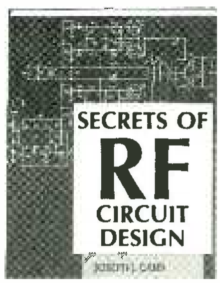
2672H **$49.50**
This "one-stop" sourcebook bridges the gap between data books and the designer's search for the right component. Covers how linear ICs are fabricated, how they work, what types are available, and techniques for designing. 624 pp.



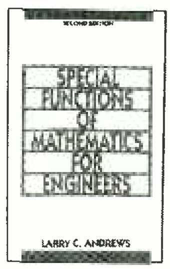
3589H **$27.95**
A practical toolbox reference for anyone in the electronics field. Phagan guides you through the practical calculations needed to design and troubleshoot circuits and components.
352 pp., 270 illus.



3540H **$26.95**
This guide brings you up-to-date on today's most advanced power supply circuits, components, and measurement procedures. Covers switching rates up to 3-MHz and higher as well as the 20-kHz standard. 176 pp.



3710H **$32.95**
Understand the basics of receiver operation, the proper use and repair components in RF circuits, and principles of radio signal propagation from low frequencies to microwave.
416 pp., 411 illus.



001848H-XX **$63.00**
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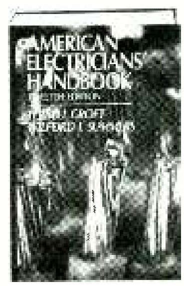

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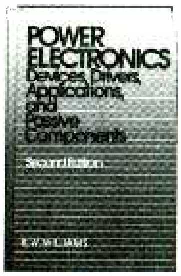

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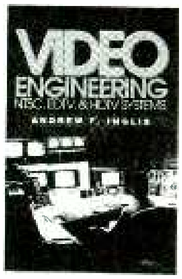

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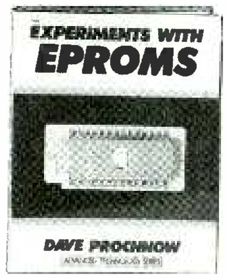
Get valuable information on the production, recording, editing, transmission, distribution, and display of video signals in this valuable guide.
300 pp., 120 illus.



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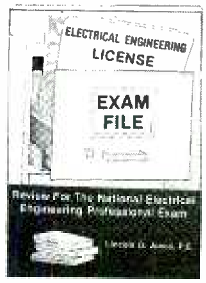
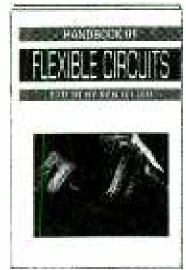
This complete EPROM instruction manual provides a detailed explanation of underlying theory, plus 15 different projects, including programmers, erasers, and EPROM-based circuits. 240 pp. *Softcover*



585247H **$31.95**
The fully updated sixth edition of this popular manual brings you clear, complete guidance on every type of question you're likely to encounter on the P.E. exam in Electrical Engineering. 282 pp.



586166H-XX **$59.95**
This handbook methodically guides you to the optimum use of flexible circuit technology—how to avoid both under-using features and over-stressing products. It will be a welcome working reference for just about anyone in the circuit industry. 288 pp. *Counts as 2*

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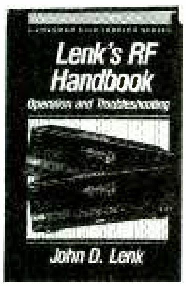
570 pp.



037504H **$39.50**
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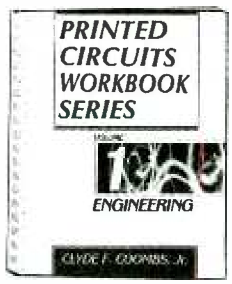

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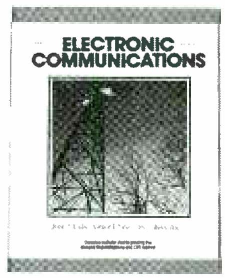

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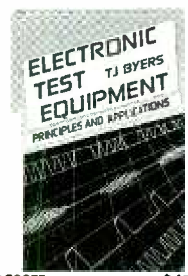

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Cellular Digital Packet Data (CDPD), a related technology could provide universal *wireless* digital connectivity. But there's a lot of in-fighting in the CDPD community about how to do what needs to be done. But there's no question that it does need to be done!

Similarly, several firms are now marketing simple programs that allow messages to be sent from a computer to a beeper. And MCI Mail has announced a service that will deliver text-based messages from its Email service to beepers.

Computer networking faces a related set of problems: How do you interconnect several geographically dispersed local-area networks efficiently so that it will serve different parts of one company—or even several companies? The recent newly coined concept of the *Virtual Corporation* could be the answer. (See the February 8, 1993 issue of *Business Week* or the book by the same name for more information.) Why can't worker A at company X simply send a message to worker B at company Y without a hassle? That kind of *transparent connectivity* is urgently needed, but it's still a long way off.

To sum up, the long-term objective of telecommunications is to provide an easy-to-use, high-bandwidth, on-demand connectivity between every node in a country—and perhaps eventually an integrated global network.

Next month the computer and entertainment industries will be examined and this discussion will be wrapped up.

Product watch

Probably the most unusual software program ever reviewed here is a small masterpiece called Derive (see the July 1990 installment of this column for an in-depth review). It is a symbolic math program that can solve equations numerically and symbolically. Unlike most of the programs in this genre, Derive can run on low-end machines.

The new version 2.5 adds many enhancements to its mathematical functions and user interface. In addition, its publisher has introduced an extended version, Derive XM, that runs on a 386-based computer or higher. It can handle as much as 4 gigabytes of memory to solve large problems. No student should be without Derive!

Contact the company for its current listing of more than a dozen books about Derive that will be helpful in learning algebra, trigonometry, and calculus.

Outside In is a Windows file viewer with a twist: it allows you to copy and paste data out of the file being viewed. That's handy when you've got a file created by someone else in a format you don't have. Supported files include dozens of word processors, spreadsheets, databases, and graphics.

These include Word, WordPerfect, Excel, Lotus, Quattro, dBASE, Paradox, BMP, GIF, PCX, EPS, TIFF, and WMF. Outside In even allows you to view the contents of ZIP files (however, the new version 2.0 of PKZIP is not yet supported). The company should make it available for more users on a BBS or CompuServe network.

Microsoft has released a "multimedia" version of Word for Windows on a CD-ROM. The CD-ROM contains the complete word processor which includes several versatile extras: a drawing module, an equation editor, and a charting module, among others. It also contains an incredible amount of documentation accessible through the Windows help engine, and half a dozen reference works.

These include The American Heritage Dictionary, Roget's Thesaurus, the Hammond Atlas, the Concise Columbia Encyclopedia, the World Almanac 1992, and two books of quotations. The reference works include many sound, animation, and video clips integrated with the word processor.

A send button permits the sending of all or part of an article to the word processor, complete with a footnote citing the source. Conversely, one can highlight a word in the word processor, press a button, and see a definition in one or all reference works. A CD-ROM and a sound card are needed to access all its multimedia features. Following the extensively hyperlinked material can keep one fascinated for hours. Multimedia Word for Windows is a must-have item for any serious writer or researcher.

The market for portable Ethernet adapters is exploding. In response, several companies have introduced low-cost, but capable units. For example, Katron's PE-300B (BNC) and PE-300T (10Base-T) has a list price of $225, and is sold with a complete set of drivers: Novell, Lantastic, TCP/IP, PC-NFS, and NDIS (for Windows for Workgroups). You don't get a pass-through parallel port, but at that price, who cares? Good stuff!

Newsbits

MS-DOS 6.0 should be available when you read this, but sans some networking, Email, and disk-compression capabilities. Microsoft's application programming interfaces (API's) are multiplying like fruit flies. Originally there was the standard Windows API, which was subsequently joined by Win32, the 32-bit basis of Windows NT.

Then Microsoft introduced Win32s, a subset of Win32 that would run 32-bit code in the 16-bit Windows 3.x environment. Now we have Win32c, ostensibly for the "Chicago" version of Windows, due in 1994, that splits the difference in capabilities between 3.x and NT, including an object-oriented file system, and preemptive multitasking.

The U.S. Semiconductor industry has staged a comeback, with sales moving slightly ahead of those of Japan in 1992. Projections look even better for 1993. General Magic, an Apple Computer spinoff, has attracted the attention of several international heavy-hitters in computers and consumer-electronics; their focus will be on a scripting language for personal communicators. More later.

IBM has recently brought its multimedia-related development groups and partnerships (including Kaleida and the venture with NBC) together under an umbrella organization called Fireworks Partners. Ω

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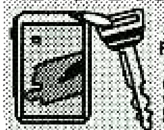

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TA-50A/B	Multi-Purpose Melody Generator ▲	13.85	17.20
TA-50C	Multi-Purpose Melody Generator (Melody such as Happy Birthday Wedding Match etc.)▲	14.65	18.71
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TA-201	Microphone/Auxiliary Mixer, Power Amp. ▲	19.79	27.79
TA-202	Walkman Booster/Aux Stereo Power Amp. ▲	28.50	38.50
TA-300	30W Multi-Purpose Single Channel Amp ▲	25.00	31.00
SM-302	60W + 60W Stereo Power Amplifier (with Mic input case & transformer included)▲▲★	73.00	85.00
TA-323A	30W + 30W Stereo Pre-Main Amp ▲	31.50	42.80
TA-377A	State of the Art Fully Complementary systemmetrical Fet Pre-Amp. ▲▲▲	59.95	75.00
TA-400	40W SOLID STATE MONO AMP. ▲	28.00	34.93
TA-477	120W Mosfet Power Mono Amp. ▲▲	68.00	85.00
SM-720	120W + 120W AC/DC Stereo Hi-Fi & Pre-Main Amp. (case & transformer included) ▲▲★	75.00	89.00
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TA-1000A	100W Dynamic Class "A" Main Power Mono Amp. ▲▲	50.00	65.00
TA-1500	100W+100W New Class"A" DC Stereo Pre-Main Amp▲▲▲	73.70	95.81
TA-2200	DC Fet Super Class "A" Pre-Amp ▲▲▲	47.70	58.24
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TA-2800	BI-FET IC Pre-Amp. w/3 way tone control ▲▲	48.90	63.57
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TY-8	Electronic Lotto ▲	15.00	21.00
TY-11A	Multi-Functional Control Switch ▲	8.50	10.50
TY-12A	Digital Clock w/Timer ▲	25.00	32.00
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TY-36	AC/DC Quartz digital Clock ▲	19.00	26.20
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TY-45	20 Steps Bar/Dot Audio Level Display ▲▲	38.45	46.14
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LG-1925	5" 19" 11½"	TA-477, TA-800MK2, TA-1500, TA-1000A, TA-3600 AF-3	38.00
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#002	36V x 2.3A	TR-503, TA-323A, TA-400, TA-300,	23.00
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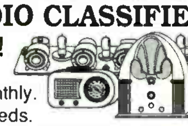

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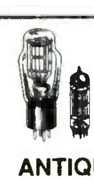

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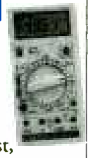

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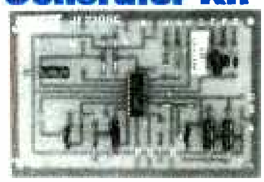

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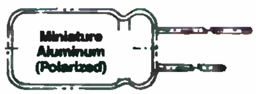

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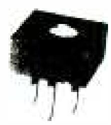

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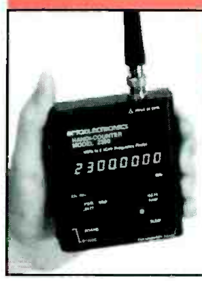

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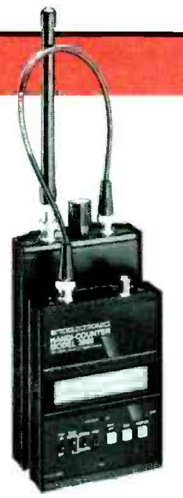

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