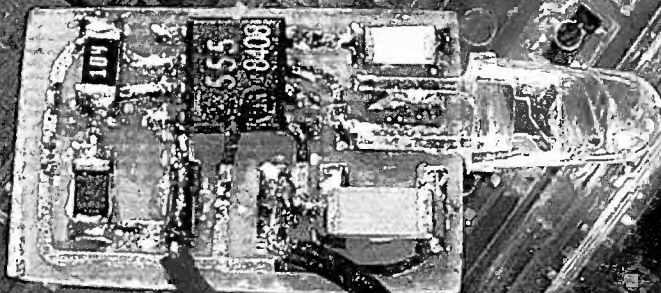


Radio Electronics



SURFACE-MOUNT TECHNOLOGY

AN
INTRODUCTION
TO THE
PACKAGING REVOLUTION

SURFACE MOUNT TECHNOLOGY

- 91 **INTRODUCTION TO SMT**
A new packaging technique, not a new technology, that's forever changing the way that we build electronics circuits.

- 98 **HAND SOLDERING**
Soldering SMC's is easy, once you know how!

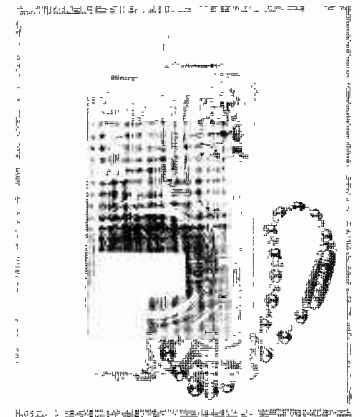
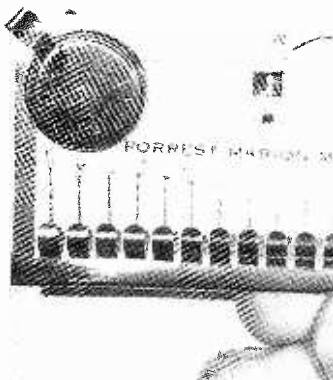
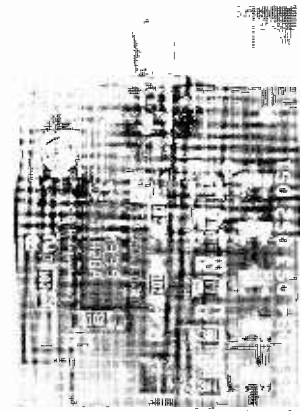
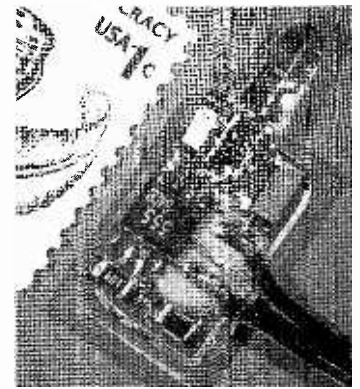
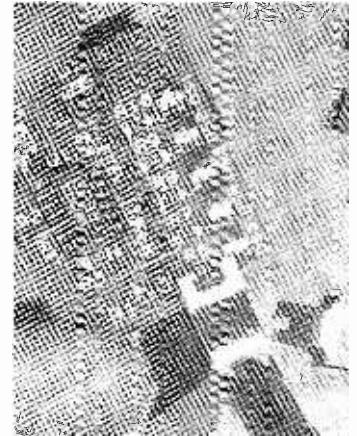
- 99 **SMT PROJECT: LED FLASHER**
An attention-grabber that's smaller than a postage stamp.

- 101 **SMT PROJECT: LIGHT METER**
A bargraph light meter so tiny it can be worn as a charm.

- 103 **SMT PROJECT: AN I-R REMOTE ON A KEYCHAIN**
It's so thin, it mounts inside an ID tag!

- 107 **CONDUCTIVE INKS AND ADHESIVES**
Who needs solder or a PC board?

- 111 **SMT PROJECT: A BUSINESS-CARD TONE GENERATOR**
Build this circuit on a piece of paper.



Surface-Mount Technology

Surface-mount technology is literally changing the shape of electronics manufacturing and packaging.

Introduction to SMT

FORREST M. MIMS, III

THE COMPACT SIZE OF MICROCASSETTE RECORDERS, CAM-corders, and credit-card size calculators and radios is not a result of radically new solid-state developments. Rather, those amazingly tiny personal electronic devices are made possible by a clever electronic component packaging and assembly means known as *surface mount technology*.

In Surface Mount Technology, or SMT, both components and conductive traces are installed on the same side of a substrate or surface. Many kinds of substrates can be used, including ceramic, paper, plastic, and both rigid and flexible printed-circuit boards.

Though components used for conventional through-hole circuit board assembly can be modified for SMT, the vast majority of SMT components, like those shown in Fig. 1, are considerably smaller than their conventional through-hole counterparts. That means that a circuit assembled with SMT components is much more compact than an identical circuit assembled with conventional components.

Surprising as it may seem, SMT is not a new technology. Its roots can be traced to the development of miniature circuit assemblies in the United States during World War II. Similar techniques were applied to the assembly of circuit boards for

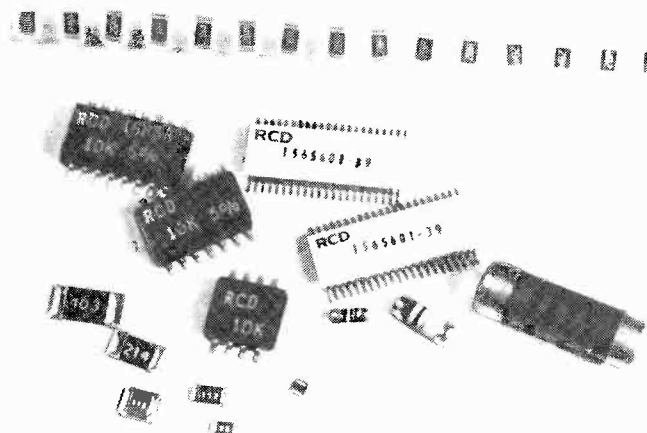


FIG. 1—SURFACE-MOUNTABLE COMPONENTS are supplied in a wide range of miniature package types.

hearing aids. Many of the components and techniques used in the well established field of hybrid microcircuits are used in SMT.

Though SMT has a history at least 30 years long, only in the past decade has it made major inroads in consumer

electronics. In coming years SMT will impact virtually everyone whose career or avocation is electronics. Those who choose not to become familiar with SMT do so at their own peril, for SMT will inevitably replace most conventional circuit assembly methods during the 1990's.

Of course, none of that is news to the electronics technicians who service the personal electronic products mentioned above as well as electronically-controlled 35-mm cameras, pocket and laptop computers, and a host of other products. They have learned, sometimes the hard way, that troubleshooting and repairing SMT circuitry requires different techniques and tools than those used with conventional through-hole circuits.

Engineers, product managers, and entrepreneurs have found that surface-mount technology offers a vitally important means for competing with off-shore electronics manufacturers. Moreover, the economics of SMT are such that circuits can often be produced on-shore using automated production equipment for less money than having them built off-shore.

Finally, SMT provides electronics experimenters and inventors with unprecedented miniaturization capabilities. The proverbial "garage inventor" can now produce functional prototype circuits every bit as tiny as the personal-electronic products popularized by the Japanese; and he can produce an SMT circuit in the same time required to produce a conventional circuit.

Advantages of SMT

The advantages of SMT that we've outlined so far are only some of the reasons the electronics industry is moving so rapidly to SMT. Here is a brief discussion of each of the advantages of SMT:

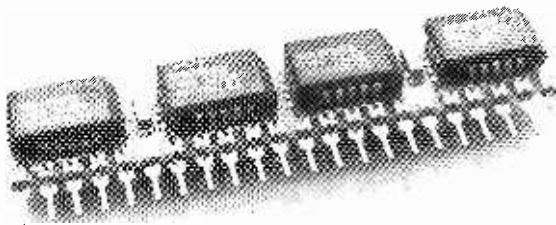


FIG. 2—SMT CAN REDUCE the area of circuit boards. This small Texas Instruments' memory module is made from four SMT 64K × 1 RAM's and four chip capacitors.

● **Reduced Circuit-Board Size**—The compact size of Surface-Mountable Components (SMC's) can substantially reduce the area of circuit boards. Figure 2, for example, shows a miniature Texas Instruments SIP (Single In-line Package) 64K × 4 memory module made from four 64K × 1 RAM's and four chip capacitors.

Texas Instruments and other manufacturers have found that an SMT memory board requires from 30 to 60 percent of the area required by an equivalent board assembled with conventional through-hole DIP (Dual In-line Package) integrated circuits. A surface-mountable SOT-23 transistor occupies only a tenth of the board space of a conventional TO-92 transistor package. A 44-pin surface-mountable PCC (Plastic Chip Carrier) integrated-circuit package occupies only 27.5 percent of the board space required by a standard 40-pin DIP.

A few years ago, TI engineers made an SMT memory board that had been previously assembled with standard

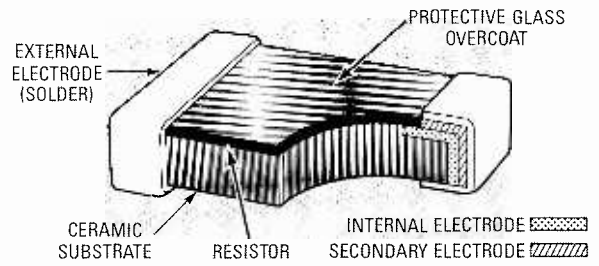


FIG. 3—INSIDE A LEADLESS CHIP RESISTOR. The construction is identical to that of a thick-film resistor deposited directly onto a ceramic substrate.

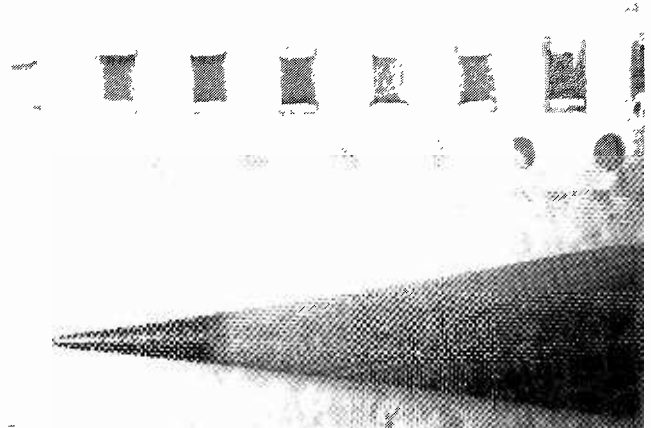


FIG. 4—A STRIP OF CHIP RESISTORS supplied on tape. The pencil point in the photograph is shown for scale.

DIP's. The area of the original board was 152.5 square inches while the area of the SMT version was 62.4 square inches, or only 41 percent of the area of the original board. Ray Prasad, the SMT Program Manager at Intel Corporation, has observed that a 4- × 4-inch board containing half a megabyte of 256K DRAM memory DIP's can contain a full megabyte of surface-mountable DRAM's. If both sides of the board are used, the board can hold 2 megabytes.

SMC's are considerably lighter than their through-hole counterparts. For example, the 8-pin DIP version of National Semiconductor's popular LM308M operational amplifier weighs 600 milligrams. The SO (Small Outline) version of the same IC weighs only 60 milligrams. The low weight of SMC's and the smaller circuit boards they require combine to give typical SMT boards a 5-to-1 weight advantage over conventional boards. Furthermore, the very low profile of SMC's keeps SMT boards very thin and gives them as much as an 8-to-1 volume advantage over conventional boards.

SMT boards are not necessarily used only in highly miniaturized products. Consider, for example, the coming generation of small footprint desktop computers. Those machines will be made possible by 3.5-inch disk drives and SMT. As for add-on peripheral cards, two or more SMT cards will fit in the same space required by a conventional board.

● **Double-Sided Circuit Boards**—Conventional circuits are often installed on boards that have printed or etched wiring on both sides. Plated-through holes provide interconnections between the two sides of the board.

SMT can also make use of double-sided boards but with a new twist. Components can be installed on *both* sides of an SMT board, thereby greatly increasing the savings in space over boards assembled with conventional components. Since many SMC's have a much lower profile than conventional components, an SMT board having components on *both*

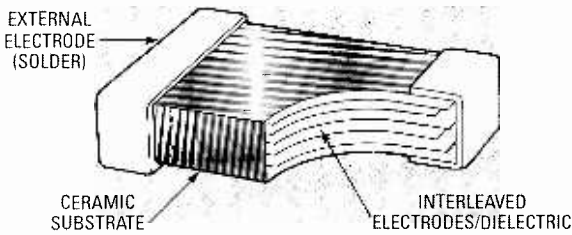


FIG. 5—INSIDE A CERAMIC CHIP CAPACITOR. The device is a sandwich of interleaved metal film and dielectric layers.

MONOLITHIC CERAMIC CHIP CAPACITORS

X7R/BX	100	100	100	100	100	100
COG (NPO)	100	100	100	100	100	100
	0805	1206	1210	1808	1812	1825



FIG. 6—CHIP CAPACITORS, like these from American Precision Industries, come in a variety of sizes and values.

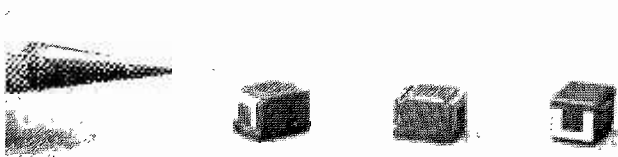


FIG. 7—SMT INDUCTORS are available in values that range from a few tens of nanohenries to one millihenry.

sides can be thinner than a board assembled with conventional components.

- **Subminiature Circuits**—SMT is a spinoff of hybrid microcircuit technology, and some SMT circuits are nearly as tiny as their hybrid cousins. Moreover, subminiature SMT circuits are considerably cheaper than hybrid circuits and prototypes can be assembled in as little as a day using inexpensive assembly tools. Now engineers, technicians, and experimenters can assemble tiny circuits on a low budget and without special facilities.

- **Automated Assembly**—Conventional through-hole components can be installed on circuit boards by means of automated assembly machines. SMT, however, is much more compatible with automated assembly equipment. Unless the board includes plated-through holes, the time-consuming chore of drilling holes in the circuit board is eliminated. SMC's have no wire leads to cut, bend, and insert. For those and other reasons, SMT boards can be automatically assembled much more quickly than conventional boards using through-hole components.

Although automated pick-and-place SMT assembly equipment is expensive, it's also very fast. At the low end are machines that pick and place up to several thousand SMC's per hour. Faster machines can pick and place from 15,000 to 20,000 SMC's per hour. Sophisticated multihead pick-and-place machines can operate at rates exceeding 500,000 SMC's per hour. Automated assembly, the chief driving force behind the rapid acceptance of SMT, will be covered in more detail in the next article.

- **Lower Cost**—The cost of individual SMC's has fallen

rapidly in recent years, but SMC's generally cost more than their through-hole counterparts. Nevertheless, SMT can reduce overall board cost for a variety of reasons. According to National Semiconductor, for instance, a savings of up to 40 percent results from the elimination of drilled holes required for conventional-component leads and pins and the reduction of plated-through holes and conductive trace layers in multi-layer boards.

- **Other Advantages**—Some advantages of SMT are less obvious than those listed above. For instance, the compact size of SMT boards can significantly improve a waveform's rise and fall times, and reduce crosstalk in high-performance logic systems. Those advantages are a result of shorter current paths and reduced pin-to-pin capacitance and mutual inductance. Finally, there is the undeniable advantage that SMT is the wave of the future. Those firms that adopt SMT today will be better prepared to compete tomorrow.

Disadvantages of SMT

Since SMT will eventually become the dominant circuit-assembly technology, it's important to fully understand its limitations and drawbacks. They include:

- **The SMT Learning Curve**—Before the advantages of SMT can be realized, the new SMT user, whether a large corporation or a home experimenter, *must* fully understand the many pitfalls that can trap the unwary. Some companies have learned about the pitfalls of SMT the hard way. They committed to manufacturing a new product using SMT *before* fully understanding the potential problems. Whether through overconfidence or ignorance, the end result in several such cases has been a very costly disaster. It's important to keep the principle of the SMT learning curve foremost in mind as you review the rest of the drawbacks.

- **SMC Standardization**—As recently as 1983, only around 300 specific SMC's were available in the United States. According to Bourns, Inc., by the end of 1986 some 15,000 specific SMC's were available. While that increase has helped spur the rapid growth of SMT, it has been accompanied by standardization problems. Supposedly identical components, especially semiconductors, made by different manufacturers may have slightly different dimensions. In view of the close tolerances required for SMT circuit-board design, dimensional compatibility is an essential requirement. Even when identically configured components are available from two or more manufacturers, each company may package its SMC's for different automated assembly formats. The SMT industry recognizes the standardization problem and is working toward solutions. Meanwhile, engineers and parts buyers for companies entering SMT for the first time are often surprised by the lack of standardization that currently exists.

- **SMC Availability**—While some 15,000 components may be available as SMC's, not all of them may be available when needed. The author's experience has been that ordering SMC's from major electronics distributors can be trying. It's particularly frustrating to order an assortment of sub-miniature SO integrated circuits and receive a package of monster DIP's having the same part numbers. It is extremely important that before committing to an SMT product, manufacturers find one or more reliable sources for the components. And care must be taken to be sure that the supplied components will be identically packaged and both functionally and dimensionally equivalent.

- **High Start-Up Expense**—The start-up cost of SMT for

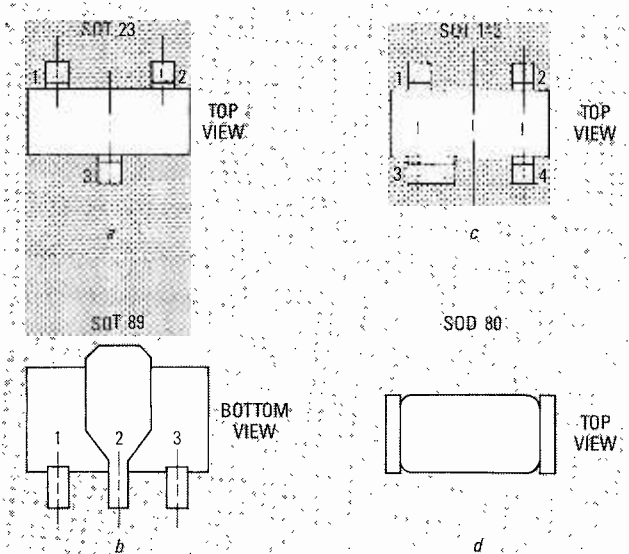


FIG. 8—FOUR MAJOR SO package outlines.

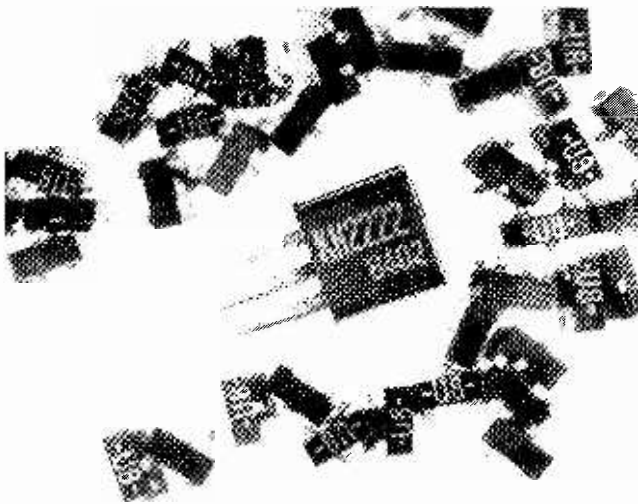


FIG. 9—A TO-92 TRANSISTOR dwarfs its SOT-23 counterparts.

both manufacturers and individual experimenters can be high. For manufacturers, automated production equipment is by far the most expensive investment. Experimenters face the problem of acquiring new assembly tools and a stock of surface-mountable resistors, capacitors, LED's, diodes, transistors, and integrated circuits. While the cost of an individual SMT project may be only slightly higher than the same project assembled with through-hole components, acquiring a sufficient stock of SMT components can easily cost a few hundred dollars or more. That situation will change when retail and mail-order electronics dealers begin offering kits of SMC's.

● **Soldering**—The components of virtually all manufactured through-hole circuit boards are wave soldered. A variety of soldering options, each with various advantages and disadvantages, is available to the SMT user. They include single and double-wave soldering, and reflow soldering. Wave soldering requires that the SMC's be attached to the circuit board with a droplet of non-conductive adhesive. Reflow soldering involves the use of solder paste or cream. The paste is screened over the SMC footprints or pads, or applied directly to the pads with either an automated or a hand operated syringe. The terminals of the SMC's, which adhere to the

sticky paste, are soldered to the pads when the board is heated in a convection oven, in a vapor-phase chamber, or by infrared lamps. Some SMC's are connected in place with conductive adhesives. SMT soldering methods, including their advantages and drawbacks, will be discussed in detail elsewhere in this section. Suffice it to say that a careful understanding of whichever soldering method is selected is crucial to the production of functioning, reliable SMT circuits. In the final analysis, nothing replaces practical, hands-on experience.

● **Troubleshooting and Repair**—The best way to fully appreciate the differences between conventional and SMT circuitry is to take a peek inside a handheld video camcorder. The optics, focusing motor, gears, and image sensor of the typical camcorder are virtually surrounded by thin circuit boards that are peppered with hundreds of tiny SMC's. The sight of those boards will provide convincing proof that servicing SMT circuits requires a completely different set of tools and skills than those that are required to service conventional through-hole circuits.

Since most SMC's are very closely spaced and do not have leads, conventional test instrument probes may not be suitable. Fortunately several companies now make a variety of probes and clips specifically intended for connection to SMC's. Desoldering and resoldering SMC's requires specially shaped soldering iron tips that permit all the terminals of an SMC to be simultaneously heated. Hot air desoldering and soldering tools can also be used for that purpose if care is taken to avoid inadvertent desoldering of nearby SMC's. In short, servicing SMT circuits requires new skills and much more attention to detail than the servicing of conventional through-hole circuits. The observation about the vital role of practical, hands-on experience given in the discussion of soldering surface-mountable components applies equally well to servicing SMT circuits.

● **Other Drawbacks**—Some of the pitfalls awaiting new SMT designers are less obvious than those discussed so far. Thermal overload is a good example. Since surface-mountable semiconductors are so small, they dissipate less heat than their conventional counterparts. That, and the fact many such devices can be densely packed together on a compact circuit board, can lead to unanticipated thermal-overload problems in your designs.

Another drawback is that SMT boards require tighter dimensional tolerances than conventional through-hole boards. In addition, board designers and draftsmen must become acquainted with the configuration of the many different kinds of SMC's. Computer-aided drafting software may have to be updated or even replaced if it doesn't include an SMT capability.

Surface-mountable components

Many, but not all, through-hole components have a surface-mountable counterpart. Physical limitations often prevent a conventional component from being manufactured as an SMC. For example, high-capacity capacitors and power transformers are simply too large. And the pinouts and chip dimensions of some IC's don't readily lend themselves to standard surface-mount packages. Nevertheless, most circuits can be assembled using SMT, even if some conventional through-hole components are required.

It's important for SMT circuit designers, draftsmen, and service technicians to be aware of the general physical configurations and operating parameters of the various families of

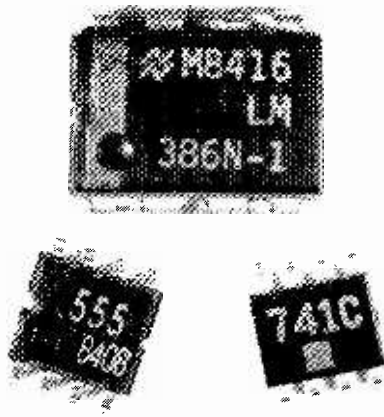


FIG. 10—TWO SO INTEGRATED CIRCUITS and a conventional 8-pin mini-DIP.

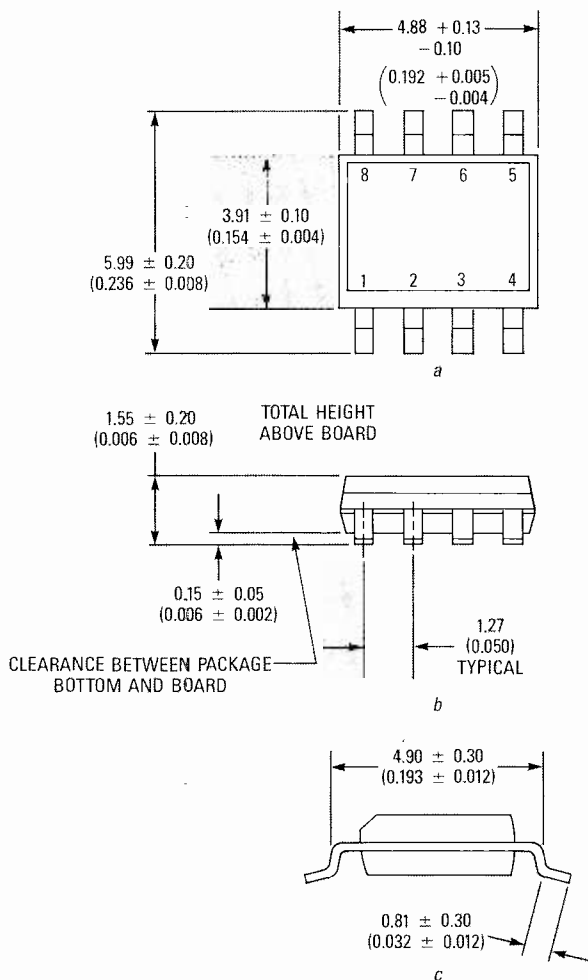


FIG. 11—TOP VIEW (a), side view (b), and front view (c) of a Texas Instruments 8-pin SO integrated circuit.

SMC's. What follows is a quick tour of the most important families of SMC's. All SMC's in those families are available individually or in quantity. SMC's intended for automated assembly are supplied in reels of paper or embossed plastic tape, or in magazines. Some automatic assembly equipment is equipped with vibratory feeders that can be loaded with non-packaged leadless chip components, such as resistors and capacitors.

Chip resistors

Chip resistors are the most widely produced of all SMC's. Originally developed for use in hybrid microcircuits, chip-resistor technology was well established when SMT was adopted for consumer and industrial products.

Figure 3 shows the cross section of a typical leadless chip resistor. The construction of the device is identical to that of a thick-film resistor deposited directly on the ceramic substrate of a hybrid microcircuit. The nickel barrier between the inner electrode and the solder coating prevents the electrode from leaching during soldering. Without the nickel barrier, leaching may impair the connection between the chip resistor and the external circuit.

Figure 4 shows the very small size of chip resistors. The taped resistors in the photo are classified as 1206, a type designation indicating a physical size of 1.6×3.2 millimeters. Other types are the 0805 (1.4×2.0 mm) and 1210 (2.6×3.2 mm). The resistance range of most chip resistors is 10 ohms to 2.2 megohms. Some companies offer values up to 10 megohms and even higher.

Trimmers and potentiometers

Both single- and multi-turn trimming potentiometers are available in surface-mountable configurations. They are made from ceramic or high-temperature plastics to protect them from the heat of immersion soldering. The smallest single-turn trimmers measure less than 4×4 millimeters. Multi-turn trimmers, which closely resemble their through-hole counterparts, measure 6.35×6.35 mm (0.25 inch) or 8.9×8.9 mm (0.35 inch).

Although surface-mountable trimmers are adjustable, it's important to realize that most of those devices are not designed for repeated adjustments. A typical trimmer, for example, might be rated for no more than 10 adjustment cycles. Another consideration is the adjustment mechanism itself. Most trimmers are designed to be adjusted by means of a miniature screwdriver or special tool. The required slot or slots may not be compatible with all kinds of automated pick-and-place equipment. Also, trimmers that require a special adjustment tool can pose a major problem when only a screwdriver is available.

Chip capacitors

Like chip resistors, leadless chip capacitors were developed originally for use in hybrid microcircuits. There are three principle categories of surface-mountable chip capacitors: multilayer ceramic, electrolytic, and tantalum. Four out of five chip capacitors are ceramic multilayer devices. As shown in Fig. 5, a ceramic chip capacitor is a sandwich of interleaved layers of metal film and ceramic dielectric. At opposite ends of the chip, every other metal layer is interconnected by an external metal electrode. Often a nickel layer is added to prevent leaching of the internal metal layers.

Ceramic chip capacitors, like the ones in Fig. 6, are rugged, very stable, and highly reliable. Capacitance values ranging from 1 pF to 1 μ F are available. Package styles identical to those of chip resistors described above (0805 and 1206) are available, as are larger packages. Unlike chip resistors, the size of a chip capacitor is directly related to its value.

For high capacity, electrolytic and tantalum chip capacitors are available. Tantalums are available in values from 0.1 to 100 μ F. Aluminum electrolytics, which are larger than tantalums, are available in values from around 1.5 to 47 μ F.

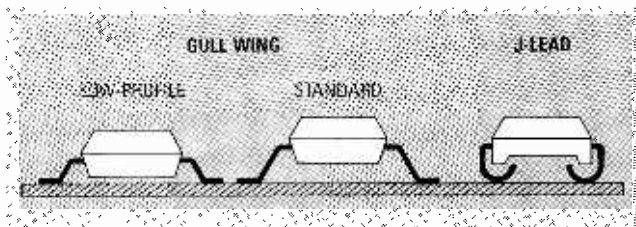


FIG. 12—GULL-WING VS. J-LEAD SMC packages. J-lead packages can be mounted using sockets

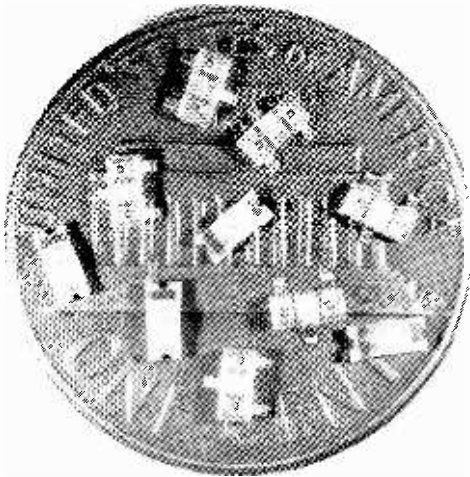


FIG. 13—SOT-23 DUAL-CHIP red LED's and single-chip green LED's are dwarfed by a penny.

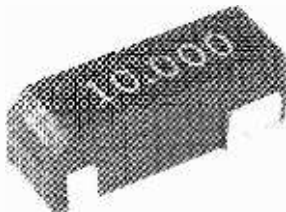


FIG. 14—COMPONENTS SUCH AS CRYSTAL FILTERS, relays, switches, and crystals are available as SMC's. An SMC crystal is shown here.

Those capacitance ranges continue to be expanded as new products are added.

Inductors

Many kinds of surface-mountable leadless and formed-lead inductors, and even toroidal transformers, are available. Inductance values range from a few tens of nanohenries to one millihenry. Figure 7 shows several surface-mountable inductors.

Discrete semiconductors

Many diodes, transistors, and other discrete semiconductors are available in miniature surface-mountable packages. Figure 8 shows the outlines of the four major package styles SOT-23 (Fig. 8-a), SOT-89 (Fig. 8-b), SOT-143 (Fig. 8-c), and SOD-80 (Fig. 8-d). The SOD (Small Outline Diode) package is a leadless cylinder used for diodes. The SOT (Small Outline Transistor) packages are used for transistors, diodes (1 or 2 chips), and various optoelectronic components. Figure 9 compares the SOT-23 transistor with its conventional through-hole counterpart.

Referring back to Fig. 8, note the configuration of the leads

of the SOT packages. The SOT-23 and SOT-143 packages are equipped with formed leads in a gull-wing configuration. The SOT-89 leads are not formed since they emerge from the lower side of the package.

The package configuration determines the power dissipation of any semiconductor. SOT-23 and SOT-143 devices can dissipate from 200 to 400 milliwatts. SOT-89 devices can dissipate from 500 to 1000 mW.

Integrated circuits

Surface-mountable integrated circuits have been available since Texas Instruments developed the gold-plated flat pack IC in the early 1960's. Today more than a dozen families of surface-mountable IC packages are in use.

The most popular surface-mountable IC package, the Small-Outline (SO) configuration developed by Philips, resembles a miniature DIP. An SO device occupies around a fourth the board space of an equivalent DIP. Of even more importance is the very low profile provided by the SO package. Figure 10 shows two 8-pin SO devices together with a conventional 8-pin mini-DIP for a size comparison, and Fig. 11 is an outline view of an 8-pin SO device. Note that the pins of SO devices are placed on 50-mil centers rather than the 100-mil spacing found on DIP's.

While the leads of most SO devices have a gull-wing configuration, a newer design popularized by Texas Instruments has flat pins that bend under the IC package in a J configuration. The chips mounted on the SIP shown in Fig. 2 are J-lead devices.

Figure 12 compares the gull wing and J-lead formats. Gull-wing devices are easier to solder and replace. They also provide sufficient flexibility to prevent the SO package from fracturing should the board be slightly bent. The J-lead devices use less space and, unlike gull wing devices, can be installed in sockets.

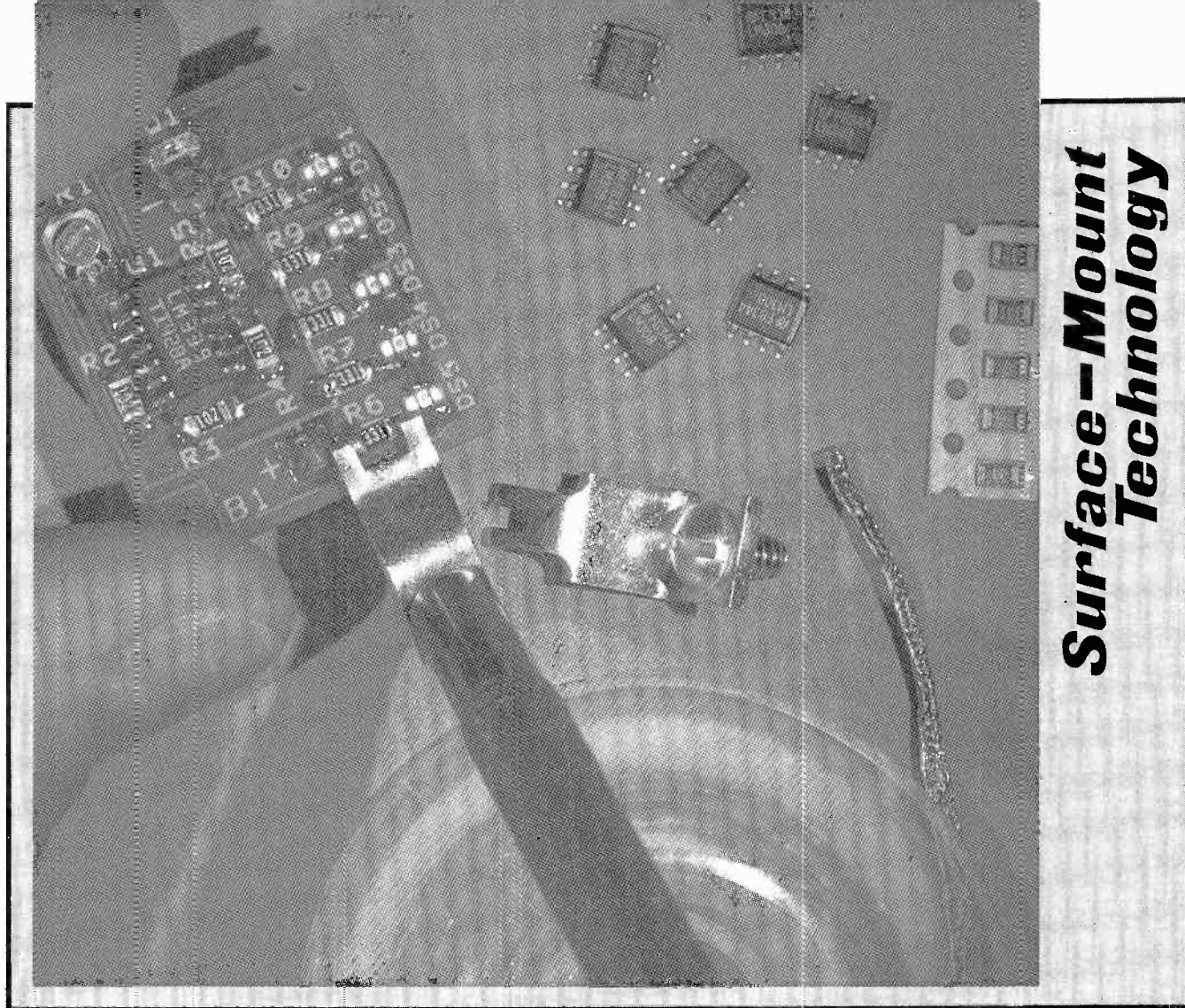
Chips that require more than 28 pins are generally installed in square Plastic Leaded Chip Carriers (PLCC's). The PLCC uses J-shaped leads and has up to 84 or more leads around its perimeter. Many new microprocessors and other large-scale IC's are offered in PLCC's.

Recently, there has been considerable interest in using tape- or wire-bonded chips in SMT circuits, particularly those in which the pin count is high. The wire-bonding process involves cementing a chip directly to a circuit board and making connections to the chip by means of gold wire in the same manner in which connections are made between chips and pins in packaged IC's. The bonded chip is then protected by a small blob of epoxy. The tape bonding process, also known as TAB (*Tape Automated Bonding*), is easier to implement because individual chips are supplied on a tape with completed electrical connections. The tape is actually a string of connected lead frames similar or identical to those used to make packaged IC's. Epoxy protects the delicate chips and connection leads from damage. TAB chips can be used in automated assembly.

Other Surface Mountable Components

In addition to the component families discussed above, there are many other surface-mountable devices. For example, many optoelectronic components are available, including phototransistors, optoisolators and many kinds of one- and two-chip infrared and visible LED's (see Fig. 13). Also available are ceramic filters, relays, switches and crystals (see Fig. 14).

Surface-Mount Technology



Hand-Soldering SMC's

FORREST M. MIMS, III

Once you master the techniques, soldering SMC's is easy, and fast.

THE EASIEST WAY TO HAND-SOLDER SMC'S TO A CIRCUIT board is to use soldering tools and materials, such as soldering tweezers and hot-air soldering/desoldering systems, which are designed specifically for that task. Unfortunately, specialized SMC soldering tools can be expensive and difficult to locate. However, it is safe to assume that such items will become more economical and widely available in coming years. In the meantime, SMC's can be installed using only the common tools shown in Fig. 1. Those tools include an ordinary soldering pencil and a soldering iron equipped with a slotted tips designed for SMC's.

There are two chief differences between hand-soldering conventional through-hole components and SMC's. First, SMC's are installed and soldered on the foil side of a circuit board. Second, the absence of wire leads and pins inserted through holes means that the SMC's must be secured in place during soldering.

In industry, small droplets of adhesive are used to secure SMC's in place for wave soldering. While wave soldering may be impractical for hobbyist applications, the same technique for securing SMC's in place is used when hand-soldering circuits. For reflow soldering, SMC's are held in place by

sticky dabs of solder paste or cream that are placed over each footprint before the SMC's are placed on the board. Reflow soldering can also be used by hobbyists.

Let's now examine some hand- and reflow-soldering techniques.

Conventional soldering

It's surprisingly easy to solder or "tack" SMC's in place using only a handheld iron and small-diameter wire solder. Solder 25 mils (0.025 inch) in diameter works best, but 30-mil solder, which is more readily available, can also be used. The only special requirement is that the SMC must be held in place until at least one terminal or pin is soldered.

It's possible to use various kinds of adhesives to cement an SMC in place for hand soldering. That, however, can unnecessarily complicate what is essentially a very simple procedure. The adhesive must not be allowed to flow over the SMC's footprints, must be non-corrosive, and must be allowed to set before the SMC's can be soldered. For those reasons, we have experimented with two simpler and faster methods.

One method is to secure one side or corner of an SMC in

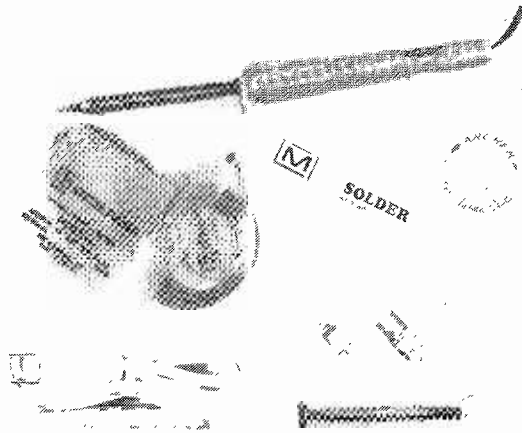


FIG. 1—SMC's CAN BE HAND SOLDERED using only the common tools and materials shown here.

place with masking tape as shown in Fig. 2. An exposed terminal or corner pin can then be soldered. The tape is then removed and the remaining terminals or pins can be soldered.

Another method is to place a tiny bead of reusable adhesive between the terminals on the bottom side of the SMC. Suitable reusable adhesives include *Plasti-Tak*, *Fun-Tak*, and *Stikki-Wax*. Those and similar adhesives are widely available at department stores.

Use a toothpick, a sharply pointed probe, or pointed tweezers to apply the adhesive. Then grasp the SMC with pointed tweezers, place it on its footprints, and press it in place. It is important that the SMC be pressed flat against the board. Too much adhesive will keep the SMC suspended slightly above the board and may even cause adhesive to creep between a terminal and its footprint.

After an SMC is attached to the board with tape, cement, or reusable adhesive, carefully touch the tip of a soldering pencil to the junction of a terminal and its footprint. After a

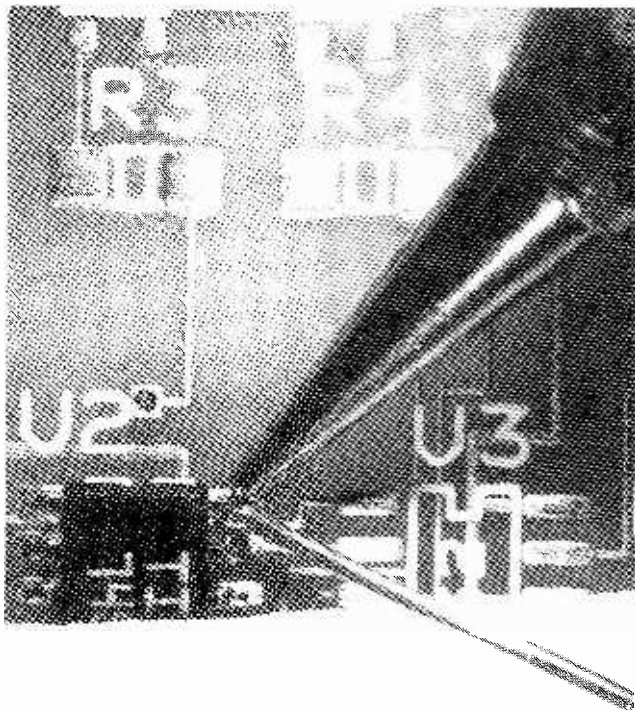


FIG. 2—ONE SIMPLE METHOD of securing an SMC in place is to tape down one side with masking tape.

second or so, lightly touch the end of a length of solder to the junction and immediately remove both the iron and the solder. A shiny solder fillet should neatly bond the terminal to the footprint.

Until you gain some hands-on SMC soldering experience, *always* inspect the completed junction with a magnifying lens before moving to the next terminal or SMC. If you use too much solder or form a solder bridge, use desoldering braid to carefully remove the excess solder. Place an unused section of desoldering braid over a footprint and press it in place with a soldering iron tip. Within a second or so, capillary action will wick the excess solder on the footprint into the braid. Remove the iron and braid and go on to the next footprint as needed. Be sure to use a fresh section of braid at each footprint. Clip off used sections of braid as necessary. If necessary, reapply a small amount of solder.

Reflow soldering

The most straightforward approach to mounting SMC's is reflow soldering. The SMC is held in place with tweezers while a soldering iron presses one end terminal or corner pin against a pretinned footprint. The tinned layer then melts and reflows around the terminal or pin and the footprint. Since no additional solder is used, the tinned layer must include enough solder to provide a good joint.

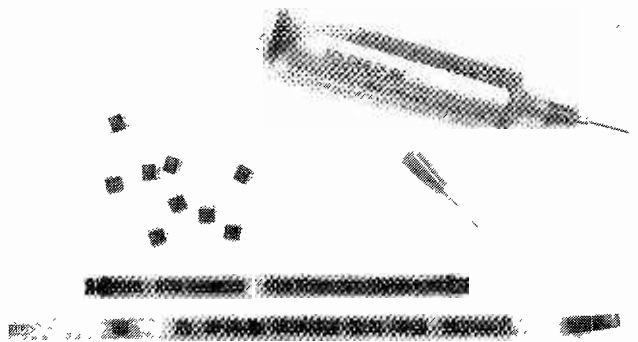
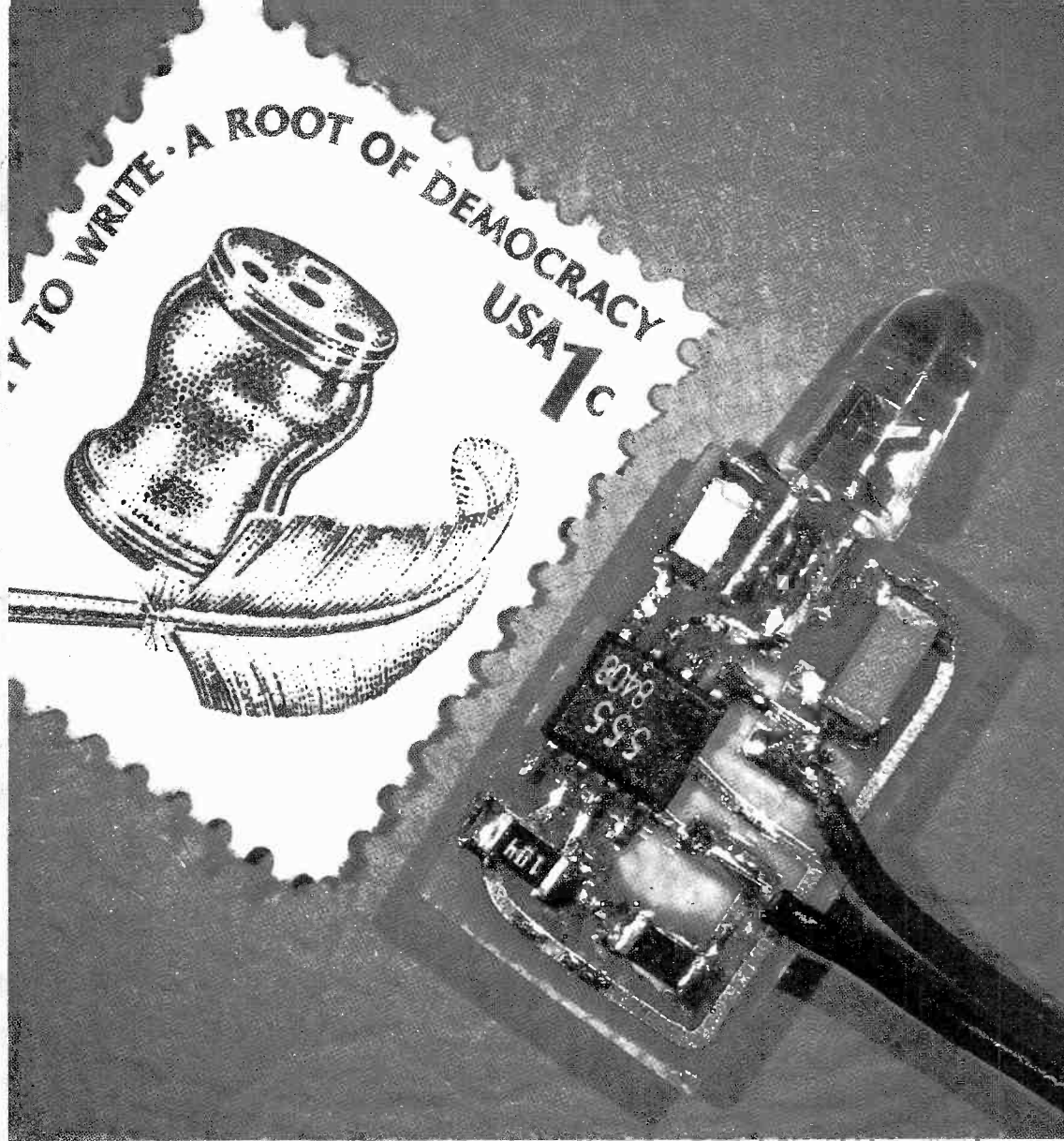


FIG. 3—SOLDER PASTE OR CREAM is available in a syringe. That makes dispensing the paste or cream convenient, once you get the hang of how it's done!

Reflow soldering works best with SMC soldering tools that simultaneously heat all the pins or terminals of the chip being soldered. When a standard soldering iron is used, only one pin or terminal at a time can be heated. That can lead to problems when working with chip SMC's. If the tinned layer is too thick, only the terminal being reflow soldered will be pushed through the molten solder against the footprint; the remaining terminal will remain atop the tinned layer over its footprint. Also, the SMC will be badly tilted when the second terminal is soldered. On the other hand, if the tinned layer is too thin, there will be insufficient solder to form the bond. Therefore, consider other soldering techniques when working with chip components.

Reflow soldering with solder paste or cream is particularly interesting since all the SMC's are soldered in place in a single operation without a soldering iron. Instead, the entire board is heated in a convection oven or on a hot plate. Unfortunately, solder pastes and creams are not always readily available, have a limited shelf life, and have instructions that must be strictly followed. Nevertheless, the method is so efficient that it warrants discussion here.

continued on page 87



**Surface-Mount
Technology**

SMT PROJECT: **LED FLASHER**

FORREST M. MIMS, III

Use surface-mountable components to build this subminiature LED flasher.

A GOOD WAY TO APPRECIATE THE MINIATURIZATION POTENTIAL of Surface-Mountable Components (SMC's) is to assemble the subminiature LED flasher described in this article. Besides teaching you the basics of how to assemble a simple circuit using SMC's, the flasher has many practical uses. It can, for example, function as a warning flasher, indicator, a tracking beacon for night-launched model rockets or in a number of other applications.

A flasher made with conventional through-hole components can be assembled on a circuit board of about the same size. But while the conventional circuit is more than 0.4-inch thick, the surface-mount version is less than 0.1-inch thin. That means that the surface-mountable circuit can be easily slipped inside a slim slot or a space that might never be used or be usable otherwise.

How it works

Figure 1 is the circuit for the flasher. In operation, the 555 is connected as an astable multivibrator whose frequency of oscillation is given by $1.44/(R1 + 2R2)C1$. With the values shown in Fig. 1, LED1 will flash once each second. The rate can be speeded up by reducing the value of R1 or C1. Resistor R3 is a current limiter.

For best results, the LED should be an AlGaAs super-bright unit. At night the flashes from such an LED can be clearly seen from more than several hundred feet away. Keep in mind that the light level from the LED is directly proportional to the supply voltage. Although Fig. 1 specifies a 9-volt supply, the circuit can be powered by from 3 to 12 volts. Figure 2 shows the relative power output of the LED over that range of supply voltages.

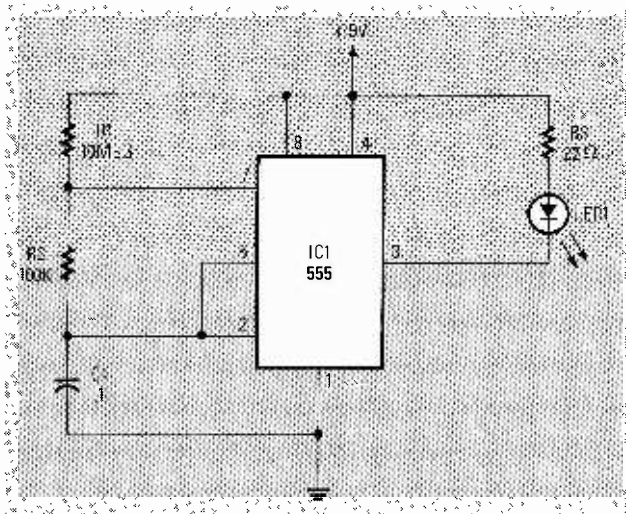


FIG. 1—WHEN THIS LED FLASHER is assembled using SMC's, the assembly is about 0.1-inch thick.

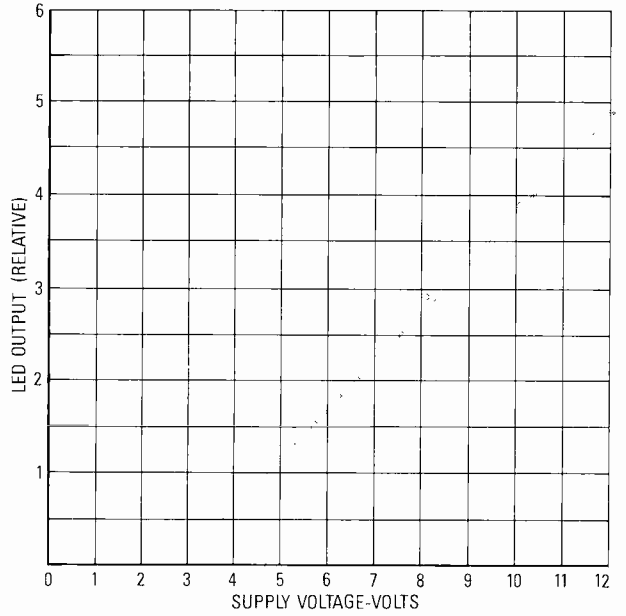


FIG. 2—RELATIVE OUTPUT of a super-bright LED is a function of its supply voltage.

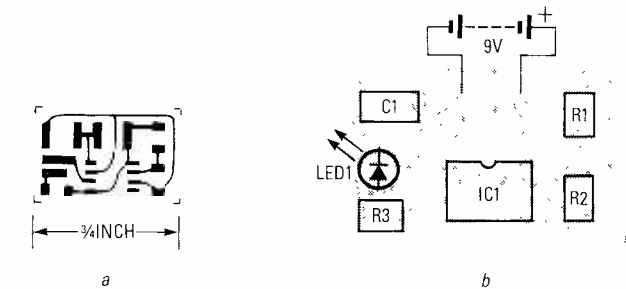


FIG. 3—USE THE PC PATTERN shown in a to etch the board. The parts layout is shown in b.

Preparing the board

The circuit should be assembled on a thin PC board. A pre-etched board and all necessary components are available from the source given in the Parts List. You can also make your own board using the pattern shown in Fig. 3-a. However or wherever you obtain your board, the component layout is shown in Fig. 3-b.

PARTS LIST

- R1—10 megohm's, chip resistor, 1206 size SMC
 - R2—100,000 ohm's, chip resistor, 1206 size SMC
 - R3—22 ohm's, chip resistor, 1206 size SMC
 - C1—0.1 μF, ceramic chip capacitor, 1206 size SMC
 - IC1—555 timer, SO-8 package
 - LED1—super-bright red LED, see text
 - Miscellaneous: PC board, 9-volt battery clip, 30-mil solder, reusable adhesive, etc.
- An etched circuit board, super-bright LED, and all SMC's are available for \$10.00, including postage and handling, from Gilbert Electronics, P.O. Box 95, Leesville, TX 78122. Texas residents please add appropriate sales tax.

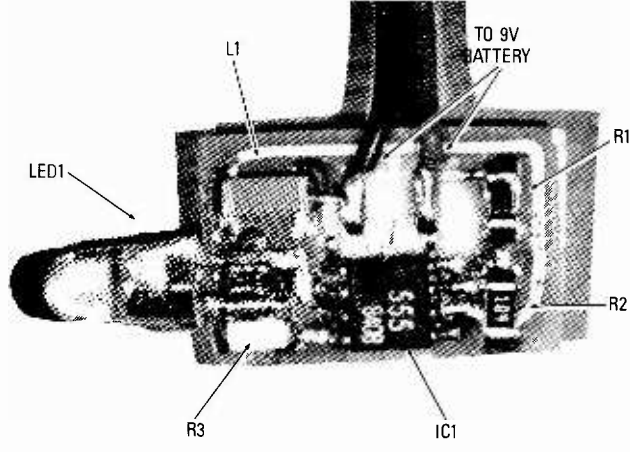


FIG. 4—THE COMPLETED CIRCUIT BOARD. The light from the super-bright LED can be seen for several hundred feet.

The circuit can be assembled in less time than an equivalent conventional circuit since no holes need be drilled in the circuit board. Although an experienced technician can install the components with a 30-watt soldering iron having a wedge tip, for best results use a 15-watt pencil iron having a pointed or conical tip.

Begin assembly by tinning the component footprints on the board. First, use an abrasive cleanser or steel wool to polish the copper traces. Wash and dry the board. Then use masking tape to attach a corner of the board to a flat, movable surface placed on your workbench.

Tinning the board takes just a few minutes. Just touch the soldering iron tip to a footprint for a second or so and then touch the end of a length of 30-mil rosin-core solder to the footprint. When the solder flows over the footprint, immediately remove the iron and solder and proceed to the next footprint. Be sure to rotate the board for best access to each footprint.

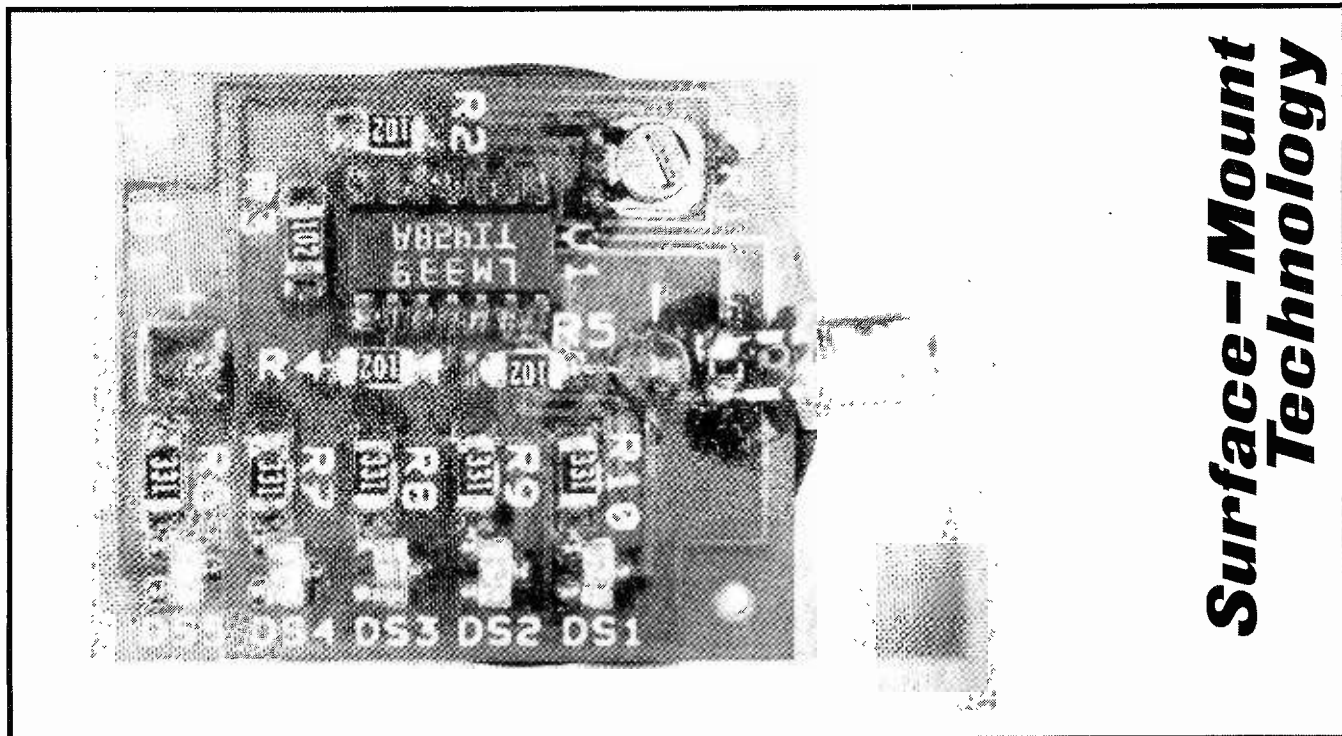
After the footprints on the board are tinned, remove any excess solder from the footprints with desoldering braid. That procedure will also remove any solder bridges.

After the board is tinned and the excess solder is removed, remove any solder balls or splashes from the traces and the substrate. Then use a defluxing agent to remove the flux residue from the board.

Installing the SMC's

Begin assembly of the LED flasher by first attaching the 555 to the board. Use the methods described in the article on SMC soldering, which can be found elsewhere in this section.

continued on page 88



SMT PROJECT: *LIGHT METER*

FORREST M. MIMS, III

*Here's a simple
"dark meter" that you can
build using SMC's.*

IN THIS ARTICLE WE WILL SHOW YOU A SIMPLE LIGHT METER with a built-in four-element LED bargraph readout that combines the advantages of analog and digital displays. Since the number of illuminated elements in the bargraph increases as the light reaching a phototransistor decreases, the circuit can be considered a "dark meter." A bonus feature of the circuit is that it can also be used as a four-step timer or as a simple resistance indicator.

The circuit shown in Fig. 1 can be assembled on a tiny circuit board having an area of only about 1.25 square inches, a size made possible by the use of surface-mountable components. Consequently, the circuit is much more compact than an equivalent circuit assembled from conventional through-hole components.

Though the circuit is configured as an inverse light meter or "dark meter," it can be revised so that the number of glowing elements increases with the light level. It can also be used as a timer or resistance indicator by omitting phototransistor Q1. Even if none of the applications for the circuit are of interest, you might want to assemble it anyway since it provides an excellent hands-on introduction to surface-mount technology.

How it works

There is nothing new about the design of the circuit in Fig. 1, which is often called a parallel or "flash" analog-to-digital converter. To understand how the circuit works, it's necessary to review the operation of the basic inverting comparator shown in Fig. 2. In that circuit, a reference voltage is applied to the non-inverting input of an operational amplifier operated without a

feedback resistor. That provides a two-state (off-on) output voltage instead of the linear output that characterizes an op-amp operated with a feedback resistor.

A voltage input is applied to the inverting input of the op-amp. When that input exceeds the reference voltage, the output of the op-amp is low; as far as the LED is concerned, the output is ground. Therefore, the LED switches on. Series resistor R1 limits current to the LED, thereby protecting both the LED and the output-driver stage of the op-amp. When the input voltage is below the reference voltage, the output from the op-amp swings to near the supply voltage (output high). The output LED, which no longer receives sufficient forward bias, then switches off.

The circuit is called a "comparator" since it compares the voltages at its two inputs and switches *on* when one exceeds the other. The circuit shown in Fig. 2 can be changed from an inverting comparator to a non-inverting comparator simply by switching the connections to the inputs. Then the output will swing from low to high when the input voltage exceeds the reference voltage.

Referring back to Fig. 1, IC1 is a quad comparator in a 14-pin SO package. Resistors R1 through R5 form a 4-stage voltage divider with taps connected to the non-inverting inputs of each comparator. The reference voltage delivered to each comparator is determined by the setting of trimmer R1.

Each comparator in Fig. 1 functions exactly like the model comparator in Fig. 2. Therefore, the outputs from the comparators will swing, in sequence, from high to low as the input voltage rises above the reference voltage applied to each comparator. The output LED's will then switch *on* in sequence as the voltage rises.

When the circuit is configured as a light meter, the inverting inputs of the comparators are connected in common to the

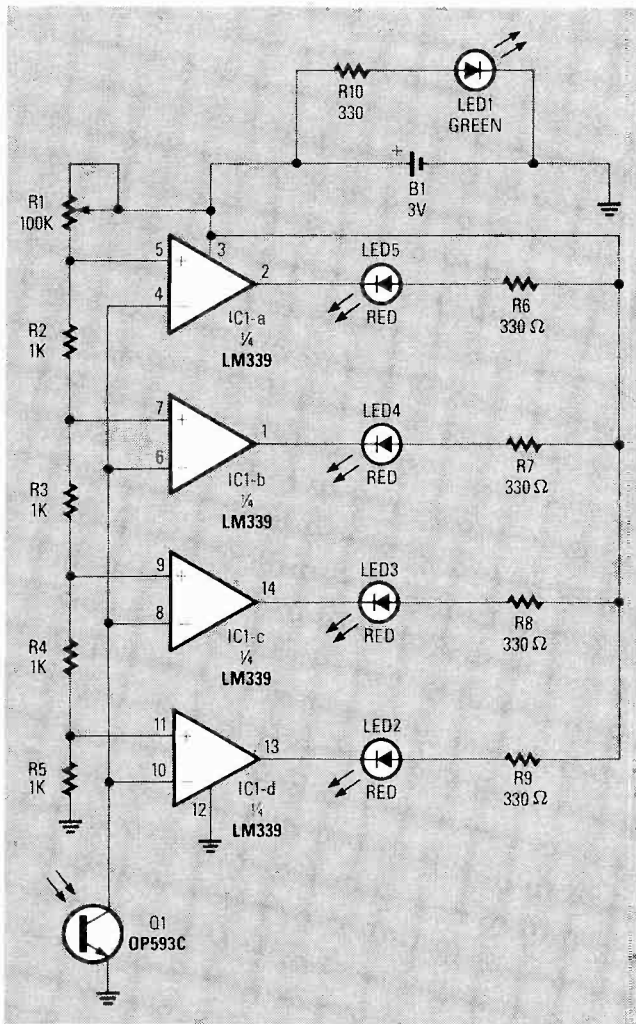


FIG. 1—USING SURFACE-MOUNT COMPONENTS this bargraph “dark meter” can be assembled on a circuit board with an area of just 1.25 inches.

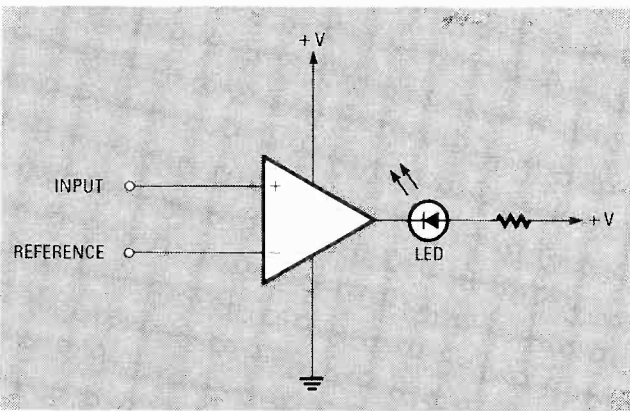


FIG. 2—IN AN INVERTING COMPARATOR, the output is low when the input voltage exceeds the reference voltage; the output is high when the input is lower than the reference voltage.

collector of phototransistor Q1. When Q1 is illuminated, its collector-emitter junction conducts, thereby placing all the inverting inputs within a few millivolts of ground. For most settings of R1, each of the four reference voltages exceeds that value. Therefore, when Q1 is illuminated, the output from each comparator is high and its respective indicator LED is off. As the light level at Q1 is gradually decreased, the voltage at the inverting inputs rises until it exceeds the first comparator's reference voltage (pin 10). The output from that comparator (pin 13) then

PARTS LIST

All resistors are 1206 size SMC's unless noted

R1—100,000 ohms, trimmer potentiometer, Micro-Ohm RV43B-CV or equivalent

R2–R5—1000 ohms

R6–R10—330 ohms

Semiconductors

IC1—LM339 quad comparator, SO-14 package

LED1—Green LED, SOT-23 package, ROHM SLM-13M or equivalent

LED2–LED5—Red LED, SOT-23 package, ROHM SLM-13V or equivalent

Q1—OP593C NPN phototransistor (TRW), or equivalent

Other components

B1—CR2320 or similar 3-volt lithium coin cell

Miscellaneous: Lithium coin cell holder (Keystone P/N 107), PC board, Reusable adhesive or masking tape, 25 or 30 mil solder

A complete kit including a drilled, etched, and plated PC board, Q1, all SMC's, battery holder and solder is available from the Heath Company, Benton Harbor, MI 49022 for \$19.95 plus postage and handling; for credit-card orders, call 800-253-0570. Michigan residents must add appropriate sales tax. Specify catalog number SMD-1.

swings from high to low and LED1 switches on. Additional LED's switch on in sequence as the light level continues to fall.

Incidentally, note that the common inverting inputs appear to be floating when Q1 is fully switched off (dark). Actually, a few tenths of a volt appear between those inputs when Q1 is dark. The inputs can be connected to the positive supply through a pull-up resistor, but leaving them “floating” makes the applications discussed at the end of this article possible.

Preparing the circuit board

Figure 3-a shows a suggested layout for the circuit board; the board itself is shown in Fig. 3-b. Also, an etched, silk-screened,

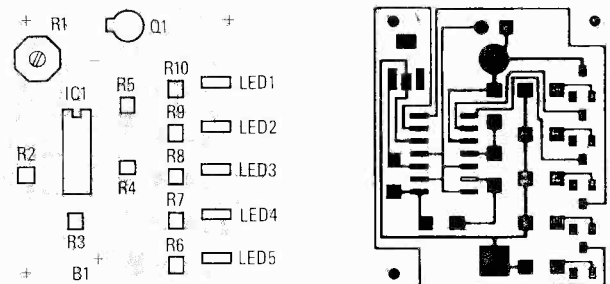


FIG. 3—USE THIS LAYOUT *a* when building the circuit. The PC board is shown in *b*.

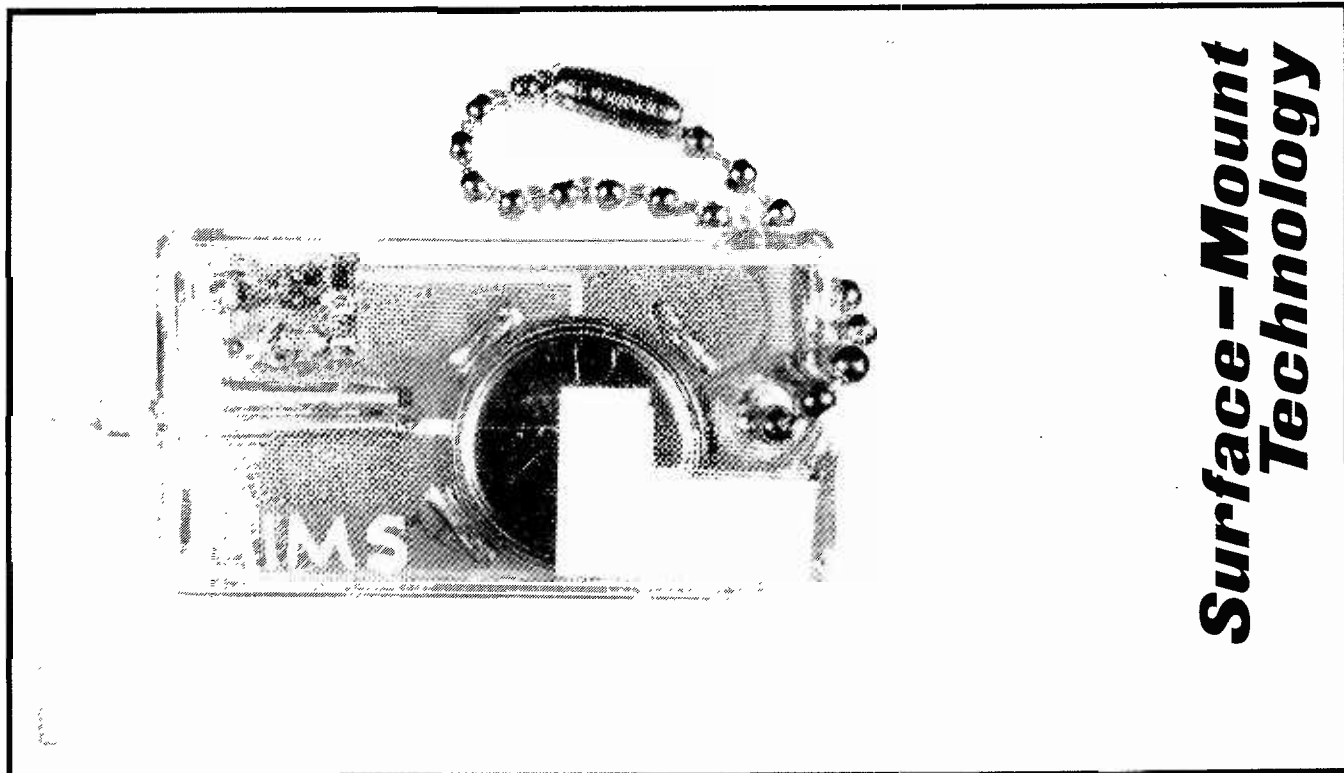
and pre-tinned board is available as part of a kit that includes all necessary components; see the Parts List for more information. Note that the board in the kit also includes a solder-mask coating that both simplifies soldering and greatly reduces solder-bridge problems. The board also includes drilled mounting holes for a Keystone 107, or equivalent, lithium coin-cell holder.

If you build your own board, follow the tinning procedure given in the LED-flasher project described elsewhere in this special section. Also review the SMC soldering procedures given elsewhere in this special section before soldering SMC's to the circuit board.

Begin construction by installing the LM339. Be sure to solder a corner pin first. If the device stays aligned over the remaining pads, then continue soldering.

Next, install the chip resistors one at a time. If you use the tape method to hold the chip resistors in place, you can solder one terminal of each resistor; then you solder the remaining terminals. You can use the same approach when installing the LED's. No matter which method you use, until you become an experi-

continued from page 106



SMT PROJECT: I-R REMOTE ON A KEYCHAIN

FORREST M. MIMS, III

Use surface-mount technology to build an infrared transmitter small enough to fit on your keychain.

ONE OF THE MAJOR CAPABILITIES OF SURFACE-MOUNT TECHNOLOGY is that experimenters and prototypers can assemble ultraminiature, fully functioning circuits only a few millimeters thin. For example, you can make an optoelectronic remote-control transmitter that is so small that it can be slipped inside a plastic identification-tag holder, yet it's powerful enough to activate a receiver located more than 10 feet away.

The transmitter, shown in Fig. 1, projects a pulse-modulated red or near-infrared beam. Although a 555 timer is often used as an LED driver in this kind of application, the simple two-transistor driver shown is a better choice because it can drive an LED with greater current. Moreover, it can be powered by a supply of less than one volt.

How it works

Referring to Fig. 1, assume that Q1 and Q2 are initially off when power switch S1 is closed. Capacitor C1 then begins charging through resistors R1 and R2, and LED1. Eventually the charge on C1 becomes high enough to switch Q1 on, which then switches Q2 on.

When Q2 is on, LED1 is connected directly across battery B1 through Q2's emitter-collector junction. Meanwhile, C1 discharges to ground through Q1's base-emitter junction. Eventually the charge on C1 falls below that necessary to keep Q1 on. Transistor Q1 then switches off and, in turn, switches

Q2 off. The LED is then switched off. The charge/discharge cycle is then repeated at a frequency that is determined by C1's value. The circuit drives the LED with 725 pulses per second using the values given in the Parts List.

Preparing the circuit board

An ultra-thin circuit board is required if the project is to fit inside the thin label space of a plastic ID-tag holder. A

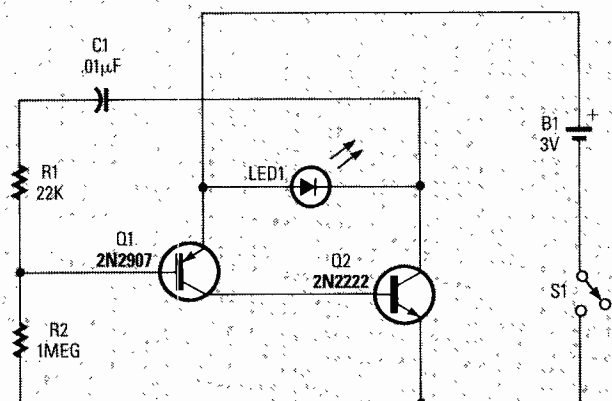


Fig. 1—THE KEY-CHAIN TRANSMITTER uses two transistors to generate a red or near-infrared beam that pulsates at approximately 725 Hz.

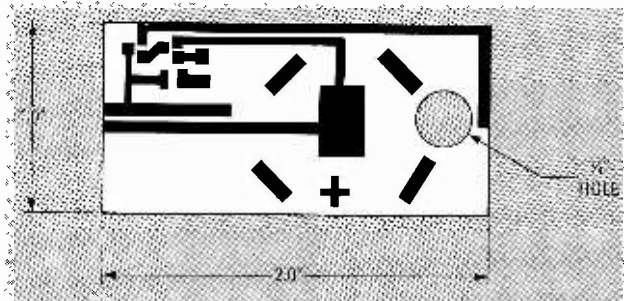


FIG. 2—USE THIS TEMPLATE as a general guide when making the printed-circuit board.

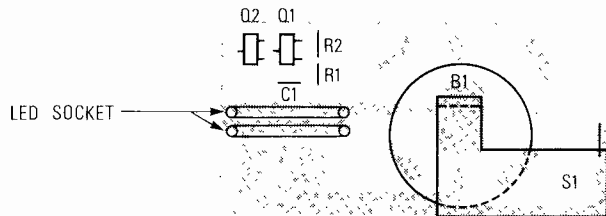


Fig. 3—THE COMPONENT LAYOUT is somewhat unusual because the LED's socket is made from thin tubing, while the battery is secured by four bumps of solder.

double-sided copper-clad board only 7-mils thick that is ideal for the project is available from the Edmund Scientific Co. (101 E. Gloucester Pike, Barrington, NJ 08007). A 12 × 18 inch sheet of the board, catalog number E35,652, sells for only \$2.50.

Although the transmitter is assembled on only one side of the board, keep in mind that SMC's can be mounted on both sides of a double-sided circuit board. The foil pattern for the board is shown in Fig. 2; use it as a general guide and apply the resist by hand using a small brush, which is a somewhat faster way to make a small board compared to using the photo-resist technique.

Hand-made board

Use a pair of scissors to cut the board to size, then polish the foil with fine steel wool. Use a 1/4-inch hole punch to create the hole for the keychain, then place the various components including B1, a 2016 lithium coin cell, on the board in the approximate locations shown in Fig. 3. Mark their terminal or pin locations on the board with a pencil. Then remove the parts and pencil in the required terminal footprints and interconnection traces. Be sure to include four marks around the perimeter of the lithium cell. Later, solder bumps will be placed on the marks to keep the coin cell in its proper place.

Finally, use a sharp-pointed resist pen to trace over the penciled traces and footprints. Use a straightedge for best results and be careful to avoid smearing the ink.

After the resist dries, cover the back side of the board with a protective layer of tape. Then immerse the board in an etchant solution. Etching time can be speeded up by agitating the solution. After the board is etched, thoroughly rinse the board under running water.

Unless you plan to attach the SMC's to their footprints with conductive adhesive, the footprints of the etched board should be plated with a thin layer of solder or tin. A dip-and-dunk tin-plating solution is available from The DATAK Corporation (Guttenberg, NJ 07093). Alternatively, you can melt a thin layer of standard rosin-core solder over each footprint. For best results, the solder layer should be thin and flat.

PARTS LIST—TRANSMITTER

- R1—22,000 ohms, SMT size 1206
- R2—1 Megohm, SMT size 1206
- C1—0.1 μF, SMT size 1206
- Q1—2N2907, PNP transistor, SOT-23 package
- Q2—2N2222, NPN transistor, SOT-23 package
- LED1—Light-emitting diode, near-infrared or super-bright red
- B1—3-volt lithium coin cell, type 2016
- Miscellaneous: circuit-board material, plastic keychain ID-tag holder, solder, masking tape, wire, etc.

Therefore, after all the footprints are coated, use desoldering braid to remove excess solder and solder bridges.

Installing the SMC's

The SMC's can be attached to the board with either conductive adhesive or solder. Both methods are described in detail elsewhere in this special section. If you use solder, the method of temporarily securing the SMC's in place with tape works best. Attach the SMC being soldered to the board with a bit of masking tape across one of its ends and solder the exposed terminal or pins with a small amount of solder. If necessary, make sure the SMC is flat against the board by pressing it down with a pencil eraser while the solder is still molten. Then remove the tape and solder the remaining terminal or pins.

After the SMC's are soldered in place, prepare a socket for the LED by cutting two 0.5- to 0.65-inch lengths of 62.5 mil (1/16 inch) O.D. brass tubing purchased from a hobby shop. Prepare the tubes for soldering by burnishing them with steel wool or fine sandpaper. Insert the wire from a bent paper clip in one end of one tube and melt a line of solder along its entire length. Repeat the procedure for the second tube. Then use the paper clip to hold one of the tubes in place over its footprint and remelt the solder on both the tube and the footprint until the tube is bonded in place. If necessary, apply some additional solder to the side of the tube away from the second tube's location. Repeat the procedure for the second tube. Be sure to keep solder from entering the open ends of

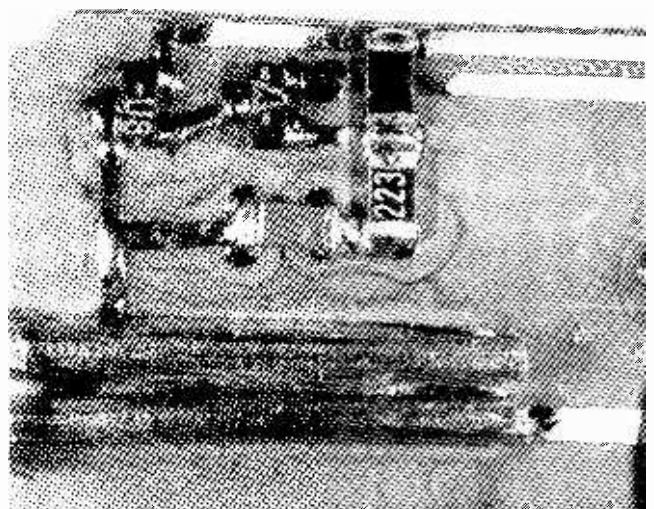


Fig. 4—THIS CLOSE-UP SHOWS how really small the components are. The transistor, labeled U8, is actually smaller than the resistor and capacitor chips. The two "giant" horizontal tubes near the bottom are the LED socket.

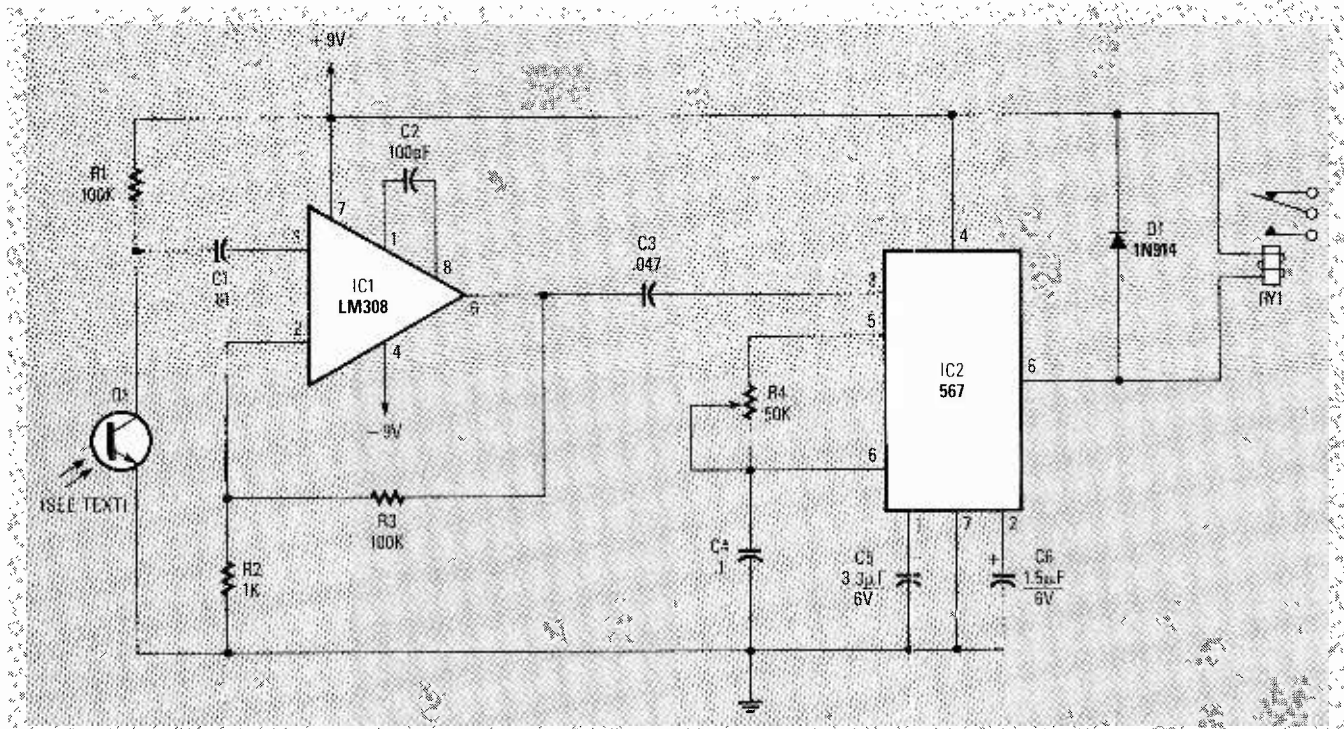


Fig. 5—IF YOU NEED A RED-LIGHT RECEIVER, try building this circuit. Most of what's needed is probably lying somewhere around your shop. Relay RY1 can be any low-current relay rated from 5 to 9-volts DC; such relays are called "sensitive relays."

the tube, especially the end closest to the edge of the circuit board. Fig. 4 shows the tubes, and the Q1/Q2 circuit soldered to the board.

Switch S1 is a *squeeze switch* made from an L-shaped piece of circuit board, as shown in Fig. 3. The exact shape of the switch is unimportant so long as it fits the allowed space. Solder a short length of wire-wrap wire to the lower side of the base of the L. With the exception of a narrow strip of exposed copper along the end of the lower side of the L (the dashed line in Fig. 3), cover both sides of the L with a clear tape. Solder the exposed end of the wrapping wire to the adjacent positive circuit-board foil. Then attach the copper L to the board with a hinge made from a strip of clear tape.

Testing the circuit

Test the circuit before installing it in an ID-tag holder. First, insert the leads of a red AlGaAs super-bright LED into the LED socket (be sure to observe polarity). Then place B1 on the board (positive side down) and press the squeeze switch. The LED should glow. When the LED is pointed toward a phototransistor or solar cell connected to the input of an audio amplifier, a 725-Hz tone should be heard from the amplifier's speaker.

If the circuit is working properly, remove the LED and slip the circuit inside the ID-tag holder. You might want to first place a self-adhesive label on the back side of the board. You can leave the label blank or record the circuit's operating parameters on it. At least two kinds of plastic keychain ID-tag holders are available from office supply companies. The one used for this project, which has a retail cost of approximately 70 cents, has a 2-mm high slot at one end, opposite the hole for the keychain.

After the circuit is inside the holder, insert the LED into its holder through the 2-mm slot. The slot also simplifies removal of the circuit board: Simply push the board out with a

small screwdriver or a flat implement passed through the slot. Adjusting the squeeze switch can be tricky. If the LED stays on when the board is slipped inside the tag holder, bend the exposed copper end of the L slightly upward. If excessive pressure is required to close the switch, expose additional copper by removing a narrow strip of the tape with a knife.

Suitable remote-control receivers

The keychain transmitter can be used to trigger various kinds of optoelectronic receivers. The circuit for a suitable receiver is shown in Fig. 5. The circuit uses a 567 tone decoder to help prevent triggering by any unauthorized transmitters.

In operation, pulsed infrared or visible light is received by Q1 and transformed into a pulsed voltage. Any NPN phototransistor can be used for Q1. The signal from Q1 is amplified 1,000 times by IC1, an LM308 high-input impedance operational amplifier, and is passed to IC2, a 567 tone decoder. Resistor R4 and capacitor C4 determine IC3's center frequency. Resistor R4 is a potentiometer rather than a fixed resistor to permit the receiver to be tuned. IC3's output drives RY1, a low-current relay.

The receiver can be assembled on a printed-circuit board using either conventional or surface-mountable components. Both IC1 and IC2 are available in small outline packages.

Test the receiver by pointing the transmitter at Q1 while carefully adjusting the receiver's R4. With R4's wiper set near its midpoint, the relay should pull in when Q1 is receiving the transmitter's signal. For best results, bright ambient light must not be allowed to strike Q1; otherwise, Q1 may become saturated and fail to respond fully, or at all, to incoming pulses from the transmitter. If ambient light proves to be a problem, place one or two pieces of developed color film in front of Q1 to serve as a near-infrared filter, and insert a near-infrared LED into the transmitter.

LED FLASHER

continued from page 100

tion. Refer to the component placement diagram in Fig. 3 to make sure the 555 is oriented properly. Then solder each terminal in place.

Continue assembly by installing the resistors and C1 one at a time and soldering them in place as we've described. The value of the resistors is given by a code in which the last digit indicates the number of zeros. Thus the code 104 indicates a resistance of 10 followed by 4 zeros or 100,000 ohms.

Install the LED next. For the utmost in miniaturization, you can use a chip LED. For high-brightness applications, use a leaded device. Cut the leads 0.2 inch from the LED, place them over their respective footprints (be sure to observe polarity), and secure the LED in place with tape. Then solder

the leads in place. Repeat that procedure for the leads from a 9-volt battery clip. Figure 4 shows the completed board.

Testing the Circuit

Carefully inspect the completed circuit to make sure that all the components are properly positioned. Pay particular attention to the orientation of the 555 and the polarity of the LED and battery clip leads. And be sure to remove any solder bridges and balls.

The LED should begin to flash as soon as a 9-volt battery is connected to the circuit. Operation of the circuit will be identical to that of a flasher made with through-hole components. The thinness of the SMC flasher, however, means that it can be installed in previously unusable locations. And the relative ease and speed with which it can be assembled should convince even the most skeptical builder that surface-mount technology is an idea whose time has come. **R-E**

LIGHT METER

continued from page 102

each hand-solderer of SMC's, it is essential to carefully inspect each and every junction with a magnifying lens.

Next, solder trimmer R1 to the board. Since cementing R1 to the board might interfere with its rotor if you are not careful, it's best to use a bit of masking tape to secure R1 in place for soldering.

If you want to use the circuit as a light meter, solder Q1 in place next. However, if you want to use the circuit for one of the specialized applications that we'll describe later on in this article, you should omit Q1 and, instead, solder a pair of stranded, insulated hookup wires to its two mounting holes.

Note that Q1 is a conventional through-hole component. The prototype used a tiny surface-mount phototransistor (Stettner Electronics CR10TE1). However, that meant that the phototransistor was aligned in the same direction as the readout. The result was that someone viewing the readout could cast a shadow over Q1, affecting accuracy.

To overcome that, the surface-mountable version of Q1 was replaced with a leaded phototransistor that can be installed facing away from the person viewing the readout.

The leads of the phototransistor are installed in two holes drilled in the circuit board adjacent to the negative battery holder terminal. The emitter of Q1, which is indicated by a small protruding tab (see Fig. 4-a), must be installed in the hole connected to the negative battery-holder terminal. Therefore, bend Q1's leads as shown in Fig. 4-b and insert both leads through the bottom side of the circuit board so that Q1 points away from the circuit board as shown in Fig. 4-c. When the

circuit is complete, Q1's leads will emerge from the board under the battery-holder. Therefore, be sure to keep those leads close to the board. Solder Q1's leads to their footprints and clip off the excess lead lengths.

Complete assembly of the board by installing the lithium coin-cell holder on the underside of the board. Be sure to orient the holder so that its positive terminal (the uppermost battery contact) is inserted in the hole marked +. Solder the terminals in place and clip off the protruding pins. Use caution; the clipped terminals may fly away from your clippers with considerable force.

Testing the circuit

If you have installed Q1, the circuit will function as a light meter when lithium cell B1 is installed in its holder. LED1 will glow to indicate the power is on. Use a jeweler's screwdriver to adjust trimmer R1 for the desired sensitivity. For best results, perform the adjustment with the circuit in subdued light. Generally, LED2-LED5 will switch off when Q1 is brightly illuminated. Those LED's will then glow in sequence as the light reaching Q1 is progressively reduced.

You can switch the circuit off by removing B1. Or, you can slip a small piece of paper or thin plastic under, or a short length of heat-shrinkable tubing over, the uppermost battery-holder electrode.

Going further

As noted previously, when Q1 is omitted the circuit can be used for other applications. For example, when a discharged capacitor is connected in the circuit in place of Q1, LED2-LED5 will glow in sequence as the capacitor is charged by the small voltage appearing at the common non-inverting inputs. One application for that configuration is as a timer whose period is determined both by the size of the capacitor and the setting of resistor R1.

The timing intervals can be increased by increasing the value of the capacitor. A new timing cycle can be started at any time by momentarily shorting the capacitor.

Another interesting application is to use the circuit to indicate resistance. When the input leads are open, all the LED's will glow. If a variable resistance is connected to the circuit in place of Q1, LED2-LED5 will glow in sequence as the resistance is lowered. We're sure that you have often wished for a visual continuity checker.

Finally, keep in mind that the circuit as presented here functions as a parallel array of inverting comparators. It can be revised to function as a parallel array of non-inverting comparators simply by reversing the connections to the inputs of the four comparators. **R-E**

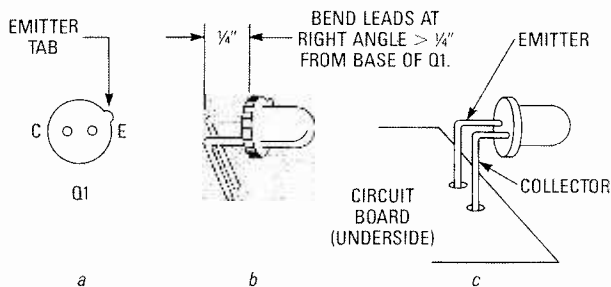


FIG. 4—THE PHOTOTRANSISTOR'S EMITTER is indicated by the tab (a). When installing the device, bend the leads (b) and mount it so that it is pointing away from the circuit board (c).

*Who needs copper foil
and solder when you can
use these conductive
inks and adhesives?*

Conductive Inks and Adhesives

FORREST M. MIMS, III

FOR MANY YEARS, THE HYBRID MICROELECTRONICS INDUSTRY has used electrically-conductive inks and adhesives to interconnect components, and to bond them both mechanically and electrically to a substrate. Those same inks and adhesives can also be used with all sorts of surface-mountable components.

While conductive inks and adhesives are usually used with standard circuit boards or ceramic substrates, they also make possible some very unusual and even novel circuit-assembly methods. For example, they permit surface-mountable components and even complete circuits to be installed on paper, plastic, glass, wood, painted surfaces, and many other substrates. Do-it-yourself examples of such circuits are presented elsewhere in this special section.

Figure 1 shows an assortment of conductive inks and adhesives. Whether or not you decide to experiment with conductive inks and adhesives now, chances are you will encounter those versatile counterparts of copper foil and solder sometime in the future. Therefore, let's take a close look at both conductive inks and adhesives.

Conductive inks

Electrically conductive liquids and pastes that can be applied to a substrate to form a network of interconnections are collectively known as *conductive inks*. Those materials are usually much more viscous than drawing ink, and often

resemble paints. Indeed, conductive paints and coatings are available that will add RF shielding to enclosures.

Conductive inks are often used to repair broken traces and to form new traces on etched circuit boards. For decades, however, their chief application has been to form conductive traces on hybrid microelectronics substrates. Generally, a conductive-ink pattern is screen or stencil printed on a ceramic substrate that is then fired in an oven. The result is a very tough and permanent conductive network. Additional conductive layers can be added if previously-applied conductive layers are first coated with a dielectric paste.

Figure 2 shows a very simple hybrid microcircuit, a micro-switch Hall-effect sensor assembled on a thin ceramic substrate. The Hall sensor is installed behind the oval protrusion. The three shaded rectangles are thick-film resistors that have been screened onto the substrate. Upon close examination, two of them show the thin slice marks that result from laser trimming, a method used for tuning a low-tolerance thick-film resistor to a precise value. The Hall sensor, the resistors, and the three terminals are interconnected by a solderable conductive ink that has been screened onto the substrate and then fired.

The conductive property of an ink is provided by powdered gold, silver, and other metals. Gold, while expensive, provides very low resistance and long-term stability. Silver is cheaper than gold but has several times its resistance. Further-



FIG. 1—CONDUCTIVE INKS AND ADHESIVES are available from a variety of manufacturers.

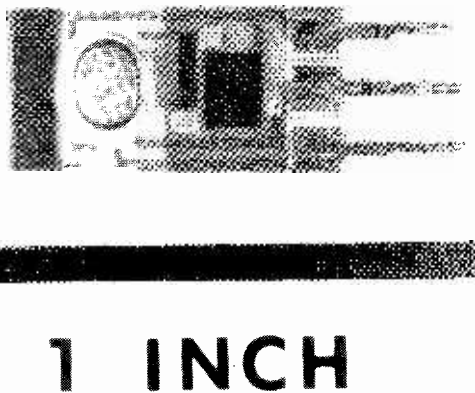


FIG. 2—THIS MINIATURE THICK-FILM hybrid microcircuit uses conductive ink for its interconnections.

more, silver may migrate from the fired ink over time. Alloys of platinum and gold or silver are used when it is necessary to solder to the fired ink. Copper and nickel are used as inexpensive substitutes for gold and silver. Both, however, have higher resistance and other less-desirable characteristics.

The resistance of conductive inks is often specified in terms of sheet resistivity. Sheet resistivity, which is given in terms of ohms-per-square centimeter, is the electrical resistance across opposite sides of a square pattern of conductive material. Resistance of conductive inks can also be given in terms of a line of material having specified dimensions. The resistances of several common inks used in the hybrid-microelectronics industry are shown in Table 1.

Ink properties

The ideal conductive ink would be an inexpensive material having zero sheet resistivity, a short curing time, and an

TABLE 1

Conductor Composition	Sheet Resistivity (ohms/square cm)	Line Resistance (1" × 0.02")
Gold	0.003	0.15 ohm
Silver	0.020	1.00 ohm
Palladium Silver	0.035	1.75 ohms
Platinum Gold	0.100	5.00 ohms

Source: "Designers Handbook on Thick Film Microcircuits," Paine Instruments, Inc.

unlimited shelf life. It would be non-corrosive, simple to apply, odorless, non-flammable, and non-toxic. It would be available in bulk for screen printing, and in a handheld pen for the instant preparation of SMC-prototype circuit boards and for the repair of conventional boards.

Though many different kinds of conductive inks are available, none possess all of the properties of the ideal material we've outlined. Inks blended with powdered gold or silver provide the lowest resistance, but they are expensive. Copper and nickel-filled inks are inexpensive, but their higher resistance can affect the operation of a circuit if not properly compensated for.

Another drawback to conductive inks is that shelf life is relatively short, usually ranging from six months to a year. Still another disadvantage is that some materials require special handling since they may be hazardous to health. And while some conductive inks will dry fairly rapidly in open air, others require that you select either heat or a considerably longer drying time.

Applying inks

In an industrial setting, conductive inks are usually applied by screening or stenciling. Those methods require considerable preparation time and often are impractical when only a few boards are needed.

Fortunately there are several ways to apply conductive inks by hand to make relatively simple circuit boards. It's even possible to make multiple-layer boards by interspersing conductive layers with a layer of insulating material.

Before going on, a few caveats are in order. The best conductive inks can be very expensive. Also, the physical properties of various inks, both when liquid and after hardening, can be very different. The metal particles in a conductive ink generally do not remain in suspension. Instead, they sink to the bottom of their container under a layer of syrupy carrier fluid. Therefore, for lowest resistance it is essential that the particles be thoroughly mixed with the carrier before the ink is applied. Shaking alone may not be adequate; stirring may be required. Finally, the carriers of most conductive inks are volatile and may be flammable, hazardous to health, or both. Therefore, it is essential to use conductive inks in a well ventilated area and to follow the safety instructions provided with a specific product.

The ideal way to apply conductive ink by hand would be with a drawing pen. However, the author has been unable to find a pen intended for that application. It is possible to load conventional drawing pens with conductive ink. But, the viscous nature of most conductive inks means that they must first be thinned with a suitable solvent or carrier. The drawback to that procedure, aside from it being rather messy, is that thinning increases the resistance of the ink. Furthermore,

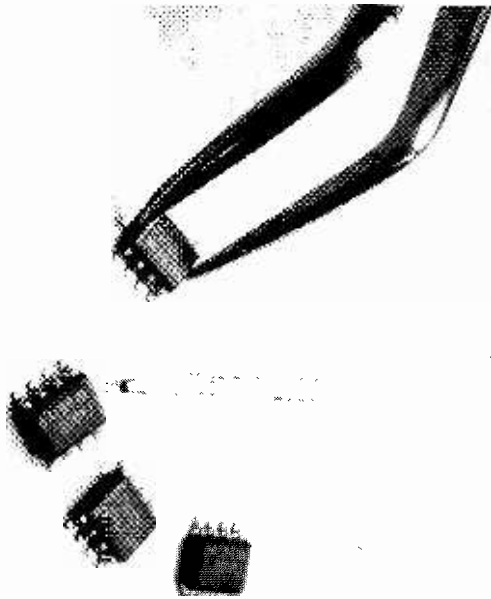


FIG. 3—USING THE TRANSFER METHOD to apply conductive adhesive to the pins of an SO device.



FIG. 4—THESE TWO CONDUCTIVE INKS are low priced, readily available, and suitable for hand application.

considerable experimentation may be needed to arrive at the best combination of pen-orifice size, ink, and thinner.

A simpler method is to apply the ink dot-matrix style; that is, a droplet at a time, by means of a small wire dipped into the material. Generally, dipping the wire into the ink will pick up enough fluid for several dots. The dots should be placed close together so they form a continuous line. That is best done by a quickly tapping the end of the wire against the substrate while moving it in the desired direction. With practice, you can form closely-spaced component footprints and both curved and straight lines. While that low-tech method is both slow and tedious, it works quite well with simple circuits. In fact, a complete interconnection pattern for a circuit consisting of an IC and half a dozen outboard components can be produced in 10 minutes or so.

Another method is to use a hand-held automatic dispensing syringe to form lines consisting of precisely metered dots of material. The necessary equipment, however, is expensive. A conventional syringe with a hand-depressed plunger can be used but only after some experience has been gained to avoid dispensing too much material.

It's best to experiment before selecting a method for hand applying a conductive ink. Then, before beginning work, plan each step carefully. For best results, use a pencil to draw the outline of the circuit on the substrate. If you use a transparent substrate such as Mylar, you can draw the circuit outline on a sheet of white paper that is then placed under the substrate, allowing you to trace several circuits from a single pattern.

Using inks as adhesives

The composition of some conductive inks and adhesives is very similar. And there are some inks that can provide a relatively strong bond to an SMC terminal or pin. Therefore, it follows that some conductive inks can double as conductive adhesives.

The surface-mount circuit builder can exploit the adhesive property of some conductive inks to speed up the assembly of simple prototypes. For example, the author has assembled a number of miniature circuits using only a lacquer-based conductive ink. First, the footprints for a component are formed with the material. The SMC is then placed on the footprint. Additional component footprints are made and their SMC's are positioned in place. Interconnections between the footprints are made as the circuit is assembled. Any remaining interconnections are formed after all the SMC's are in place. Though the lacquer-based ink hasn't the strength of a conductive adhesive, circuits assembled in that fashion have survived being dropped on the floor from a distance of as much as a few feet.

Conductive adhesives

Heretofore, the principle application of adhesives in surface-mounting technology has been to use non-conductive materials to bond SMC's to a circuit board in preparation for wave soldering. Although considerable literature and many application notes on the use of non-conductive adhesives for that purpose have been published, comparatively few publications about surface-mount technology even discuss conductive adhesives. That is surprising, particularly since conductive adhesives provide a fast and reliable method of attaching SMC's to a circuit board without using solder. Moreover, conductive adhesives are well suited for use with heat-sensitive components, and they can be used to make quick circuit repairs and modifications when soldering equipment is either unavailable or impractical.

The ideal conductive adhesive would be an inexpensive, single-part material having zero electrical resistance, a short curing time, and an infinite shelf life. It would be non-corrosive, simple to apply, provide a strong bond, and be easily reworked. Finally, it would be odorless, non-flammable, and non-toxic.

While the perfect conductive adhesive has yet to be formulated, a surprising number of products possess many of those properties. Adhesives blended with powdered gold or silver provide the lowest resistance, but they are expensive. Copper and nickel-filled adhesives provide reasonably low resistance for less cost.

Some conductive adhesives have novel properties. For

instance, some can actually be soldered-to using conventional tin-lead solder. And some conductive adhesives are thermoplastics that can be reworked merely by reheating the existing adhesive. In other words, a connection can be heated until the adhesive softens enough for the SMC to be removed. A replacement SMC can then be bonded in place with fresh adhesive or, with some materials, by heating the joint once again.

Unfortunately, the typical shelf-life of conductive adhesives ranges from two months to a year, with six months being fairly typical. Another drawback is that some materials require special handling since they may be hazardous to health. While those drawbacks are certainly undesirable, they are not unique to conductive adhesives. Indeed, most adhesives, conductive or otherwise, have limited shelf lives and some require special handling.

Conductive-adhesive types

Regardless of their conductive filler, conductive adhesives can be divided into several major classes. The two most important are:

- **Thermosetting adhesives.**—Those adhesives have proven their reliability during many years of use in the electronics industry. Thermosetting adhesives provide a very strong, inflexible bond. They are cured by means of a chemical reaction that is initiated by a chemical catalyst, heat, or ultraviolet radiation. The resulting bond is permanent, and cannot be reworked unless the adhesive is first shattered or dissolved with a solvent. Examples of thermosetting adhesives include 1- and 2-part epoxies, acrylics, and also, the polyesters.

- **Thermoplastic adhesives.**—Those adhesives do not undergo a chemical change when a bond is formed. Therefore, they can be reworked simply by applying heat until the material softens enough to remove the bonded component. A second application of heat permits a replacement component to be attached. Though thermoplastic adhesives provide a weaker bond than thermosetting adhesives, the fact they can be reworked makes them well-suited for many applications in which they will be subjected to only mild mechanical stresses. Examples of thermoplastic adhesives include nylon, polyimide siloxane, and various proprietary materials. Very flexible thermoplastic adhesives can be formulated by mixing synthetic or natural polymers (e.g. neoprene or rubber) in a solvent or other suitable carrier.

Applying conductive adhesives

In an industrial setting, dots of conductive adhesive are applied to each SMC footprint by screening, an array of pins, or an automatic syringe dispenser. The SMC's are then placed over the footprints and the adhesive or ink is allowed to cure or dry.

There are several ways to apply conductive adhesives by hand. A hand-held automatic dispensing syringe will place a precisely metered quantity of material over each footprint. The necessary equipment, however, is expensive. Fortunately, there are some very simple alternatives.

The simplest method is to dip a toothpick or wire into the adhesive to pick up a small droplet of material. The droplet is then touched to the desired footprint. If the material is slow drying, the conductive material can be applied to all the footprints before the SMC's are installed. If the material is fast drying, only the material required for an individual SMC should be applied.

It's possible to apply conductive adhesive to the footprints using a syringe or similar applicator. However, that application method requires some experience to avoid applying too much material. A toothpick or wire applicator gives the same-sized droplet each time.

An alternate way to hand-apply conductive adhesive is the transfer method. In that method, the adhesive is applied to the terminals or pins of an SMC instead of to its footprints on the circuit board. An advantage of the transfer method is speed, since all the terminals or pins on one side of an SMC can be coated with material in a single operation. To use that method, first place a few drops of material on a flat surface such as a glass microscope slide or paper card taped securely to a work surface. Then grasp the SMC with tweezers and simply dip each terminal or pin into the material as shown in Fig. 3. With practice, all the pins on one side of a small outline IC can be dipped at once. The SMC is then placed over its footprints on the circuit board.

No matter which application method you use, always remember that conductive adhesives, like many other adhesives, may be flammable or hazardous to health. Therefore, always work in a well-ventilated area and be sure to follow the safety precautions provided with the product.

Conductive-ink and -adhesive manufacturers

An acrylic-based, silver-filled ink that is easy to mix and to apply by hand is made by the Hysol Division of the Dexter Corporation. The product number is *140-18-Q*. That material adheres well to paper, cardboard, wood, phenolic, polystyrene, vinyl and butyrate.

Another silver-filled ink that is easy to mix and to apply is Amicon's *C-225-3*. That ink adheres well to paper, polyester film, phenolic, and ceramic.

Dynaloy, Inc. sells an evaluation kit containing four 50-gram bottles of either epoxy-base or polyester-base silver-filled conductive ink. Each 200-gram kit costs \$100. Those inks are more viscous than the preceding ones and must be stirred to mix the silver particles and the carrier.

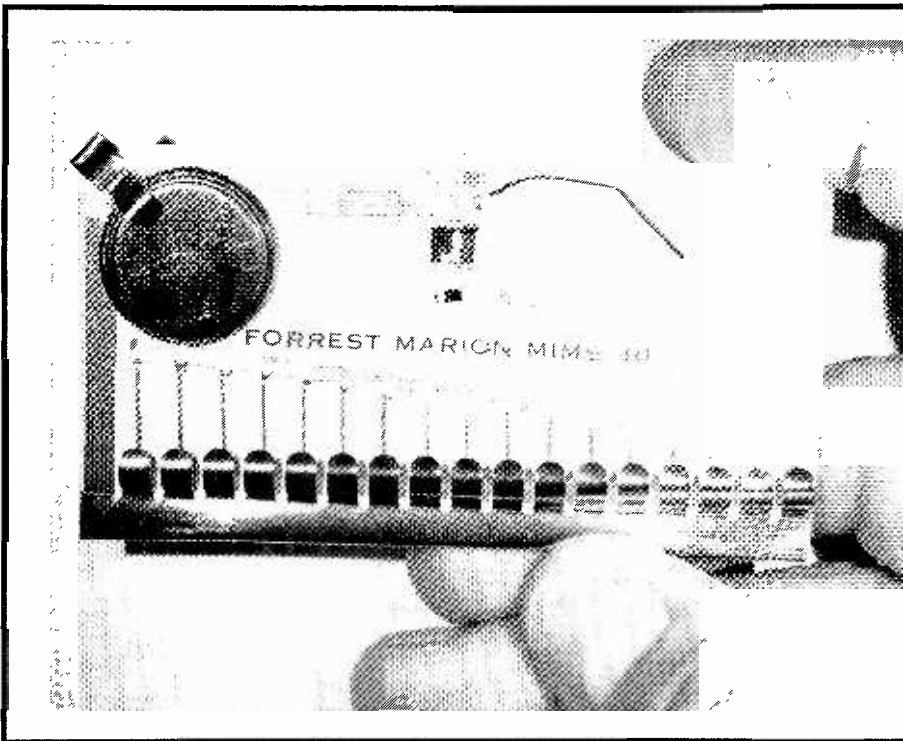
Most inks can be cured by placing a freshly prepared substrate under a desk lamp. For best results, however, be sure to refer to the instructions supplied with the product.

If you can't find the industrial-grade inks described above, don't despair. GC Electronics sells conductive inks for repairing etched circuit boards that are also suitable for bonding SMC's to a circuit board. Their highly conductive *Silver Print* (Cat. No. 22-201) is \$21.62 for half a troy ounce (price subject to change with the price of silver). GC's *Nickel Print* (Cat. No. 22-207), has a higher resistance than *Silver Print*, but the two-ounce bottle shown in Fig. 4 costs only \$3.83. Both of those products can be ordered from GC Electronics or purchased at many electronics dealers.

If those GC products aren't readily available, you can obtain satisfactory results with a silver-filled conductive lacquer available from some automotive parts stores that sell NAPA parts. The product, which is dyed to resemble copper, is Loctite Quick Grid Window-Defogger Repair Kit. The kit, which sells for around \$7.25, includes a small bottle containing 0.05 fluid ounces of silver-filled lacquer. It is also shown in Fig. 4.

Dynaloy, Inc. sells various one-part conductive-epoxy pastes that are well-suited for conductive bonds. An evaluation kit containing 50 grams each of one pure-silver and two silver-alloy adhesives costs \$100. Conductive adhesives are also available from Amicon.

R-E



**Surface-Mount
Technology**

SMT PROJECT: A BUSINESS-CARD TONE GENERATOR

Who needs a PC board?

FORREST M. MIMS, III

SURFACE MOUNT TECHNOLOGY OFFERS CIRCUIT BUILDERS entirely new methods of assembling solid-state circuits. For example, the circuit shown in Fig. 1 can be installed without solder on an ordinary paper business card. The prototype version of the circuit was built in around 90 minutes.

The primary value of this particular circuit-on-paper is that it vividly illustrates some of the unique capabilities provided by surface-mount technology. Among the more interesting techniques it will show you is how to form resistors simply by drawing them in place with a graphite pencil.

How it works

Referring to Fig. 1, the circuit for the tone generator consists of a 555 timer connected as an astable oscillator. The circuit's frequency of oscillation is controlled by resistors R1-R17 and C1. The output from the 555 drives a piezoelectric-buzzer element. Note that Fig. 1 specifies a power supply voltage of 6. Keep in mind that selected 555's and low power 555's can be powered by 3 volts.

Circuit assembly

Figure 2 shows both the conductor traces and the component layout for the assembled circuit. For the circuit to fit on a business card, two specialized components are required. The piezoelectric-buzzer element is a miniature 0.7-inch diameter unit made by Murata Erie North America, Inc. (2200 Lake Park Drive, Smyrna, GA 30080). The keyboard is a

section of clip-on cylindrical-radius contacts made by Tech-Etch, Inc. (45 Aldrin Road, Plymouth, MA 02360). One finger from a contact section is used for the battery clip. An 18-finger section, which we'll call the switch strip, is used for the keyboard.

The circuit also requires conductive ink and adhesive-

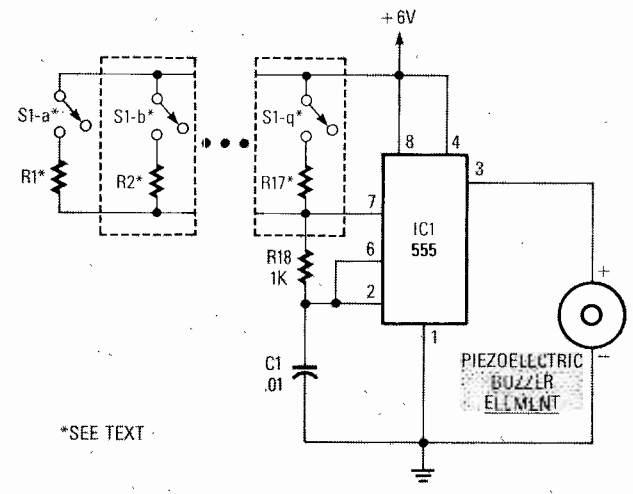


FIG. 1—A SIMPLE TONE-GENERATOR. Resistors R1-R17 consist of nothing more than lines drawn with a graphite pencil.

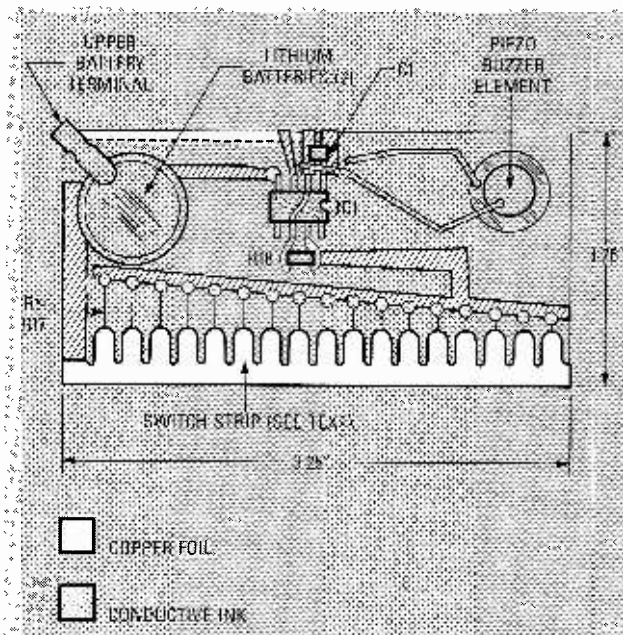


FIG. 2—WHO NEEDS A PC BOARD? As show here, the entire circuit can be mounted on a piece of paper or cardboard, like a business card.

backed copper foil. Many kinds of conductive inks can be used. Silver-filled inks, however, will work best. Adhesive-backed copper foil is available from The Datak Corporation (3117 Patterson Plank Road, North Bergen, NJ 07047).

Begin assembly of the circuit by using conductive ink and a suitable applicator (a wire or a sharp toothpick) to interconnect pins 4 and 8 on the back side of the 555. Set the 555 aside to allow the ink to dry.

Next, follow the layout in Fig. 2 and apply adhesive-backed copper strips to a business card. Note that a single strip is placed along the upper left side of the back of the card.

Cut an 18-finger section from a length of the cylindrical-radius contacts to form the switch strip. Clip off the left-most flexible finger from the switch strip and slip the strip over the lower side of the card. Use a pencil to make a small mark directly below each contact finger, and then remove the switch strip.

Use a multimeter to measure the resistance of lines drawn on paper with various kinds of pencils. While some pencils produce non-conductive lines, others produce lines having an easily measured resistance. Select a sharp pencil that produces lines having relatively low resistance to draw 17 parallel lines between the marks under the contact fingers and the copper strip that runs diagonally across the lower center of the business card.

When the silver-filled ink on the lower side of the 555 is dry, attach the device to the card with a small piece of reusable adhesive or wax. Then use very small pieces of the same adhesive material to attach C1 and R18 to the card at the locations shown in Fig. 2. Note that C1 is mounted between two thin copper strips while R18 is simply attached to the card

PARTS LIST

- R1-R17—graphite pencil lines, see text
- R18—1000 ohms, 1206 package
- C1—.01 μ F, 1206 package
- IC1—555 timer, SO-8 package

Miscellaneous: Lithium coin cells (2 each, 2016 or 2020 type), piezoelectric buzzer (Murata-Erie MSJ-70383, or equivalent), switch strip (see text), battery terminal (see text), adhesive-backed copper foil, conductive ink, graphite pencil, business card, etc.

below the 555. After the three SMC's are in place, clip the connection leads of the piezoelectric-buzzer element to a maximum length of 1.5 inches and remove 0.1 inch of insulation from the end of each lead. Attach the element to the upper right corner of the card with transparent tape.

Next, connect the pins of the 555 to the respective copper-foil conductors with small droplets of silver-filled ink. Apply the ink with a sharp toothpick or piece of wire. Also apply droplets of ink between the terminals of C1 and the copper-foil strips on which C1 rests. Then form traces of conductive ink between the terminals of R18 and pins 6 and 7 of the 555.

Use care when applying conductive ink. Too much ink will result in a short circuit should some of the ink run under the components. Be sure to follow any precautions supplied with the ink you select.

Next, form a path of conductive ink across the top of the 555 to interconnect pins 2 and 6. Then apply small droplets of conductive ink at the junction of each graphite resistor (R1-R17) and the diagonal copper conductor. Also apply conductive ink at the junctions of the various copper foil traces.

Fasten the leads from the piezoelectric-buzzer element to the card with clear tape so that the exposed ends of its leads are positioned over the copper foil traces connected to pins 1 and 3 of the 555. Secure the leads to the foil with droplets of conductive ink.

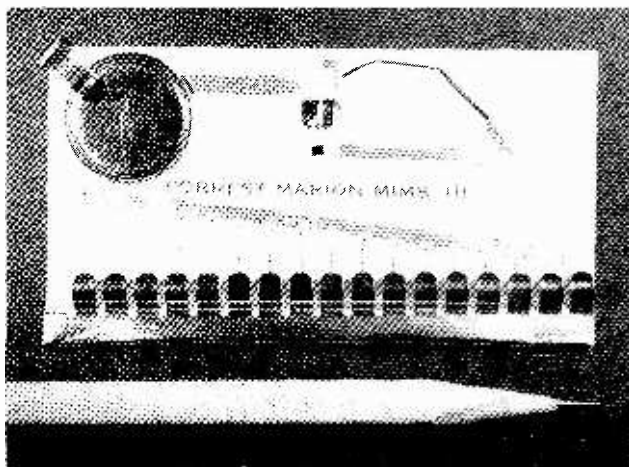


FIG. 3—THE AUTHOR'S PROTOTYPE. Pressing different contacts will cause different pitched tones to be produced.

After the conductive ink has dried, slip the switch strip over the bottom side of the card as shown in Fig. 2. Crimp the ends of the strip slightly to secure the switch strip in place. Crimping will also insure that the switch strip makes good electrical contact with the copper trace applied to the left border of the card.

Cut a single finger from a length of cylindrical-radius contacts to form the upper battery terminal. Place a layer of tape under all but the end of the flexible-finger portion of the terminal. The tape is necessary to prevent a possible short should the edge of one or both coin cells make contact with the terminal. Crimp the clip-on portion of that terminal to the upper-left corner of the card as shown in Fig. 2.

Figure 3 is a photograph of the completed circuit. Figure 4 is a highly magnified view of a droplet of conductive ink over the junction of one of the graphite resistors and the diagonal copper strip. Figure 5 is a highly magnified view of C1. Note that Fig. 5 also shows a droplet of conductive ink bonding one

BUSINESS-CARD TONE GENERATOR

continued from previous page



FIG. 4—A DROPLET OF CONDUCTIVE INK connects a graphite resistor to the copper strip.



FIG. 5—A CLOSE-UP OF C1. To its right, a droplet of conductive ink bonds one lead from the buzzer to a foil strip.

HAND-SOLDERING SMC's

continued from page 98

Solder paste or cream is offered in convenient syringe applicators by Alpha Metals and Multicore Solders. Figure 3 shows a syringe of solder paste that contains 1.5 ounces of 63%-tin/37%-lead solder paste. Note that when a paste or cream is supplied in that manner, it's generally necessary to mix the material before use by rolling the barrel of the syringe against a hard surface. After the needle is attached and the plunger is installed, a small quantity of material can be applied directly to each SMC footprint as shown in the opening of this article.

It's best to practice applying the paste on a piece of paper first. That will allow you to learn how to cope with unforeseen situations such as how to deal with paste that continues to emerge from the needle after you have coated a footprint. (Hint: Keep some paper towels handy.)

If the syringe method proves too tricky, you can apply the solder paste or cream directly to the terminals and pins of the SMC's themselves using what is called the transfer method. First, place some paste or cream on a clean, flat surface; a glass microscope slide works well. Next, use tweezers to pick up an SMC and then dip its terminals or pins into the paste. When all the terminals or pins are coated with a thin layer of the material, place the SMC on its footprints on the circuit board. The sticky flux will hold the SMC in place while you repeat that procedure for any remaining devices.

of the wires from the piezoelectric-buzzer element to its respective copper strip.

Testing the circuit

Carefully inspect the circuit to make sure no errors have been made. Then insert a stack of two lithium coin cells under the upper battery terminal (positive sides down). A tone should be heard when one of the switch-strip fingers (keys) is pressed against its respective graphite line on the surface of the card.

Caution: Use care to avoid shorting the terminals of one or both coin cells. Lithium cells may explode when shorted.

When the circuit works properly, try pressing each of the keys in turn. That test will illustrate the difficulty of drawing graphite lines having uniform resistance per unit length. The prototype circuit yielded a rather irregular sequence of tones as each key was pressed in ascending order.

The circuit has no power switch. When the circuit is not being used, insert a slip of paper between the lithium coin cells and the upper battery terminal or remove the coin cells.

Going further

Whether or not you choose to build this circuit, I hope the construction details presented here have given you some new ideas about the unique possibilities offered by combining surface-mountable components and conductive inks. While you might not wish to build miniature circuits on paper business cards, you can build such circuits on glass, plastic, wood, painted metal and many other substrates. In short, a circuit can be built on virtually any available surface. For example, the author has used silver-filled ink and SMC's to build LED transmitter circuits directly on the battery holders that power the circuits.

R-E

After all the components are in place, inspect the board to make sure each SMC terminal or pin is properly positioned. You must then cure the board by preheating it long enough to drive off the volatile solvents from the paste or cream. The curing procedure is very important because it precludes the formation of unwanted solder balls and reduces the thermal shock that the board and its SMC's are subjected to during reflow soldering.

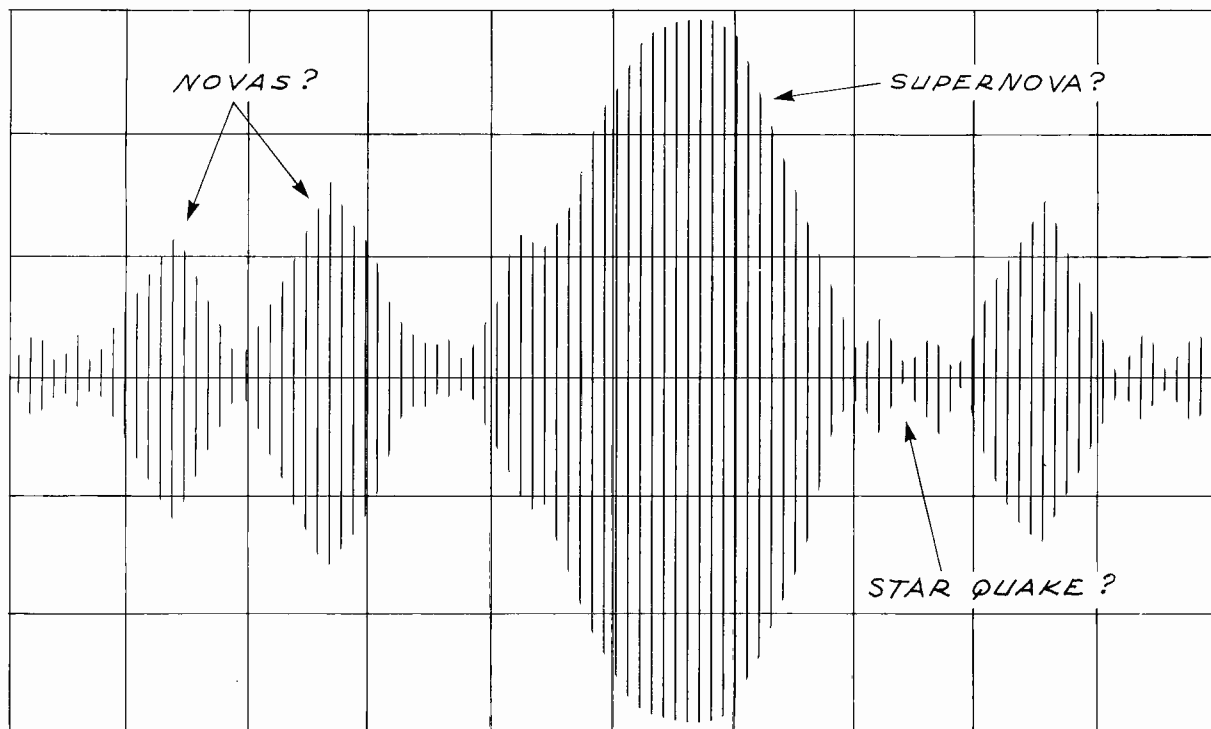
IMPORTANT: Various solder pastes and creams may require different curing times and temperatures. They may also require different reflow soldering times and temperatures. Therefore, it is essential to refer to the manufacturer's literature about a specific product to avoid unreliable solder connections.

With that *caveat* in mind, a typical curing procedure is to heat the board in a convection oven for from 10 to 30 minutes at 85°C. After the paste is cured, the board is removed and the oven temperature is increased to the melting temperature of the solder. The board is then placed back in the oven until the solder melts and then quickly removed. Alternatively, if the board can withstand the temperature, it can be reflow soldered by placing it on a hot plate. Another alternative is to use a desktop vapor-phase system such as Multicore Solders' *Vaporette*.

Once again, it is essential to carefully follow the instructions for a particular solder paste or cream. Also, it's very important to avoid overheating the SMC's. Most, but not all, SMC's can withstand the temperature of molten solder for 10 seconds.

R-E

Gravitational Impulses



New data shows repeatable and predictable gravity detected from the center of the milky-way galaxy. Build a simple gravity detector and observe that phenomena for yourself.

GREGORY HODOWANEC

THE MAIN PROBLEM TODAY IN ATTEMPTING to observe gravity signals has been the insistence by astrophysicists that only the quadrupole radiated gravity signals predicted by Albert Einstein are permissible in the universe; even though quadrupole-type gravity signals have eluded detection. On the other hand, monopole-type gravity signals that exist profusely in the universe are produced by Newtonian gravity gradients, which are easily detected with a simple device developed by the author.

New scalar definition

A field in physics may be defined as a region in space which is under the influence of some "effect": typically an electric, magnetic, or gravitational effect. Vector type fields must be described in terms of both magnitude and direction. Less understood is the theory of fields that are scalar in nature and described in terms of magnitude alone. A common example of a scalar field is temperature: even though the gradient of such a field will be vectorial. Less well-known are the scalar aspects of gravitational, electric, and magnetic fields.

The author uses the term *scalar* in a

unique way. When all the vectors of a force are directed *parallel* to each other, the force can be fully specified by a magnitude only. Therefore, any two forces whose vector fields run *parallel* to each other will interact (as scalars) in a simple algebraic superposition with no need to use vector analysis.

A scalar electric field is realized by the application of a voltage between two parallel plates, where all the electric lines of force are *parallel* to each other. A scalar magnetic field is realized in the H-fields that emanate from the end of a bar magnet into the space just beyond the magnet. Such a "curl-free" magnetic field is scalar for only a short dis-

tance because that is the region where the magnetic flux lines are all *parallel*. Similarly, the earth's gravitational-field is also a scalar field because the gravity flux is *parallel* and directed downward only.

It is the author's presumption that scalar gravitational, electric, and magnetic fields may interact with each other only when the fields run exactly *parallel*. Taking that theory a step farther means that energy can be transferred from one scalar field to another.

Capacitor charging

Traditionalists recognize the polarization "effect" in a dielectric that is placed between the parallel plates of a capacitor. If a DC voltage is applied to the plates of a capacitor, an electric field will develop between the plates. A traditionalist would see the electric field as a vector force directed from the negative plate to the positive plate. The magnitude would depend upon the intensity of the electric field generated by the movement of electrons from one plate to the other. But few traditionalists recognize the scalar nature of such parallel electric fields, and their possible interaction with other similarly directed (scalar) fields; primarily,

The author has developed a device to detect gravity waves, and explains its operation with a new scalar field theory. We are publishing the results of some of his experiments in the hope it will foster experimentation in gravity detection. By confirming the author's data, new ideas and concepts might emerge to form the basis of a new technology.

Earth's ever-present gravity field. The presence of a scalar gravity field on the plates of a capacitor will cause the molecules to polarize just as though an external DC voltage were being applied.

In Fig. 1, the dielectric in the capacitor is shown polarized by the Gravity-fields; that results in a potential difference across the capacitor that drives a current. Because the gravity-fields are modulated by various universe and terrestrial processes, the energy components are both DC and AC in nature. Therefore, as long as the vectors of the gravitational and electric fields run parallel to each other, then both fields can be considered scalar fields, which means energy from one field can be transferred to the other. The gravity field may be visualized as squeezing the plates, however minutely.

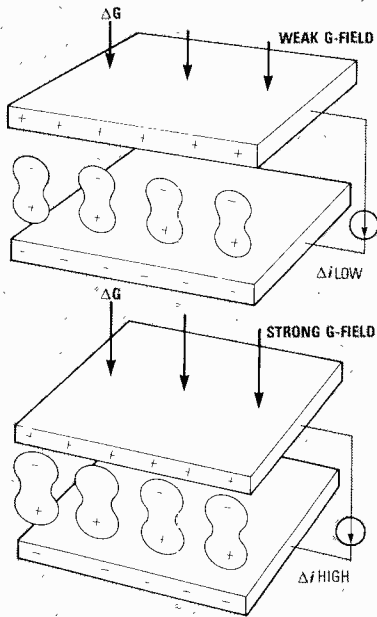


FIG. 1—POLARIZATION EFFECT IN A CAPACITOR is due to the actions of a gravity field. The change in current flow, Δi , through the capacitor is proportional to the gravity field, ΔG .

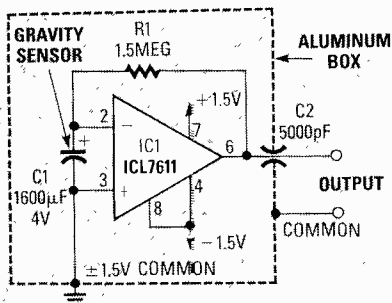


FIG. 2—THE BASIC GRAVITY DETECTOR is a current-to-voltage converter. The current through capacitor C1 is proportional to changes in the strength of the gravity field. IC1 amplifies the signal generated across capacitor C1 to drive a chart recorder or digital multimeter.

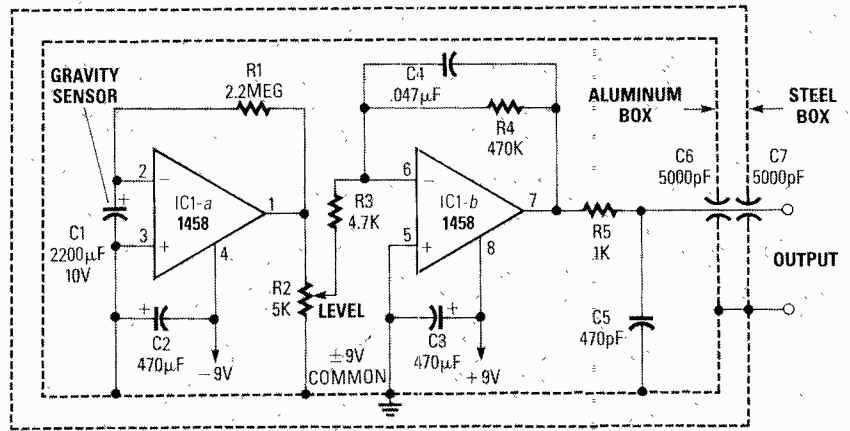
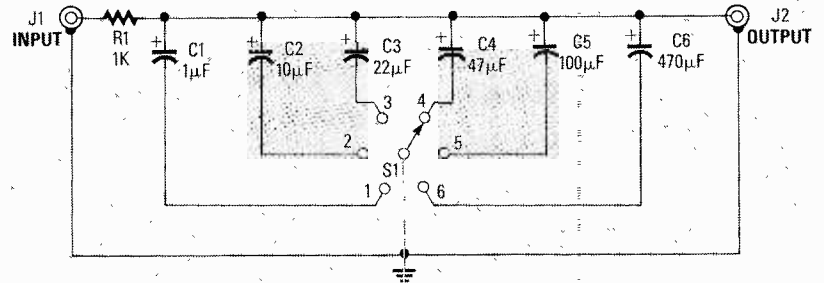


FIG. 3—A BUFFERED GRAVITY DETECTOR increases the detector's sensitivity to gravity fields, and also adds frequency stability to the detector. The aluminum box, the outer steel enclosure, and feedthrough filter capacitors C6 and C7, isolate the detector from electromagnetic interference (EMI).



S1 POSITION	FILTER CUT-OFF	S1 POSITION	FILTER CUT-OFF
1	1KHz	4	21Hz
2	100Hz	5	10Hz
3	45Hz	6	1Hz

FIG. 4—GRAVITY DETECTOR OUTPUT FILTERING will limit the detectors response to certain astronomical distances. The lower cut-off frequencies of 21 Hz to 1 Hz are best for gravity sensing within our own galaxy. Most of the author's chart recordings were done using a 10 Hz filter. The filter should be placed in a RFI shielded enclosure.

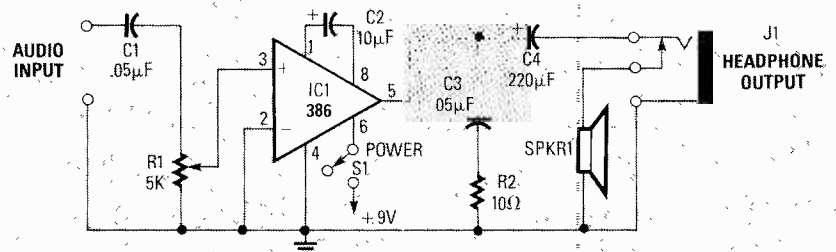


FIG. 5—A SIMPLE AUDIO AMPLIFIER can be used to listen to gravity signals that sometimes contain a musical rhythm.

Thermal tests were conducted at an independent laboratory. Heating the electrolytic capacitor in a shielded hot oil bath (75°C), and cooling in a shielded ice bath (0°C) had no discernible effect on signal output. However, chilling in a shielded dry-ice bath (-79°C) resulted in a steady decrease in amplitude, frequency, and burst rate until the only signal remaining was the 1.5 volt DC. The question was raised: Shouldn't the

burst rate have remained constant if caused by gravity waves. The laboratory found that the total effective capacitance decreases rapidly at temperatures less than -30°C. A 300 to 400 fold decrease was observed at -79°C, so that 1600µF at -79°C would have an actual capacitance of only 4µF; effectively, there was very little capacitance in the detector at that temperature, which would account for the diminished burst rate.

PARTS LIST

BASIC GRAVITY DETECTOR

R1—1.5 Megohms, ¼-watt
 C1—1600 µF, 4 volts, electrolytic
 C2—5000 pF, Feedthrough type
 IC1—ICL7611 (Intersil) op-amp
 Aluminum Enclosure

BUFFERED GRAVITY DETECTOR

All resistors are ¼-watt, 5%

R1—2.2 Megohms
 R2—5000 ohms, potentiometer
 R3—4700 ohms
 R4—470,000 ohms
 R5—1000 ohms

Capacitors

C1—2200 µF, 4 volts, electrolytic
 C2—C3—470 µF, 10 volts, electrolytic
 C4—.047 µF, ceramic disc
 C5—470 pF, ceramic disc
 C6—C7—5000 pF, feedthrough type

Semiconductors

IC1—LM1458 (National) op-amp

Miscellaneous: Aluminum enclosure, Steel box.

LOW PASS FILTER

All resistors are ¼-watt, 5%

R1—1000 ohms
Capacitors, 10 volts, electrolytic

C1—1 µF
 C2—10 µF
 C3—22 µF
 C4—47 µF
 C5—100 µF
 C6—470 µF

Other components

J1—J2—coaxial connector
 S1—SPGT rotary switch

Miscellaneous: Aluminum enclosure RF shielded.

AUDIO AMPLIFIER

All resistors are ¼-watt, 5%

R1—5,000 ohms, potentiometer
 R2—10 ohms

Capacitors

C1, C3—.05 µF, ceramic disc
 C2—10 µF, 10 volts, electrolytic
 C4—220 µF, 15 volts, electrolytic

Semiconductors

IC1—LM386 (National) linear audio amplifier

Other components

J1—Phone jack, 2-circuit type, with one circuit normally closed
 SPKR1—8–16 ohms miniature speaker

OTHER GRAVITY DETECTOR

All resistors are ¼-watt, 5%

R1—200 ohms, potentiometer
 R2—2 Megohms, potentiometer

Semiconductors

IC1—LM741 (National) op-amp

Miscellaneous: Aluminum enclosure RF shield.

REFERENCES

Hodowanec, Gregory. *All About Gravitational Waves*, **Radio Electronics**, April, 1986, pages 53–56.
 Hodowanec, Gregory. *Rhythmic Cosmology*, 1985.

Brownian agitation of the electron-ion structure in capacitors is attributed only to thermal actions by traditionalists. While thermal actions contribute to some aspects of white-noise, the author concludes that much of the white-noise, and especially the low-frequency $1/f$ type impulse noise, is very much independent of the thermal environment. Indeed, the energy causing noise of those types is directly attributable to gravitational fields. The $1/f$ noise is simply the mathematical expression for the rate of occurrence of gravity field events. It is termed $1/f$ noise because the stronger impulses are generated less frequently than the more moderate impulses, and the moderate impulses are seen less frequently than the weaker impulses.

An electrochemical or battery effect does occur in electrolytic capacitors, thereby introducing an additional small voltage component across the capacitor; however, the electrochemical voltages are very small when compared to the gravity field effects, and can, therefore, be neglected.

A flat (planar) type of capacitor posi-

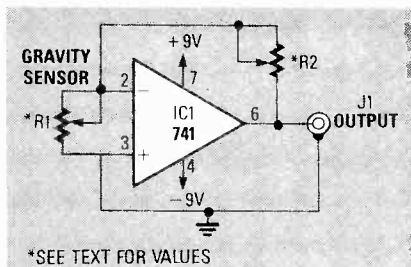


FIG. 6—A GRAVITY DETECTOR THAT USES a resistor sensor to detect gravity signals. Like the capacitor sensor, the resistor sensor is a $1/f$ noise detector. Shield the detector unit from possible RFI interference.

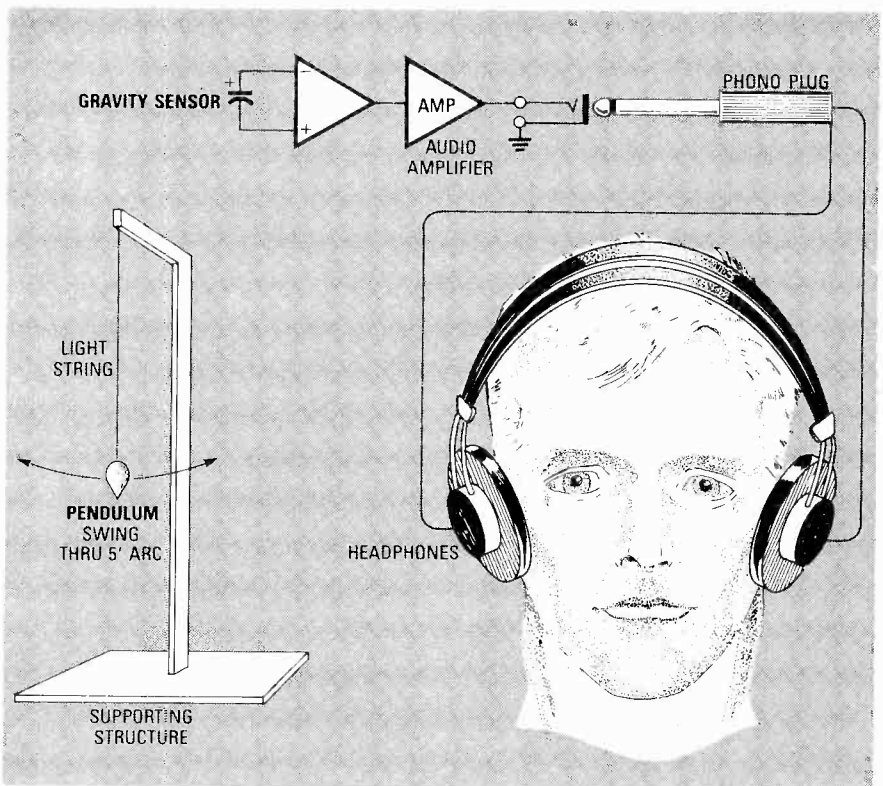


FIG. 7—A PENDULUM IN MOTION will disturb the underlying structure of the universe. Adjust the detector's volume for a good response to the swinging disturbance of the vacuum. Even though the pendulum will eventually stop swinging, the disturbance in the universe continues to remain!

tioned so that the flat side is up, is more effective as a gravity detecting element than a tubular-type of capacitor. Different capacitor types (electrolytic, mylar, polystyrene, paper, ceramic disc, etc.) will give the same response to the gravity field provided the effective capacitances are equal.

Gravity detectors

A scalar gravity-signal detector is shown in Fig. 2. The small gravity-impulse current generated across capacitor C1 is coupled to the input of IC1 for amplification. IC1 functions as a current-to-voltage converter. The capacitance, C1, and the feedback resis-

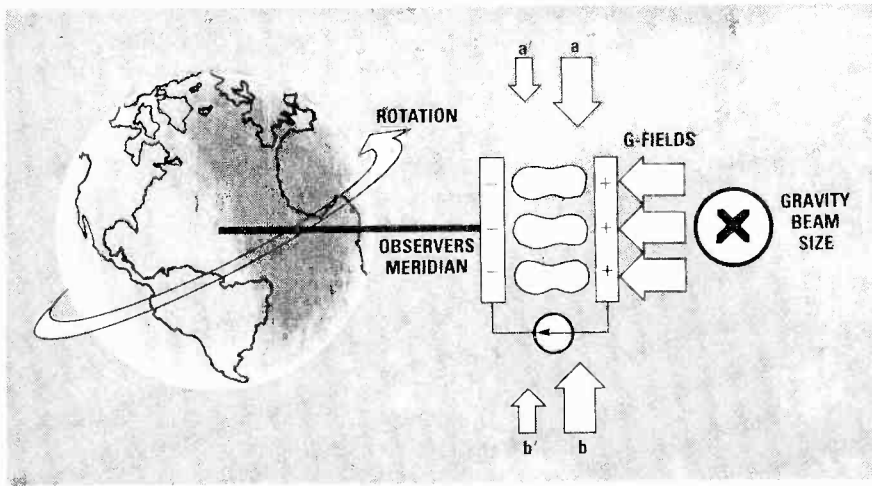


FIG. 8—THE POLARIZATION EFFECTS on a capacitor are caused by the g-fields, X, perpendicular to the flat capacitor plates. As the Earth spins, the capacitor sensor sweeps across the cosmos in a beam like fashion. G-field components, *a* and *b* that are tangential to the flat capacitor plates do not affect the capacitor.

tance, R1, are chosen sufficiently high in value so that input circuit "resonances" are very much less than 1 Hz.

Varying C1's value will have an affect on the response time to gravity-field fluxuations: that is because the op-amp's output is a harmonic type oscillation, where the polarization "stress" induced in the capacitor's dielectric by gravity flux is also "restored" by the reverse electric potential developed by the feedback resistance in that circuit. Therefore, the "oscillations" are a function of both the sensing capacitance and the feedback relationship, and will, thus, have different frequencies for different capacitor and feedback resistor values.

The use of CMOS op-amp ICL7611 enables efficient operation with a ± 1.5 volt battery supply. The unit is assembled in a small aluminum box with the batteries enclosed within the box, and the output is brought out with a feedthrough capacitor in order to eliminate any possible response to ambient RF-type signals.

An improved gravity sensor is shown in Fig. 3. The extra op-amp, ICI-b, will add additional gain and frequency stability. Op-amp output off-set components may be included, however, the author found nulling the op-amp to be unnecessary. The gravity detector is enclosed within an aluminum box which is also within another heavy steel box in order to shield the detector from any electromagnetic interference (EMI). A highly permeable magnetic mu-shield was also used to guard the detector against the Earth's magnetic field, and stray magnetic fields generated by the power company's AC line voltage. However, the author found mu-shielding unnecessary. Tests showed no apparent difference in data when using a mu-shield, or when the aluminum box was used alone.

Most gravity detection will require additional output filtering, as shown in Fig. 4. The cut-off frequencies of the filter will limit the detectors response to certain astronomical distance ranges. For example, if the output shunt-capacitance is about $470\mu\text{F}$, then the response appears to be largely limited to our own immediate group of galaxies. With lower values of output shunt-capacitance, i.e., a higher filter cut-off frequency, the response will include gravitational effects from deeper in space.

Scalar fields of the gravitational type are generated profusely in the universe. The individual impulses of gravity gradients will be heard as a "noise spectrum" through an audio amplifier, or seen as "grass" on an

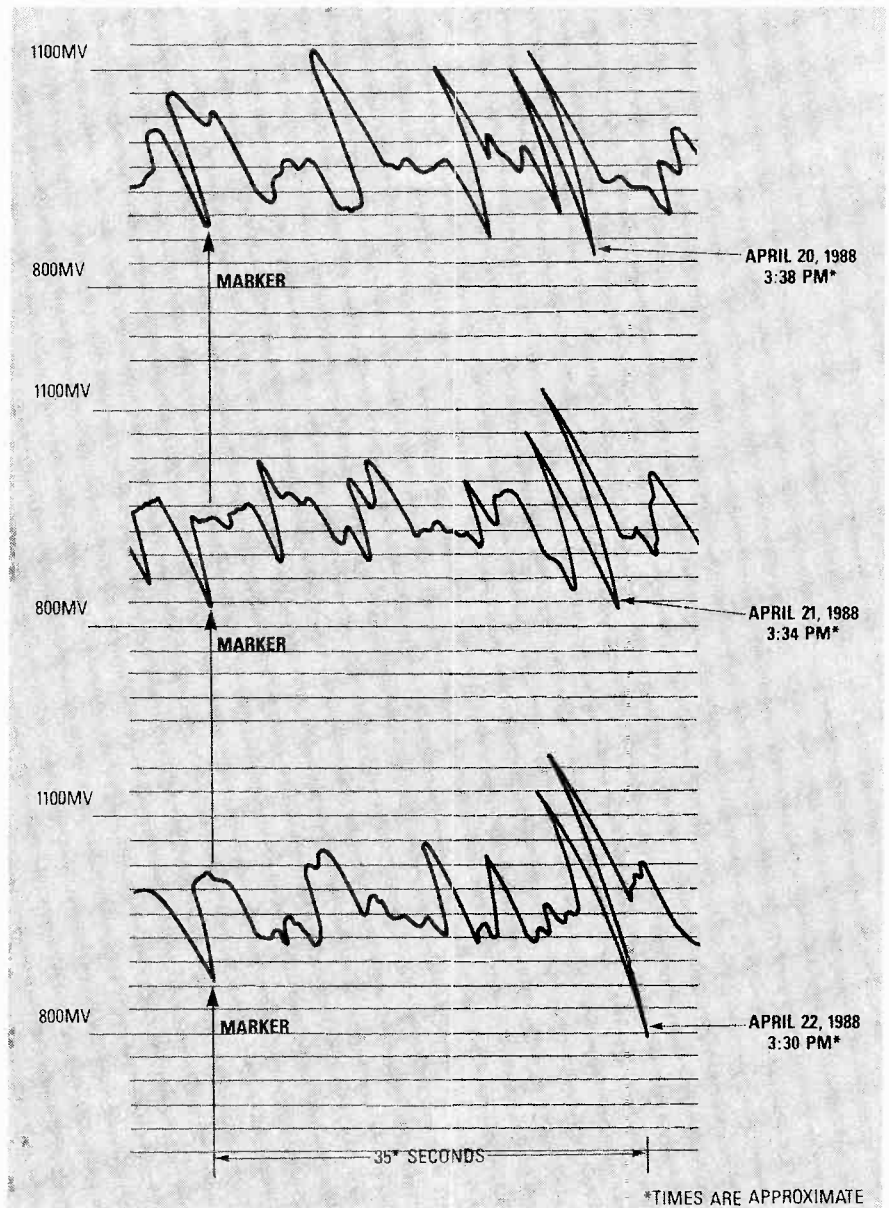


FIG. 9—DATA SHOWS REPEATABLE AND PREDICTABLE gravity impulses detected from the center of the Milky-Way galaxy. A sidereal day is about 23 hours and 56 minutes. If measurements of astronomical events are timed from an Earth's position, then the event should be seen about 4 minutes earlier each day by civil (24 hour) time. That fact is shown by the author's data, where the galaxy center appears four minutes earlier on three successive days.



FIG. 10—TWO COMMON ASTRONOMICAL GRAVITY EVENTS. A Supernova burst causes a modulated g-field, while a Black Hole causes a reduced g-field.

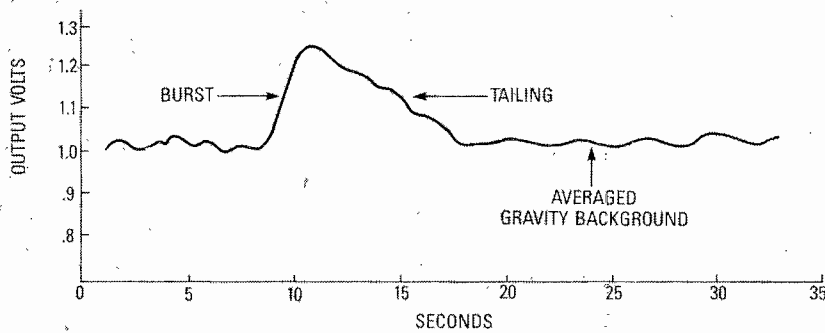


FIG. 11—TYPICAL NOVA GRAVITY RESPONSE.

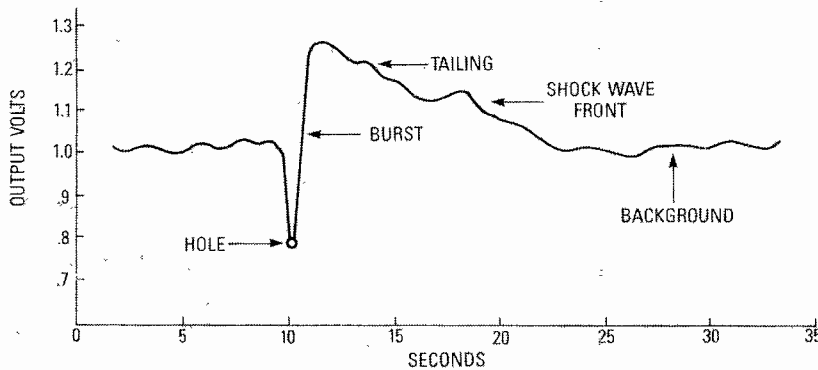


FIG. 12—TYPICAL SUPERNOVA GRAVITY RESPONSE.

oscilloscope. Figure 5 shows a simple audio amplifier that can be used with the detector. The readily available LM386 IC has a gain of about 200. The author also used an audio amplifier available from Radio Shack (#277-1008) with good results.

Another simple gravity detector shown in Fig. 6 uses a low-cost LM741 op-amp. Here, the $1/f$ noise is generated in a carbon composition resistive element rather than in a capacitive element. The current impulses developed in the resistor by gravity signals

are also highly amplified and converted to voltage impulses by the op-amp. To facilitate the more critical adjustment of the Fig. 6 circuit, both the input resistance and the feedback resistance are made variable. Input resistance R_1 is generally in the order of 100 to 200 ohms for most of the IC's tested. For optimum results, the feedback resistance R_2 is generally in the order of 1000 to 10,000 times R_1 's value. The experimenter should first adjust the input resistance to about 150 ohms, and then adjust the feedback resis-

tance for maximum $1/f$ noise response. Then, re-adjust the input resistance for optimum results.

The output voltage from the gravity detector can be used to drive either a chart recorder, or fed to a DMM (Digital MultiMeter) and plotted by hand. The detector's output voltage varies quite slowly, with most observations taking several seconds or minutes to record.

Gravity Communication

Present-day communication systems largely make use of the interaction of electric and magnetic flux fields in a vector type radiation field, i.e., electromagnetic waves, to convey information between distant points at the speed of light. Such systems range over the entire electromagnetic spectrum, from the very low frequencies (VLF) to the super high frequencies (SHF), reaching past the microwave frequencies and well into the optical range of frequencies. Such vector-type radiation fields have been extensively developed over the years and are in common use today. However, according to the author's theories, scalar-type radiation fields, such as the gravitational field, might eventually be useful to convey information "instantly"

Scientists recognize the physical universe in basic terms such as mass, energy, fields, etc., and all else is but an integration of such factors. The author theorizes that gravitation has 'infinite' wavelengths and are thus not wave-like. Moreover, gravitational impulses travel at Plank's time interval of about 5.4×10^{-44} seconds, and do not propagate at the speed of light—a slow speed when compared to Plank's time constant. The gravity impulse is a monopole and appears to travel almost instantaneously everywhere in the universe.

Listening to the sounds of scalar gravity signals with the audio amplifier can be quite

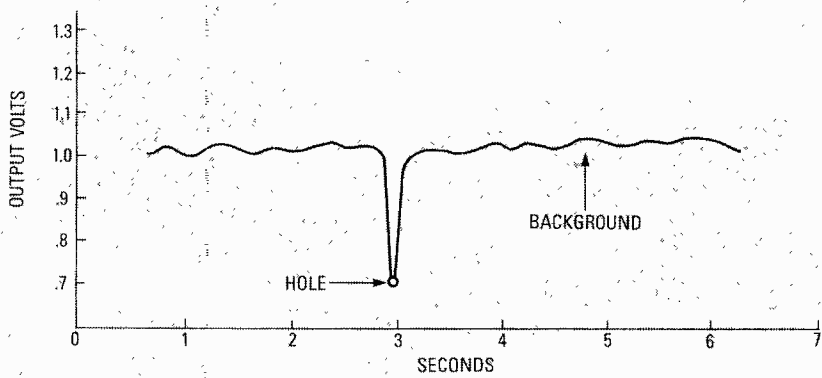


FIG. 13—ANCIENT BLACK HOLE GRAVITY RESPONSE.

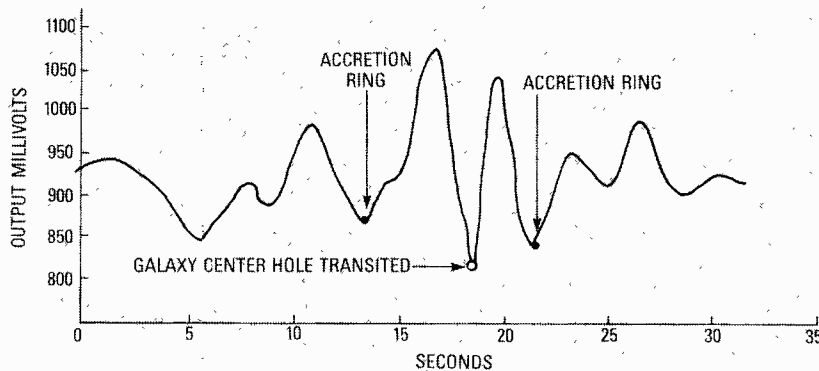


FIG. 14—MILKY-WAY GALAXY CENTER GRAVITY RESPONSE.

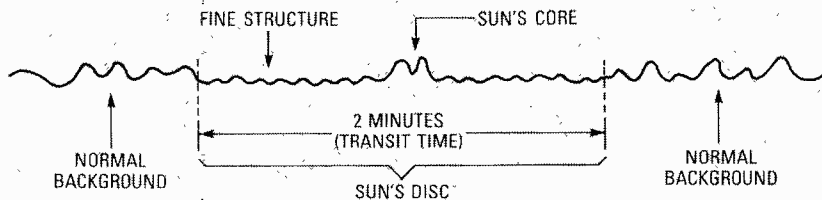


FIG. 15—OUR SUN'S CORE GRAVITY RESPONSE.

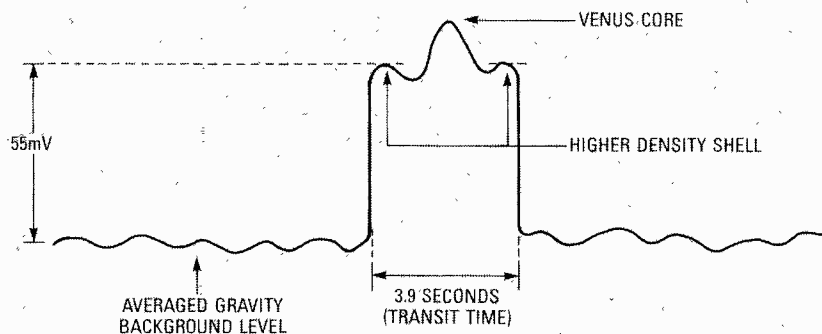


FIG. 16—VENUS PLANETARY GRAVITY RESPONSE.

impressive. Adjust the amplifier's sound level for best response to the particular sound being studied. Of particular interest may be some of the coherent "musical" sounds which appear to come from the same direction of space on a daily basis. At the author's location of 42° N. Latitude, those sounds appear to originate from the Perseus and Auriga regions of our Galaxy when

those regions appear in the author's zenith. Perhaps some of those signals might be extraterrestrial intelligence signals, and experimenters interested in SETI (Search for Extra-Terrestrial Intelligence) might want to investigate that aspect of the detection process. Since gravity impulses travel everywhere almost instantaneously, communication between different galactic cultures

would not be limited by the long time intervals required by speed-of-light communication by radio-wave.

Man-made scalar flux signals are largely due to oscillating or rotating masses. A translation of mass will generate signals that are due to the perturbations of an apparent standing-wave pattern in the universe's background radiation. That those modulations are truly due to mass in motion can be seen by oscillating a pendulum, or rolling a mass, which will disturb the gravitational background. The author has detected the oscillation of a pendulum 150 feet away that appeared to have the same response in detected intensity as when the pendulum was only 5 feet away. A local translation of mass will appear as a strong rushing sound in the detector's audio output.

As shown in Fig. 7, an interesting pendulum experiment can be performed with a two pound weight that is suspended by a light-weight string from a height of six feet. Set the pendulum in motion with about a five foot arc length. Adjust the detector volume for a good response to the swinging disturbance of the vacuum, i.e., the universe. Even though the pendulum will eventually stop swinging, the disturbance in the universe continues to remain! That effect appears to be typical of gravitational perturbations in the universe. Apparently, once the gravity disturbance is generated, the gravity impulses tend to propagate continually until dissipated or over-ridden in some way. It appears that gravitational communications will probably require some sort of modulation that can defeat the continuing propagation characteristics of the vacuum.

Gravity astronomy

Astronomy, in recent years, has undergone a revolution in both theoretical considerations and observational methods. The revolution has not only opened new observational techniques at electromagnetic frequencies other than visible light, but has also given evidence that our universe, in its furthest reaches, also obeys the same scientific principles as those observed here on Earth. Among the new observational methods were attempts to detect gravitational signals. Such signals would be a new window into the universe, and would disclose many aspects not observable with the present-day electromagnetic techniques.

The astronomical gravity signal detection units are special modifications of the basic gravity detector. The modifications are: the input resonance frequency is normally kept much less than one hertz per second, additional amplification is used, and the output is passed through a low pass filter.

The effectiveness of the capacitor element as a detector in gravity-signal astronomy is shown in Fig. 8. The earth's gravity field is in parallel with the polarized electric field in the planar capacitor dielectric. Furthermore, it can be shown that any gravity com-

continued on page 129

WORKING WITH TRIACS AND SCR's

Twenty-eight practical SCR and Triac circuits.

RAY MARSTON

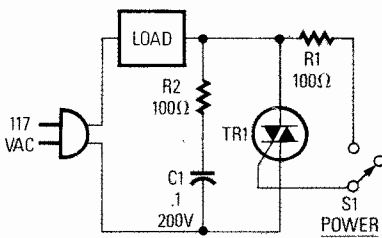


FIG 1—AC POWER SWITCH, AC triggered.

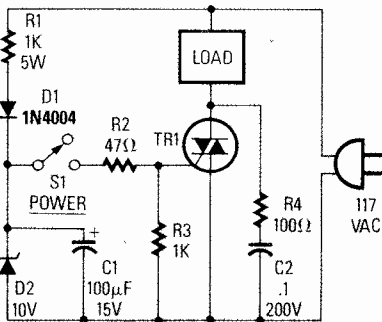


FIG 2—AC POWER SWITCH, DC triggered.

LAST TIME WE DISCUSSED BASIC SCR AND Triac theory, paying particular attention to the principles of synchronous and asynchronous triggering. (See **Radio-Electronics**, September 1987.) This time we'll present a number of practical circuits for which the user need only select an SCR or Triac having suitable voltage and current ratings. Let's start off by looking at several Triac circuits that can be used to control some line-voltage-powered devices.

Asynchronous designs

As explained last time, a Triac may be triggered (turned on) either synchronously or asynchronously. A synchronous circuit always turns on at the same point in each half-cycle, usually just after the zero-crossing point, in order to minimize RFI. An asynchronous circuit does not turn on at a fixed point, and the

initial current surge generated during turn-on at a non-zero point of the AC cycle can generate significant RFI. Triac turn-off is automatically synchronized to the zero-crossing point, because the device's main-terminal current falls below the minimum-holding value at the end of each half-cycle.

Figures 1-8 show a variety of asynchronous Triac power-switching circuits. In Fig. 1, the Triac is gated on (whenever S1 is closed) via the load and R1 shortly after the start of each half-cycle; the Triac remains off when S1 is open. Note that the trigger point is not line-synchronized when S1 is closed initially; however, synchronization is maintained on all subsequent half-cycles.

Figure 2 shows how the Triac can be triggered via a line-derived DC supply. Capacitor C1 is charged to +10-volts DC (via R1 and D1) on each positive half-cycle of the line. The charge on C1 is what triggers the Triac when S1 is closed. Note that all parts of the circuit are "live," and that makes it difficult to interface to external control circuitry.

Figure 3 shows how to modify the previous circuit so that it can interface with external control circuitry. Switch S1 is simply replaced by transistor Q2, which in turn is driven from the photo-transistor portion of an inexpensive optocoupler. The LED portion of the optocoupler is driven from a 5-volt DC source via R4. Opto-couplers have typical insulation potentials of several thousand volts, so the external circuit is always fully isolated from the line.

Figure 4 shows an interesting variation of the previous circuit. Here the Triac is AC-triggered on each half-cycle via C1, R1, and back-to-back Zeners D5 and D6. Note that C1's impedance determines the magnitude of the Triac's gate current.

The bridge rectifier composed of D1-D4 is wired across the D5/D6/R2 network and is loaded by Q1. When Q1 is off, the bridge is effectively open, so the Triac turns on shortly after the start of each half-cycle. However, when Q2 is on, a near-short appears across D5/D6/R2, thereby

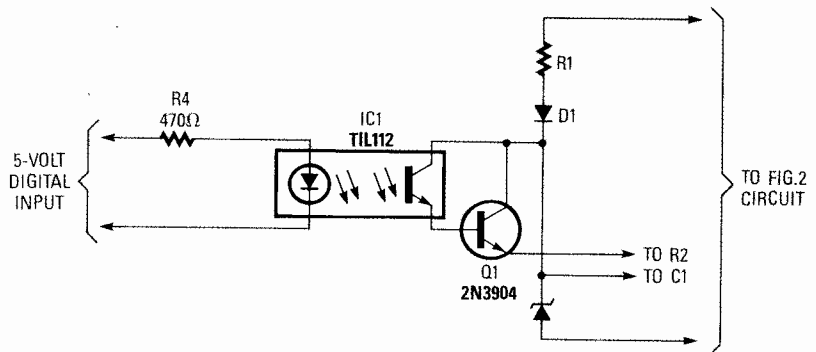


FIG 3—OPTICALLY ISOLATED AC power switch, DC triggered.

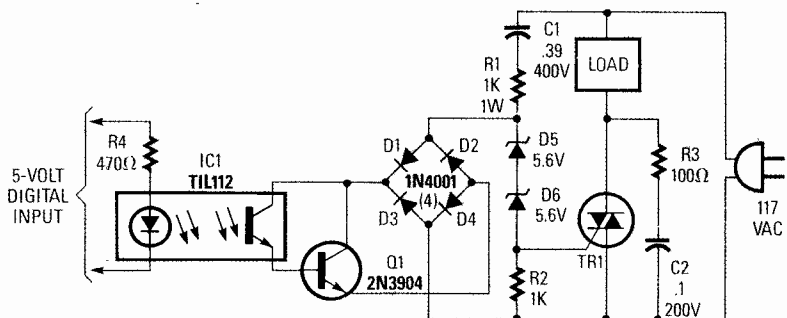


FIG 4—OPTICALLY ISOLATED AC power switch, AC triggered.

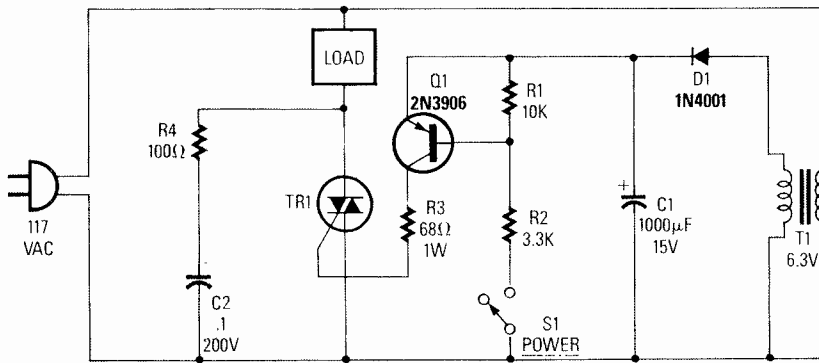


FIG 5—AC POWER SWITCH with transistor-aided DC triggering.

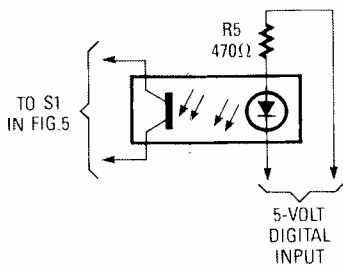


FIG 6—TRIGGER THE PREVIOUS CIRCUIT with an optocoupler.

inhibiting the Triac's gate circuit, so it remains off.

Figures 5 and 6 show several ways of triggering the Triac via a transformer-derived DC supply and a transistor-aided switch. In the Fig. 5 circuit, Q1 and the Triac are both turned on when S1 is closed, and off when it is open. In practice, of course, S1 could be replaced by an electronic switch, enabling the Triac to be operated by heat, light, sound, time, etc. Note, however, that the whole of the Fig. 5 circuit is "live." Figure 6 shows how to modify the circuit so that it is suitable for use with an optocoupler.

To complete this section, Figures 7 and 8 show several ways of triggering a Triac from a fully isolated external circuit. In both circuits, triggering is obtained from an oscillator built around unijunction transistor Q1. The UJT operates at a frequency of several kHz and feeds its output pulses to the Triac's gate via pulse transformer T1, which provides the desired isolation. Also in both circuits, S1 can easily be replaced by an electronic switch.

In the Fig. 7 circuit, Q2 is wired in series with the UJT's main timing resistor, so the UJT and the Triac will turn on only when S1 is closed. In the Fig. 8 circuit, Q2 is wired in parallel with the UJT's main timing capacitor, so the UJT and the Triac turn on only when S1 is open.

Synchronous designs

Figures 9–18 show a number of power-switching circuits that use synchronous triggering.

Figure 9 shows the circuit of a synchronous line switch that is triggered near the zero-voltage crossover points. The Triac's gate-trigger current is obtained from a 10-volt DC supply that is derived from the network composed of R1, D1, D2, and C1. That supply is delivered to the gate via Q1, which in turn is controlled by S1 and the zero-crossing detector composed of Q2, Q3, and Q4.

Transistor Q5 can only conduct gate

current when S1 is closed and Q4 is off. The action of the zero-crossing detector is such that either Q2 or Q3 turns on whenever the instantaneous line voltage is positive or negative by more than a few volts, depending on the setting of R8. In either case, Q4 turns on via R3 and thereby inhibits Q5. The circuit thus produces minimal RFI.

Figure 10 shows how to modify the previous circuit so that the Triac can only turn on when S1 is open. In both circuits note that, because only a narrow pulse of gate current is sent to the Triac, average consumption of DC current is very low (one milliamper or so). Also note that S1 can be replaced by an electronic switch, to give automatic operation via heat, light, time, etc., or by an optocoupler, to provide full isolation.

A number of special-purpose synchronous zero-crossover Triac-gating IC's are available, the best-known examples being the CA3059 and the TDA1024. Both devices incorporate line-derived DC power-supply circuitry, a zero-crossing detector, Triac gate-drive circuitry, and a high-gain differential amplifier/gating network.

Figure 11 shows the internal circuitry of the CA3059, together with its minimal external connections. AC line power is applied to pin 5 via a limiting resistor

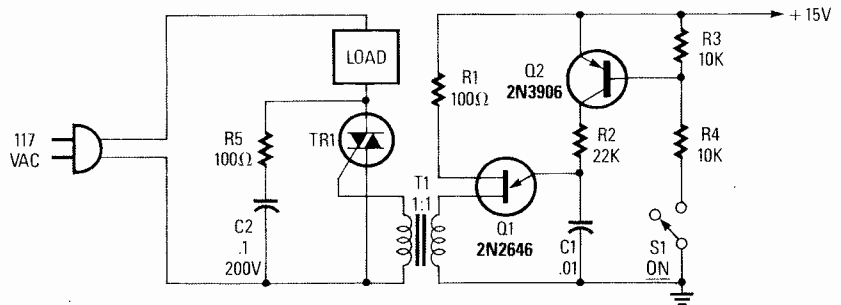


FIG 7—TRANSFORMER-COUPLED AC power switch. The Triac turns on when S1 is closed.

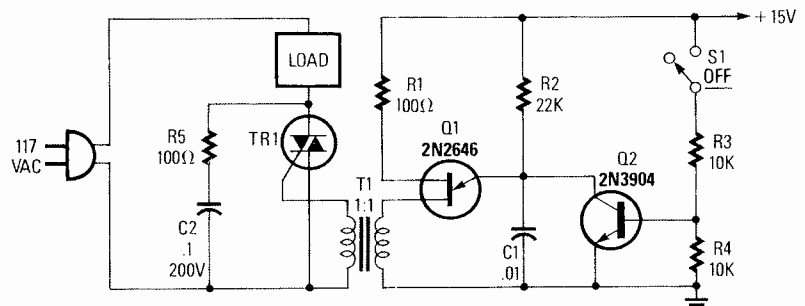


FIG 8—ISOLATED-INPUT AC power switch. The Triac turns on when S1 is open.

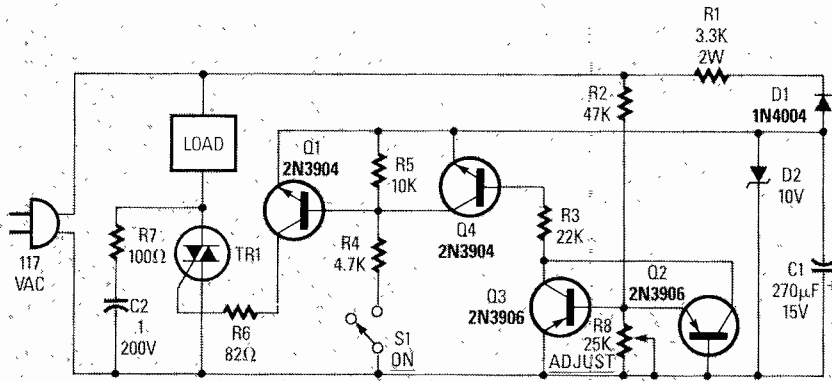


FIG 9—ZERO-CROSSING synchronous line switch. The Triac turns on when S1 is closed.

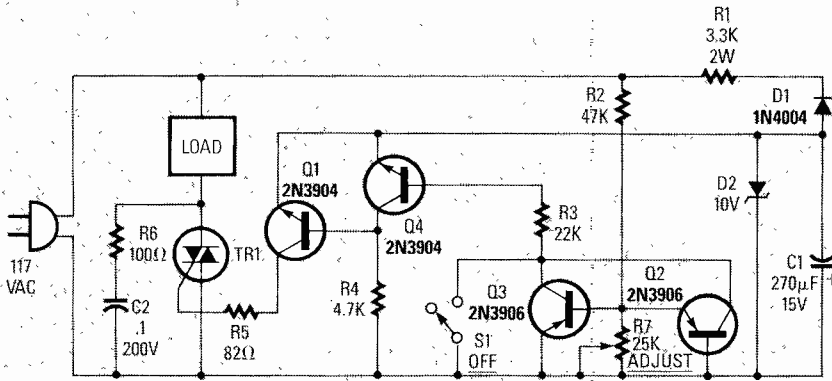


FIG 10—ALTERNATE synchronous line switch. The Triac turns on when S1 is open.

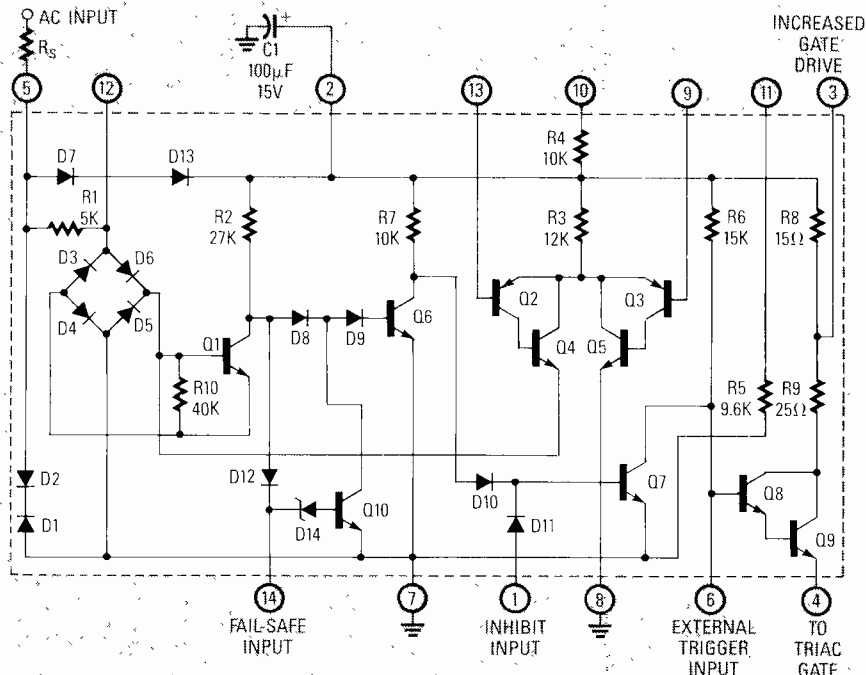


FIG 11—THE CA3059'S internal circuit and necessary external components.

(R_S), which should have a value of 12K at 5W for 117-volt use. Diodes D1 and D2 function as back-to-back zeners that limit the potential on pin 5 to ± 8 volts. On

positive half-cycles, D7 and D13 rectify that voltage and generate 6.5 volts across external capacitor C1. That capacitor stores enough energy to drive all internal

circuitry. It also provides adequate drive to the gate of the Triac, and a few mA of current are available for powering external circuitry.

Bridge rectifier D3–D6 and transistor Q1 function as a zero-crossing detector, with Q1 being driven to saturation whenever the pin-5 voltage exceeds $-3V$. Gate drive to an external Triac can be provided (via pin 4) from the emitter of the Q8/Q9 Darlington pair; that current is available only when Q7 is off. When Q1 is on (i. e., the voltage at pin 5 exceeds $-3V$), Q6 turns off through lack of base drive, so Q7 is driven to saturation via R7, so no current is available at pin 4.

The overall effect is that gate drive is available only when pin 5 is close to zero volts. When gate drive is available, it is delivered as a narrow pulse centered on the crossover point; the gate-drive current is supplied via C1.

The CA3059 incorporates several transistors (Q2–Q5) that may be configured as a differential amplifier or a voltage comparator. Resistors R4 and R5 are externally available for biasing the amplifier. Q4's emitter current flows via the base of Q1; the configuration is such that gate drive can be disabled by making pin 9 positive relative to pin 13. The drive can also be disabled by connecting external signals to pin 1, pin 14, or both.

Figures 12 and 13 show how the CA3059 can provide manually-controlled zero-voltage on/off Triac switching. Each circuit uses a switch (S1) to enable and disable the Triac's gate drive via the IC's differential amplifier. In the Fig. 12 circuit, pin 9 is biased at $V_{CC}/2$ and pin 13 is biased via R2, R3, and S1. The Triac turns on only when S1 is closed.

In Fig. 13, pin 13 is biased at $V_{CC}/2$ and pin 9 is biased via R2, R3, and S1. Again, the Triac turns on only when S1 is closed. In both circuits, S1 handles maximums of 6 volts and 1 mA. In both circuits C2 is used to apply a slight phase delay to pin 5 (the zero-voltage detecting terminal); that delay causes gate pulses to be delivered after the zero-voltage point, rather than straddling it.

Note that, in the Fig. 13 circuit, the Triac can be turned on by pulling R3 low, and that it can be turned off by letting that resistor float. The circuits shown in Fig. 14 and Fig. 15 illustrate how that ability can increase the versatility of the basic circuit. In Fig. 14, the Triac can be turned on and off by transistor Q1, which in turn can be activated by any low-voltage circuit, even CMOS devices. And Fig. 15 shows how to use the circuit with an optocoupler.

Figure 16 shows how the Signetics TDA1024 can be used in a similar circuit to provide optically coupled zero-voltage Triac control.

To complete this section, Fig. 17 and Fig. 18 show several ways of using the

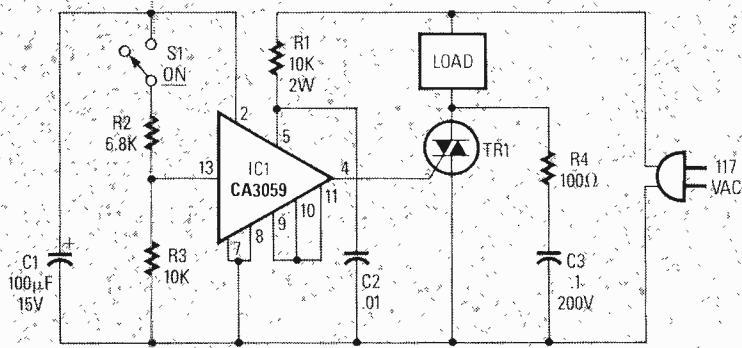


FIG 12—ZERO-VOLTAGE line switch built from the CA3059.

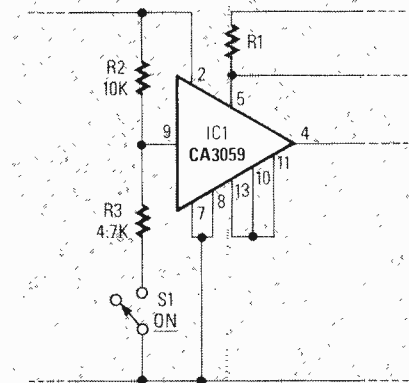


FIG 13—ALTERNATE CA3059 zero-voltage switch.

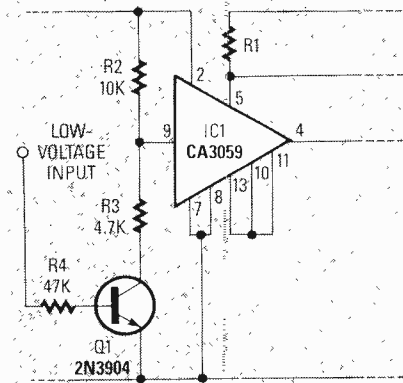


FIG 14—TRANSISTOR-CONTROLLED CA3059 switch.

CA3059 so that the Triac operates as a light-sensitive dark-operated power switch. In both designs the IC's built-in differential amplifier is used as a precision voltage comparator that turns the Triac on or off when one of the comparator input voltages goes above or below the other comparator input voltage.

Figure 17 is the circuit of a simple dark-activated power switch. Here, pin 9 is tied to $V_{CC}/2$ and pin 13 is controlled via the R2-R5 resistive string. In bright light, photocell R4 has low resistance, so the voltage at pin 9 exceeds that at pin 13, and the Triac is disabled. In darkness, the photocell has a high resistance, so the pin

13 voltage exceeds that at pin 9, and the Triac is enabled. The circuit's switching point is set with R3.

Figure 18 shows how a degree of hysteresis or "backlash" can be added to the previous circuit. Doing so prevents the Triac from switching in response to small changes (passing shadows, etc.) in ambient light level.

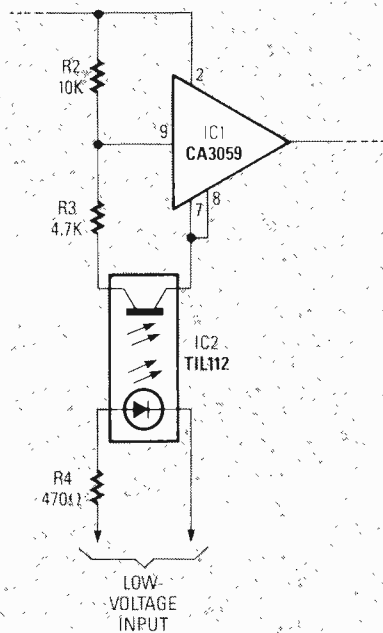


FIG 15—OPTICALLY COUPLED CA3059 switch.

Electric-heater controllers.

A Triac can easily be used to provide automatic room-temperature control by using an electric heater as the Triac's load, and either thermostats or thermistors as the thermal feedback elements. Two

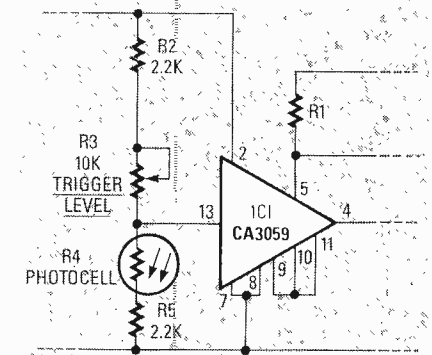


FIG 17—DARK-ACTIVATED zero-voltage switch.

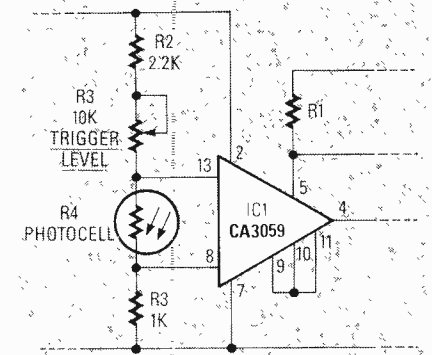


FIG 18—DARK-ACTIVATED zero-voltage switch with hysteresis.

methods of heater control can be used: automatic on/off power switching, or fully automatic proportional power control. In the former case, the heater turns fully on when room temperature falls below a preset level, and it turns fully off when the temperature rises above that level.

In proportional power control, the average power delivered to the heater is automatically adjusted so that, when room temperature is at the preset level, the heater's output power self-adjusts to precisely balance the thermal losses of the room.

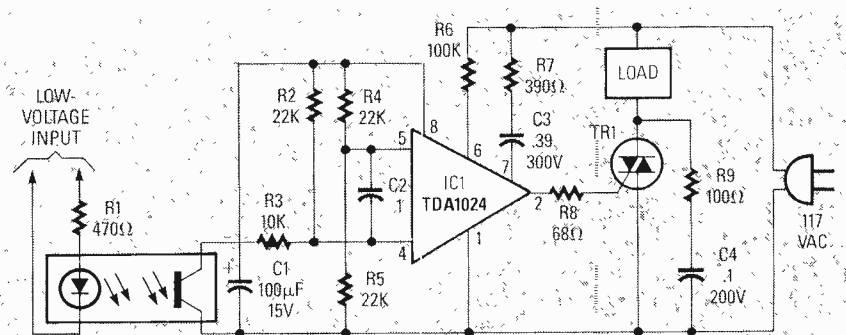


FIG 16—OPTICALLY COUPLED TDA1024-based zero-voltage switch.

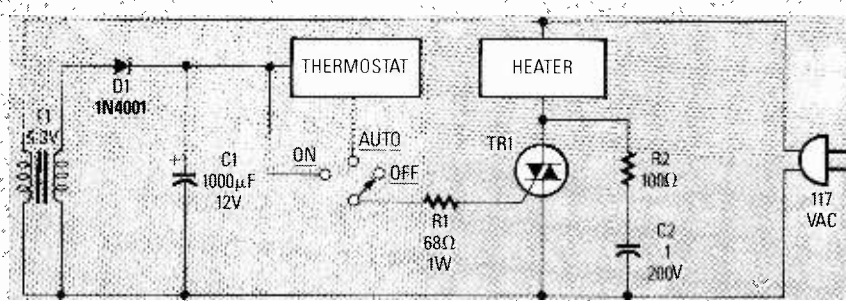


FIG 19—THERMOSTAT-SWITCHED heater controller.

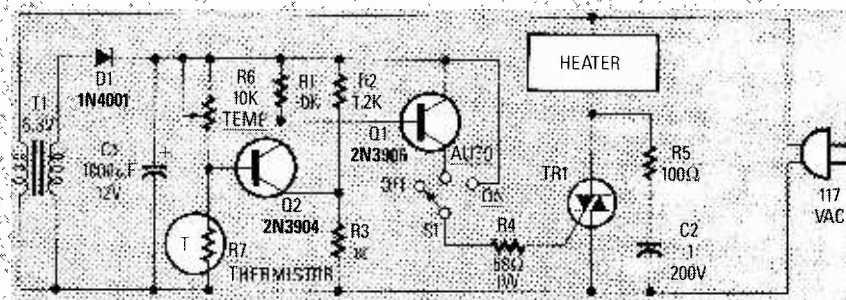


FIG 20—THERMISTOR-SWITCHED heater controller.

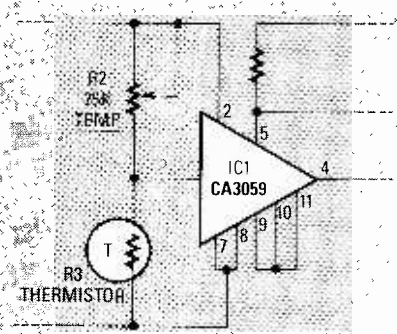


FIG 21—HEATER CONTROLLER with thermistor-regulated zero-voltage switching.

Because of the high power requirements of an electric heater, the circuit must be carefully designed to minimize RFI generation. The designer's two main options are to use either continuous DC gating or synchronous pulsed gating. The advantage of DC gating is that, in basic on/off switching applications, the Triac generates zero RFI under normal running conditions; the disadvantage is that the Triac may generate very powerful RFI as it is turned on. The advantage of synchronous gating is that no high-level RFI is generated as the Triac turns on; the disadvantage is that the Triac generates continuous low-level RFI under normal running conditions.

Figures 19 and 20 show several DC-gated heater-controller circuits. In both cases the DC supply is derived via T1, D1, and C1, and the heater can be controlled either manually or automatically via S1. The Fig. 19 circuit is turned on and off by the thermostat, depending on its temperature.

The Fig. 20 circuit, on the other hand, is controlled by Negative Temperature Coefficient (NTC) thermistor R7 and transistors Q1 and Q2. The network composed of R2, R3, R6, and R7 is used as a thermal bridge, and Q2 acts as the bridge-balance detector. Potentiometer R6 is adjusted so that Q2 just starts to turn on as the temperature falls to the desired level. Below that level, Q2, Q3, and the Triac are all fully on; above that level all three components are cut off.

Because the gate-drive polarity is al-

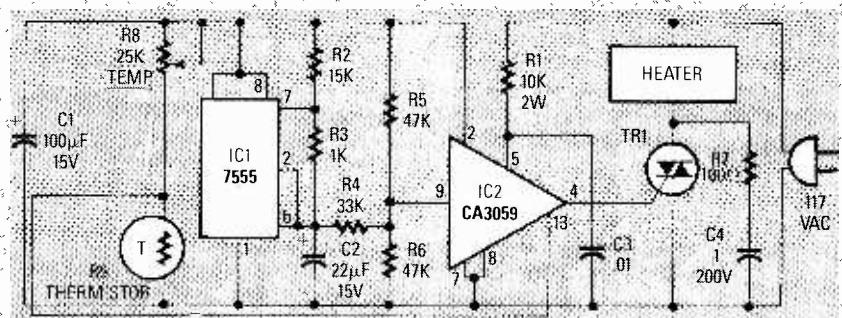


FIG 22—HEATER CONTROLLER with precision temperature regulation.

ways positive, but the Triac's main-terminal current alternates, the Triac is gated alternately in the +I and +III quadrants, and gate sensitivity varies tremendously between them. (See our discussion of gate sensitivity in the September issue.) Consequently, when the temperature is well below the preset level, Q1 is driven fully on. Therefore, the Triac is gated on in both quadrants, so it provides full power to the heater. However, when the temperature is very close to the preset value, Q1 is driven on "gently," so the Triac is

gated in the +I mode only, and the heater operates at half maximum power drive. The circuit thus provides fine temperature control.

Synchronous circuits

Figure 21 shows how a CA3059 can be used to build a synchronous thermistor-regulated electric-heater controller. The circuit is similar to that of the dark-activated power switch of Fig. 17, except that the thermistor (R3) is used as the sensing element. The circuit is capable of maintaining room temperature within a degree or so of the value set by R2.

To complete our discussion of heater controllers, Fig. 22 shows the circuit of a proportional heater controller that is capable of maintaining room temperature within 0.5°C. In that circuit a thermistor-controlled voltage is applied to the pin-13 side of the CA3059's comparator, and a repetitive 300-mS ramp signal, centered on $V_{CC}/2$, is applied to the pin-9 side of the comparator from astable multivibrator IC1.

The action of the circuit is such that the Triac is synchronously turned fully on if the ambient temperature is more than a couple of degrees below the preset level, or is cut fully off if the temperature is more than a couple of degrees above the preset level. When the temperature is within a couple of degrees of the preset value, however, the ramp waveform comes into effect and synchronously turns the Triac on and off once every 300 mS, with a Mark/Space (M/S) ratio that is proportional to the temperature differential.

For example, if the M/S ratio is 1:1, the heater generates only half of maximum

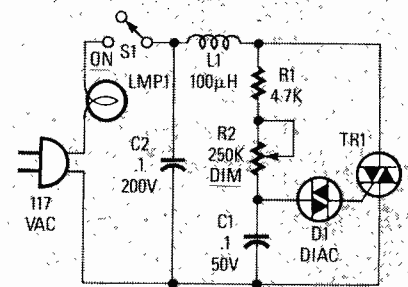


FIG 23—SIMPLE LAMP DIMMER.

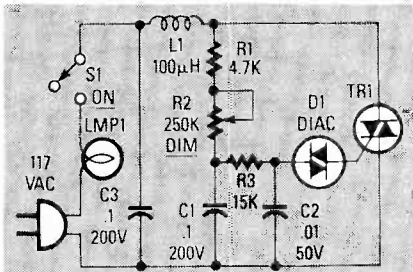


FIG 24—IMPROVED LAMP DIMMER with gate slaving.

Lamp-dimmer circuits

A Triac can be used to make a lamp dimmer by using the phase-triggered power-control principles discussed last time. In that type of circuit, the Triac is turned on and off once in each line half-cycle, its M/S ratio controlling the mean power fed to the lamp. All circuits of that type require the use of a simple LC filter in the lamp's feed line to eliminate RFI.

The three most popular methods of obtaining variable phase-delay triggering

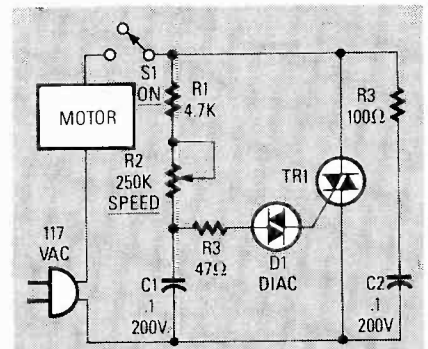


FIG 27—UNIVERSAL-MOTOR light-duty speed controller.

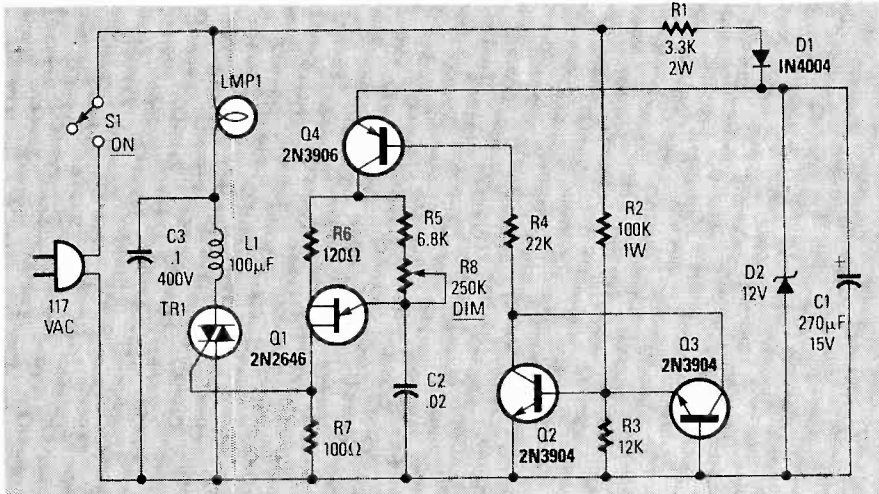


FIG 25—UJT-TRIGGERED zero-backlash lamp dimmer.

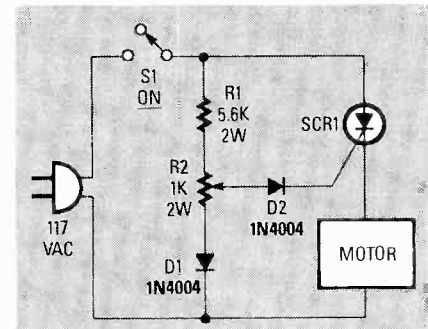


FIG 28—SELF-REGULATING UNIVERSAL-MOTOR heavy-duty speed controller.

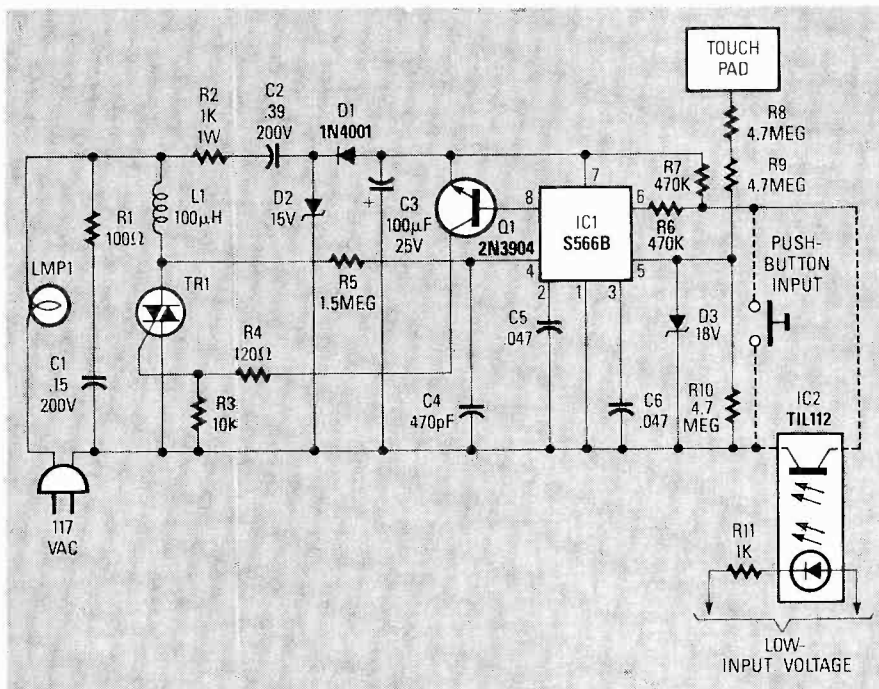


FIG 26—SMART LAMP DIMMER controlled by a Siemens S566B.

power, and if the mark/space ratio is 1:3 it generates only one quarter of maximum power. The net effect is that the heater does not switch fully off, but generates just enough output power to match the thermal losses of the room precisely. As a result, the circuit provides very precise temperature control.

are: (1) Diac plus RC phase-delay network; (2) line-synchronized variable-delay UJT trigger; (3) special-purpose IC as the Triac trigger.

Figure 23 shows the circuit of a Diac-triggered lamp dimmer. A defect of that type of design is that it suffers from considerable control hysteresis or backlash.

If the lamp is dimmed by increasing the R2's value almost to maximum, the lamp will not go on again until R2 is reduced to about 80% of the former, at which it burns at a fairly high brightness level. Backlash is caused because the Diac partially discharges C1 each time the Triac fires.

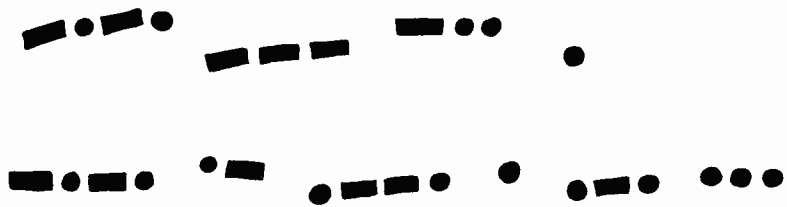
Backlash can be reduced by wiring a 47-ohm resistor in series with the Diac, to reduce its effect on C1. An even better solution is to use the gate-slaving circuit shown in Fig. 24, in which the Diac is triggered from C2, in which "copies" C1's phase-delay voltage, but provides discharge isolation through R3.

If backlash must be eliminated altogether, the UJT-triggered circuit shown in Fig. 25 can be used. The UJT (Q1) is powered from a 12-volt DC supply built around Zener diode D2. The UJT is line-synchronized by the Q2-Q3-Q4 zero-crossing detector network, in which Q4 is turned on (thereby applying power to the UJT) at all times *other* than when line voltage is close to zero.

So, shortly after the start of each half-cycle, power is applied to the UJT circuit via Q4, and some later time (which is determined by R5, R8, and C2), a trigger pulse is applied to the Triac's gate via the UJT.

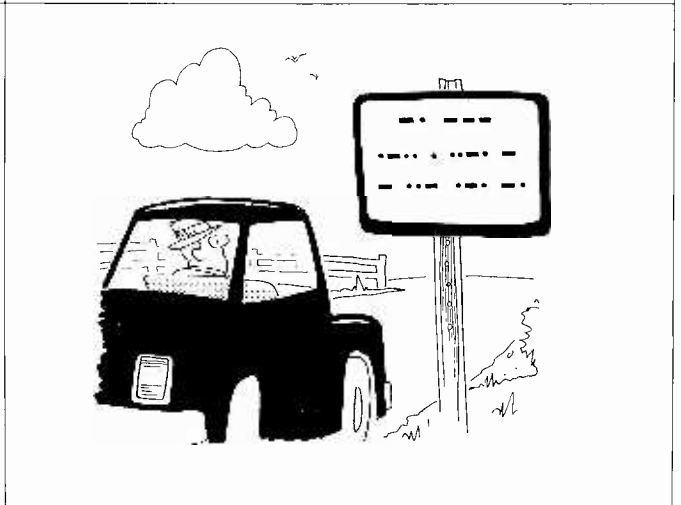
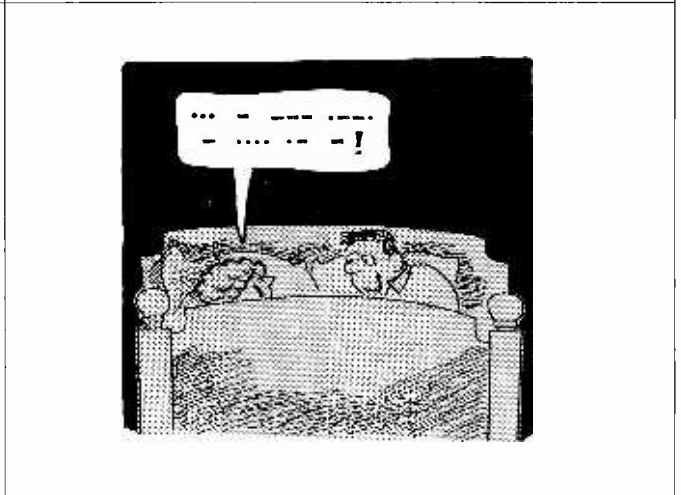
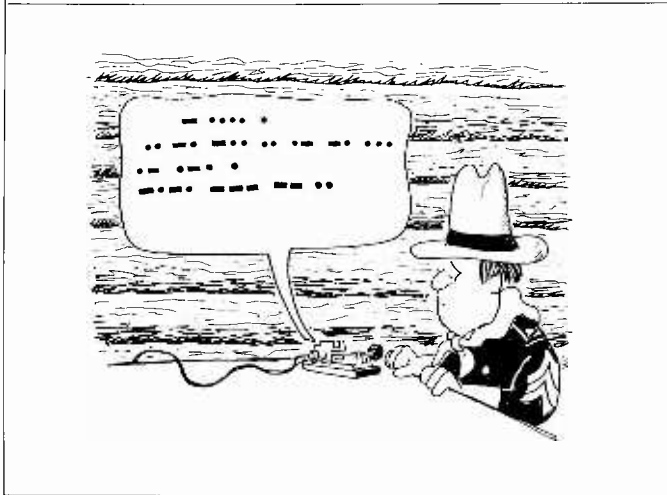
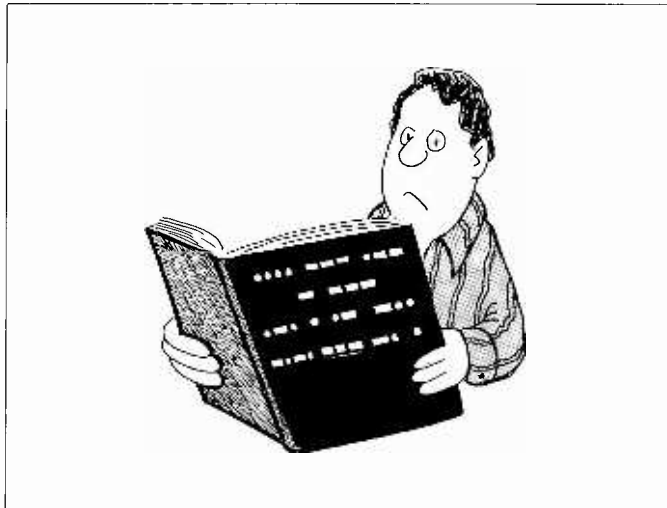
Figure 26 shows how a dedicated IC, the Siemens S566B "Touch Dimmer," can be used to build a smart lamp dimmer that can be controlled by several devices simultaneously: a touch pad, a pushbutton switch, or an infrared link.

continued on page 164



(CODE CAPERS)

by JACK
SCHMIDT





POOR MAN'S STORAGE SCOPE

DUKE BERNARD

With nothing more than an oscilloscope, a video camera, and a VCR, hobbyists can have many of the advantages of fancy logic analyzers and digital storage scopes.

WHEN A NEWLY DESIGNED PIECE OF ELECTRONICS equipment or an existing piece of equipment that has gone bad is being debugged, it's common practice to trace signal paths by using an oscilloscope. With digital equipment, logic analyzers are often used to check timing and even store the waveforms on floppy disk for future evaluation. Such equipment is very convenient to use, but very expensive.

When professional designers do a thorough job of evaluating a new design, they record the waveforms at each major node in the system. Traditionally, that has been done by taking Polaroid photographs of oscilloscope traces. The process requires fastening the scope probe to a circuit trace on a printed circuit board long enough to take the photograph, developing the print, recording the appropriate oscilloscope scales, and then moving on to the next location to repeat the process. Things proceed in an orderly manner when documenting a new design that is working properly, though it surely helps to have an assistant. However, when either a new design or an existing system is faulty, circuit tracing usually becomes less orderly, with the scope probe stuck here and there looking for suspect signals.

Life gets even more interesting when the system works perfectly 99% of the time, but has a glitch that causes an error every few hours or so. In industry, troubleshooting such a glitch generally calls

for powerful logic analyzers that can be triggered by the fault condition and then recall the signals that preceded the error. Unfortunately, the hobbyist and the small-business electronics professional generally cannot afford the tens of thousands of dollars that such equipment costs.

With a little ingenuity, however, commercially available video equipment can be made to do many of the tasks of much more expensive equipment, and in some cases do it better. Unlike most commercial logic analyzers, which record only one's and zero's, the technique described in this article works well for either digital or analog signals. It was first used by the author to find an intermittent failure in an asynchronous coupled multi-CPU digital system. It has subsequently been used for debugging simpler systems. It can also be used to turn a simple oscilloscope into a storage scope for reviewing transient waveforms.

The concept is simple and rather straightforward. All that is required is a VCR with top-quality special effects; that is, clean, jitter-free stop frame, fast forward and reverse, and slow motion such as that provided by the top-of-the-line four-head units or the new digital VCR's that feature digital frame storage. A video camera and a video monitor complete the list of required equipment.

A word about the video camera: A high-end unit is not required; a simple

black-and-white surveillance camera will do fine. However, if an expensive color camera is used, to prevent burning the image tube care should be taken not to leave the camera pointed at a very bright trace on the scope for long periods of time. That is less of a concern if the camera uses a solid-state imager.

More savings

In addition to the obvious savings in equipment cost, it's interesting to compare the number of oscilloscope traces that can be recorded on a two hour roll of VCR tape versus the cost of trying to capture the same amount of information on film. Assume that for recording the waveforms of a new system, each point in the system is recorded for 10 seconds. That is generally enough time to record the scope settings and what point in the circuit is being monitored on the voice track. That yields six traces recorded per minute, or 720 in two hours. At about 50 cents a print for instant film, to record as many traces the cost would be \$360. Compare that to the cost of even the highest quality T120 tape. At even faster recording speeds an even greater savings can be realized.

While hard copies are often desired in addition to the tape recordings, the taped waveforms can be reviewed at leisure and the most important ones photographed off the TV monitor, although with some lim-

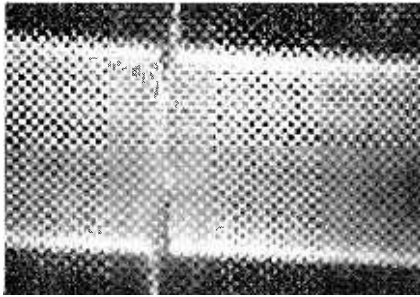


FIG. 1—USING A VCR, this glitch in the system clock waveform was found.

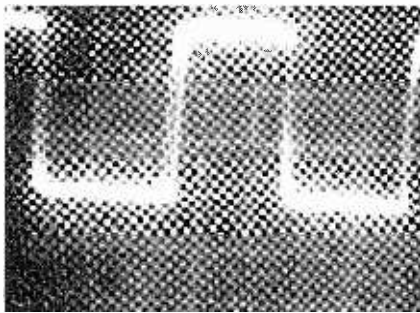


FIG. 2—FURTHER INVESTIGATION found a waveform with a timing shift during alternate leading edges.

itations. Meanwhile, a very extensive set of waveforms have been captured, which can be reviewed later if the system develops a problem.

A typical application

The problem that initiated the effort to record oscilloscope traces with a VCR was one of those periodic, hard-to-trace glitches that had cropped up during the testing of a new design. In frustration, we decided to record various oscilloscope waveforms with a VCR until one was found that changed appreciably just before the system being tested recorded an error (since the system being tested had a real time clock, it was possible to let it run to give an indication of when an error occurred).

Once an error was noted, the VCR tape was advanced to the approximate time of the error and the waveforms were examined. Finally, a glitch was found on the system's clock waveform; that is shown in Fig. 1. At first, the glitch was thought to be the direct cause of the error, but it wasn't. However, by knowing what to look for, the same conditions that created the glitch in the clock waveform (several high-current devices switching simultaneously) were programmed, and more waveforms were recorded.

The waveform shown in Fig. 2, a sub-clock signal, was found to be the culprit. As shown by the dual-trace leading edge, the signal's timing changed on alternate leading edges during the time that the system clock had the disturbance, causing a synchronization problem. That timing change was further traced to ringing on the waveform, as shown in Fig. 3.

Budget storage scope

Having found the VCR so useful in recording occasionally occurring waveform disturbances for future review, we looked into using a VCR as a "poor-man's" storage oscilloscope. Events that happen as a transient rather than a repetitive occurrence are hard to capture on an ordinary oscilloscope. One example is speech. With so much interest in speech synthesis and speech recognition, it's often necessary to observe the patterns created by different words and compare their similarities and differences. But since speech waveforms are transient in nature, it's hard to do comparative work using only a standard scope.

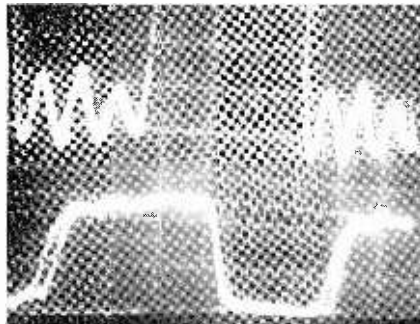


FIG. 3—RINGING ON THE WAVEFORM was finally found to be the cause of the problem.

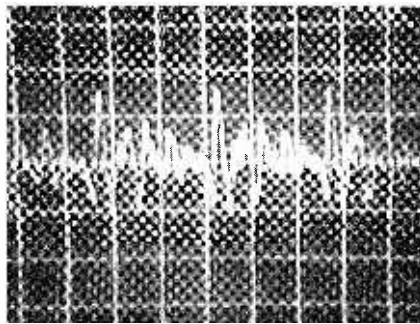


FIG. 4—THE WORD "HELLO" as captured by a video camera and a VCR. The varying intensity of the trace is caused by using a time base longer than a single TV field (about 16 milliseconds).

Recording a waveform on a VCR and then playing it back a frame at a time allows the repetitious patterns in certain speech sounds to be observed. Part of the word "hello" as captured by a VCR is shown in Fig. 4. Note the non-uniform appearance of the trace. That is caused by using a time base that is longer than the TV field rate of 16 milliseconds ($1/60$ second). Then, the camera can not capture a trace in a single field; instead it does so over two or more fields, causing a stroboscopic effect. The fainter parts of the image are seen only because of image persistence on the CRT screen and/or in the camera pickup. That does not prevent you from examining the waveform, since you can use the frame advance to examine the event one frame at a time, but it does make it difficult to obtain a good hard

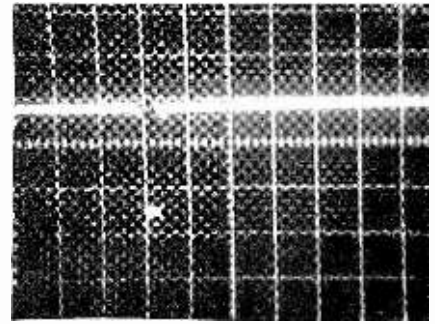


FIG. 5—A CAMERA/VCR SETUP is ideal for viewing short duration transients, such as a voltage interruption caused by a relay's contact bounce.

copy (photograph) from the monitor, as evidenced by Fig. 4.

To get good results when using a VCR's frame-advance feature as a poor-man's storage scope requires some experimenting to obtain the proper trace intensity. Since most video cameras can accommodate fairly low light levels, a trace barely visible when viewed directly may show up quite well when viewed on a TV monitor. To set intensity, then, repeatedly trigger the scope, adjusting the trace intensity until it looks right on the monitor.

Let's close out our discussion by looking at a simple application. One problem that plagues circuit designers is that of contact bounce, a mechanical problem that all mechanical switches and relays are subject to.

Figure 5 shows the output waveform from a relay. When the contacts close, the voltage goes high, triggering the scope. A few milliseconds later, however, the contacts bounce open and closed, creating a momentary voltage interruption.

The transient caused by the bounce can disrupt the proper operation of a circuit and is often difficult to eliminate. But by using a VCR to record the scope trace, you can study the waveform at leisure, allowing you to be certain that your fix is working properly.

Other uses

As you can see, a VCR can make collecting and analyzing data over long periods of time much easier, especially if you can't afford an expensive logic analyzer or a storage scope. And a VCR can be used to record any instrument's readings over time.

For example, the author has used a VCR to record changes in an oscillator's frequency versus temperature. After connecting them to the circuit under investigation, a frequency meter and an electronic thermometer were placed side-by-side and their readings were recorded by a VCR as the circuit was warmed. Fast-forward scanning was later used to find appropriate temperature intervals, allowing the oscillator frequency-versus-temperature data points to be recorded very quickly.

R-E

BLUE BOX

continued from page 32

office to silence the ringing signal. When Pop released S4, the folks can talk to Junior without Junior getting charged because his AMA tape did not show his call was answered—the DC loop must be closed for at least three-seconds for the AMA tape to show Junior's call was answered. All the AMA tape showed is that Junior let the phone ring at the old homestead for almost 30 minutes; a length of time that no Bell Operating Company is likely to believe twice!

A modern Red Box is simply a conventional telephone that's been modified to emulate the vintage 1940 military field telephone. Aside from the fact that the operating companies can now nail every Red Box user because all modern billing equipment shows the AMA information concerning the length of time a caller let the target telephone ring, it's use has often put severe psychological strain on the users.

Does getting electronics mixed up with psychology sound strange? Well it isn't because it's what helped Ma Bell put an end to indiscriminate use of the Red Box. The heyday of the Red Box was the 1950's and 1960's. Mom and Pop were lucky to have finished high school, and almost without exception, both elementary and high schools taught honesty and ethics. Mom and Pop didn't have the chance to take college courses in *Stealing 101* that masqueraded under quaint names such as *Business Management*, *Marketing*, or *Arbitrage*. When Junior tried to get the old folks to use his "free telephone" they just wouldn't go along. So Junior installed the Red Box at his end. He gave one ring to notify the family to call back. When Pop called Junior, it was Junior who was using the Red Box. Problem was, Junior didn't know that the AMA tape for Mom and Pop's phone showed a 20- or 30-minute ringing. When Ma Bell's investigators showed up it was at the old homestead; and it was only then that the folks discovered their pride and joy had been taught to steal.

There are no hard facts concerning how many Red Boxes were in use, or how much money Ma Bell lost, but one thing is known: she had little difficulty in closing down Red Boxes in virtually all instances where the old folks were involved because Mom and Pop usually would not tolerate what to them was *stealing*. If you as a reader have any ideas about using a Red Box, bear in mind that the AMA (or its equivalent) will get you every time, even if you use a phone booth, because the record will show the number being called, and as with the Blue Box, the people on the receiving end will spill their guts to the cops.

R-E

WIDEBAND AMPLIFIER

continued from page 34

tween the NE5205 case and the groundplane. If you prefer, electrically-conductive epoxy may be used for that.

Capacitors C1, C2, and C3 are 0.1- μ F surface-mounted high-frequency ceramic chips. A small drop of quick-drying adhesive such as *Crazy Glue* will hold them stationary during soldering. Solder coupling capacitors C1 and C2 to their respective pads on the input and output signal traces. Bridge the gap between V_{CC} and the small ground plane with decoupling capacitor C3 and solder it into place.

The last step in the assembly portion of the project is to strap the top and bottom ground planes together. Don't run long wires to do that. A better, and a far easier way to accomplish the task is with inexpensive, self sticking $\frac{1}{4}$ -inch copper tape; the kind used in making stained-glass windows. (The tape can be purchased at most craft centers.) Wrap the tape around the edge of the board to the top and bottom ground planes and then flow-solder the tape to the copper foils.

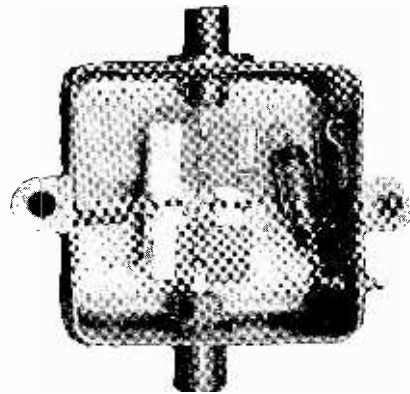


FIG. 7—THE AMPLIFIER CAN BE BUILT into existing equipment, or made part of a stand-alone device, such as this CATV amplifier.

Applications

The amplifier can be used in a wide variety of applications, such as a CATV line amplifier, a 70-MHz satellite amplifier, or a composite video amplifier. The circuit can also improve the operation of 2- to 160-meter amateur radio equipment; AM, FM, CB, and shortwave radios; 50-ohm test equipment; frequency counters; and oscilloscopes. By using a phantom power source on the signal lead, it can even be used as a rooftop antenna pre-amplifier, such as shown in Fig. 6. Your application will determine whether or not a case is needed. The board either can be incorporated in a piece of existing equipment or mounted in an RF-tight case (see Fig. 7) for stand-alone use.

R-E

GRAVITY

continued from page 119

ponent arriving from other directions such as vectors a and b will be largely canceled because those vector components are not parallel with the electric field in the capacitor; leading to reduced gravity components a' and b' . Only the gravity components arriving along a line through the observer's meridian and the center of the earth will be most effective in exciting the capacitor element of the gravity detector.

Gravity telescope

The gravity-signal detector "sees" the zenith of the observer's celestial sphere through a very small aperture. That small aperture "beam" sweeps across the celestial sphere (at the observer's latitude) at the rate of the earth's rotation. In that respect, the earth's rotation has a period of 23 hours, 56 minutes, and 4.1 seconds of civil (ordinary) time, and that period is called a *sidereal day*.

As shown in Fig. 9, the Milky-Way galaxy center as observed on the author's meridian appears predictably about four minutes earlier each day with respect to standard (civil) times. Also note that another gravity event occurs approximately 35 seconds before the galaxy-center appears, which was used by the author as a marker. The author suggests that the chart recordings are gravity signals emitted from the Milky-Way galaxy center, and *not* random electrical fluxuations that traditionalists call noise.

To locate astronomical objects, use a circular-type-chart star finder, which is more generally known as a planisphere. The charts are calibrated for different Earth latitudes in standard (civil) times for each day of the year.

The sky charts, or planispheres, are also calibrated in terms of right ascension and declination, so that objects may be located in terms of those parameters if they are known. For example, the galaxy center is known to be located in the Sagittarius constellation region in the southern hemisphere at about 17.7 hours right ascension and about -29° declination. Locating that spot on the meridian of the observer's celestial sphere will enable the experimenter to use the planisphere to determine the day and time of day when the Milky-Way galaxy center will appear there.

The gravity detection process is shown in Fig. 10 for two common galactic gravity events. A Supernova implosion will generate an oscillatory modulation of the g -field to an observer at position "A". A Black Hole, on the other hand, will actually reduce the g -field for an observer at position "B". The effects of those cosmic events, and others, will now be considered in more detail.

continued on page 162

COMMERCIAL ZAPPER*continued from page 40*

sure that the buffer amps (IC1-a-IC1-d) are not in the same physical package as the processing amps (IC2-a-IC2-d). Also, good decoupling capacitor should be used with high-frequency op-amps such as TL074. Use a 1- μ F tantalum or a 10- μ F electrolytic (C15) for decoupling.

Alignment and troubleshooting

To align the commercial killer, adjust the detector-gain potentiometer (R41) to maximize the number of comparator transitions during commercials. Begin by connecting the commercial killer to the stereo receiver's tape-monitor loop. Set the receiver to FM and select the tape-monitor mode. Because the audio level may vary from station to station, tune to the station of greatest intended use. And remember, the commercial killer works best with easy-listening formats. During commercials, adjust R41 to maximize attenuation by watching the FADE LED. Slight readjustment may be necessary to provide the fewest zapping errors without performance degradation.

If the commercial killer fails to work, make sure that the power supply is providing the correct voltage, and that V_{REF} is about 13.5 volts.

If the voltages are correct, then verify that you can obtain waveforms like those shown in Fig. 3-Fig. 5. If the peak signal level at the inverting input of IC2-b cannot be adjusted (via R41) to exceed 2.5 volts, the signal level out of the receiver may be unusually low, so the value of R41 may need to be increased.

If the rate of transitions at TP4 is low during music and high during commercials (but attenuation is not proportional to the rate of transitions), verify the following.

- When there is no signal present, the voltage at TP5 should be within 0.2 volts of the voltage at the non-inverting input of IC1-c.
- During a commercial, the voltage at TP5 should be at least three volts less than the voltage at the non-inverting input of IC1-c.

If the first condition is not met, there will be attenuation during music. Diode D4 should be reverse-biased with no signal present. If it is not, and if the voltage at TP4 is about eight volts, it may be necessary to reduce R18.

If the second condition is not met, there will be insufficient attenuation during commercials. If TP4 is approximately eight volts with no signal present, it may be necessary to decrease R19 or R20.

Last, if fading occurs, but the LED does not light, it may be connected to the circuit backwards. **R-E**

DIGITAL SPEEDOMETER*continued from page 52*

voltage at the appropriate pins of each IC. After debugging any problems, apply a test signal to the speedometer. Connect a sine-wave generator to P1 and apply a one-volt peak-to-peak signal. For test purposes, set S1 so that the first three switches are off, the next three are on, and the last two are off (00011100). Also, set the generator's frequency to 138 Hz. If everything is working correctly, the seven-segment LED's should display a value of 60, and at least some of the discrete LED's should be lit.

Installation

The most difficult part of construction is installing the speedometer in an automobile. The two main tasks are installing the PC-board assembly and installing the magnetic sensor and magnets.

To install the boards, first choose a suitable mounting location for the unit, one that provides a good view of the device, but does not obstruct the driver's field of vision. After choosing your mounting location, prepare it to receive the speedometer. Whether you are building a custom enclosure or planning to install the assembly in the dash, use a front panel that will both protect the display and make it readable in bright sunlight.

Smoked Plexiglass makes an excellent front panel, especially if it is lettered and masked. Masking is accomplished by painting the area not occupied by displays or LED's. The easiest method is to mask all areas that are occupied by displays and LED's on the back side of the front panel and then paint the back side of the panel with black spray paint. Apply several coats to ensure a uniform covering. After the paint dries, peel off the masking tape and install the front panel.

The next step is to secure the magnets to the driveshaft (or output shaft) and mount the pick-up coil to the body or chassis of the automobile. To do that, you'll probably have to drive your car up on ramps. If you do not have a set of ramps, borrow or buy a set. Never get under a car that is supported only by jacks. It's also a good idea not to work under a car alone.

After raising the car, find a suitable location for mounting the magnets. On rear-wheel-drive vehicles, the best location is at the front of the driveshaft, near the transmission. At that place the driveshaft has the least vertical movement, so the magnets will maintain a constant distance from the pick-up coil. To mount the magnets, locate them around the driveshaft at 90° intervals and secure them in some way. The magnets we used in our prototype come with a strap that simplifies installation; you can purchase the

set at a local auto-parts store or from the source mentioned in the Parts List.

On a front-wheel-drive vehicle, the magnets can be mounted reliably to the outer ring of the constant-velocity joint's dust boot near the transaxle. In that type of installation, there should be a metal strap on each side of the dust boot. Mount the magnets to the strap that is located nearest the transaxle, and secure the pick-up coil and its metal strip. If the boot is not easily accessible, the magnets may be mounted directly to the output shaft or one of the drive shafts, but be sure to place them where the least amount of vertical movement takes place.

Next mount the pick-up coil to the underside of the automobile using a strip of inch-wide metal. Of course, the length of the strip and the locations of the mounting holes will depend on your installation. But you'll probably want to bend the strip so that the front of the mounting coil and its bolt are about 1/2 inch from the magnets. Figures 7-a-7-d indicate several mounting schemes for driveshaft and transaxle installations.

After the magnets and pick-up coil are installed, run the signal wires from the pick-up coil through the fire wall to where the PC boards are located. Use plenty of wire ties or plastic tape. If you purchase the pick-up coil mentioned in the Parts List, you must replace its connector with a Molex-style connector.

Run a power wire from the mounting location to the fuse box and connect it to a circuit that is active only when the ignition key is in the *on* position. Remember to hook the ground wire to the chassis ground of the automobile.

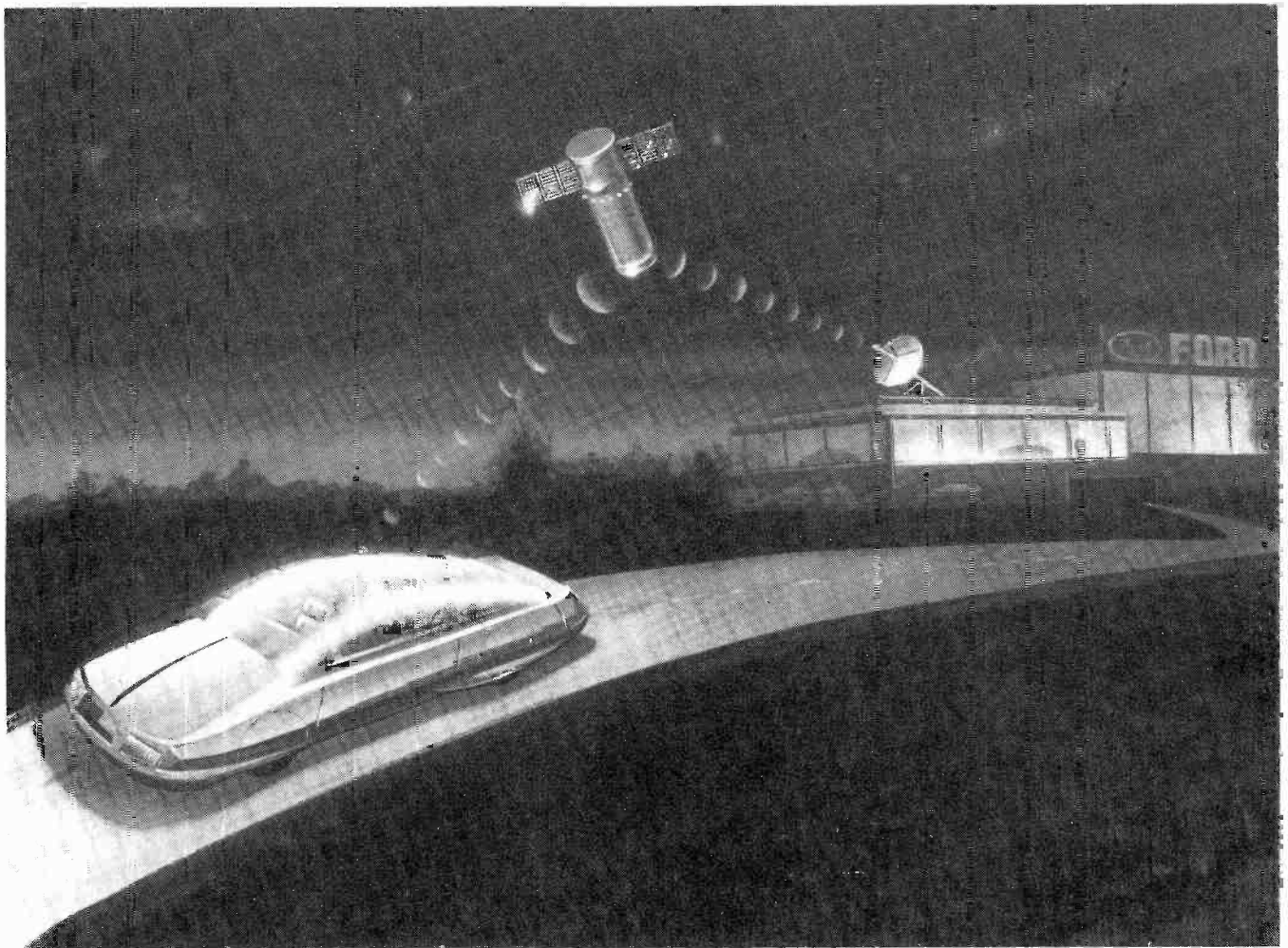
Calibration

To calibrate the speedometer, first decide whether you want the readout to be in miles or kilometers per hour. The next step can be accomplished in several ways. You can either calculate the speed of your driveshaft as discussed in the text box, or you can use the trial-and-error method.

To use the trial and error method, have a friend drive on an open stretch of highway, and, while watching your old speedometer, try setting S1 in different positions until the speedometer displays the correct value. Make sure your friend watches the road and his speed while you calibrate the speedometer! Next, have your friend drive at the "red line" speed, and set R34 so the first red LED lights up.

If the digital speedometer reads erratically while the vehicle is standing still, reduce the value of R6 from 470 ohms to 330 ohms or less. That reduces input sensitivity and prevents the unit from picking up electrical noise.

After calibration is complete, it's time for final installation. Mount the unit in its permanent housing, then secure and conceal all cables. **R-E**



THE AUTOMOTIVE WORLD OF THE 21st CENTURY

You're invited to test drive Ford's new 2001 model

Donald E. Petersen

ANY ATTEMPT TO DESCRIBE THE FUTURE is a hazardous exercise at best. By definition, it's an excursion into a world of fantasy. But fantasy can range from chimerical nonsense to a common-sense projection of a rational vision.

What follows here is the latter: a reasonable extrapolation of current automotive trends and technologies reaching out 14 years; a vision of the future of the automobile firmly based on technologies now emerging. Product planners and creative thinkers at Ford Motor Company have devoted considerable energies looking beyond conventional planning horizons—and into the 21st century.

When you think about it, 14 years ahead is not all that distant. Consider the fact that 14 years back was 1973—the year of the first OPEC-inspired energy crisis. To some of us, that doesn't seem very long ago at all.

Based on what we've learned since that time, however, it's safe to make one all-important prediction about the future: The businesses that survive into the 21st century will be the ones that have become obsessively customer-centered. We will realize the importance of producing products that meet the customers' demand for quality and supply their precise needs. We will learn, more skillfully than ever, to tap

the remarkable reserves of talent, energy, and unique ideas that the people who work in our plants and offices can bring to their jobs. We will discover new and more productive ways to energize that crucial resource and use it.

In the process of looking ahead, teams of Ford futurists have identified dozens of technologies that can be applied to our future vehicles—to their designs, to their onboard features, to the materials used in them, and to the way that they are manufactured. The technologies can provide automatic navigational guidance, security-alert protection, and adaptive peripheral vision systems.

For the driver, those technologies would mean on-board, direct-to-satellite communications links with dealer service departments allowing automatic diagnosis of any developing problems; high-efficiency air-purification systems; automatic passive-restraint systems; electronic light-emitting surfaces; auxiliary electrical power systems using photovoltaic cells integrated into the roof; and special glass coatings that reduce vision distortion from rain, repel dust, and retard formation of condensation.

Our vision of the future features modular construction of the automobile—using modules that can be easily reconfigured for urban use, for family vacations, or for long-distance travel.

But rather than just listing the features of the future car, let me invite you to imagine what it would be like to enter the showroom of a Ford dealer featuring the newly introduced 2001 model.

A future vision

As you enter the showroom, your first glimpse of the car conveys its strikingly aerodynamic appearance. As you move closer, you notice that its appearance results from more than just the “clean” basic shape. There are no apparent door handles, rear-view mirrors or antennas. The glass, which comprises all of the vehicle above the belt line, is flush with the lower body and shaped with compound curves to conform to the car’s smooth aerodynamic form.

A Customer Information Specialist (CIS) introduces herself and explains the vehicle’s overall Airflow Management System—which includes such automatic features as variable ride-height control, variable skirts and spoilers that cancel all induced lift, and variable air inlet/outlet ducts—all under the coordinated control of a central electronic command system.

She points out the wide tires that blend into smooth, disc-like, body-colored wheels and explains how the tire-reinforcing cords are continuous with, and flow into the molded plastic wheels, resulting in a perfectly balanced, light-weight, high-performance integral element.

As you stroll around the car, you wonder at the apparent lack of turn-signal indicators, side marker lamps, or tail/brake lights. The CIS explains that all of those functions are now accomplished by electronic light-emitting surfaces, which have been integrated into the glass and selected body areas, and are almost invisible unless they are lighted.

When lighted, the areas become highly visible and vary in intensity, color, and shape to clearly communicate the driver’s intent and the vehicle’s operating condition, such as its rate of deceleration or acceleration. She illustrates her explanation by activating the left turn signal. Instantly, you see a large, bright, flashing

yellow arrow appear on the bottom left region of the rear window area.

To open the car door, the CIS demonstrates the Keyless Entry feature, which is activated by a coded sequence of touches to sensitive areas on the side window. In response to the proper code, the door automatically opens; an exterior handle is no longer needed.

Now that the door is open, the CIS invites you to slide into the driver’s seat. The seat momentarily feels alive as it automatically adjusts to conform to your body, like a fluid-filled bean-bag chair.

She continues by explaining that the Automatic Total Contour Seat is part of an overall Individual Occupant Accommodation package that also provides individually selectable climate control and audio programming for each occupant.

The CIS points out that in place of rear-view mirrors, there are multiple electronic cameras that are individually programmable for the best direction and size of field. Those cameras are small and “look out” through the glass, so they are almost impossible to detect.

They display on a 3-segment screen located on the upper rim of the Driver Information Module and portray the environment behind and to both sides of the car. There are absolutely no blind spots, and the system senses non-visible infrared radiation; it works equally well at night and during inclement weather.

She points out that the same technology also operates a forward-looking infrared system that provides driver vision during heavy fog, rain, or snow conditions in the form of a heads-up display on the windshield where driver attention focuses.

The CIS now invites you to watch a short video presentation that illustrates some of the car’s construction details.

Modular construction

The holographic video show introduces the automobile as a breakthrough in the development of modular construction. You watch as 3-D representations of the vehicle’s basic building blocks appear out of nowhere and slowly rotate into correct positions, while a voice explains the advantages of that modular assembly.

You learn that the basic vehicle module is an occupant-protecting “cage” constructed of heat-treated alloy steel pre-forms that are bonded together with structural adhesives to form an incredibly strong and resilient structure. The narrator states that two-, four-, and six-passenger modules are available.

Front and rear-end modules attach to the central occupant cocoon with what appear to be about a dozen bolts. The integrated engine/transmission powertrain is itself a sub module that can be installed in either a front or rear module. For applications where 4-wheel drive is required, or where “dual power” is con-

sidered an asset, a powertrain module may optionally be installed in both the front and the rear.

Required tailoring of parameters such as suspension rates, damping characteristics, and brake proportioning is accomplished by appropriate programming of the central electronic control system.

The steering is also under electronic control—which automatically orchestrates complex 4-wheel steering responses to completely normal driver inputs. That effectively extends the performance range of the vehicle during any radical maneuvers.

The video show concludes by showing how the completed assembly of modules—which is basically a drivable vehicle—is skinned by large plastic panels which are corrosion-proof, damage-resistant, and easily replaced if required. A full-length, smooth plastic underpan reduces air turbulence under the vehicle and provides some drag-free “ground effects” road handling.

The CIS points out that additional modules will be introduced from time to time as market research uncovers new consumer needs. She emphasizes that all modules will be readily interchangeable, and it is even possible to rent a module and temporarily reconfigure the vehicle for short-term purposes such as vacations.

Flying the simulator

The CIS suggests that you spend a few minutes in the dealer’s vehicle simulator which will demonstrate the operation of various features. She explains that the simulator is based on aerospace flight-simulator technology.

Upon entering it and closing the door you are amazed at how life-like the experience is. The CIS joins you on the passenger side and gives you an operator authorization code that’s needed to activate the simulator.

Of course, the conformable seat has already adjusted to you, but you’ve experienced that earlier. You adjust the Adaptive Peripheral Vision sensors and the sound system to your preference. You notice that the sound system couples low-frequency response to your body directly through your seat, greatly enhancing the realism.

The CIS explains that you can now make several more personal-preference adjustments. The first is Climate Control. You select a temperature of 68° F, whereupon she reaches for her individual Occupant Accommodation control pad and selects a temperature of 72° F for her side.

Now you begin to “drive” the simulator while the CIS uses a special control to call up a range of road surfaces. As you begin to acquire a feel for the “vehicle,” she suggests that you experiment with the driver-preference controls which determine effective suspension-spring rates

and damping characteristics. Also, you experiment with the controls that program the steering effort, steering sensitivity, and simulated road-feel feedback. You converge on a combination of settings which feels best for you.

Since you are now "driving" the simulator in a more spirited fashion, the CIS asks if you would like to experiment with the instrument format. You sequentially review each of the 12 basic pre-programmed information formats as they appear on the colored flat-panel display of the Driver Information Module. Ultimately, you opt for an electronic representation of a few basic analog gauges augmented by a variable color bar-chart which graphically displays that all of the vehicle's critical systems are operating within their normal range.

As you really extend yourself at simulated high speed along a twisting road, you feel the conformable seat grip you tighter. Also, the instrumentation display simplifies to an easier-to-read, less-distracting format.

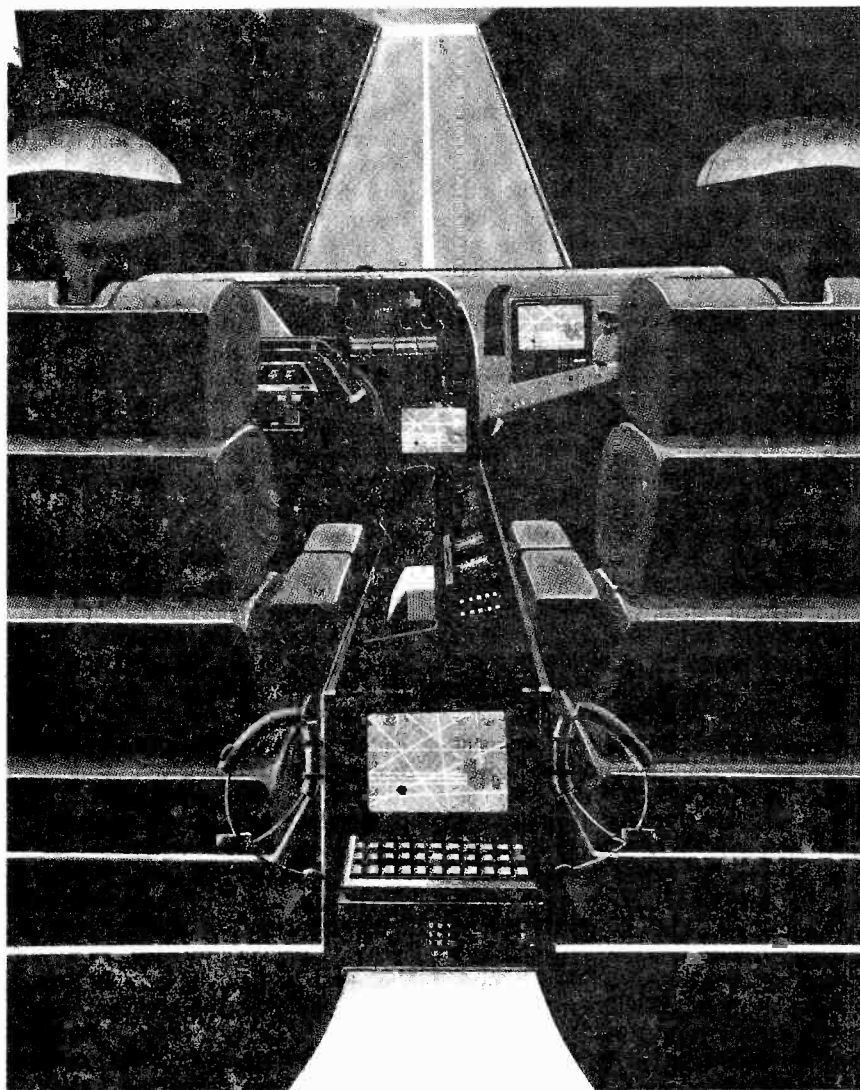
After several minutes of that, you do manage to find the limit and spin-out. You shut off the simulator and remark to the CIS how useful that experience was to you. You had no previous idea that a "road car" could be stably controlled at such high rates of lateral acceleration. You mention that you will probably now be a better driver should an emergency situation arise. She agrees and explains that the simulator has been used effectively for advanced driver training. But now it's time to try the real thing.

21st-century automotive service

On your way to the parking area where the demonstrator vehicle is parked, you pass by the dealer's service area and the CIS introduces you to the service manager. He describes the recent changes that have occurred in his department.

First, the new vehicle's central control-system contains a self-diagnostic feature that pinpoints the source of virtually all problems. Because of the car's highly modular construction, the preferred repair technique is to replace the offending module. In most cases, that can be accomplished in a couple of hours. The modules that are removed will be repaired either at the dealer's facility or at regional service centers, or they will be returned to a factory where they will be completely re-manufactured and reissued.

Continuing his explanation, the Service Manager informs you that redundant systems and "limp home" features make it highly unlikely that the vehicle would ever break down on the road. If it should occur, however, its on-board direct-to-satellite, two-way communication system will automatically contact the nearest dealer. The dealer system will analyze failure data and determine whether the



INSIDE THE CAR OF THE FUTURE. Navigation screens will keep you from getting lost, and satellite telephone hookups will put you in touch with the outside world from the start to finish of every journey.

problem can be fixed in the field using replacement modules in inventory.

If the problem is not field-correctable, a service van will drop off a loaner vehicle and transport your car back to the dealer's service department for repair.

When the Service Manager finishes his explanation, you ask about the "two-way satellite communication system" and "on-board navigation system"—two features you had not heard about before. The CIS assures you that the demonstrator contains both systems and that they will be explained during the test drive.

Driving the demonstration vehicle

As you slide into the driver's seat in the demonstrator, the CIS hands you the driver ID card that she programmed in the simulator. That card also contains the authorization code for this vehicle. Inserting the card in a slot in the Driver Information Module, you start the engine while all driver-adjustable systems automatically adjust to your preference.

It's a cold fall day—well below the 68°F setting of your Individual Occupant Accommodation control, and you're aware that you are being bathed by a gentle stream of warm air. The CIS explains that that is a Quick Heat feature, which uses energy from an auxiliary electrical power system that generates electricity using photovoltaic cells integrated into the roof glass. It stores that power in a high-energy-density solid-electrolyte battery.

As you pull out of the dealer's lot, the CIS begins to explain the communication and navigation systems. She informs you that the demonstrator you are driving has automatically established contact with a geosynchronous orbiting satellite.

She switches on the navigation system, and a map of the dealer's neighborhood appears on a flat-panel display on the right side of the Driver Information Module. A flashing dot indicates the exact location of your car. As she dials-down the resolution, the neighborhood map "zooms" to a full-city map; but the position of your car

is still readily apparent. She points to the map and suggests that you head for a nearby freeway.

She then programs the navigation system to guide you to the freeway entrance by using audible commands, and a pleasant voice instructs you: "Turn right at the next intersection and move into the left-turn lane for access to the freeway entrance ramp." The same instructions appear on the screen, superimposed over the map display.

You also learn that navigation is only one function provided by the satellite link. She pushes another button and the map is replaced by a display of local information topics including: hotels/motels, restaurants, route selection, amusements, museums, and local events.

The CIS continues by explaining the Security Alert feature. You learn that sensors integrated into the window glass and in other key locations can detect any attempt to break into or steal the car. When the sensors are stimulated, the communication and navigation systems will automatically link up with a central Customer Security Services facility operated as a customer service. The police department closest to the car will be notified and given the car's exact location. The system can also be activated manually for any necessary emergency assistance.

By now you have reached the freeway-entrance ramp. As you accelerate to the 70 mph speed limit, the CIS introduces you to the Automatic Guidance feature. You learn that this feature uses the navigation system in conjunction with data from on-board sensors to provide totally automatic vehicle guidance on certain of our interstate highways.

This particular highway has been "mapped," so the CIS shows you how to engage the guidance feature while continuing to explain that within a few years, a complete interstate "grid" of highways will be "mapped" and reserved exclusively for automatic-guidance-equipped vehicles.

As the automatic system takes over, you release the controls and observe that the demonstrator vehicle tracks smoothly down the center of the lane at a constant 70 mph. As you gradually close in on a slower-moving car ahead in your lane, the demonstrator automatically signals for a lane change and pulls smoothly to the left, passing the slower vehicle.

The CIS explains that even when the vehicle is not being automatically guided, constantly operating features of the guidance system will prevent unsafe lane changes and passing maneuvers. The system will also detect upcoming road hazards, such as an ice patch, and help the driver to respond appropriately. In an emergency, that constantly operating system will take over so that it is almost impossible for the car so equipped to hit another object.

Your demonstrator completes its pass, signals for a lane change and pulls into the right lane while smoothly avoiding a piece of truck-tire tread lying in the road between lanes. The CIS suggests that you take the upcoming exit ramp, so you switch off the automatic guidance system and notice that it does not relinquish control until you conclusively demonstrate that you are back in command.

The road back to the dealership is lightly traveled and twisting so you engage in a mild version of the performance driving you enjoyed in the simulator. The demonstrator confirms all of your simulator impressions. You try to skid to a stop, but your car refuses to lock its wheels. It just stops rapidly, but smoothly, while maintaining your full steering control. You try to spin the wheels on gravel when accelerating away from construction at an intersection, but you can't do it. The car just accelerates smoothly, automatically determining the maximum rate it can attain.

Nearing the dealership, you pass a road-repair crew generating a cloud of dust and spreading hot tar on the road's shoulder. As you pass this scene, you real-

ize that you did not detect the expected odor of tar "The air-purification system filtered it out," the CIS explains. You also remark that no dust stuck to the windshield even when you stopped momentarily in the dust cloud. "It's electrostatically repelled," she explains, and she also mentions that the windshield has a special coating inside and out which reduces vision distortion from rain and greatly retards the formation of any condensation on the glass surfaces.

As you near the dealership, the CIS explains that this car can electronically communicate with others. Soon, all new vehicles on the road will have that feature. That capability also functions as an adjunct to audible horns and sirens, and is a particularly useful way for emergency vehicles to warn near-by drivers, particularly in urban areas where sirens are used less often.

Placing your order

As you return to the showroom, the CIS accompanies you to an interactive Vehicle Specification Selection and Order Coordinating Terminal where you work out the exact combination of features and options you wish to order.

She helps you to consider the relative virtues of the various powertrain options. You select a higher horsepower unit for rear module/rear drive installation. That basic engine adapts to various fuels—including gasoline and alcohol. You select gasoline, since that's the prevalent fuel in your area.

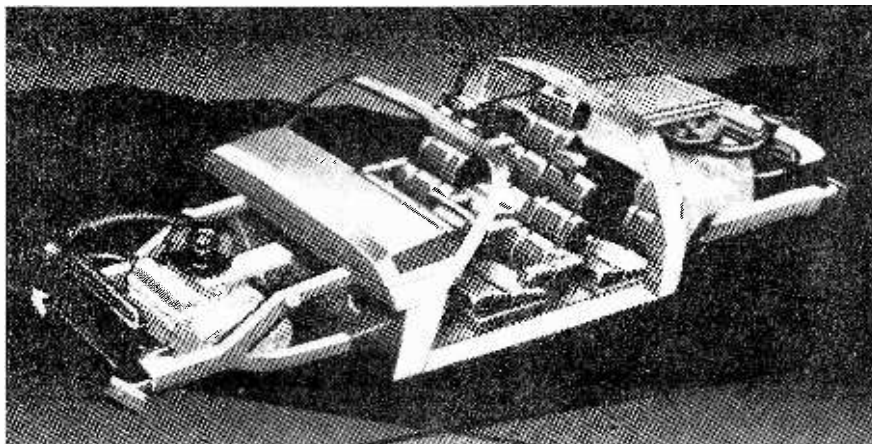
The CIS mentions that a hydrogen-fueled powertrain with high-performance capabilities is in the final stages of development and suggests that you may be interested in trading in your gasoline-fueled powertrain and upgrading to the hydrogen unit in a couple of years.

When you finish the specification process, the CIS explains that your order is now being entered, analyzed, and scheduled at the factory. Just as she finishes her explanation, the terminal displays a message that your order has been placed and your car will be delivered to your dealer—exactly 15 days from now.

After thanking the CIS for her help, she invites you to tour the manufacturing complex where your car will be constructed. The complex is only about 120 miles away, and a tour takes about half a day. That sounds great to you, and it is conveniently arranged.

21st-century manufacturing

The first stop on your tour of the manufacturing complex is a small auditorium where your tour guide explains that you will see a short film that explains some of what you'll see later. You learn that all engineering and manufacturing processing is now accomplished on an integrated, computer-driven engineering, design,



MODULAR CONSTRUCTION will allow your car to be custom built and upgraded as new modules are introduced. You'll also be able to rent modules to temporarily reconfigure you car—to take a family vacation, for example.

processing and testing network that ties together all design and production centers. Even key suppliers are tied into selected parts of this network.

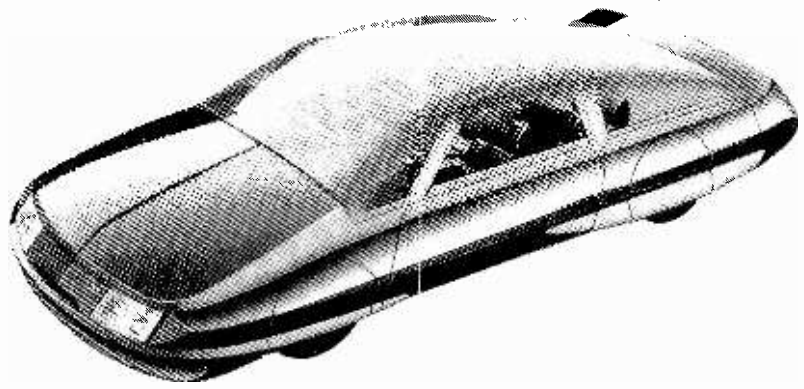
The film presents an overview of the manufacturing complex. You learn that the central Vehicle Final Assembly facility is responsible for assembling completed modules and sub-assemblies into a finished automobile. Those modules are supplied on a just-in-time basis from a ring of surrounding plants which use highly automated but flexible processes to manufacture, and remanufacture, a variety of components. Those factories are operated by a highly trained staff.

Not all manufacturing operations are represented at the complex you will tour. Engine blocks, steel structural pre-forms and major glass components are all supplied to the module-fabrication plants from central facilities. The film concludes by presenting those operations.

You see one-piece aluminum engine block/cylinder head/transmission case casting with ceramic inserts being processed by evaporative-casting techniques. You watch large pieces of thin glass being laminated to transparent plastic and molded into complex shapes which are lightweight but shatterproof.

The film's concluding sequence shows steelmaking in which plasma melting techniques are used to produce carefully controlled, high-purity alloy steel, which is cast into a thin slab requiring minimum hot rolling before it is cold-rolled into a finished sheet. Some of the sheet steel is electrolytically coated with a nickel alloy for outstanding corrosion resistance and is supplied in that form to other Ford manufacturing locations. Other sheet material is roll-formed into a structural preform which is cut to length, stretch-formed and selectively heat-treated by lasers.

The real tour starts in the Powertrain Module Factory. There you watch as robots that, in your guide's words, can "see," "learn" and "think for themselves," perform the complex task of assembling a high specific output, high



THE ALL-GLASS TOP OF FORD'S 2001 MODEL is flush with the body, giving the car excellent aerodynamic performance.

RPM, internal combustion engine within a "monoblock" casting which also houses the integral Continuously Variable Ratio transmission.

The highly automated assembly process makes it difficult for you to see all of the operations, but you are able to visually confirm your tour guide's claim that many of the engine's internal components are fabricated from high performance plastic composite materials.

The guide also points out that the engine's various covers and "pans" are installed with structural adhesives and are not removable in the field.

As you study the finished powertrain modules at the end of the assembly line, you notice that they are all fully integrated units, devoid of any "hung-on" accessories. For control purposes, a single electrical umbilical is provided to plug into the vehicle's central control-system.

Your next stop is the Greenhouse Fabrication Factory where you watch large formed-glass pieces being unloaded from trucks onto a line for Magnetic Vacuum Sputter Deposition. That process, your guide explains, is used to deposit multiple thin films of exotic materials to insulate the car's interior from the sun.

That, you are told, allows smaller/lighter air conditioning systems and prevents degradation of the car's interior ma-

terials from ultraviolet radiation. The coatings also impart cosmetic color to the glass, control glare, and reduce the tendency to fog. In other operations, various sensors and antennas required for features such as keyless entry, intrusion detection and satellite communication are integrated into the greenhouse structure.

You next visit the Exterior Panel Fabrication Factory where large panels are injection-molded from high performance thermoplastics or formed from reinforced thermoset plastic composites with finished color gel coats in large presses.

Your tour also includes stops at the Suspension Module Assembly plant and the various structural module fabrication plants where you watch robots apply fast-curing structural adhesives to bond elements into an integral structure.

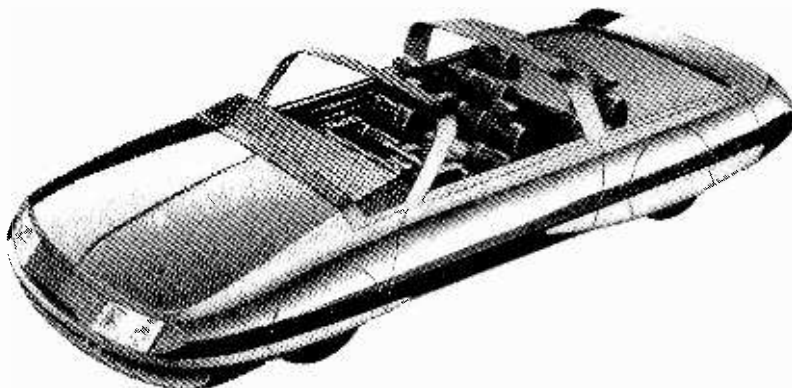
All modules leave their various assembly plants complete with all sensors, actuators and control electronics and a single electrical power-distribution bus.

Your tour ends at the Final Vehicle Assembly plant where all modules arrive on a coordinated, just-in-time basis and are assembled by robots, with minimum human assistance, into a completed vehicle. A comprehensive computer-directed final checkout procedure completes the manufacturing process.

On your drive home from the plant tour, you think about the seven days remaining until you take delivery. You can hardly wait!

R-E

Well, there you have it. A look at 21st century transportation technology, materials, and manufacturing processes as we at Ford Motor Company now anticipate them to be. To me, it's a fascinating prospect. But getting from here to there will be even more fascinating. While I expect to be happily retired and playing golf in Palm Springs when 2001 comes around, what we do for the remainder of this decade and into the 1990's will determine whether or not this scenario comes anywhere near reality. And, as I noted at the outset, how we treat our customers and how we treat our own people will make all the difference.—Donald E. Petersen



THE INTERIOR OF FORD'S FUTURISTIC automobile is revealed in this photo by the removal of the glass top.

AMAZING SCIENTIFIC & ELECTRONIC PRODUCTS

PLANS

Build Yourself — All Parts Available in Stock
 LC7— BURNING CUTTING CO., LASER \$20.00
 RUB4— PORTABLE LASER RAY PISTOL \$20.00
 TCC1— 3 SEPARATE TESLA COIL PLANS TO 1.5 MEV \$25.00
 IOG1— 10N RAY GUN \$10.00
 GRA1— GRAVITY GENERATOR \$10.00
 EML1— ELECTRO MAGNET COIL GUN/LAUNCHER \$8.00

KITS

With All Necessary Plans
 MFT3K— FM VOICE TRANSMITTER 3 MI RANGE \$49.50
 VVPM7K— TELEPHONE TRANSMITTER 3 MI RANGE \$39.50
 BTC3K— 250,000 VOLT 10-14" SPARK TESLA COIL \$249.50
 LHC2K— SIMULATED MULTICOLOR LASER \$44.50
 BLS1K— 100 000 WATT BLASTER DEFENSE DEVICE \$69.50
 ITM1K— 100 000 VOLT 20" AFFECTIVE RANGE INTIMIDATOR \$69.50
 PSP4K— TIME VARIANT SHOCK WAVE PISTOL \$59.50
 STA1K— ALL NEW SPACE AGE ACTIVE PLASMA SABER \$59.50
 MVI1K— SEE IN DARK KIT \$199.50
 PTV1K— SPECTACULAR PLASMA TORNAO GENERATOR \$149.50

ASSEMBLED

With All Necessary Instructions
 BTC10— 50 000 VOLT-WORLD'S SMALLEST TESLA COIL \$54.50
 LGU40— 1MW HeNe VISIBLE RED LASER GUN \$249.50
 TAT30— AUTO TELEPHONE RECORDING DEVICE \$24.50
 GVP10— SEE IN TOTAL DARKNESS IR VIEWER \$349.50
 LIST10— SNOOPER PHONE INFINITY TRANSMITTER \$169.50
 IPG70— INVISIBLE PAIN FIELD GENERATOR MULTI MODE \$74.50

• CATALOG CONTAINING DESCRIPTIONS OF ABOVE PLUS HUNDREDS MORE AVAILABLE FOR \$1.00 OR USE OUR PHONE FOR "ORDERS ONLY" 603-673-4730.

PLEASE INCLUDE \$3.00 PH ON ALL KITS AND PRODUCTS PLANS ARE POSTAGE PAID SEND CHECK, MO, VISA, MC IN US FUNDS

INFORMATION UNLIMITED
 P.O. BOX 716 DEPT. RE. AMHERST, NH 03031

Try the Radio Electronics

bulletin board
system

(RE-BBS)
516-293-2283

The more you use it the more useful it becomes.

We support 300 and 1200 baud operation.

Parameters: 8N1 (8 data bits, no parity, 1 stop bit) or 7E1 (7 data bits, even parity, 1 stop bit).

Add yourself to our user files to increase your access.

Communicate with other R-E readers.

Leave your comments on R-E with the SYSOP.

RE-BBS
516-293-2283

MARKET CENTER

FOR SALE

NICKEL Cadmium batteries all sizes. Best prices. Communications Packs and inserts for amateur and commercial applications. Any quantity. Custom built packs available. For catalog, SASE to: CUNARD ASSOCIATES, R.D. 6 Box 104, Bedford, Pa 15522.

LOW prices. Caps, switches, transistors, ICs. Flyer SASE, SANTECH 11 Revere place, Tappan, NY 10983. (914) 359-1130.

IS it true. Jeeps for \$44 through the Government. Call for facts! 1 (312) 742-1142. ext.4109-A.

TESLA Coils—Kirlian Electrophotography—Plasma Bulbs...Science Plan & Technical Book Catalogue \$1. SCIENTIF, Box 1054EX, Duvall, WA 98019.

DESCRAMBLERS. All brands. Special: Combo Jerrold 400 and SB3 \$165. Complete cable descrambler kit \$39. Complete satellite descrambler kit \$45. Free catalog. MJG INDUSTRY, Box 531, Bronx, NY 10461-0531.

ENGINEERING software. IBM/compatibles. CompDes Circuit Design, Basic electricity through circuit designs. Compmath — General mathematics through statistics. CompView — Digital Analysis, waveforms and filters. \$49 (614) 491-0832. **BSOFT SOFTWARE**, 444 Colton Road, Columbus, Ohio 43207.

SB3 closeout \$49.95 Hurry! **SCIENTIFIC ATLANTA**, 8535w/ remote; compatible with Jerrold, Regency, Eagle, Hamlin, and Sylvania. Scrambling \$169.95, SASE — RADD/TCC 104 S. Broadway, Peru, IN. 46970.

WANTED

INVENTORS! AIM WANTS — ideas, inventions, technology, improvements on existing products. We present ideas to manufacturers. **Confidentiality guaranteed.** Call toll free in U.S. and Canada 1-(800) 225-5800.

SATELLITE TV

RECEIVERS, feeds, LNA's, LNB's, dishes, all components and accessories. SSR decoders — decodes digital audio from VCI's. Call we have it all! Best Prices Too! **CASCADE ELECTRONICS**, P.O. Box 414, Dundee, IL, 60118 (312) 888-8121.

SATELLITE Descrambling, cable descrambling, send stamp for catalog. **COMMUNICATIONS ENGINEERING**, 76 Boulevard, Hudson Falls, NY 12839.

VIDEOCYpher II, DESCRAMBLING MANUAL, schematics, both video and audio encoding, DES, cloning, muskateering, EPROM codes. (HBO, Cinemax, adult channels). \$13.95, \$2 postage. **CABLETRONICS**, Box 30502R, Bethesda, MD. 20814.

FREE CATALOG systems upgrades Uniden Chaparral etc. save \$\$\$\$ **SKYVISION** 2020 Collegeway, Fergus Falls, Mn. 56537. (218) 739-5231.

BUSINESS OPPORTUNITIES

PC board design, documentation **PLOTTING** services, EE designer, HiWire/SmartWork, Schema, CAD SYSTEMS SUPPORTED. Call (609) 586-4469.

PLANS & KITS

PROJECTION TV. Convert your TV to project 7 foot picture...Easy! Results comparable to \$2,500 projectors...Plans and 8" Lens \$24.95...Professional Systems available...Illustrated Catalog Free... **MACROCOMA** 15XHB Main Street, Washington Crossing, PA 18977...Creditcard Orders 24 hrs. (215) 736-3979.

CATALOG: HOBBY/BROADCASTING/HAM/CB:CABLE TV, transmitters, amplifiers, bugging devices, computers, **PANAXIS**, Box 130 EE, Paradise, CA 95967.

KITS*PARTS*PLANS*. We have hard to find parts! Variable Tuning Capacitors, Tuning Coils, Crystal and Magnetic Headphones, Germanium Diodes, **CRYSTAL** and **SHORTWAVE RADIO KITS**. Very Inexpensive. Send .25¢ stamp for catalog. **YEARY COMMUNICATIONS**, 12922 Harbor #800-E, Garden Grove, CA 92640.

ROOM SURVEILLANCE TELEPHONE



This telephone looks and works like a normal telephone, except it has a secret built in room monitor. If anyone else calls this telephone, it rings and works as usual, and the monitor will not turn on. Only YOU can call and listen to all room conversations by using a secret code and never be detected!
 \$175.00 — 6 month Warranty — Phone Snoop Catalog \$3.00
LISTEN ELECTRONICS, 603 Elgin, Muskogee, OK 74401. 1-800-633-TAPS

DESCRAMBLING new secret manual. **BUILD YOUR OWN DESCRAMBLERS** for **CABLE**, and **SUBSCRIPTION TV**. Instructions, schematics, for SSAVI, gated sync. sinewave (HBO, Cinemax, Showtime, adult) \$8.95, \$2 postage. **CABLETRONICS**, Box 30502R, Bethesda, MD 20814.

EDUCATION & INSTRUCTION

SHORTCUT to engineering. Practical circuit theory simplified. Course plus programming \$12. **BAY-SHORE PRESS**, 981 Indian Beach Drive, Sarasota, FL 34234.

MAGIC! Four illustrated lessons plus inside information shows you how. We provide almost 50 tricks including equipment for professional effects. You get a binder to keep the materials in, and a one-year membership in the International Society of Performing Magicians with a plastic membership card that has your name gold-embossed. You get a one-year subscription to our quarterly newsletter, "IT'S MAGIC!" Order now! \$29.95 for each course + \$3.50 postage and handling. (New York residents add applicable state and local sales tax.) **THE MAGIC COURSE**, 500-B, BiCounty Boulevard, Farmingdale, NY 11735, or telephone (516) 293-3751 and ask for Nancy Estrada.

SOMEONE YOU KNOW

HAS A RARE DISORDER

- That may be fatal or disabling
- That many doctors don't recognize
- That may have no cure or treatment
- That is one of 5000 disorders with a total of 20 million victims

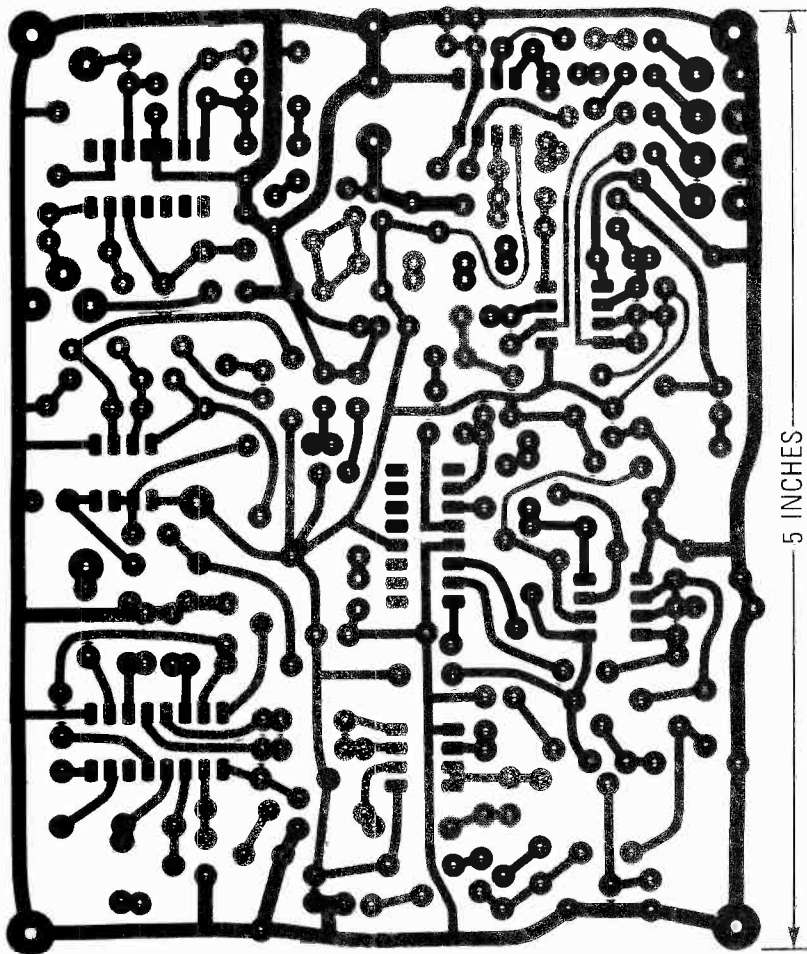
NORD is a coalition of non-profit agencies, researchers, and individuals that helps by providing information and promoting research. Your membership helps.

NORD

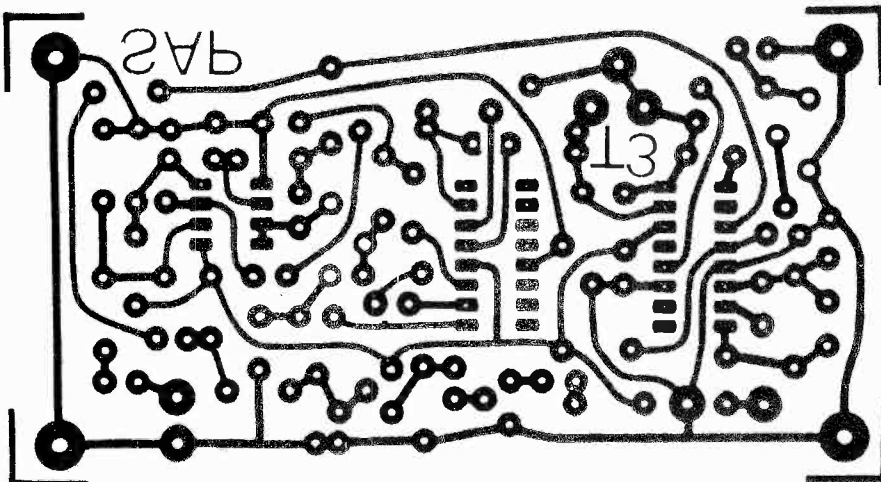


**National Organization
for Rare Disorders**
1182 Broadway, Suite 402,
New York, N.Y. 10001
212-686-1057

PC SERVICE



ENJOY THE BENEFITS OF MULTICHANNEL TV SOUND with our stereo-TV decoder. The foil pattern for the PC board is provided here; construction and installation information can be found beginning on page 11.



One of the most difficult tasks in building any construction project featured in **Radio-Electronics** is making the PC board using just the foil pattern provided with the article. Well, we're doing something about it.

We've moved all the foil patterns to this new section where they're printed by themselves, full sized, with nothing on the back side of the page. What that means for you is that the printed page can be used directly to produce PC boards!

Note: The patterns provided can be used directly only for *direct positive photoresist methods*.

In order to produce a board directly from the magazine page, remove the page and carefully inspect it under a strong light and/or on a light table. Look for breaks in the traces, bridges between traces, and in general, all the kinds of things you look for in the final etched board. You can clean up the published artwork the same way you clean up your own artwork. Drafting tape and graphic aids can fix incomplete traces and doughnuts, and you can use a hobby knife to get rid of bridges and dirt.

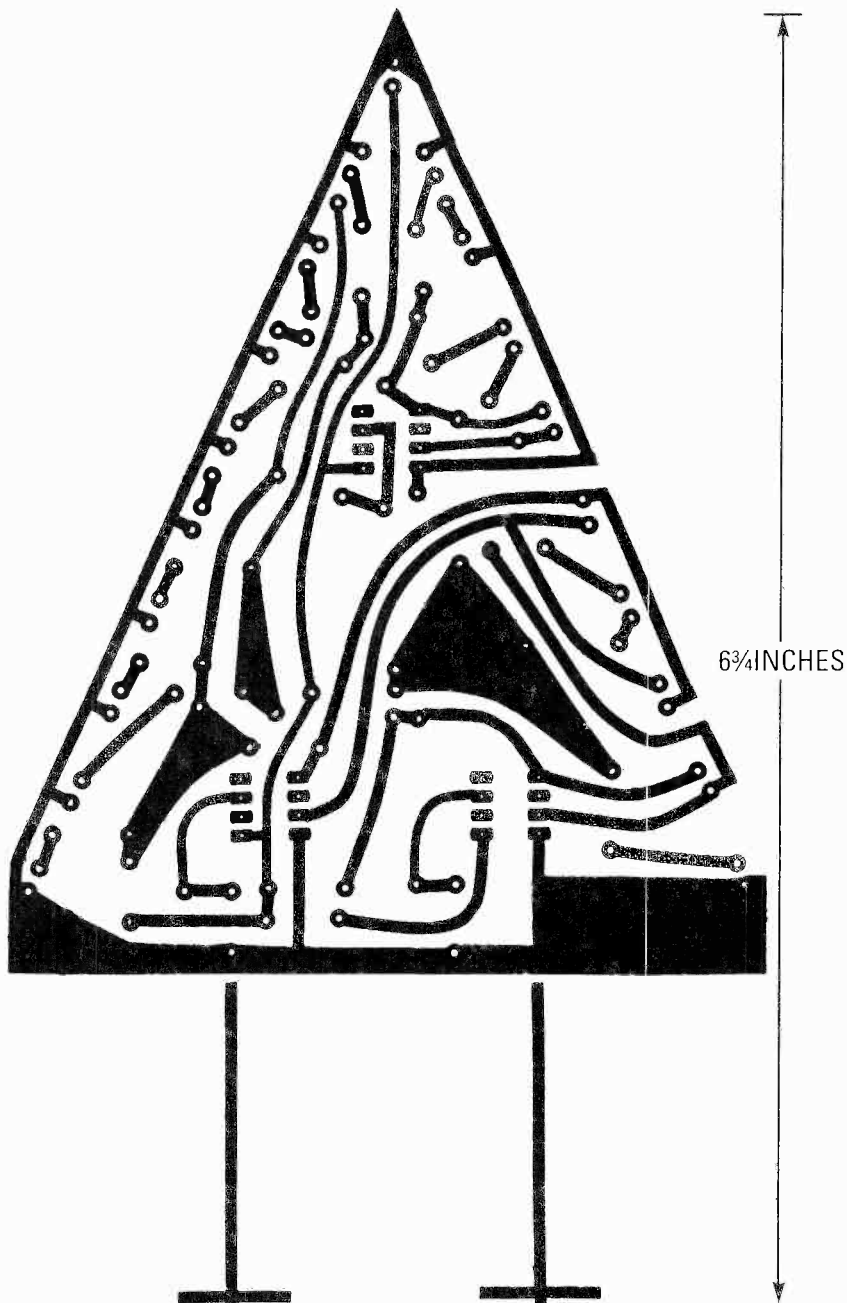
An optional step, once you're satisfied that the artwork is clean, is to take a little bit of mineral oil and carefully wipe it across the back of the artwork. That helps make the paper translucent. Don't get any on the front side of the paper (the side with the pattern) because you'll contaminate the sensitized surface of the copper blank. After the oil has "dried" a bit—patting with a paper towel will help speed up the process—place the pattern front side down on the sensitized copper blank, and make the exposure. You'll probably have to use a longer exposure time than you are probably used to.

We can't tell you exactly how long an exposure time you will need but, as a starting point, figure that there's a 50 percent increase in exposure time over lithographic film. But you'll have to experiment to find the best method for you. And once you find it, stick with it. Don't forget the "three C's" of making PC boards—care, cleanliness, and consistency.

Finally, we would like to hear how you make out using our method. Write and tell us of your successes, and failures, and what techniques work best for you. Address your letters to:

Radio-Electronics
Department PCB
500-B Bi-County Blvd.
Farmingdale, NY 11735

THE SAP ADAPTER'S PC pattern is shown at left.

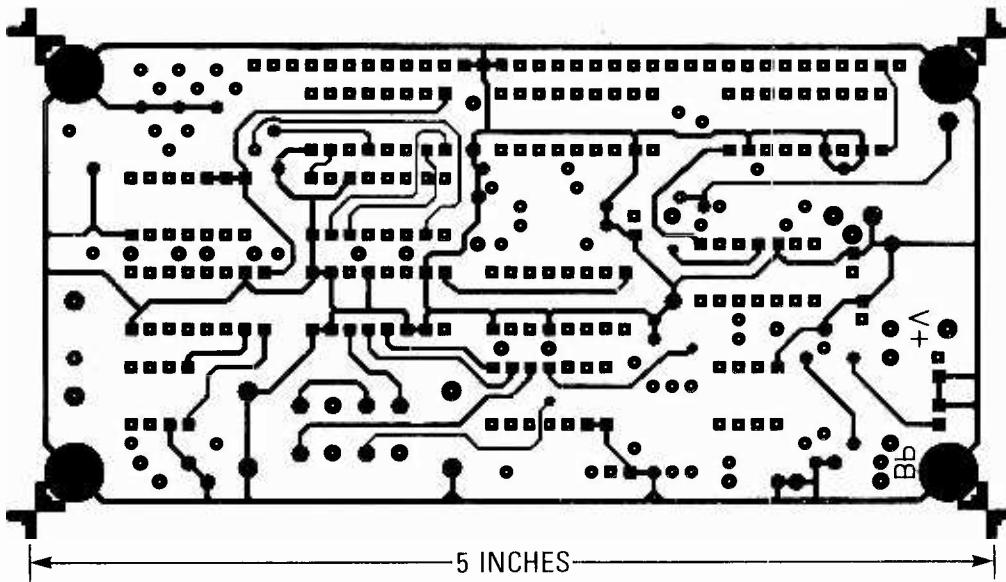


LIGHT UP THE HOLIDAYS with the electronic Xmas tree. The PC board for that project is shown here.

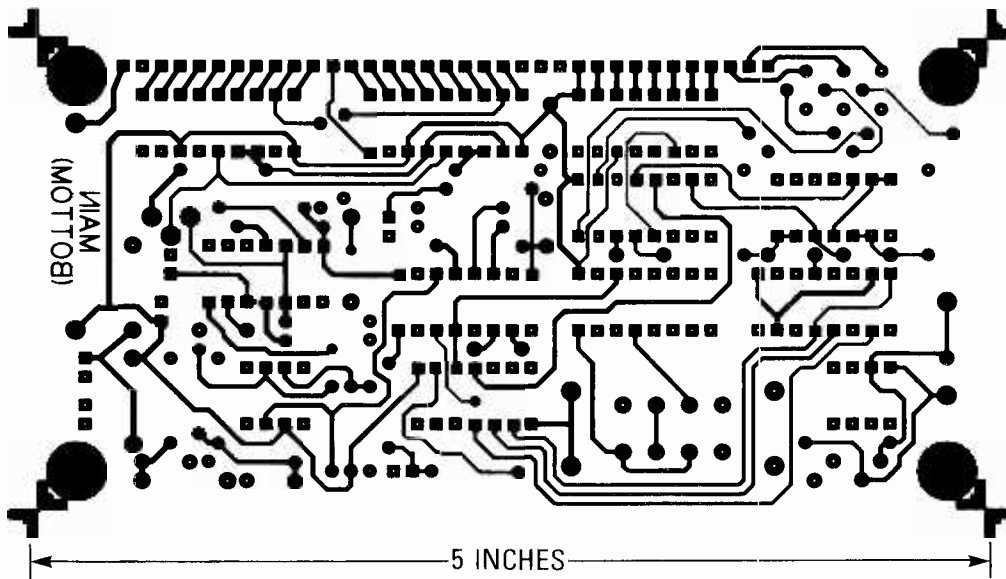


← 1 INCH →

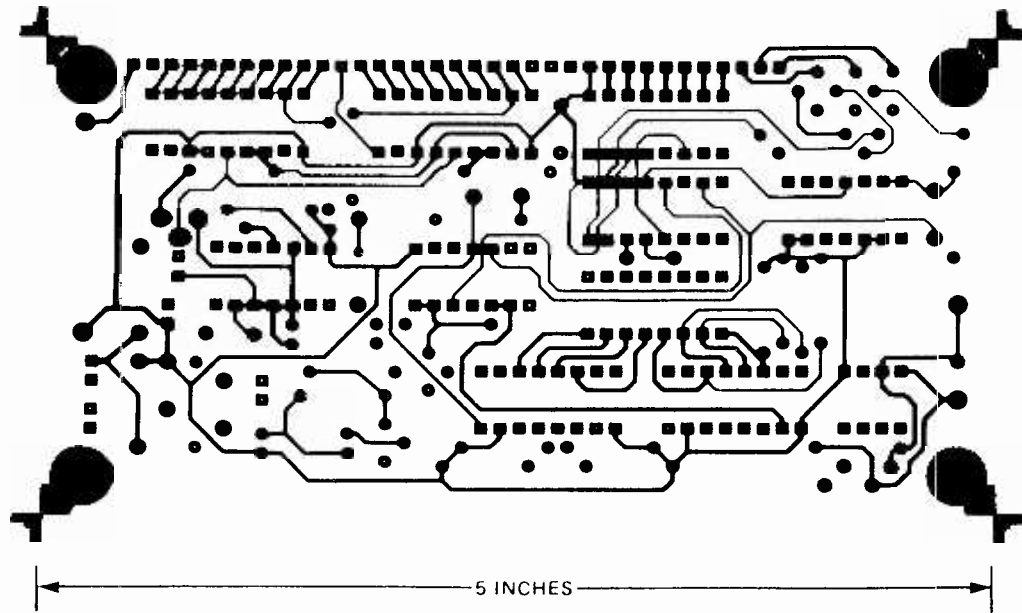
OUR ELECTRONIC SCARECROW can help chase away a less than determined burglar. If you chose to build that circuit on a PC board, here's a pattern that's appropriate.



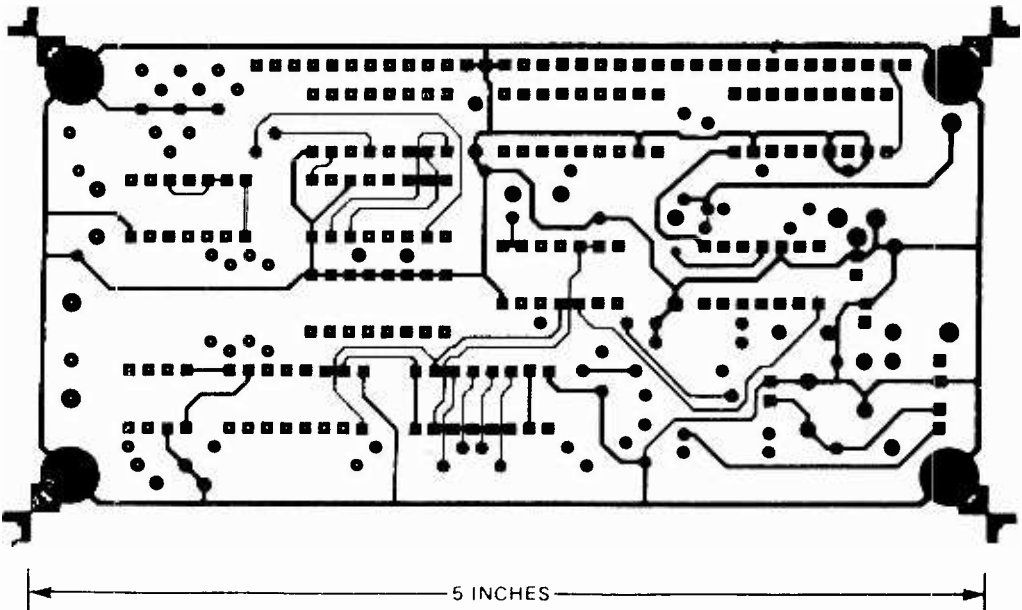
THE COMPONENT SIDE of the digital tachometer.



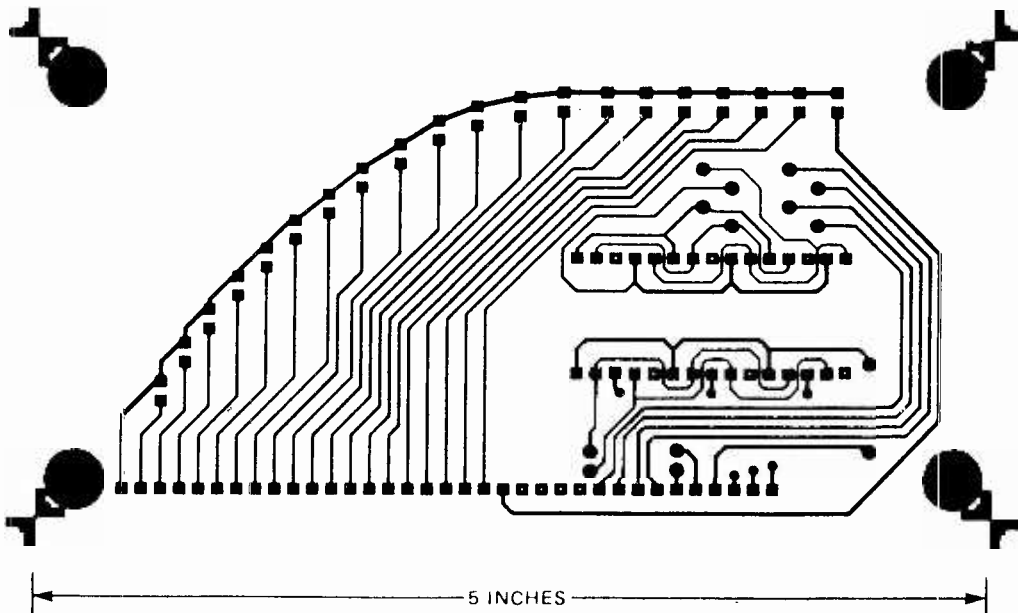
THE SOLDER SIDE of the digital tachometer is shown here.



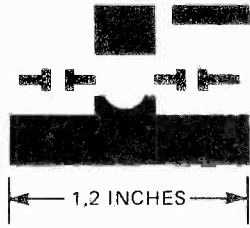
THE SOLDER SIDE of the speedometer's main board is shown here.



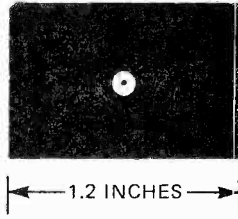
THE COMPONENT SIDE of the speedometer's main board. When mounting components, be sure to solder all leads completely.



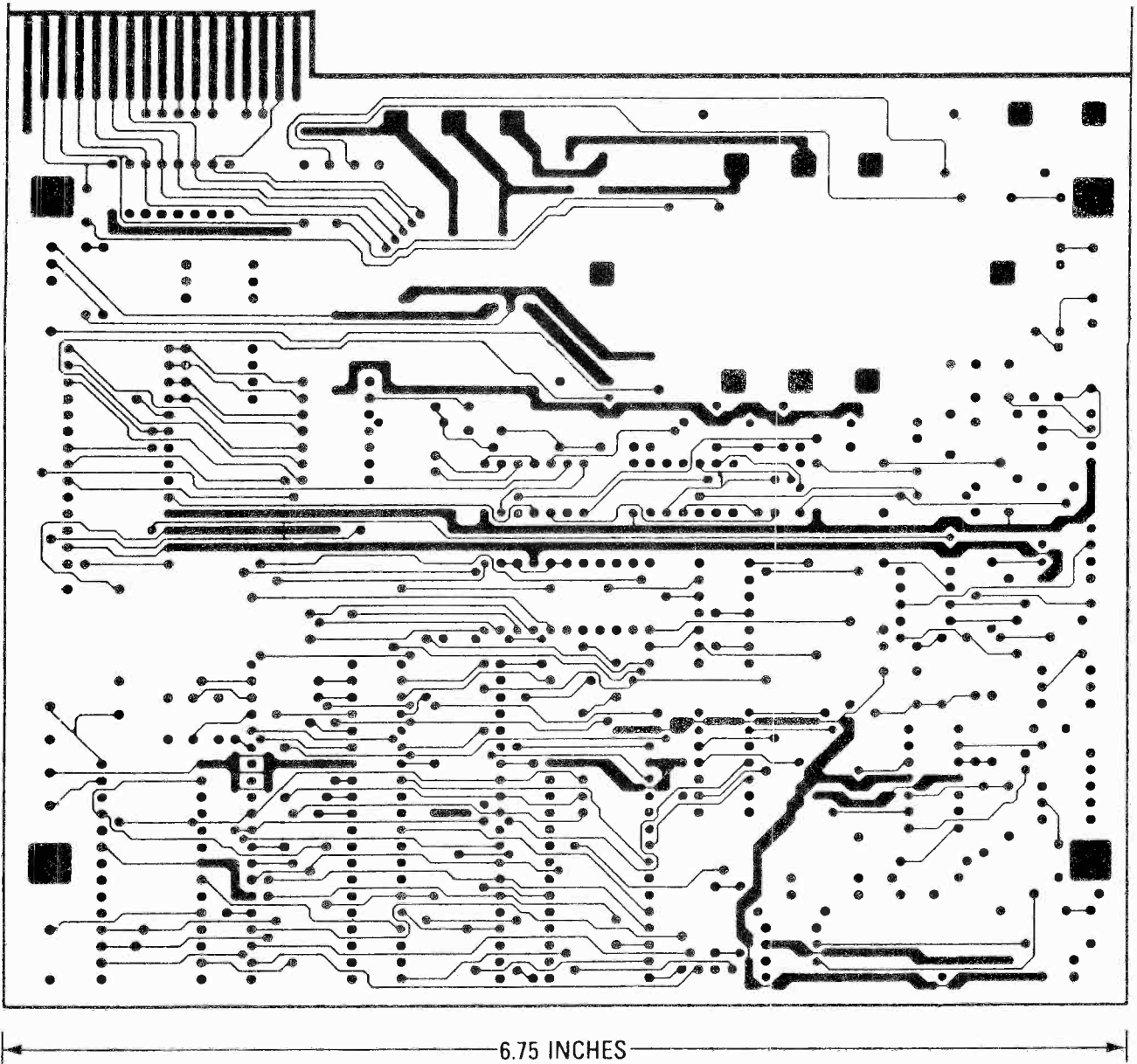
THE SPEEDOMETER'S DISPLAY BOARD. It is connected to the main board using 35 jumper wires.



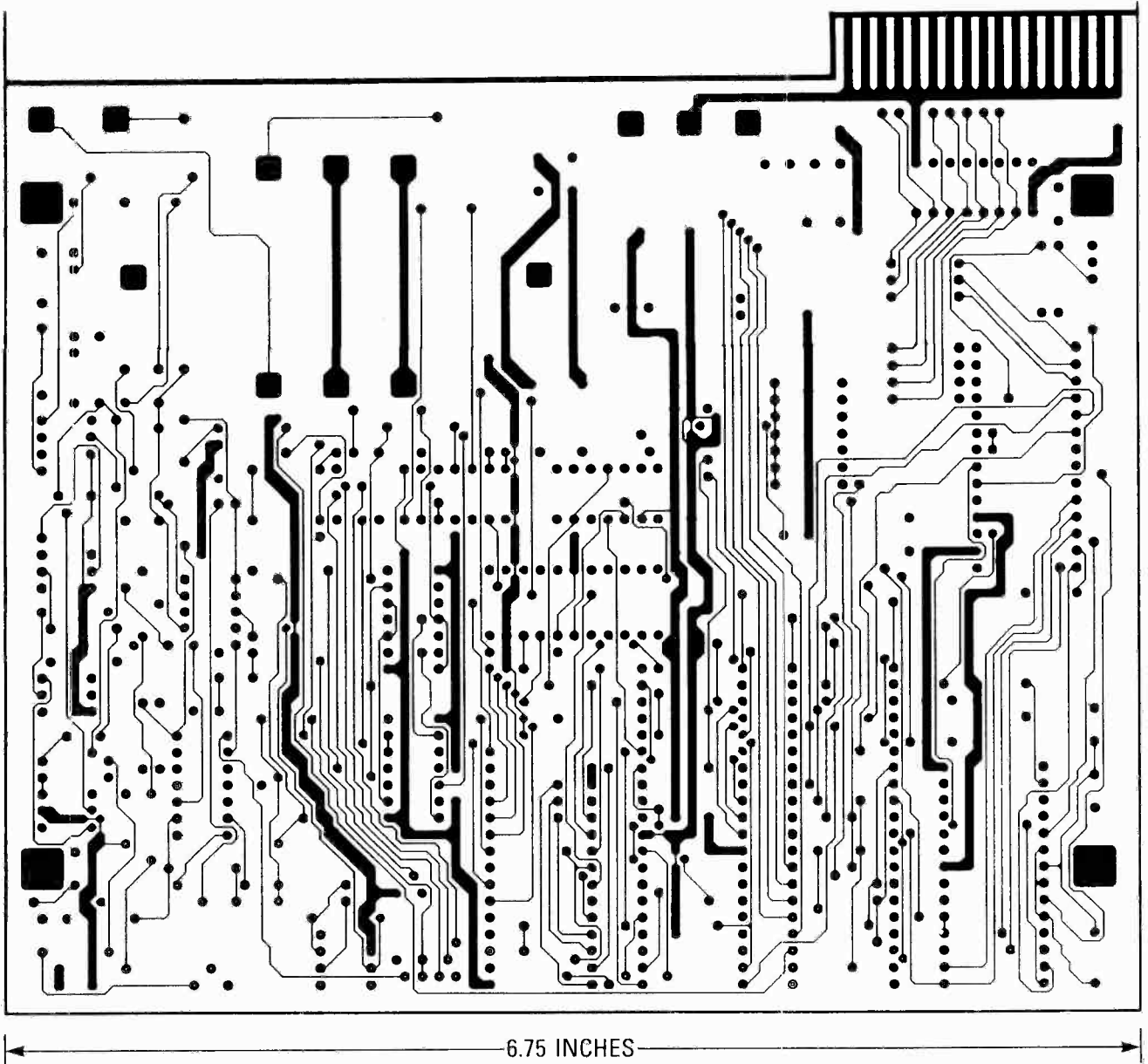
SOLDER-SIDE DIRECT-ETCH FOIL PATTERN for the wideband amplifier. The story begins on page 45.



COMPONENT-SIDE DIRECT-ETCH FOIL PATTERN for the wideband amplifier.



THE COMPONENT SIDE of the double-sided Phonlink PC board.



THE SOLDER SIDE of the Phonlink PC board is shown here.

MASTER THE NEW ELECTRONICS WITH MCGRAW-HILL'S

Contemporary Electronics Series

The fast, easy and low cost way to meet the challenges of today's electronic innovations. A unique learning series that's as innovative as the circuitry it explains, as fascinating as the experiments you build and explore.

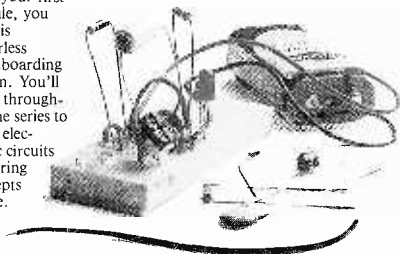
From digital logic to the latest 32-bit microprocessor, the McGraw-Hill Contemporary Electronics Series puts you into the electronic picture one easy step at a time. Fifteen unique Concept Modules, sent to you one every 4-6 weeks, give you a handle on subjects like optoelectronics, robotics, integrated circuits, lasers, fiber optics and more.

Each Concept Module goes right to the heart of the matter. You waste no time on extraneous material or outdated history. It's a fast, efficient, and lively learning experience... a non-traditional approach to the most modern of subject matter.

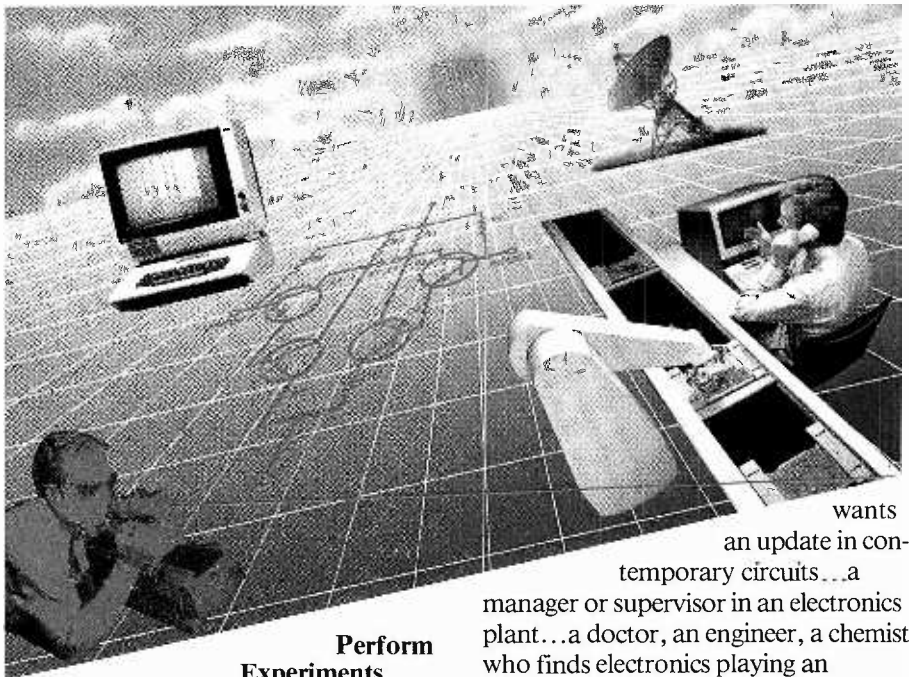
Unique Interactive Instruction

With each module, you receive a McGraw-Hill Action Audio Cassette. Each tape is a dynamic discussion that drives home the key facts about the subject. Your learning

With your first module, you get this solderless breadboarding system. You'll use it throughout the series to build electronic circuits and bring concepts to life.



experience is reinforced through interaction with vividly illustrated text, audio cassettes, and actual electronic experiments. Indexed binders preserve backup material, notes, and tapes for convenient referral.



Perform Experiments in Contemporary Electronics

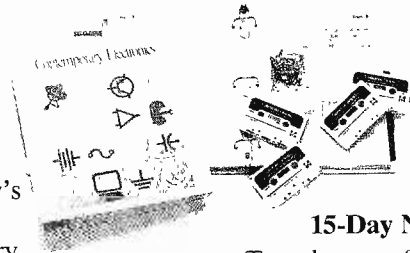
Throughout your series, laboratory experiments reinforce every significant point. This essential experience... dynamic, hands-on demonstrations of theory in practice... will help you master principles that apply all the way up to tomorrow's latest VLSI (Very Large Scale Integrated) circuitry.

In your very first module, you'll use integrated circuits to build a digital oscillator, verifying its operation with a light emitting diode (LED). You'll learn to identify passive and active components, understand concepts common to all electronic circuits.

For Anyone Interested in Electronics

The Contemporary Electronics Series is designed for anyone from hobbyist to professional. It's for you if you're looking for new fields of interest... if you're a teacher who

wants an update in contemporary circuits... a manager or supervisor in an electronics plant... a doctor, an engineer, a chemist who finds electronics playing an increasingly important role in your work. It's even for electronics engineers or technicians who feel their training needs freshening up. It's the quickest, most convenient, probably least expensive way to do it. And the only one that gives you hands-on experience.



15-Day No-Risk Trial

To order your first module without risk, send the card today. Examine it for 15 days under the terms of the order form and see how the Contemporary Electronics Series gets you into today's electronics. If card has been used, write us for ordering information.



McGraw-Hill
Continuing Education Center
3939 Wisconsin Ave.
Washington, D.C. 20016

ACID RAIN

continued from page 42

points. Connect the circuit to a VOM, and adjust the potentiometer for a reading of 94 μA . Then disconnect the sensor assembly from the main circuit and connect the battery-potentiometer combination in its place. Adjust R1 until the meter reads exactly 100 μA , which corresponds to a pH of 2.5.

The other pH points are established by

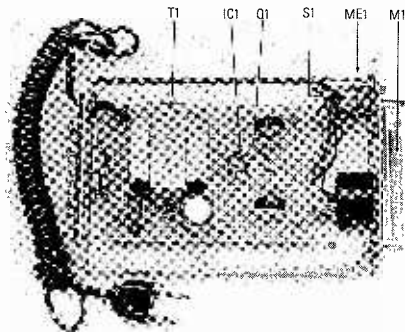


FIG. 5—THE ELECTRONIC COMPONENTS mount on a piece of perfboard; they are connected by point-to-point wiring. The terminal strip provides connections to the remote-mounted sensor and solenoid.

feeding a known current to the circuit and noting the position of the needle. Those positions correspond to the pH's shown in Table 1. If you want to interpolate in-between values, keep in mind the fact that the scale is not linear.

Installation and use

The best location for the sensor assembly is on a post, as shown in Fig. 6, away from trees and buildings. If it's mounted on the side of a house, be sure that the bracket you use is long enough to place the funnel beyond roof or eave run-off.

Don't be alarmed if the meter indicates some acidity. A pH of 6.0 to 6.5 is normal and unharmed. However, environmentalists warn of dire consequences for continuously higher readings.

For example, at continuous pH levels of 5.0 to 5.5, lawns and garden plants will

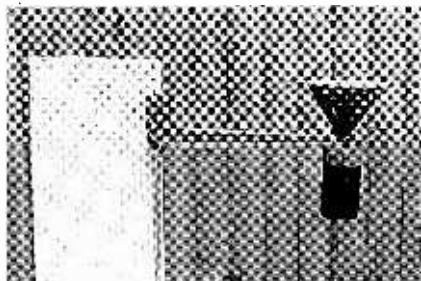


FIG. 6—THE SENSOR ASSEMBLY should be mounted on a long bracket that is screwed to a post. The post should be mounted away from overhanging eaves; and don't mount it under a tree.

begin to turn brown, and soil will need added lime. A pH of 4.5 in ponds and lakes will start killing fish, and, when pH reaches a level of 4.0, a clear blue appearance, although beautiful, will indicate a "dead" body of water. A pH of 3.5 will cause rapid deterioration of painted surfaces. A continuous pH of 3.0 will result in erosion of structural limestone, and entire forests will die. Last, if the meter indicates 2.5 or less, you may be living near an active volcano!

After taking readings from accumulated rainfall, the funnel should be drained, leaving S1 in the DRAIN position only long enough to drain the funnel, as most inexpensive solenoid valves are not designed for continuous duty. Inspect the electrodes several times a year, and if any corrosion forms, swab it off with a weak ammonia-water solution, and then flush the electrodes with distilled water.

For studying the long-term effects of acidity, the output of the meter could be connected to a chart recorder. And the meter may also be used to test your local tap, pond, and stream water by pouring a sample into the funnel. **R-E**

BURGLAR ALARM

continued from page 26

battery holder to the panel using RTV adhesive; the holder should be located just below the holes for the LED's. Then mount the key switch in the appropriate hole. Wire the switch and the battery holder to the appropriate points on the board, keeping lead lengths as short as possible. Bend the LED's 90° so that they are parallel with the board. Position the LED's in the holes you previously drilled for that purpose so that they protrude about 1/8 inch. Finish up by securing the board to the top of the battery holder with a piece of double sided tape. Fig. 3 shows how it should look.

The unit can be installed just about anywhere. We suggest mounting it in your door frame for a professional look.

Although the circuit doesn't actually do anything, you should make it a habit to "arm" and "disarm" it as appropriate. That little bit of theater will help convince a burglar who is "casing" your home that it is indeed protected as advertised. **R-E**

DIGITAL DASHBOARD FOLLOW-UP

As a follow-up to "Build This Digital Tachometer for your Car" and "Build This Digital Speedometer for your Car", I would like to note a few minor corrections that may help any readers who are building those projects.

First, in the digital-tachometer article, D2 and D4 on the parts-placement diagram should be interchanged, and so should D5 and D6. The 10- μF capacitor labeled C14 on the schematic is C4.

In the digital-speedometer article, the schematic reference to IC5 should be labeled 4001 instead of 4011. The pick-up coil input should read P1 not P2. Also on the schematic, C12, a 0.1- μF bypass capacitor, was omitted. Getting on to the parts-placement diagram, the set of pads between S1 and IC6 should be labeled C7.

After several units were built using IC's from different manufacturers, a problem developed that caused the digital readout to occasionally jump to a reading of "000" during normal operation. That timing problem can be corrected by soldering a .001- μF capacitor across pins 8 and 10 of IC7 on the tachometer; across pins 11 and 13 of IC5 on the speedometer.

The cause of the problem is that the MC14553 needs a minimum amount of time between the latch and reset pulses. If the CD4001 NOR gate used to build the projects is too fast—has too little propagation delay—the reset pulse will arrive before the internal latches have stabilized and locked in the current reading.

Because of the exceptional response to the digital tachometer and digital speedometer, and a significant number of requests for kits, Dakota Digital (R.R. 5, Box 179-E, Sioux Falls, SD 57107) has expanded its product line as follows:

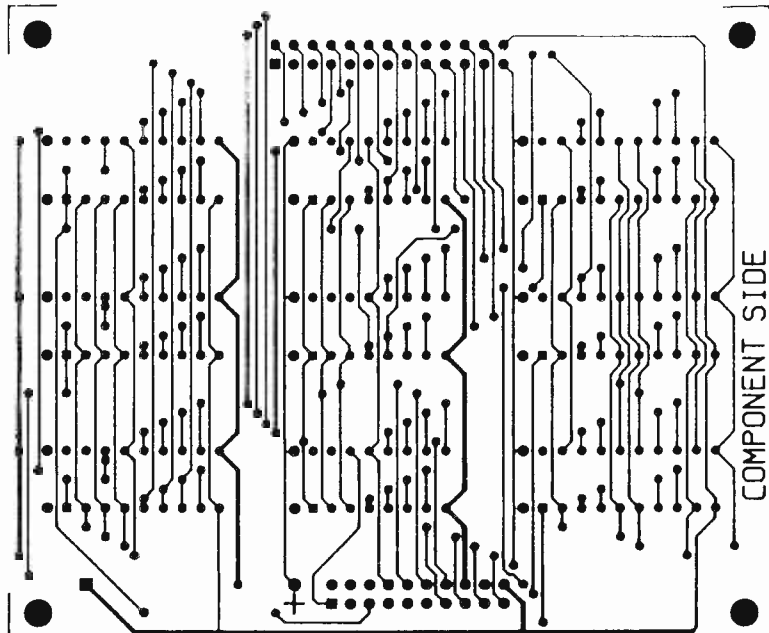
For the digital tachometer: Display board (#430103), \$6.95; main board (#430104), \$12.95; parts kit (#2002-KIT), \$75.00; Assembled and tested (#3002-UNIT), \$99.95.

For the digital speedometer: display board (#430105), \$6.95; main board (#430106), \$12.95; pick-up coil (#2701278), \$11.95; magnet set (4) (#2701279), \$4.95; parts kit (#2004-KIT), \$75.00; assembled and tested unit (#3004-UNIT), \$99.95.

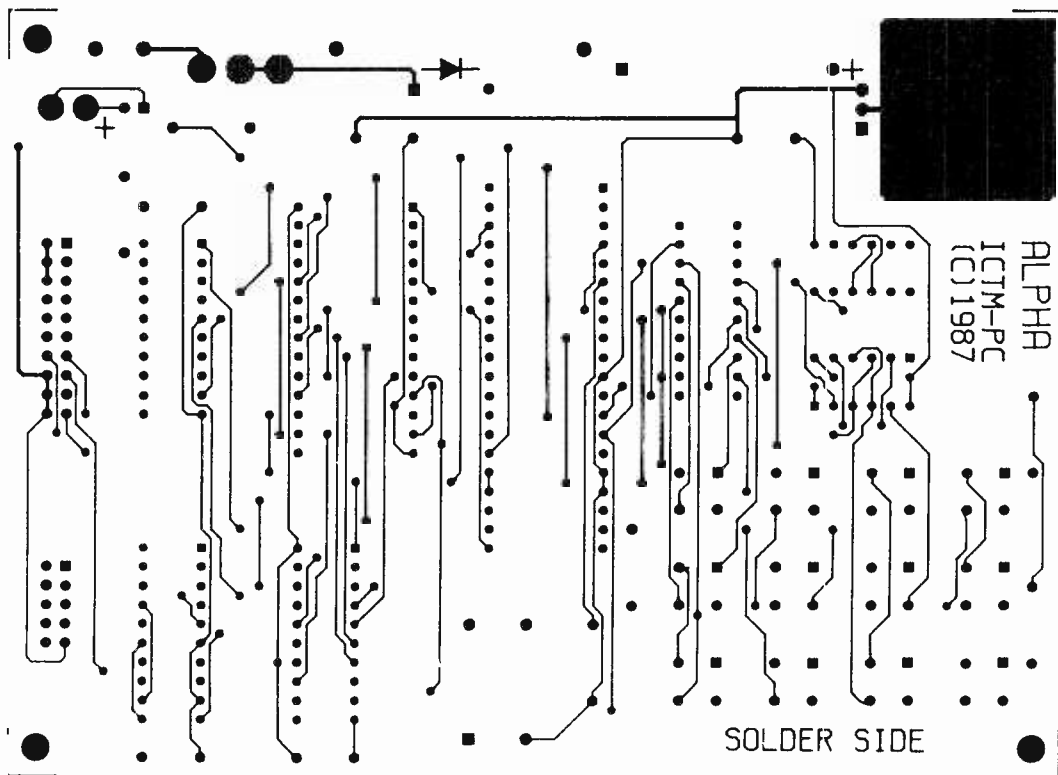
Add 5% shipping and handling to all orders. South Dakota residents must add 5% sales tax.

ROSS ORTMAN

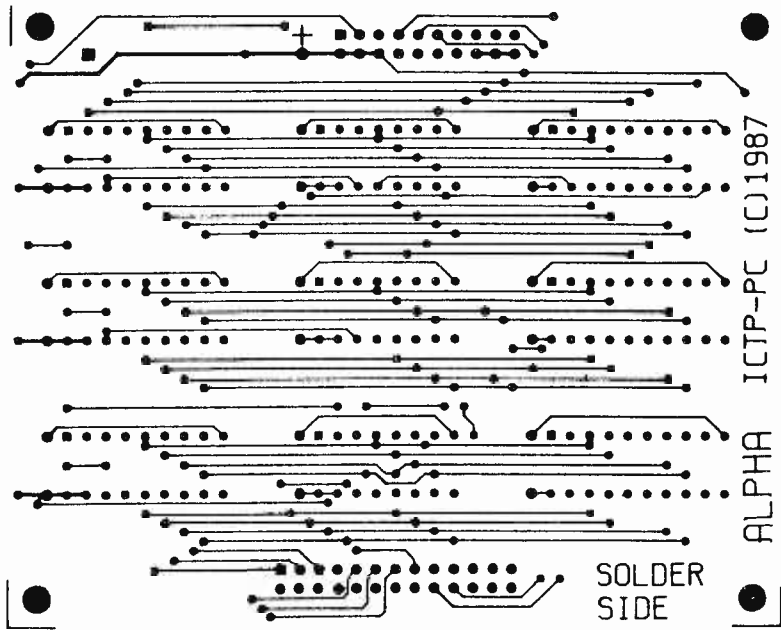
R-E



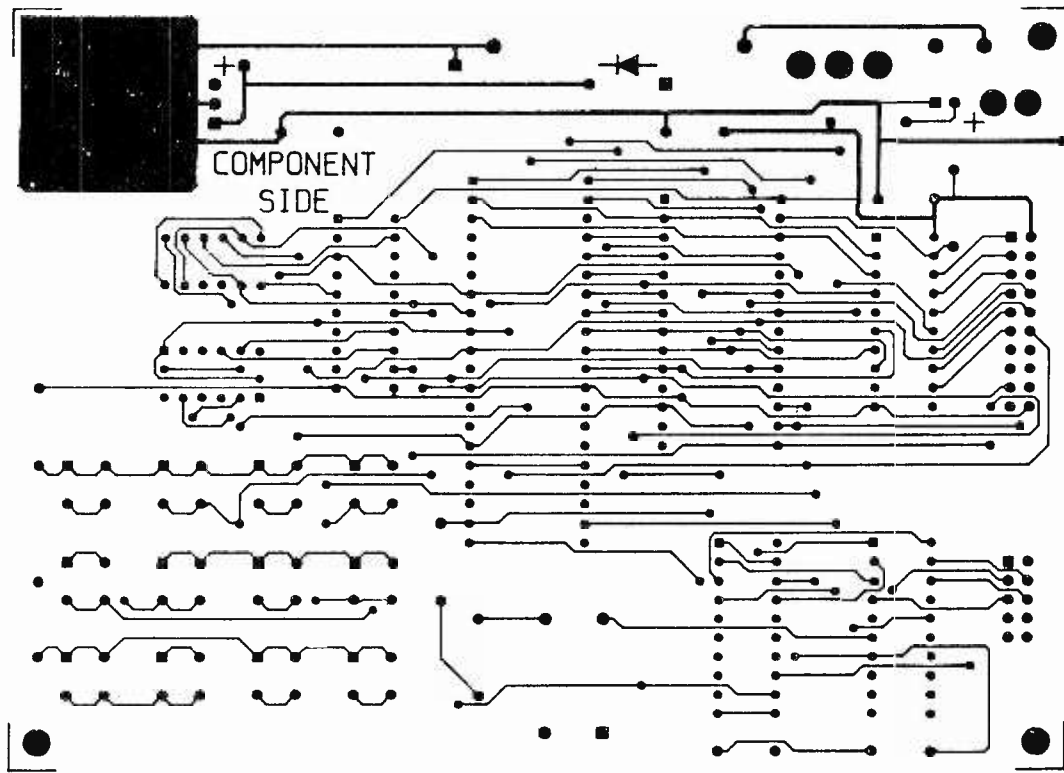
THE IC TESTER'S DRIVER BOARD. The component side is shown at left.



THE SOLDER SIDE of the IC Tester's main board is shown above.



THE IC TESTER'S DRIVER BOARD. The solder is shown at left.



THE COMPONENT SIDE of the IC Tester's main board is shown above.

NEW IDEAS

Sound-effects generator

HERE'S A CIRCUIT THAT PROVIDES GREAT fun for kids. It can generate a European police-car siren, bird noises, spaceship sounds, etc. In addition, it can be put to serious use as a doorbell, an alarm, etc. It's easy to build, uses readily-available parts, and is inexpensive.

How it works

A block diagram of the circuit is shown in Fig. 1. As you can see, the

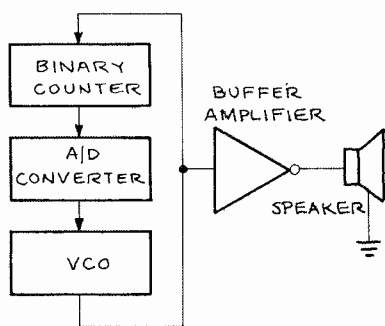


FIG. 1

circuit consists of four parts: a binary counter, a D/A converter, a VCO, and an audio output amplifier. The speed at which the counter counts depends on the frequency of the output of the VCO, which in turn is determined by the output of the counter. That feedback loop is what gives this circuit its characteristic output.

Referring to the schematic in Fig. 2, the initial frequency of oscillation is determined by potentiometer R11. The VCO first oscillates at a relatively low frequency, and gradually picks up speed as the control voltage supplied by the D/A converter increases.

The D/A converter is simply the group of resistors R1-R8. When none of IC1's outputs is active, little current will flow into the base of Q1, so the VCO's control voltage will be low. As more and more counter outputs become active, base current increases, and there-

by so does the VCO's frequency of oscillation.

The VCO itself is composed of IC2-a, IC2-b, Q1, and the timing network comprising D1-D4, C1, R10, and R11. The diode bridge functions basically as a voltage-controlled resistor.

The buffer amplifier is made up of the four remaining gates from IC2, all wired in parallel. Volume is sufficient for experimental purposes, but you may want to add an amplifier, speaker, or both.

Construction

Use any convenient means of wiring the circuit—point-to-point, wirewrap, etc. Layout is not critical; just be sure to connect the power supply to the IC's correctly.

Press S1; you should get a sound from the speaker. The sound you get will depend on the position of R11. To vary the effect, try tapping on S1.—Edwin B. Tupue

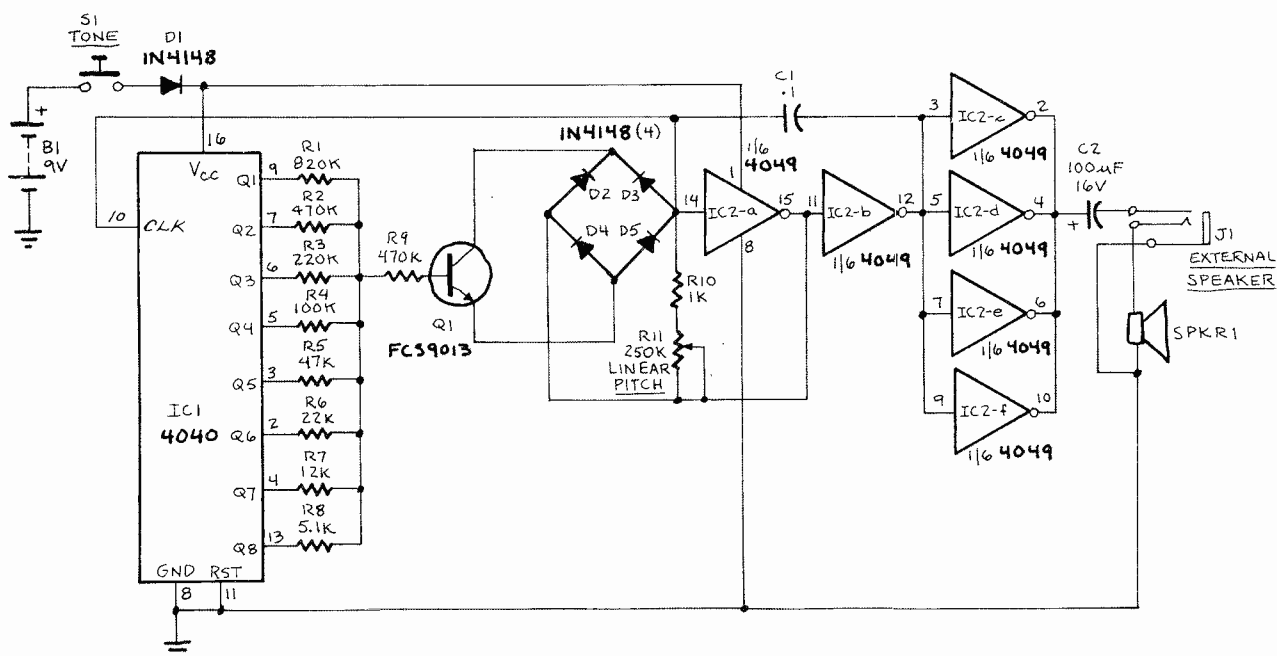


FIG. 2

Broadcast-band RF amplifier

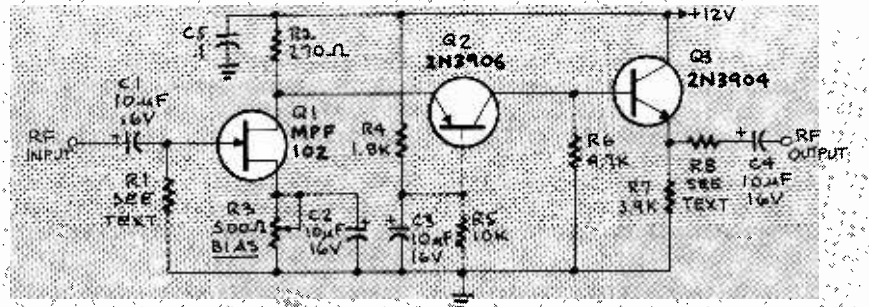


FIG. 1

UNLESS YOU OWN A TOP-OF-THE-LINE receiver or car radio, your AM reception may not be as good as it should be. The reason is that few low- to mid-price receivers and radios include RF amplifiers. By adding one yourself, however, you can improve reception at minimal cost. The RF amp shown here uses readily available parts, has wide bandwidth, and is very stable. In addition, by varying the values of several resistors, you can match the amplifier's input impedance to your antenna, and its output impedance to your radio.

How it works

The complete schematic is shown in Fig. 1. The circuit has a frequency response ranging from 100 Hz to 3 MHz; gain is about 30 dB.

Field-effect transistor Q1 is configured in the common-source

self-biased mode; optional resistor R1 allows you to set the input impedance to any desired value. Commonly, it will be 50 ohms.

The signal is then direct-coupled to Q2, a common-base circuit that isolates the input and output stages and provides the amplifier's exceptional stability.

Last, Q3 functions as an emitter-follower, to provide low output impedance (about 50 ohms). If you need higher output impedance, include resistor R8. It will affect impedance according to this formula: $R8 \approx R_{OUT} - 50$. Otherwise, connect output capacitor C4 directly to the emitter of Q3.

Construction

The circuit can be wired up on a piece of perfboard; a PC board is not necessary, although one can be used. However you build the circuit, keep lead lengths short

and direct, and separate the input and output stages. You may have space to install the amplifier in your receiver. Otherwise, installing it in a metal case will reduce stray-signal pickup. You'll have to provide appropriate connectors on the case. Connect the amplifier to the antenna and radio using short lengths of coax.

The circuit has only one adjustment. Connect a source of 12-volt DC power to the circuit, and adjust R3 so that there is a 1.6-volt drop across R2.

If you're not sure of the impedance of your antenna, connect a 500-ohm potentiometer for R1, and adjust it for best reception. Then substitute a fixed-value resistor for the potentiometer.

You may want to follow the same procedure with the output circuit (R8), if you're not sure of your receiver's input impedance. Common impedances are 50, 75, and 300 ohms, so the same 500-ohm potentiometer can be used.

You can connect an external antenna through the amplifier to a receiver that has only a ferrite rod antenna. Connect the amplifier's output to a coil composed of 10–15 turns of #30 hookup wire wound around the existing ferrite core, near the existing winding. To obtain best reception, experiment with the number of turns and their placement. You may need to reverse the connections to the coil if output is weak.—D. J. Housley

Audible logic tester

A LOGIC TESTER WITH AN AUDIBLE indicator can be handy when troubleshooting or testing a crowded circuit board. It allows you to keep your eyes on the circuit, rather than on an LED on the tester. The project described in this article is just such a tester. It provides an audible indication of the logic level of the signal presented to its input. A logic high is indicated by a high tone, a logic low is indicated by a low tone, and oscillation is indicated by an alternating tone. The input is high impedance, so it will not load down the circuit under test. It can be used to troubleshoot TTL or CMOS logic.

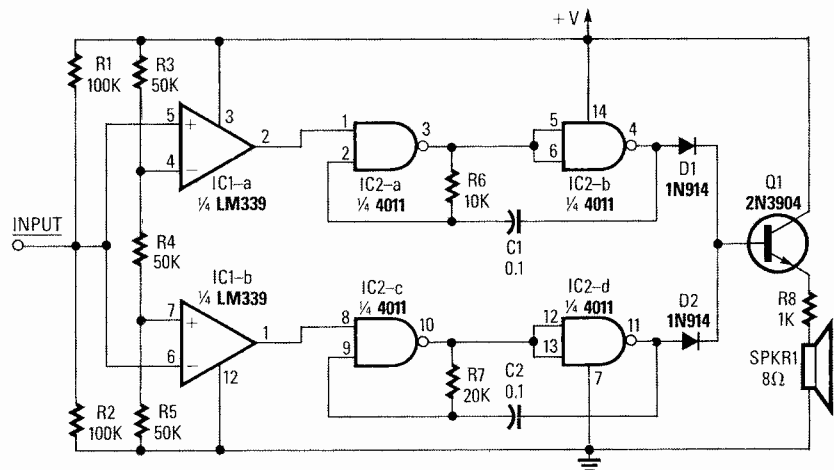


FIG. 1

Outdoor light controller

MOST AUTOMATIC YARD LIGHTS ARE controlled using just a simple photocell. However, since the ambient light levels at dawn and dusk change rather slowly, that approach usually results in some flickering just before the light fully locks on or off, which can significantly shorten bulb life. That can be avoided by using the controller shown in Fig. 1. That circuit *snaps* the light on or off, depending on whether ambient light levels are rising or falling.

How it works

The key to the circuit's operation is an optocoupler made up of a neon bulb (NE2 type) and a CdS photocell whose resistance varies inversely with light from 10K to 100K; those components are enclosed in a light-tight housing. A Diac/Triac combination is used to provide the snap-switch effect. A second CdS photocell acts as the main sensor.

As evening approaches the resistance of R6 begins to increase. When it reaches a threshold level, which is set by adjusting R1, the Diac triggers the Triac and causes the neon bulb to light. Even a momentary flicker of the bulb is sufficient to reduce the resistance of R5, causing the Diac to trigger the Triac, which lights the neon bulb, and so on.

The circuit

A schematic of the circuit is shown in Fig. 1. The input section determines whether the logic level is high or low, and enables the appropriate tone generator; it consists of two sections of an LM339 quad comparator. One of the comparators (IC1-a) goes high when the input voltage exceeds 67% of the supply voltage. The other comparator goes high when the input drops below 33% of the supply. Resistors R1 and R2 ensure that neither comparator goes high when the input is floating or between the threshold levels.

The tone generators consist of two gated astable multivibrators. The generator built around IC2-a and IC2-b produces the high tone.

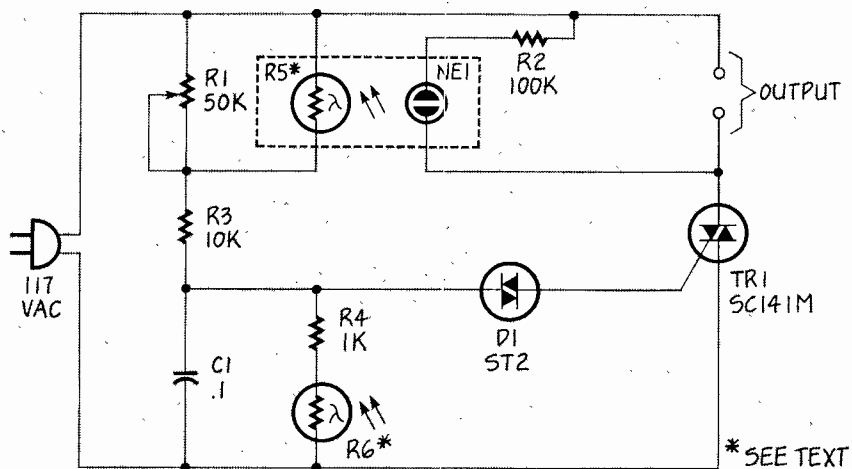


FIG.1

As morning approaches, the process is reversed. The resistance of R6 begins to decrease until it drops below the threshold level. That causes the Diac to cease triggering the Triac, which extinguishes the bulb, which causes the resistance of R5 to increase, and so on.

Most of the components can be mounted on a piece of perforated construction board and placed within a small experimenters box. Parts placement is not at all critical. All resistors, except the potentiometer and the photocells are ½-watt units. Once the threshold level for the circuit has been established, the potentiometer can be replaced by a fixed resistor of the appropriate value. Before mount-

ing R5 and NE1, place them in a light-tight enclosure. For my unit, the two were simply wrapped together using some black electrical tape.

Mount R6 so that it can be illuminated by the ambient light. However, take care to shield it from any artificial lighting. In my installation, the unit was mounted inside the lamp post, with the sensor looking out through a conveniently placed plastic lens.

To set up the unit, simply adjust the setting of R1 at dusk until the Triac is triggered. Remember that you are working with line voltages in this circuit, so take the appropriate precautions to protect yourself and others from potentially dangerous shocks.—E.J. Holtke

The one built around IC2-c and IC2-d produces the low tone.

Two diodes, D1 and D2, isolate the tone-generator outputs. Transistor Q1 is used to drive a low-impedance speaker.

The tester can be built on a small piece of perforated construction board; a PC board could also be used, if desired. Layout is not critical. The completed board should be mounted in a case. The size of its case will most likely be determined by speaker's size.

Two notes on the IC's: The 4011 is a CMOS device. As with all other CMOS devices, extra care should be exercised in handling to avoid subjecting the IC to damaging static electricity. Also, ground all unused inputs on the LM339.

The tester is designed to draw its power from the circuit under test. Therefore, the power and ground leads should be terminated by small alligator clips. Connect a spare multimeter probe to the tester's input and you are all set.

Connect the power-supply lead to the positive supply rail of the circuit under test. Connect the ground lead to the circuit-under-test's ground rail. At this point, the tester should be silent. Now, touch the probe tip to the circuit's positive supply rail. The tester should produce a high-pitched tone. Next, touch the probe to the ground rail. The tester should produce a low-pitched tone. If all is well, your tester is ready for use.—Philip L. Kane

Headlight alarm

IT'S 5:00 P.M., AND YOU'VE JUST finished a long day at the office. You climb into your car, turn the ignition switch on, and nothing happens. That's when you suddenly realize the problem: You left your headlights on this morning. Unfortunately, the realization has come about eight hours too late and now your battery is dead.

The preceding incident has probably happened to you at least once; in my case it has happened more often than I care to remember. Or at least it used to. Now, I have installed the simple circuit shown in Fig. 1 in my car. Of course, the circuit is a headlight alarm. It has saved me from embarrassment and aggravation on several occasions.

The circuit

While many cars are equipped with a headlight alarm, many more, unfortunately are not. For those cars, the circuit in Fig. 1 offers a low-cost way to add that valuable feature. Let's see how it works.

The base of Q1 is connected to the car's ignition circuit; the easiest point to make that connection

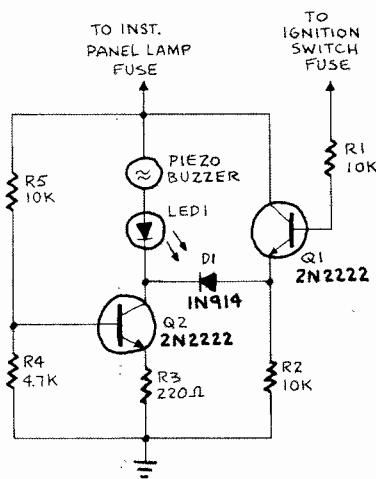


FIG. 1

is at the ignition switch fuse in the car's fuse panel. Also, one side of the piezoelectric buzzer is connected to the instrument-panel light fuse; remember that when the headlights or parking lights are on, the instrument panel is lit too. When the headlights are off, no current reaches the buzzer and therefore nothing happens. What happens when the headlights are on depends on the state of the ignition switch. When the ignition switch is on, transistors Q1 and Q2 are biased on, effectively removing the buzzer and the LED from the circuit.

When the ignition switch is turned off but the headlight switch remains on, transistor Q1 is turned off, but transistor Q2 continues to be biased on. The result is that the voltage across the piezoelectric buzzer and the LED is sufficient to cause the buzzer to sound loudly and the LED to light. Turning off the headlight switch will end the commotion quickly.

Construction

The circuit can be wired together on a piece of perforated construction board. The buzzer I used was a Radio-Shack 273-065 PC-board mounting type, but almost any similar buzzer will do. Circuit parameters are not critical, so feel free to make appropriate substitutions from your junk box to further reduce the cost.

When you are finished, house the circuit in a small, plastic experimenter's box and locate the unit on or under the dash of your car. You could also locate most of the unit behind the dash where it will be out of the way and mount only the LED where it can be seen easily. One good place would be next to the headlight switch on your dash; that will provide more of a custom look.—*Charlie Lowell*

Use an FM radio as a transmitter

SEVERAL YEARS AGO I NOTICED THAT AN FM radio generates an interference signal that can be picked up on another FM radio turned 10.7 MHz above the first one. Out of curiosity, I tried injecting an audio signal into the RF-oscillator section, and found that I now had a small transmitter.

Now that I have a VCR, I use the same technique to broadcast the TV's sound on the FM band using a portable FM radio. The circuit I use is shown in Fig. 1. The 50K potentiometer allows you to adjust the modulation level to maximum without distortion. The RC network improves the fidelity of the transmitted signal and provides DC isolation. The component values shown are provided as a starting point. They are the ones I used for my setup but may vary somewhat for different radios. Note that if you can't get the signal at 10.7

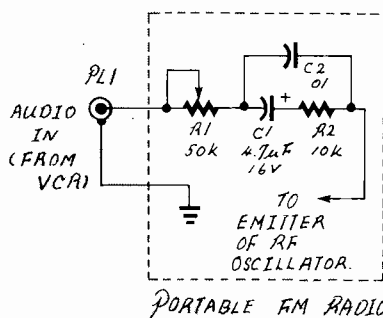


FIG. 1

MHz above the frequency setting of the first radio, try tuning at 10.7 MHz below. Also, note that both tuned frequencies must be unused, otherwise you will hear your audio on top of the audio that is already there. You might have to play with both frequencies until you find two blank spots that are 10.7 MHz apart.

When building the circuit, you

can mount the components on a piece of perforated construction board or on a terminal strip; you can mount the board or terminal strip inside the radio if there is sufficient space. The 4.7- μ F capacitor can be a tantalum, electrolytic, or non-polarized unit if you can find one, and the 0.01- μ F capacitor is a ceramic disc. Use an RCA plug for PL1 so that you can plug it into your VCR's audio output jack or any other audio source you wish.

The circuit allows using a personal stereo as wireless headphones. To use it, I just tune my personal stereo to a blank spot in the upper half of the FM band and tune the portable FM radio until the sound comes through on the headphones. Just think; you can put a tape in the VCR, put the TV in the window, go out to the car and tune in the sound. Presto—instant drive-in!—*John E. Boser.* **R-E**

Sequential flasher

HERE'S AN EASY AND INEXPENSIVE WAY to liven up a store window, decorate a Christmas tree, or create a do-nothing toy for the kids. As many as ten lightbulbs can be connected to the circuit and arranged in a circle, or in any other pattern. The lights flash sequentially; when the flash rate is about five or six Hz, an optical illusion of a "running dark spot" is produced.

How it works

As shown in Fig. 1, a 555 timer, IC1, drives a 4017 CMOS decade counter, IC2. Each of the 4017's first four outputs drives a CA3079 zero-voltage switch. Pin 9 of the CA3079 is used to inhibit output from pin 4, thereby disabling the string of pulses that IC normally delivers. Those pulses occur every 8.3 ms, i. e., at a rate of 120 Hz. Each pulse has a width of 120 μ s.

Due to the action of the CA3079, the lamps connected to the TRIAC's turn on and off near the zero crossing of the AC waveform. Switching at that point increases lamp life by reducing the inrush of current that would happen if the lamp were turned on near the high point of the AC waveform. In addition, switching at the zero crossing reduces Radio-Frequency Interference (RFI) considerably.

Construction

CAUTION: The CA3079's are driven directly from the 117-volt AC power line, so use care in building the sequential flasher. Keep lead lengths short, use insulated wire, and mount the entire circuit in a rigid, insulated enclosure.

We didn't specify part numbers for the TRIAC's, because the type will depend on the lamps you will

drive. The TRIAC's will almost certainly require heatsinks; the size of the heatsinks will depend on the amount of power the TRIAC's will have to dissipate, and that depends on the lamps you use.

You'll need a low-voltage source (+V_{CC}) to drive the 555, the 4017, and the bias inputs of the CA3079's. One possibility would be to wire up a 7805 regulator circuit and a step-down transformer.

It would also be possible to run the circuit from a 24-volt AC source. Doing so would allow the use of lamps with lower voltage and current ratings. The lower power required by the lamps would also allow use of smaller TRIAC's, smaller heatsinks, and a smaller enclosure. The circuit would also be much safer. See RCA Solid State's *Integrated Circuits for Linear Applications* for more information.—Michael Ciric

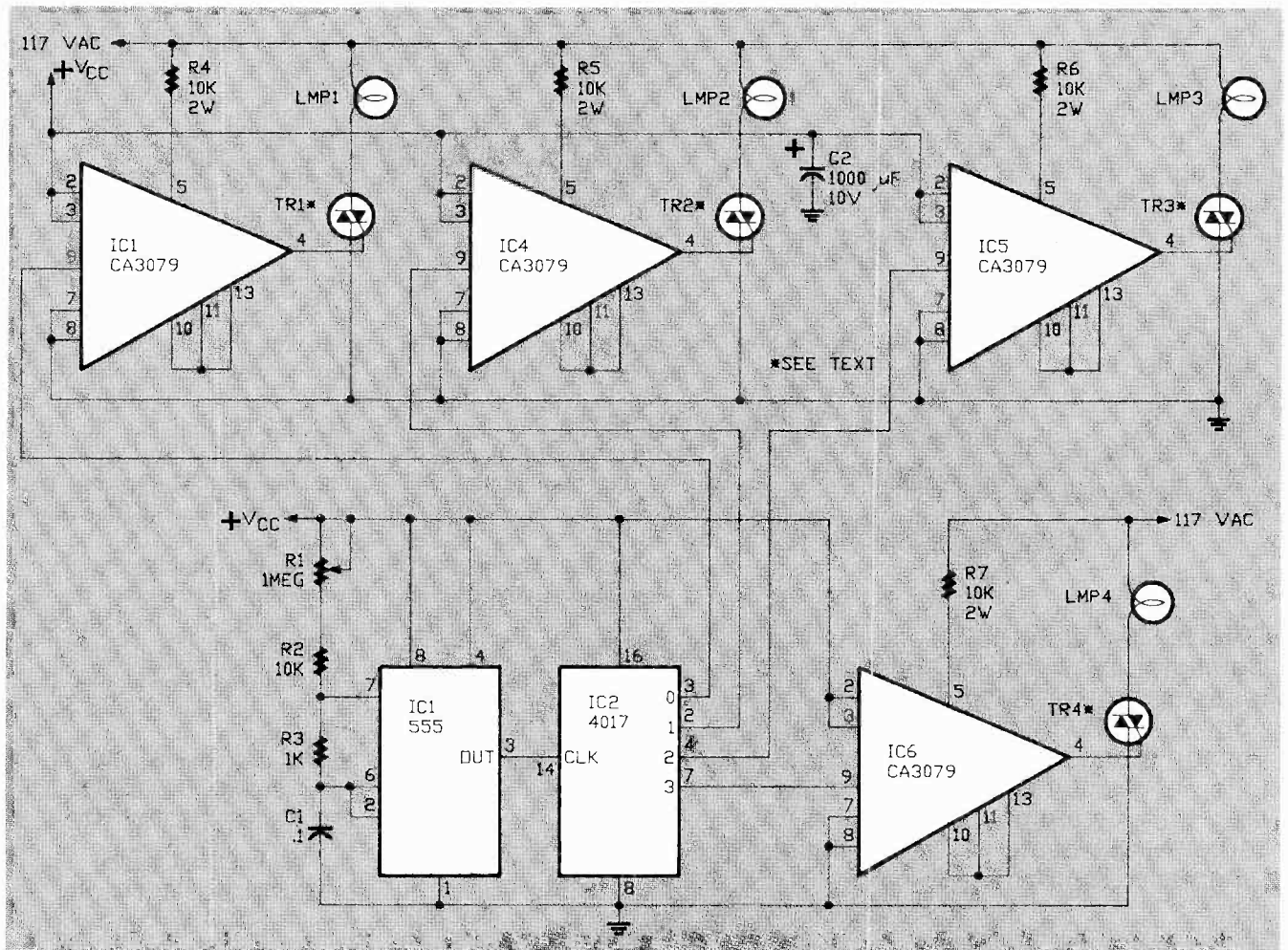


FIG. 1

Fingertip Olympics

THIS MONTH'S CIRCUIT IS A GREAT LITTLE game that's ideal for developing hand coordination, or for putting couch potatoes in the mood for the upcoming Olympic games.

The heart of the circuit, which is shown in Fig. 1, is an LM2907 (National) frequency-to-voltage converter. That low-cost IC, which is available from several of the companies that advertise in the back pages of **Radio-Electronics**, pro-

vides a voltage output that's directly proportional to the frequency at its input. That frequency is "set" by alternately closing S1 and S2, two normally-open, momentary-contact pushbuttons. The faster they're closed in sequence, the higher the frequency.

The "skill level" of the game is set by R1. The smaller the value of that resistor, the faster you'll have to hit the switches to get a measurable output. As a rule of thumb, start with a value of about 510K; if

you find that's too easy, or as you get better, substitute lower-valued units. You can also use multiple resistors and a rotary switch to set up multiple skill levels.

Setup and use

Any construction technique can be used to build the unit, but point-to-point wiring on a piece of perforated construction board is probably the simplest. For best play, the switches should be mounted about six inches or so apart, so be sure that you use a big enough piece of board.

To test, set R2 fully counterclockwise (minimum resistance) and tap the switches to make sure that there's an output, as indicated by M1. If there is, you are ready to go.

To play the game, set R2 at about mid-range, then place the unit in your lap or on a table top and begin tapping. Use two hands and go as fast as you can. The faster you tap the switches in sequence, the higher the output current. When you are tapping away at about your personal limit, readjust R2 so that M1 reads about $\frac{3}{4}$ scale (a friend is very helpful for that). Then start tapping away to see if you can get the meter to go even higher. The game can get very addictive!—
Phil Blake.

R-E

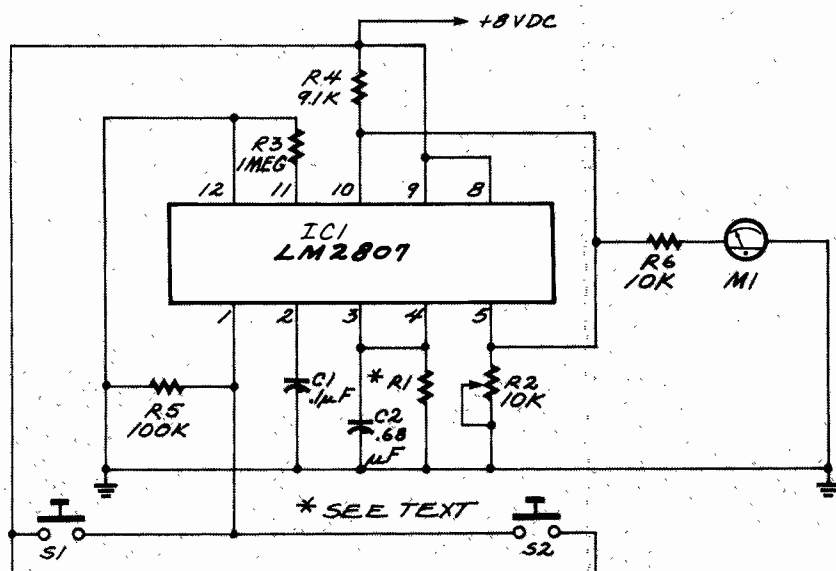


FIG. 1

Simple sine-wave generator

FOR PEOPLE WHOSE NEEDS DON'T WARRANT buying an expensive feature-filled sine-wave generator, a simple, low-cost one might often be useful. The circuit shown here is just that. It features amplitude and frequency controls, is made from low-cost components that are easy to obtain, and is powered from a 9-volt battery.

At the heart of the sine-wave generator circuit shown in Fig. 1 is an MF-10 IC made by National Semiconductor. It is part of a new generation of switched-capacitor filters that use an ingenious technique of switching internal capacitors to determine the cutoff

frequency. The output frequency of the MF-10 follows the frequency of an external clock. A square-wave input signal is fed into the device, and only the frequency of the clock signal is allowed to pass through. All other components of the input signal are filtered out. Because both the clock signal and the input signal must be square waves, a dual-output square-wave oscillator is used to simultaneously drive the clock and signal inputs. Therefore, the clock signal and the input signal are correspondingly shifted so that the MF-10 always filters out all but the fundamental frequency of the input signal. The result is a nice clean sine wave at the output.

A 555 timer operating in the astable mode generates the driving pulses and two 4518 dual BCD (Binary Coded Decimal) counters provide the square waves. A TL081 op-amp serves as an output buffer-amplifier, and potentiometers R1 and R2 are used in order to control the pulse's frequency and amplitude respectively.

The output-frequency range can be varied by changing C_x . For example, a value of 0.1 μF gives a range from about 0.1–30 Hz, and a value of 470 pF gives a range from about 10 Hz to 1.5 kHz. The maximum output frequency is 30 kHz.

The circuit can be built on a piece of perforated construction board using point-to-point wiring

Simple multi-tone generator

SOMETIMES YOU NEED A WAVEFORM having a particular shape, frequency, or amplitude that's not provided by your signal generator; or maybe you just don't own a signal generator. If you don't mind spending a bit of time experimenting with parts values, the multi-tone generator circuit described here might give you just the waveform that's needed.

The circuit shown in Fig. 1 can actually be built from parts you probably have lying around on the workbench. A bi-polar power supply is required; two 9-volt batteries wired in series, with their junction used as the "ground" will do.

How it works

Op-amp IC1 is used as a sensitive voltage comparator, whose trip level—the value at which the output changes state—is determined by potentiometer R2. The resistance of R1 in series with the resistance of phototransistor Q1 provides the feedback divider for IC1's inverting input. Since Q1's "dark" resistance—the resistance when there is no light—is very high. Very little voltage appears across R1; therefore, IC1's output will normally be high.

When power is first turned on, IC1 goes high, causing the LED to glow. However, the instant it glows

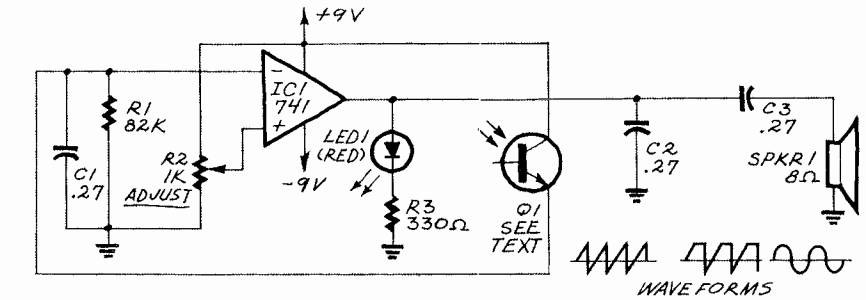


FIG. 1

it shines on Q1, causing a decrease in Q1's collector-emitter resistance, which causes a large voltage drop across R1. The comparator immediately switches to a low output, thereby turning the LED off, which restores Q1's dark resistance. The increase in Q1's resistance causes the cycle to repeat, thereby producing an oscillating output voltage.

Logically, the circuit should "lock up" because the LED and phototransistor would be competing with each other for control of the circuit, and IC1 would get stuck at some equilibrium state. Capacitor C2 prevents that from happening by keeping the LED lit slightly longer than the normal turn-off time. (C1 also helps avoid lock up, but its use isn't critical and it can often be eliminated.)

The output frequency can be changed by varying the values of C1-C3, but keep in mind that making their values too small will de-

feat their primary purpose, which is avoiding circuit lock-up.

The frequency, amplitude, and the shape of the waveform are determined by R2. Three of the typical waveforms that can be obtained by adjusting R2 are also shown in Fig. 1.

LED1 can be any red light-emitting diode. Q1 can be any phototransistor—try whatever you have lying around or can get cheaply. The only critical part of the assembly is the positioning of LED1 and Q1. They must be facing and close, and shielded from ambient light—perhaps by placing them inside a small cardboard or opaque plastic tube. Alternately, you could try substituting an optoisolator for LED1 and Q1. However, bear in mind that the spacing between LED1 and Q1 provides some control over the output waveform; an opto-isolator would eliminate that degree of control.—Mohd Amjad Khan. R-E

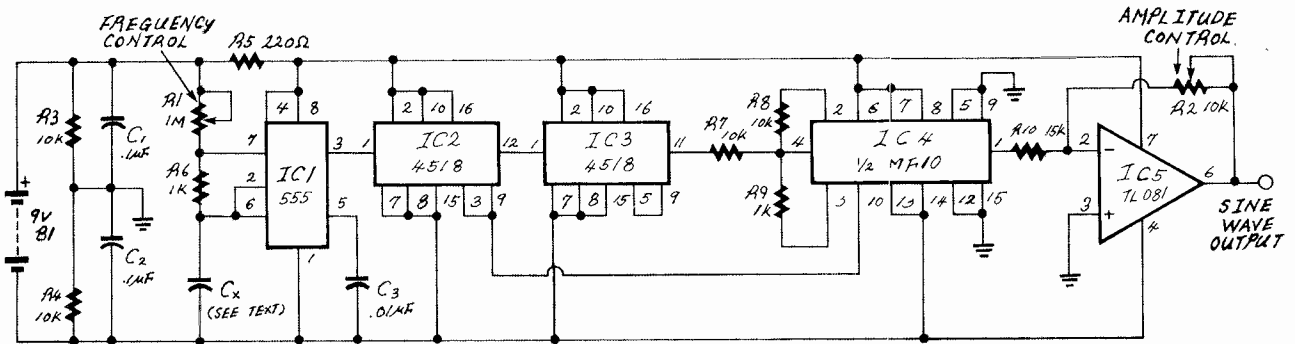


FIG. 1

techniques. Further, it is inexpensive to build, and therefore practical for use in dedicated applications where the sine-wave gener-

ator is permanently incorporated into another circuit or device.

For more information on the MF-10 switched capacitor filter IC,

write to National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051.—Dale Nassar. R-E

XMAS TREE

continued from page 28

Construction

The PC board can be made photographically using the foil pattern shown in PC Service, or the pattern can be used as a guide for applying liquid and tape resist by hand. Although the foil pattern itself is only 5-inches high, the PC board material must be $6\frac{3}{4}$ inches high because the tree's $1\frac{3}{4}$ -inch trunk is part of the PC board. Since etching large copper areas not only takes excessive time but also shortens the life of the etchant, we suggest you trim away the unwanted PC board material before you etch the board. Or, if you prefer to cut the tree to size after the pattern is etched, protect the foil of the large unused trunk area with resist and simply let the copper remain. As long as the trunk's foil doesn't come in contact with any of the circuit traces it makes no difference whether it's there or not.

If you want to decorate the front of the tree, do it before the holes for the components are drilled. For example, the author sprayed the component side with a bright automotive metallic-green paint. To prevent a defined line, a cardboard mask was held about $\frac{1}{2}$ -inch above the board. Then,

the edge of the PC board was "dusted" with a fine mist of white paint to simulate snow. After allowing for adequate drying, again using a cardboard mask, the trunk portion of the board was painted with a metallic-brown paint.

Allow the decorative paint to dry overnight before drilling the component mounting holes. Then install and solder the eight jumpers, the resistors, the IC's, and the capacitors. Then insert all the LED's, observing the polarities shown in Fig. 2. Position the LED's so that they are raised approximately $\frac{1}{2}$ inch off the board. To do that, turn the board over and lay it down on a flat surface, being careful not to allow any LED's to fall out; that can be done easily by holding a piece of stiff cardboard against the LED's while turning the board over. Keeping the board parallel to your work surface, solder one lead of each LED. Turn the board over and carefully look across the surface to see whether the LED's are straight and at the same height. If not, correct as needed. When you're satisfied with their alignment, solder the other lead of each LED.

Adding the base

Prepare the surfaces of the battery holders and the PC board for gluing by sanding the back of each holder and a $\frac{3}{8}$ -inch strip on both sides of the circuit board at the

bottom of the trunk. Mix a small amount of a 5-minute epoxy and apply some to the $\frac{3}{8}$ -inch strip on both sides of the circuit board. With the battery polarities opposite each other, sandwich the PC board between the holders. Hold the assembly firmly on a flat surface that's covered with a piece of wax paper. You will have a few minutes working time before the epoxy sets to ensure proper alignment. Make certain that the holders are even and that the circuit board is centered and upright between the holders. In about 5 minutes the glue will have set up sufficiently, and the tree can be lifted from the wax paper. Use acetone or flux remover to clean excess glue from the bottom of the battery holders. As with most other cleaners, be careful not to touch the painted surface.

After allowing at least one hour for the epoxy to cure, solder a jumper wire at one end of the battery holders, across the adjacent positive and negative terminal lugs. From the battery source ends, solder the positive and negative leads directly to the foil traces—as shown in Fig. 2. The LED's will start to flash as soon as the batteries are installed. Any LED that fails is most likely defective, or installed with reversed polarity.

You can add a final "dress up" by gluing a colorful felt material over foil traces on the back of the board. **R-E**

GRAVITY

continued from page 129

Galactic events

A few of the more prominent galactic events will be briefly described to aid the experimenter in recognizing their signatures.

Nova: A Nova is believed to be a star that ejects its outer layers in a violent explosion. As shown in Fig. 11, the large transit movement of mass creates two prominent features (or signatures) for that explosive event: the "blast" itself is then followed by the "tailing" of the blasted material as the gravity detector moves away due to the rotation of the earth. A Nova generally does not leave a lasting gravitational trace because the amount and density of the expelled material is not that great; although new Nova explosions are commonly observed.

Supernova: A Supernova is believed to be a star that exceeds a certain critical mass and then collapses to a small dense Neutron Star, or a Black Hole structure and, in that process, expels much of its gaseous material. The entire collapsing process, which occurs only in a few hundred milliseconds, is observable with the author's gravity detector. As shown in Fig. 12, a plot of a Supernova has certain prominent features. First, there is the actual collapse of the core of the star that generally appears as a sharp dip. The expulsion of the gaseous mass layer is now much

more pronounced, which again gives rise to the tailing effect like the one of an ordinary Nova. Supernova, however, also shows a mass build-up due to shock-wave action, and that might appear as a bump in the tailing response.

Black Hole: A Black Hole-type structure is generally developed by a very massive Supernova event, and is usually developed 24 to 48 hours after the event. An ancient Black Hole, as shown in Fig. 13, appears as a rather deep gravity shadow of very narrow width (time of response) since it is rather small in size—being only a few miles in diameter.

Galaxy Center: The Milky-Way center collectively generates a massive and predictable gravity response, as shown in Fig. 14.

Solar system events

Those who possess a strip chart recorder may wish to observe the planets that make up our solar system. The outer planets while massive are of low density and thus difficult to observe unless their exact time of transit on the observer's meridian is known; and even then the results are often difficult to plot. The inner planets, while denser, must be observed in a background relatively free of other cosmic events. It is unfortunate, but the gravitational background of cosmic events tend to mask solar system gravity sources.

Probably the easiest local astronomical

body to observe will be our sun. It is located on the observer's meridian at noon and at midnight. Using a low system gain, a typical scan of the Sun is shown in Fig. 15. The twin peaks of the scan seen in the center of the scan are believed to represent the nuclear core. The body of the sun is gaseous (low density), and, thus, gravitationally transparent. The sun's mass shows little differential from the averaged background level, except for the core, which shows an increase in density that measures about 50 mV above the averaged background level of about 1.5 volts.

The Moon is *not* an interesting object for gravitational observation because it's difficult to detect against a background of gravity events that tend to mask the moon's transit.

To catch the planet Venus you must know the right ascension location for the day you want to scan. A scan for Venus is shown in Fig. 16. It appears to indicate that Venus has a dense core.



I'm fixing your father's repair job on this radio.

CELLULAR TELEPHONE

continued from page 88

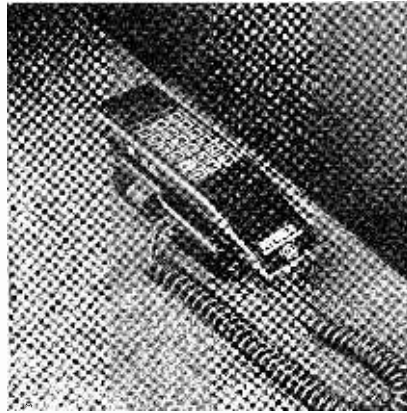
knowledge of A and B services to that indicator, causing it to flash if the service it encounters is different from the one you have selected. That notifies you that, if you have to switch services manually (perhaps you have locked into one or the other—the recommended method), that is the time to do so.

What else?

In addition to performing those invisible tasks, the sophistication of cellular phones and phone systems makes using them more convenient.

Of course, they provide such things as auto-redial, muting, and memories that can hold up to 32 phone numbers that can be dialed by just a keypress or two. But just about every phone these days has those features. Cellular phones provide even more!

A few cellular phones give you the luxury of speech recognition for hands-free dialing. It's really more than a luxury—the less your attention is diverted from your driving, the longer you're likely to be around to make more phone calls. One phone, available from AT&T, not only



THE MODEL CDL205 is from Nynex Mobile Communications.

understands what you say to it but also talks back to you. When you pick up the handset it says, "Name please," and waits for you to tell it whom to call (it can also associate names with phone numbers). If the person you are calling is one of those stored in the phone's memory, the phone will dial the number after you speak the name. If you dial the phone manually, it will announce the digits entered as you punch them in. If the line is busy, you can later tell the phone to redial the number.

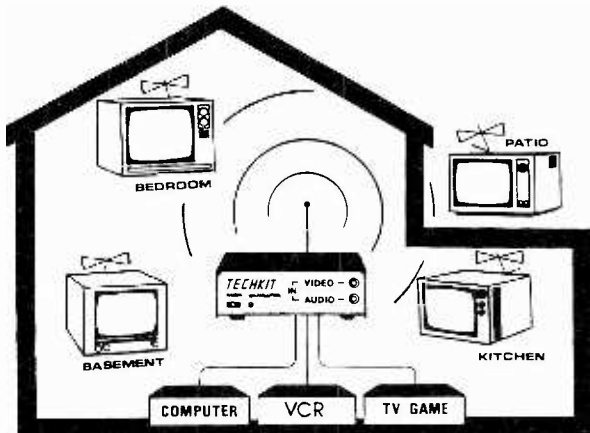
Cellular phones also use their intel-

ligence to keep you informed of situations they encounter. We've already seen what the ROAM indicator can tell you. Another indicator, labeled NO SERVICE lights if the phone encounters no response on its control channels, meaning that there is no cellular service in the area you're in at the moment. That indicator also can be used to let you know when a call is terminated, or when a signal dropout occurs.

Because they already contain a clock circuit for the control of a microprocessor, cellular phones can also provide time-keeping services. The simplest just tell you the length of the last call you made. Others tell you how long you've been engaged in the call you're currently making (that can be quite useful, since cellular phone calls are billed on a per-minute basis). Some phones can tell you how long you've been talking, the total length of time you've used the phone (the timer can be reset to zero whenever you like), and the total number of calls you've made.

Finally, if you leave them on while you're away from them, most cellular phones are able to notify you when you return if you had a call in your absence. They can't tell you who called (although at least one firm has plans to introduce an answering machine for your car), but if you were expecting a call, at least you'll know that it probably came. **R-E**

GET THE PICTURE?



Build this WIRELESS VIDEO TRANSMITTER, a fun and exciting introduction to Electronic Communication!

FEATURES:

- ★ No tedious adjustments, crystal controlled
- ★ Easy assembly
- ★ Transmits video/audio signal on UHF channel

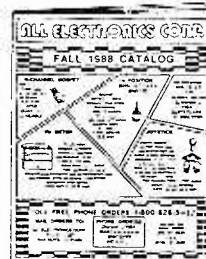
KIT INCLUDES:

- ★ Silk screened & drilled PC board, All parts
- ★ Chassis face-plate decal
- ★ Complete instructions & diagrams

Complete kit & plans for CH 14 UHF (model TK-14) or CH 15 UHF (model TK-15) ONLY \$39.95, plus \$5.00 S & H. Plans only, \$3.00. Please send cheque/money order to: **TECHKIT, 8303 Daniel Dony, Montreal, Quebec, H1E 9Z7. C.O.D.** orders require 20% deposit, Quebec residents add 9% sales tax. Please allow 3-6 weeks delivery.

CIRCLE 26 ON FREE INFORMATION CARD

ALL ELECTRONICS CORP.



WE STOCK OVER
4,000 ITEMS...
CALL OR WRITE
FOR OUR FREE
56 PAGE CATALOG
OF PARTS!

RESISTORS • CAPACITORS • DIODES
CABLES • BRIDGE RECTIFIERS •
LAMPS • CHOKE COILS • CRYSTALS • RELAYS • I.C.'S •
• CRIMP CONNECTORS • HEAT SINKS • MOTORS •
SUB MINIATURE D CONNECTORS • TRANSISTORS •
PROTO BOARDS • POTENTIOMETERS • POWER SUPPLIES
• JACKS • PLUGS • SWITCHES • FANS • PERF BOARD •
FUSES • SHRINK TUBING • TIE WRAPS • TOOLS •
KEYPADS • VIDEO ACCESSORIES • S.C.R.'S • TRANS-
FORMERS • TELEPHONE ACCESSORIES • RIBBON CABLE •
CIRCUIT BREAKERS • VOLTAGE REGULATORS •
AND MANY OTHER ITEMS.

MAIL ORDERS TO:
ALL ELECTRONICS
P.O. BOX 567
VAN NUYS, CA 91408

ORDER TOLL FREE
800-826-5432

INFO: (818)904-0524

TWX-5101010163
(ALL ELECTRONIC)

MINIMUM ORDER \$10.00

QUANTITIES LIMITED

CALIF. ADD SALES TAX

USA: \$3.00 SHIPPING

FOREIGN ORDERS

INCLUDE SUFFICIENT

SHIPPING. NO C.O.D.

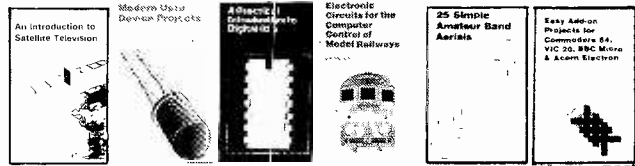
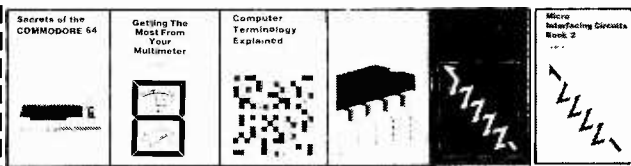


OUTSIDE THE U.S.A.
SEND \$2.00 POSTAGE
FOR A CATALOG!!

CIRCLE 22 ON FREE INFORMATION CARD

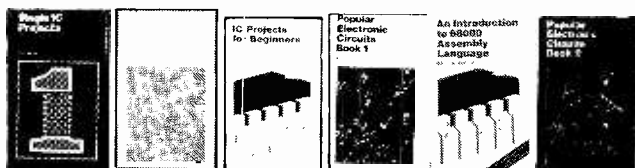
Electronics Paperback Books

GREAT ELECTRONICS PAPERBACKS FROM ETT



- BP195—INTRODUCTION TO SATELLITE TV.....\$8.00.** A definitive introduction to the subject written for the professional engineer, electronics enthusiast, or others who want to know more before they buy. 8 x 10 in.
- BP128—20 PROGRAMS FOR THE ZX SPECTRUM AND 16K ZX82.....\$5.75.** Included with each program is a flow chart and a description of what happens. Notes for converting programs for use on other computers are also included.
- BP235—POWER SELECTOR GUIDE.....\$10.00.** Complete guide to semiconductor power devices. More than 1000 power handling devices are included. They are tabulated in alpha-numeric sequence, by technical specs. Includes power diodes, Thyristors, Triacs, Power Transistors and FETs.
- BP234—TRANSISTOR SELECTOR GUIDE.....\$10.00.** Companion volume to BP235. Book covers more than 1400 JEDEC, JIS, and brand-specific devices. Also contains listing by case type, and electronic parameters. Includes Darlingtons transistors, high-voltage devices, high-current devices, high power devices.
- BP99—MINI-MATRIX BOARD PROJECTS.....\$5.00.** Here are 20 useful circuits that can be built on a mini-matrix board that is just 24 holes by ten copper-foil strips.
- BP157—HOW TO WRITE ZX SPECTRUM AND SPECTRUM+ GAMES PROGRAMS.....\$5.95.** A crystal-clear step-by-step guide to writing your own graphics games programs.
- BP117—PRACTICAL ELECTRONIC BUILDING BLOCKS—Book 1.....\$5.75.** Oscillators, Timers, Noise Generators, Rectifiers, Comparators, Triggers and more.
- BP184—INTRO TO 68000 ASSEMBLY LANGUAGE.....\$6.50.** The 68000 is a great new breed of microprocessor. Programming in assembly language increases the running speed of your programs. Here's what you need to know.
- BP179—ELECTRONIC CIRCUITS FOR THE COMPUTER CONTROL OF ROBOTS.....\$5.00.** Data and circuits for interfacing the computer to the robot's motors and sensors.
- BP126—BASIC & PASCAL IN PARALLEL.....\$4.95.** Takes these two programming languages and develops programs in both languages simultaneously.
- BP198—AN INTRODUCTION TO ANTENNA THEORY.....\$6.95** Basic concepts relevant to receiving and transmitting antennas.
- 225—A PRACTICAL INTRODUCTION TO DIGITAL IC'S.....\$4.95.** Mainly concerned with TTL devices. Includes several simple projects plus a logic circuit test set and a digital counter timer.
- BP170—INTRODUCTION TO COMPUTER PERIPHERALS.....\$5.95.** Shows how to use a variety of co computer add-ons in as non-technical a way as possible.
- 227—BEGINNERS GUIDE TO BUILDING ELECTRONIC PROJECTS.....\$5.00.** How to tackle the practical side of electronics so you can successfully build electronic projects.
- BP169—HOW TO GET YOUR COMPUTER PROGRAMS RUNNING.....\$5.95.** Shows how to identify error in program and what to do about them.
- BP194—MODERN OPTO DEVICE PROJECTS.....\$6.25.** Crammed with great projects for the experimenter. Includes sections on Fiber optics, passive Infra-Red detectors, plus an assortment of miscellaneous projects.
- BP180—ELECTRONIC CIRCUITS FOR THE COMPUTER CONTROL OF MODEL RAILROADS.....\$6.25.** It's easy to interface home computers to model railroad control. The main problem is in interfacing the computer to the system.
- BP110—HOW TO GET YOUR ELECTRONIC PROJECTS WORKING.....\$5.00.** How to find and solve the common problems that can occur when building projects.

- BP239—GETTING THE MOST FROM YOUR MULTIMETER.....\$5.75.** Covers basics of analog and digital meters. Methods of component testing includes transistors, thyristors, resistors, capacitors and other active and passive devices.
- BP36—50 CIRCUITS USING GERMANIUM, SILICON & ZENER DIODES.....\$5.00.** A collection of useful circuits you'll want in your library.
- BP37—50 PROJECTS USING RELAYS, SCR'S & TRIACS.....\$5.00.** Build priority indicators, light modulators, warning devices, light dimmers and more.
- BP39—50 FET TRANSISTOR PROJECTS.....\$5.50.** RF amplifiers, test equipment, tuners, receivers, tone controls, etc.
- BP42—SIMPLE LED CIRCUITS.....\$5.00.** A large selection of simple applications for this simple electronic component.
- BP127—HOW TO DESIGN ELECTRONIC PROJECTS.....\$5.75.** Helps the reader to put projects together from standard circuit blocks with a minimum of trial and error.
- BP122—AUDIO AMPLIFIER CONSTRUCTION.....\$5.75.** Construction details for preamps and power amplifiers up through a 100-watt DC-coupled FED amplifier.
- BP92—CRYSTAL SET CONSTRUCTION.....\$5.00.** Everything you need to know about building crystal radio receivers.
- BP45—PROJECTS IN OPTOELECTRONICS.....\$5.00.** Includes infra-red detectors, transmitters, modulated light transmission and photographic applications.
- BP48—ELECTRONIC PROJECTS FOR BEGINNERS.....\$5.00.** A wide range of easily completed projects for the beginner. Includes some no-soldering projects.
- BP49—POPULAR ELECTRONIC PROJECTS.....\$5.50.** Radio, audio, household and test equipment projects are all included.
- BP51—ELECTRONIC MUSIC AND CREATIVE TAPE RECORDING.....\$5.50.** Shows how you can make electronic music at home with the simplest and most inexpensive equipment.
- BP56—ELECTRONIC SECURITY DEVICES.....\$5.00.** Includes both simple and more sophisticated burglar alarm circuits using light, infra-red, and ultrasonics.
- BP59—SECOND BOOK OF CMOS IC PROJECTS.....\$5.00.** More circuits showing CMOS applications. Most are of a fairly simple design.
- BP72—A MICROPROCESSOR PRIMER.....\$5.00.** We start by designing a small computer and show how we can overcome its shortcomings.
- BP74—ELECTRONIC MUSIC PROJECTS.....\$5.95.** Provides the experimenter with a variety of practical circuits including a Fuzz Box, Sustain Unit, Reverberation Unit, Tremolo Generator and more.
- BP91—AN INTRODUCTION TO RADIO DXING.....\$5.00.** How you can tune in on those amateur and commercial broadcasts from around the world in the comfort of your home.
- BP94—ELECTRONIC PROJECTS FOR CARS AND BOATS.....\$5.00.** Fifteen simple projects that you can use with your car or boat. All are designed to operate from 12-volt DC supplies.



ELECTRONIC TECHNOLOGY TODAY INC.
P.O. Box 240, Massapequa Park, NY 11762-0240

SHIPPING CHARGES IN USA AND CANADA

\$0.01 to \$5.00	..	\$1.25
\$5.01 to 10.00	..	\$2.00
\$10.01 to \$20.00	..	\$3.00
\$20.01 to \$30.00	..	\$4.00
\$30.01 to \$40.00	..	\$5.00
\$40.01 to \$50.00	..	\$6.00
\$50.01 and above	..	\$7.50

SORRY No orders accepted outside of USA & Canada

Number of books ordered

Name _____
Address _____
City _____ State _____ Zip _____

Total price of merchandise \$ _____
Sales Tax (New York State Residents Only) \$ _____
Shipping (see chart) \$ _____

All payments must be in U.S. funds

Total Enclosed .. \$ _____

EH-88

