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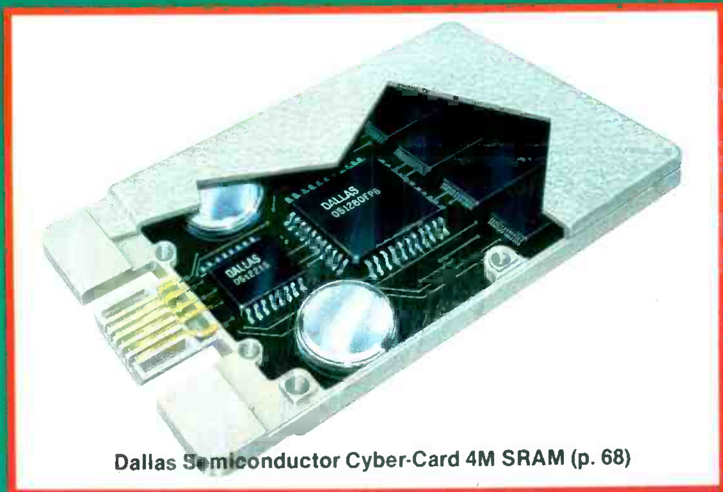

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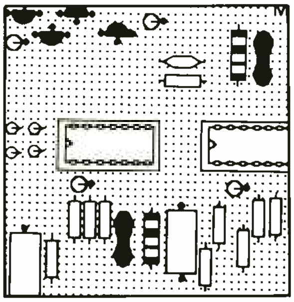
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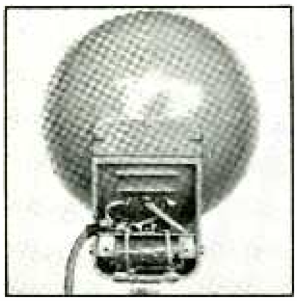
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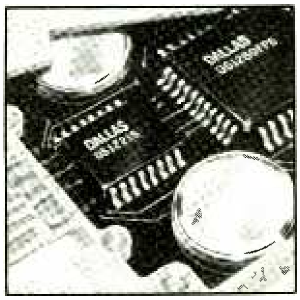
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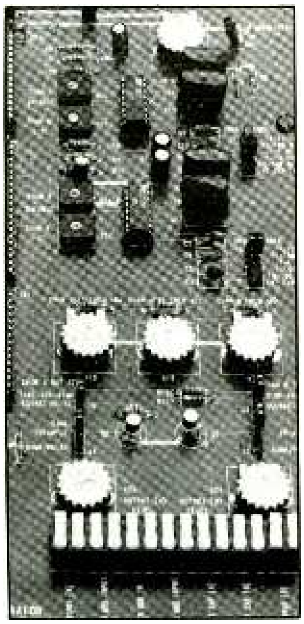
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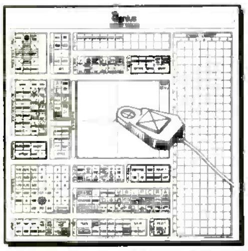

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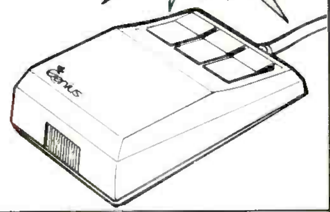

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EDITORIAL

Printed Circuits

As you know, many of our construction projects are accompanied by printed-circuit-board foil patterns and component-placement guides. Frequently, a pcb is made available for purchase at a modest price. This is noted at the end of the article's Parts List. If it isn't listed, you have to make your own board from the plans pictured or go to point-to-point connections with, say, wire wrapping.

If there are a lot of components in the circuit or you wish to make as compact a product as you can, the pcb route is the most desirable one to take. There are many ways to do this, as evidenced by the host of articles on the subject that we presented over the years. Having a foil pattern published here makes it real easy. But what if you don't have one? Again, we've presented ways to roll your own that are simple to do.

Simple and effective, that is, if your parts count isn't great or you don't care about laying out a pattern in the best way to conserve board space requirements, or you only plan to make one board rather than a number of them that might require another company to produce them on automatic production equipment. If you deal with a rather complex circuit and/or wish to hold down the size of a board as much as possible, you may turn to computerized pcb layout programs.

They're indispensable for professionals. But CAD (computer-aided design) methodologies call for a software investment that ranges from moderate ($100 to $500) to high (thousands of dollars). Furthermore, there's a rather steep learning curve for the higher-priced ones, which give you greater control over what you're doing in the end. They provide various design checks, do some automatic juggling around of foil traces and connections to provide you with the best layout, and even set up things for automated pcb production and parts assembly.

We examined a bevy of such programs, ranging in price from roughly $200 to $2,500, which we planned to present in this issue. However, we're holding off until next month in order to do as much justice to the reviews as possible.

Working with one of the programs myself, I can tell you first hand that it's easier said than done first time out. The same goes for schematic capture programs. One isn't born to it. It requires some strong efforts to work it all out and I'd guess some fair amount of time to make it an efficient alternate to hand-laid foil patterns. A few of our writers have been doing this for professional reasons over the years, however, and I've observed them moving along the CAD path at a brisk pace. So I know it can indeed be done better this way. But you've got to make the investment in dollars and put in learning and practice time to make it pay off.

The PC CAD world of rats nests, vias, autorouters, color layers, libraries, nodes, force vectors, post-processing, mirroring, solder masks, and the like can be very rewarding in both a personal sense and for career reasons. On the latter, there are plenty of well-paying job openings for people who know their way around CAD for generating both schematics and pcbs, not to mention other computerized drawing modes for engineering and manufacturing purposes.

Now that we have a batch of 386 Personal Computers, we're giving serious consideration to doing more of our drafting and printed-circuit-board work with them. Their automatic forward and back annotation will do more to ensure that foil patterns, schematics and parts lists accurately reflect each other . . . and do it fast. Additionally, a change in one area is automatically reflected in the others.

More and more, electronics and computers are being wedded to each other. Welcome to the world of high tech.

Art Salsberg

For Greater Safety

• The "Power Supply for IC Experimenting" schematic diagram that appeared in the January issue of *Modern Electronics* would benefit enormously in terms of both user and experimenter circuit safety with addition of another 1.5-μF capacitor in the other leg of the ac line input. As the circuit stands, diodes can fail and the possibility of a shock hazard exists because there is no real isolation from the ac line.

John Hoffman
Manhasset, NY

Religious Convictions Not An Issue

• As subscribers to *Modern Electronics*, my son and I admire the fact that you do *not* consider faith or religious conviction of your writers when evaluating their work for publication. It is particularly gratifying that you have chosen to continue publishing the fine works of Forrest Mims III during a time that he has suffered from the ugly discrimination of other [magazine] editors.

We continue to enjoy *Modern Electronics* and intend to renew our subscriptions.

Atlee Kohl
Irving, TX

• I just read your January Editorial and couldn't believe what *Scientific American* is doing these days. This country was founded by people of diverse religious beliefs who toiled to make sure our freedoms would be for everyone. My personal belief is that Mr. Mims is one of the most respected men of our time. To crush his pen would surely set us back into the Dark Ages.

Robert J. DeVincent Jr.
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If you have any thoughts, comments or other feedback you would like to share with us or our readers, feel free to jot them down and send them to us. Address all correspondence to *Modern Electronics*, Letters Editor, 76 North Broadway, Hicksville, NY 11801.

The Swiss Army Notebook Computer.

JAPAN RADIO GOES DIGITAL. Some radio listeners in Japan were recently treated to digital broadcasts from a satellite. It's called Radio GIGA (transmit frequency is measured in gigahertz). To receive its digital signals requires having a small satellite dish and a special tuner that's attached to a TV set. Furthermore, the commercial-free broadcasts will be scrambled in April, requiring purchase of a decoder ($230 plus $5.30 per month). For this, one will get 24-hour broadcasts of mostly "relaxing" music. It's claimed, though, that sound quality is equivalent to that of an audio compact disc, with no static or hiss to mar reception.

The broadcaster, Satellite Digital Audio Broadcasting, hopes to have 700,000 paying customers within two years. Such expectations aren't as high as you might think because there are few radio stations in Japan due to an equal-facilities policy between cities. As a result, Tokyo's 12-million people share only four FM stations (two commercial, one public and one that carries only school lectures). The digitally transmitted music will be able to be copied on digital tape recorders.

OPTICAL DISK DATA STORAGE JUKEBOX. A 5-1/4" optical disk drive "jukebox"--the LF500 Autochanger from North American Philips' LMS Company in Colorado Springs, was recently announced. It's a data backup and archival storage device rather than a simulated Wurlitzer, however. But the Autochanger does hold up to 32 removable 653MB ISO-standard optical disk cartridges, and is able to mix WORM and rewritable media. It's said to be compact enough to fit alongside a workstation or desk.

AN ELECTRONIC NOTARY. A digital time-stamping service prototype developed at Bellcore is said to be able to affix a tamper-proof time-stamp seal to any electronic document. The challenge was that, unlike with paper and ink, there hasn't been a way to tell if part of an electronic document had been tampered with if it was carefully overwritten or fully wiped out. The basis of the cheat-proof system is the creation of hidden, unalterable identifiers such as a hash value combined with electronic time stamping. In essence, it imposes a digital fingerprint.

INTEGRATED DSO TELESERVICING. Tektronix introduced the first commercial teleservicing software that incorporates three functions: data communications, data management and waveform graphics. It uses standard phones, a Hayes-compatible modem and an RS-232C interface between a Tektronix 2230 Portable Digital Storage Oscilloscope and an IBM PC/XT/AT or compatible (or two DSO's). With this, computer service waveforms can be transferred to a service center for further analysis, speeding field troubleshooting. This is a lot better than trying to describe some complicated waveforms verbally. Software price is $295.

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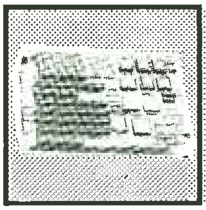

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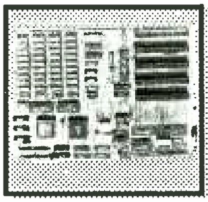

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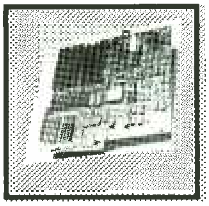

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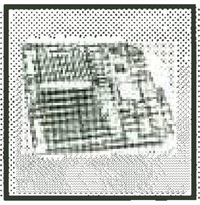

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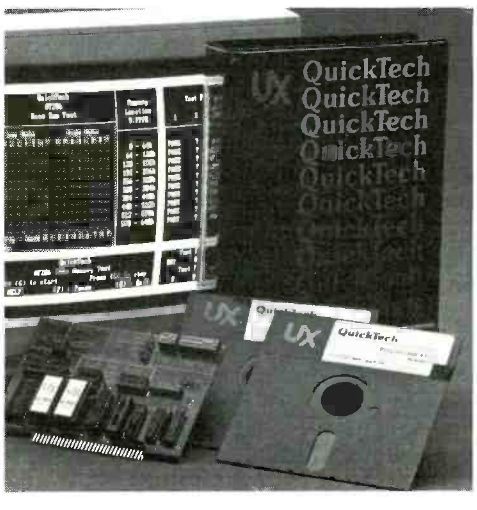

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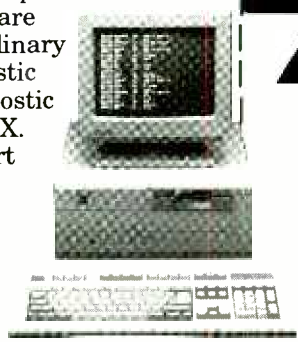

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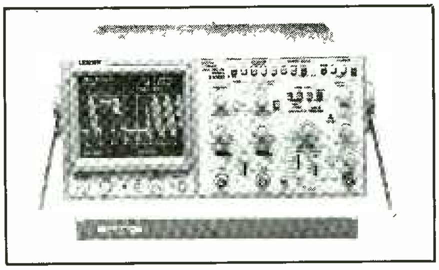
Autoranging 100-MHz Analog/Digital Scope

Leader Instruments' Model 3100D 100-MHz analog/digital oscilloscope features separate 4K memories for display and reference, 40-Ms/s maximum sampling rate and 100 Ms/s equivalent sampling. It also offers CRT read-outs with cursors for



voltage, time, frequency, phase and ratios for voltage, time and dB, as well as additional comment lines. Results can be downloaded to a computer via a GPIB interface to an HP-GL plotter for hard-copy printout.

Up to four waveforms can be stored in memory. Waveform expansion of held information is possible from ×1 to ×100, with automatic interpolation. Data stored in the display memories can be simultaneously displayed and overlaid onto data recalled from the reference memories for evaluation purposes.

Other features include: automatic horizontal and vertical ranging; selectable averaging from 2 to 256 bits; smoothing; pre-trigger view; dual timebase with calibrated delayed sweep; alternate sweep, roll mode and trigger; and universal 90-to-125-volt ac power supply.

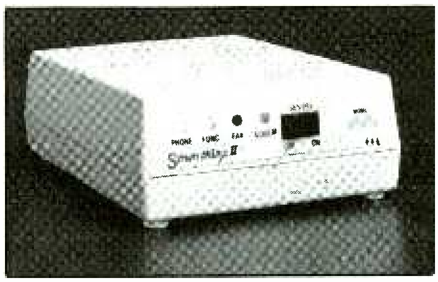
CIRCLE NO. 7 ON FREE INFORMATION CARD

Telephone-Line Autoswitch

SmartMax II™ from MaxTrek, Inc. (Hayward, CA) allows two or more devices to share a single telephone line and automatically switches any of them as needed by an incoming call. Two versions are available. The Model 6000 provides automatic switching between a telephone instrument and fax machine, while the Model 6500 adds automatic switching for a third device that can be a computer modem, credit-card terminal or other accessory.

Both models offer such common features as: simple plug-in installation for single-line phones; power to handle multiple extension telephone instruments; compatibility with US phone systems, TADs and fax machines; a sentry mode for nighttime operations; programmable ring count for more switching options; a hold feature; extended transfer and selection menu; Touch Tone® and rotary-dial transferring capability; and choice of operating modes to fit a wide variety of applications.

Power for SmartMax II comes from an ac outlet. The device con-



sumes 7.3 watts on idle and 17 watts during the ring cycle. Its ring output is 90 volts rms at 22 Hz. The input and all outputs are made via standard RJ-11 modular jacks. Ring loading is rated at 5.0 REN. The unit measures 6⅞"L × 4⅞"W × 2"H and weight 1 lb. 10 oz.

CIRCLE NO. 8 ON FREE INFORMATION CARD

SMT Pick-Up Pencil

OK Industries offers a safe and easy way of handling static-sensitive components with its new VP-150 Series vacuum pick-up pencil. The pencil is made from static-dissipative materials and offers two user-selectable vacuum deactivation modes. Continuous deactivation of the vacuum is accomplished either by removing a

finger from a bleed hole in the handpiece or using a foot-operated switch. The VP-150 can be used with OK Industries' SMT-80 board holder and SMT-815 component carousel. $176.

CIRCLE NO. 9 ON FREE INFORMATION CARD

Wireless Car Alarm

Midland International's new Model 73-375 provides a motion detector and vibration sensor for automotive security. Powered from a vehicle's cigarette-lighter socket or a cord that connects directly to a vehicle's electrical system, it also features an emergency back-up power system (battery optional) so that disconnection of the alarm from the vehicle automatically sounds the alarm.

This alarm detects motion and sounds the alarm if an attempt is made to tow or push the vehicle in which it is installed. It also detects shock conditions, such as glass breakage. When the alarm triggers, it sounds dual 110-dB sirens for 90 seconds and then automatically resets.

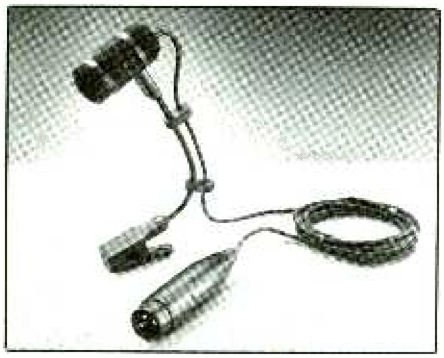
The alarm can be turned on and off with an ultra-miniature key-chain remote-control device that operates from up to 30 feet away. One beep sounds to confirm that the alarm is armed, and two beeps indicate when it is disarmed. The remote controller can also be used as a "panic" switch.

The remote controller has 2,186 user-programmable codes. The alarm unit is equipped with an external-siren jack for use with a remote siren. Shock-resistant LEDs light to indicate when power is on and the alarm is armed (the armed LED pulses to get attention) and serve as a visual deterrent to potential thieves.

CIRCLE NO. 10 ON FREE INFORMATION CARD

Specialty Microphone

Audio-Technica's Model PRO 35R remote-power condenser microphone is said to be ideally suited to close-miking applications for high-intensity musical instruments to provide undistorted output in sound fields as great as 141 dB SPL. It includes an AT8418 UniMount™ instrument mount that surrounds the



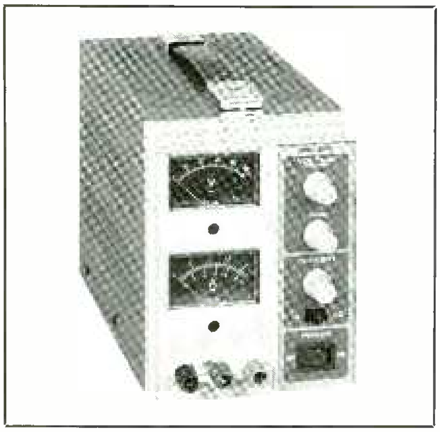
microphone with foam to eliminate instrument noise and provide wind screening. A rubber-buffered spring clamp securely mounts the microphone without marring the surface of the instrument, and a gooseneck permits precise microphone placement for optimum sound pick-up.

The PRO 35R comes with a permanently attached 5.9-foot miniature cable. The microphone itself measures 0.98 inch long and weighs just 0.25 ounce. It can be powered by any source capable of delivering 9 to 52 volts dc.

CIRCLE NO. 11 ON FREE INFORMATION CARD

Variable DC Power Supply

B&K-Precision's Model 1611 bench-type power supply offers a continuously variable 0-to-50-volt dc output at 2 amperes with 0.01% regulation and less than 1 mV rms ripple. The supply is rated for continuous operation at maximum output power without overheating. It features two analog meter movements for simul-



taneous monitoring of voltage and current output. Two current ranges are selectable and have coarse and fine adjustment controls to assure precise settings.

Built-in are reverse-polarity protection from an external dc source, overload protection, thermal protection, short-circuit protection and current limiting. The + and − outputs are fully isolated to permit either polarity to be floated or grounded according to the application. Two Model 1611 power supplies can be parallel-connected to double available output current or series-connected to double available output voltage.

Automatic mode selection chooses between constant-current and constant-voltage, with a LED lighting to inform the user which has been selected. In constant-voltage applications, a current limit can be preset such that if variations in the load cause the current to reach the preset limit, the supply automatically switches to constant-current mode.

The Model 1611 can be powered from 100- to 240-volt ac sources. It comes with hookup leads, spare fuse, parts list, user manual and schematic diagram. The supply measures 12″D × 6¾″H × 4$^{11}/_{16}$″W. $295.

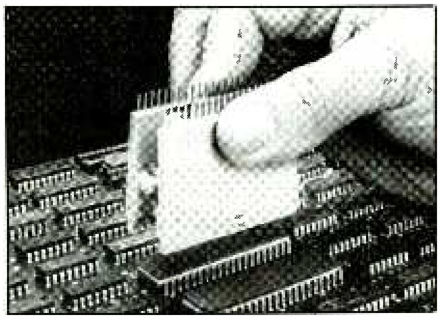
CIRCLE NO. 14 ON FREE INFORMATION CARD

CIRCLE NO. 35 ON FREE INFORMATION CARD

NEW PRODUCTS . . .

Oxide-Penetrating DIP Clip

Test clips that penetrate oxide build-up on DIP IC leads are now available from Pomona Electronics. The six DIP Clip test adapter models function similarly to standard test clips but feature a roughened stainless-steel surface coating on their serrated con-



tacts to provide good electrical connections on contaminated surfaces.

These clips provide hands-free testing of standard DIP ICs with pin counts from 8 to 40. The 0.04″-wide contacts are separated by molded insulating barriers to permit connection to be made on "live" boards without the fear of accidental short-circuiting of adjacent contacts. The upper contact pins on the clips are 0.025″ by 0.028″ to accept Wire Wraps or miniature test clips. IC jumper cables, flat ribbon cables with 8- through 40-pin sockets at one end can also be used to connect these clips with instrumentation.

Device contacts are tarnish-resistant nickel or gold-plated beryllium copper, surface coated with the roughened stainless steel. Gray glass-filled nylon provides insulation for up to 500 volts rms at 1 ampere and up to +20° F maximum.

Models 5649, 5650, 5692, 5693, 5694 and 5695 are 8-, 14-, 16-, 20-, 24- and 40-pin clips, respectively. $9.70 to $31 each.

CIRCLE NO. 2 ON FREE INFORMATION CARD

VHF SWR Analyzer

A complete picture of antenna SWR over the entire 2-meter band can be obtained with the MFJ-208 vhf SWR analyzer from MFJ Enterprises—without having to use a transmitter, SWR meter or other equipment. It permits accurate trimming of an antenna at a specific frequency, im-

mediate observation of the results when an antenna is shortened or lengthened, perfect adjustment of a mobile whip antenna, finding the ideal place on a car for a mobile antenna, seeing how SWR changes as a vehicle is driven under an overpass, checking the SWR of the input to an amplifier, and more.

In use, the antenna to be tested is simply plugged into the coaxial connector on the SWR analyzer, the analyzer is set to the frequency of interest and the SWR is read. For maximum flexibility, the battery-operated SWR analyzer can be taken to an antenna in the field for measurements, which eliminates any distorting effects that can be introduced by the coaxial line.

The SWR Analyzer operates on a 9-volt battery for portable use and on 117 volts ac with an optional MFJ-1312 adapter. It comes with an output jack into which a frequency counter can be plugged to provide digital numeric display of the test frequency. The analyzer measures 7.5″ × 2.5″ × 2.25″. $89.95, analyzer; $12.95, ac adapter.

CIRCLE NO. 3 ON FREE INFORMATION CARD

Multimeter Leads

A silicone-rubber multimeter test-lead set with right-angle or straight-shielded banana plugs and fully insulated alligator clips is available from Test Probes, Inc. (San Diego, CA). The Model TL1000 can test a maximum of 1,000 volts rms and current to 10 amperes. Cable length is 1.2 meters. Straight plugs are shielded with spring-loaded retractable safety sleeves, right-angle plugs with fixed rubber sleeves.

Two leads and two fully insulated alligator clips, the latter made of hard plastic for safety and durability, are supplied in the TL1000 package. Push-on hook tips and spade lugs are just two of the accessories that fit the TL1000. Others include adapters for meters with recessed male inputs and extender sleeves that link cables for greater length. $14.

CIRCLE NO. 4 ON FREE INFORMATION CARD

Programmable Soldering Station

Tamper-proof temperature setting, quick heating and increased thermal recovery permit a new programmable soldering station from Contact East to consistent high-quality soldering with less dwell time on pc boards and heavy ground planes. Tip temperature can be set on a numeric keypad between 400° and 899° F ±0.9° F. Once set, the temperature cannot be changed without use of a supplied programming card. A memory system permits the iron to be shut off and turned on without requiring that temperature be reset each time.

The housing, iron and cord are made of static-dissipative material for safe use in static-sensitive applications. Resistance to ground is rated at less than 2 ohms, and leakage voltage is rated at less than 0.6 mV. The station meets MIL-STD-2000, DOD-STD-2000, WS-6536E, DOD-STD-1686, DOD-HDBK-263 specifications. The 117-volt ac station comes with iron holder, sponge, programming card and 50-watt iron with three-conductor line cord. $299.

CIRCLE NO. 5 ON FREE INFORMATION CARD

(Continued on page 82)

Telephone Call Restrictor

Computerized device prevents outgoing calls to 1-900 and 976 toll numbers

By Steve Sokolowski

Some ten years ago, the telephone company introduced a new type of service that, for a predetermined price per minute, let callers dial numbers to listen to 60-second comedy skits. This dial-it service is now thriving. Now there are a horde of phone services prefaced by "1-900" for dating, sports and what have you, as well as 976 horoscope and tarot-cart reading services and credit-card applications services. Prices for using these services, which appear on your monthly telephone bill, range from 75 cents to a whopping $30 for a call that can last as short as 2 minutes.

If you are fed up with high monthly telephone bills resulting from the abuse of dial-it services by, say, your children, fight back with our Telephone Call Restrictor. When this computerized device senses any outgoing call beginning with 1900 or 976, it disconnects the telephone instrument from the line. In addition, it also detects when the 0 button on the instrument's keypad is pressed to prevent operator-assisted connections to these services.

The Call Restrictor installs between any line to which telephone instruments are connected and the telephone line. It does not interfere with normal calling. You can easily recoup its modest cost in just a month or two of lowered phone bills.

Project Overview

The Call Restrictor makes use of an inexpensive 8031 controller chip. This chip is basically a computer squeezed into a 40-pin package whose pinouts are detailed in Fig. 1. The 8031 must be told what to do. In the case of the Call Restrictor, the 8031 must monitor the telephone line to detect dialing. If the number being dialed starts with 1900, 976 or 0, the 8031 must immediately disconnect the telephone line for about 2 seconds and then reconnect it again to wait for the next dialing sequence.

The sequence of required events are permanently stored in an EPROM. Upon power-up, the EPROM program is read into a 6264 memory chip. Once this program is read, the 8031 executes each step in the required sequence. Once the restricted numbers are sensed, the program tells the 8031 to deenergize a relay whose contacts are in series with the telephone line.

When the contacts of the relay are open, the relay acts much like a telephone hookswitch. It electrically removes the telephone instrument from across the line, simulating putting the handset back in its cradle.

After the 2-second off period has timed out, the 8031 re-energizes the relay. This action closes the contacts and re-establishes connection of the instrument to the phone line. At this time, a dialtone is once again restored. At the conclusion of these predetermined events, the 8031 rearms itself.

The Call Restrictor is designed to be placed on a line that uses only tone-dial-type instruments. The 8031 responds to the dual-tone multi-frequency, abbreviated DTMF (see Dual-Tone Multi-Frequency box elsewhere in this article) signals generated when a number is punched in-

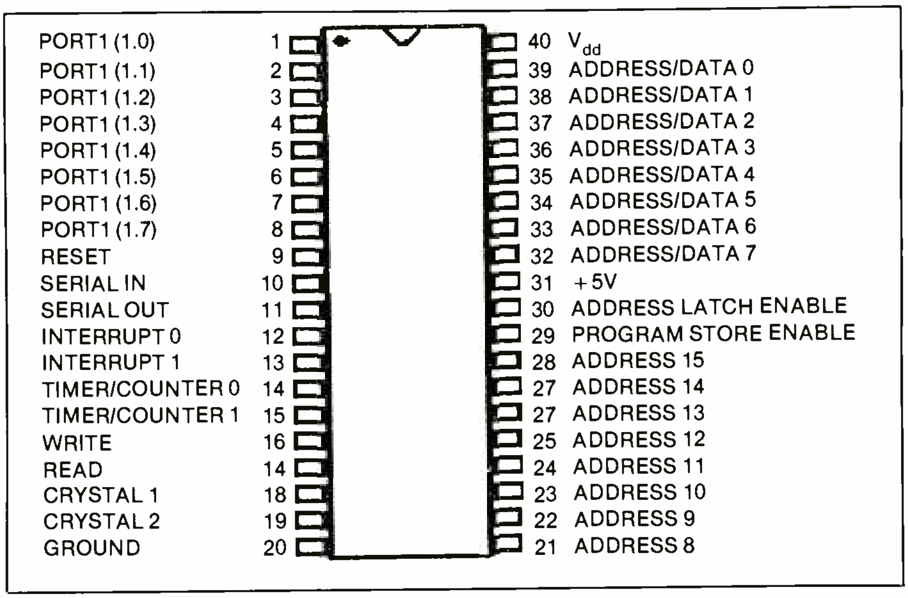


Fig. 1. Pinouts for the 8031 microcontroller used in this project.

to the instrument's keypad. By detecting and acting upon these tones, the 8031 is capable of tapping into the line via an output signal sent to the relay circuitry.

The G8870 receiver chip in the Call Restrictor is a very complicated device. Older DTMF receivers required large, bulky audio filters. The G8870, on the other hand, incorporates all the needed filtering inside an 18-pin IC. Unlike other receivers of this type, the G8870 does not need additional circuitry that would allow it to be connected directly across the telephone line.

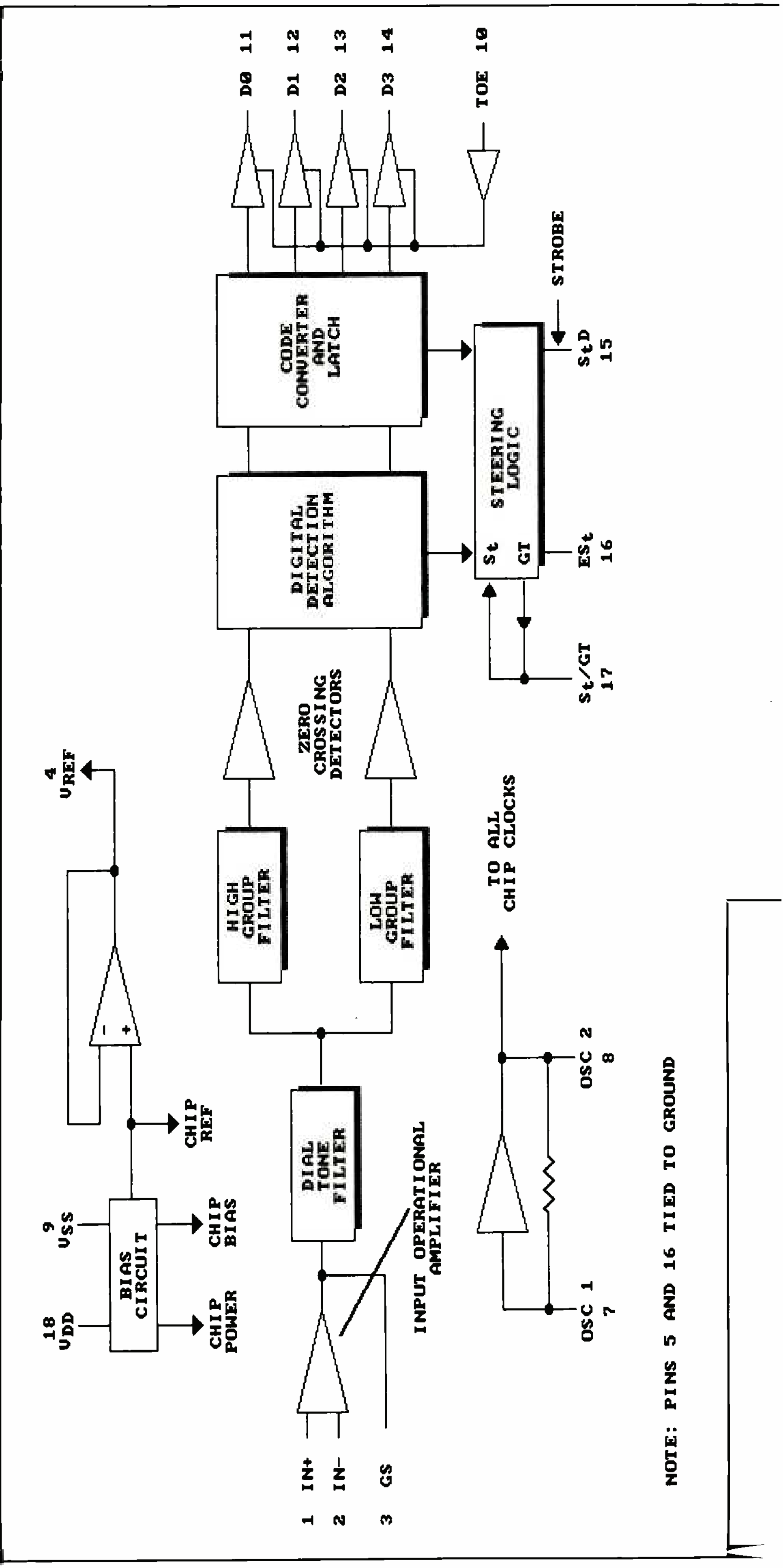
On-board the G8870 is an operational amplifier that can be wired as a differential amplifier. Details for the internal circuitry, pinouts and pin functions of this chip are shown in Fig. 2. Note that the telephone line wires across pins 1 (IN+) and 2 (IN−) through a series of resistors and capacitors that are wired to form the differential-amplifier arrangement. Internal circuitry of the G8870 divides the input dialing tones into their high and low groups, processes them and converts them into the binary table shown in the box.

Note that the G8870 chip requires a 3.58-MHz crystal for operation, while the 8031 requires a crystal that is three times higher in frequency.

About the Circuit

The Call Restrictor is a fairly complex electronic device. Because of this, the overall schematic diagram is broken into five sections, as shown in Fig. 3 (A) through (E). Section (A) illustrates the wiring required for 8031 controller *IC1*, 8K memory *IC3* and 3-to-8-line decoder *IC4* that is used to enable *IC3*, EPROM *IC5* in section (B), and DTMF receiver chip *IC6* in section (C).

Also shown in Fig. 3(C) is the transistor-driven relay (*RY1*) that interrupts and restores the telephone-line connection. Figure 3(D) shows the wiring for a second relay, *RY2*, used



Pin Functions for the G8870 DTMF Receiver/Decoder Chip

Pin	Name	Function
1	IN +	Noninverting Input
2	IN −	Inverting Input
3	GS	Gain Select—provides access to output of front-end differential amplifier for connection of feedback resistor
4	V_{ref}	Reference Voltage (nominally $V_{dd}/2$)—can be used to bias inputs to mid-rail
5	IC	Internal Connection
6	IC	Internal Connection
7	OSC1	Clock Input—3.58-MHz crystal connects between pins 7 and 8 completes internal oscillator
8	OSC2	Clock Output—see pin 7 above
9	V_{ss}	Negative power-supply voltage (normally grounded)
10	TOE	Three-state Output Enable Input—logic high enables outputs D0 through D3; internal pull-up provided on-chip
11	D0	Three-state Data Outputs—(with pins 12, 13, 14) when enabled by TOE, provide code corresponding to last tone
12	D1	See pin 11 above
13	D2	See pin 11 above
14	D3	See pin 11 above
15	StD	Delayed Steering Output—presents logic 1 when received tone pair has been registered and output latch is updated; returns to logic 0 when voltage on St/GT falls to less than V_{tst}
16	ESt	Early Steering Output—presents logic 1 immediately when digit algorithm detects recognizable tone pair; any momentary loss of signal causes ESt to return to logic 0
17	St/GT	Bidirectional Steering Input/Output Time Output—voltage greater than V_{tst} detected at St causes device to register detected tone pair and update output latch; voltage less than V_{tst} frees device to accept new tone pair; GT output resets external steering time constant, its state a function of ESt and voltage on St
18	V_{dd}	Positive power connection

Fig. 2. Details for G8870 DTMF receiver chip used in this project: (A) Block diagram of internal circuitry and (B) pin functions.

in the Call Restrictor. By placing *RY2*, a line-sense relay, in series with both the red- and green-insulated telephone-line conductors, the 8031 can intelligently detect whether or not the handset of the telephone instrument is on-hook. This is accomplished by monitoring pin 2 of *IC1* for the presence of a ground voltage.

Figure 3(E) shows the circuit details for the ac-operated power supply for the project. This is a classic full-wave bridge-rectifier arrangement with capacitive filtering and regulation to a tight + 5 volts via *IC8*.

When the Call Restrictor is in operation, the internal oscillator of *IC1* runs at 11.059200 MHz, the frequency controlled by crystal *XTAL1*. By making use of address lines A0 through A12, *IC1* can grab needed information anywhere within a range of 8,000 bits; hence, the use of 6264-15 RAM chip *IC3* in the section (A) circuitry. Although the full 8K memory locations are not used in the Call Restrictor, cost of the 6264 RAM chip is so low that no other smaller RAM need be considered.

Address lines A13, A14 and A15 are decoded into chip-enabling ground pulses with the aid of *IC4*. Binary codes generated by *IC1* at pins 26, 27 and 28 are converted into single ground control signals. By applying grounding pulses at the appropriate times with a running program, any one of eight peripheral chips can be activated simply by calling its special address. Without enabling pulses to turn on the various chips, data conflicts would occur, due to the fact that all peripheral chips are wired in parallel to the common eight-bit data bus to which pins 32 through 39 of *IC1* connect.

The Call Restrictor requires three enabling pulses. The first, at address 0 hex (0H), is used to enable program device *IC5*. With every ground pulse, *IC1* reads the program information from *IC5*. The second address is at 0E000 hex (0E000H), where the same grounding pulses are used to enable *IC6* every time you want this chip to sense the DTMF tones across the line. Because *IC6* requires a positive voltage to enable its output, one stage of hex inverter *IC7* is used to convert the ground pulses from *IC4* into the positive pulses needed by *IC6*.

The final address, at 8000 hex (8000H), uses the ground pulses to enable memory chip *IC3*. Along with the proper read and write ground pulses, *IC4* allows *IC1* to place information in and extract data from memory chip *IC3*.

Also required is the data bus over which eight-bit words are read from or written to memory. This also includes reading of program material from *IC5*. Intel uses the multiplexing technique to use pins 32 through 39 of *IC1* for both the low-order address bus and eight-bit data bus.

To extract the required address or data information at the correct time, octal D-type latch *IC2* is used. Here, pulses from −ALE pin 30 of *IC1* is used to "pulse" *IC2*. Pulsing allows the low-order address information to pass through on pins 2, 5, 6, 9, 12, 15, 16 and 19 of *IC2* while data information is stopped. Along with the enabling pulses from *IC4* and the read or write signal from *IC1*, separate address and data bus information is delivered to their appropriate chips at the proper times.

Examining sections (A) and (B) of Fig. 3, you can readily see that all address and data lines are wired in parallel with *IC3*. If not for the enabling

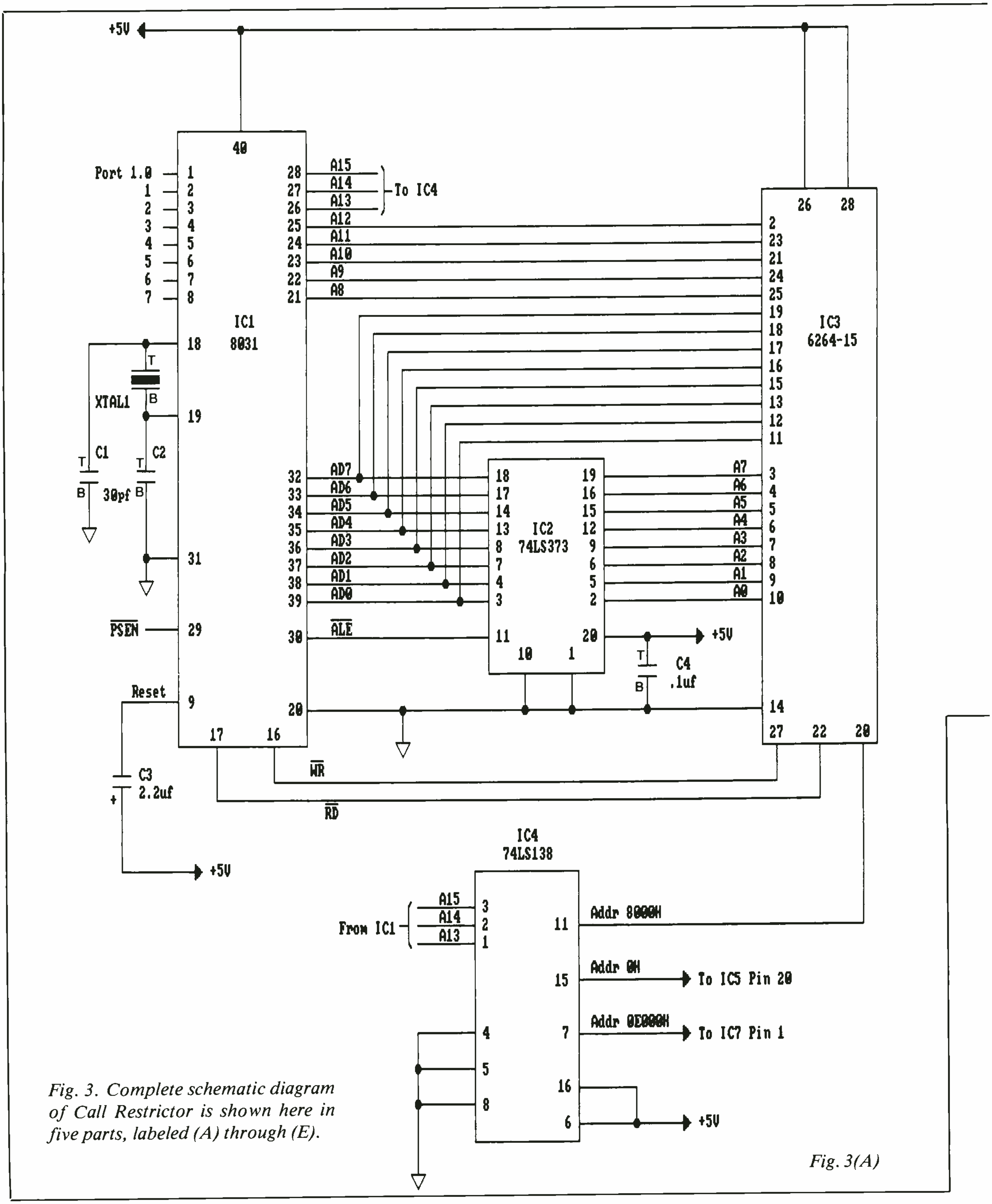


Fig. 3. Complete schematic diagram of Call Restrictor is shown here in five parts, labeled (A) through (E).

Fig. 3(A)

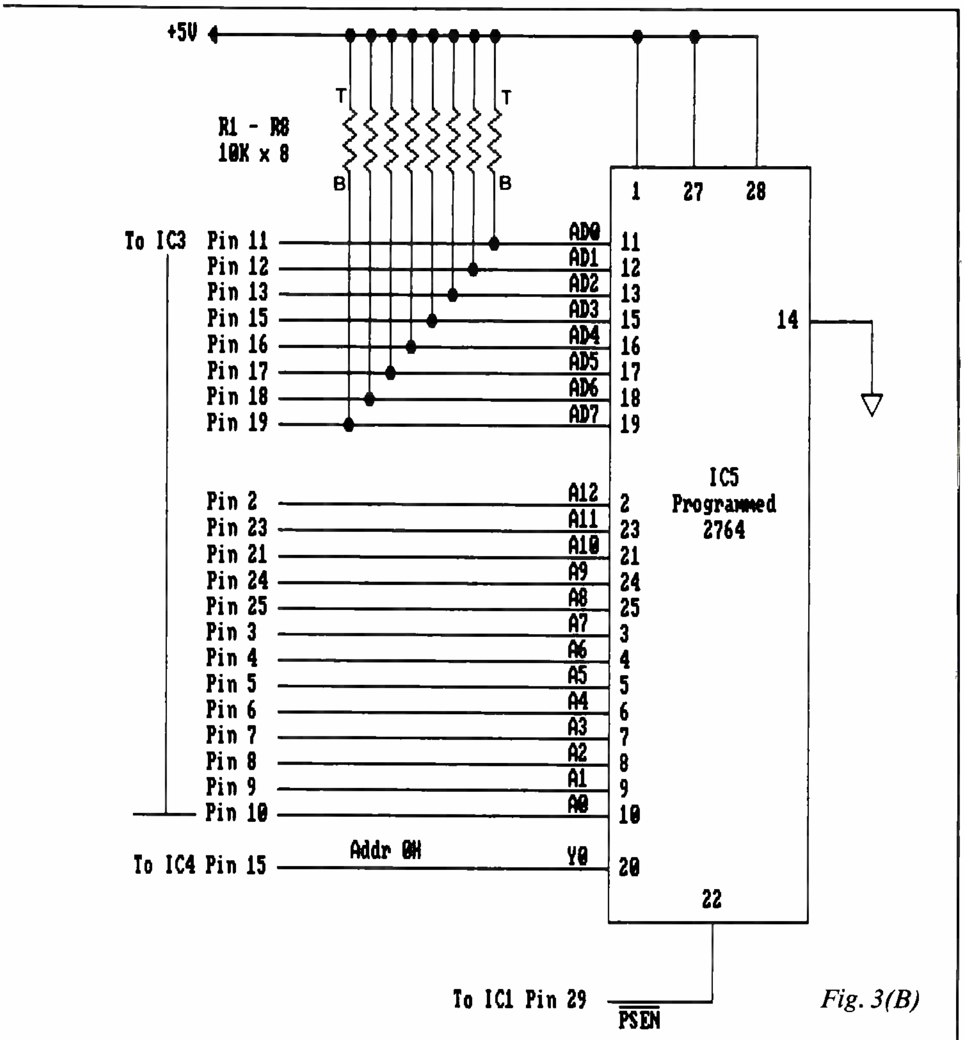


Fig. 3(B)

pulses created by *IC4*, data and address conflicts would occur between *IC4* and *IC5*. Pull-up resistors *R1* through *R8* in Fig 3(B) apply a constant +5 volts to the eight address/data lines.

Section (C) of Fig. 3 shows the interfacing required for the Call Restrictor. Points C and D connect directly across the incoming telephone line, as shown in section (D). Because of the characteristics of the differential amplifier at pins 1 and 2 of *IC6*, the direct connection between the two causes no ill effects to the telephone line. The differential amplifier also provides the FCC-mandated line-to-equipment isolation.

Note that *IC6* wires across the telephone line through *C1*, *C2*, *R9* and *R10*. Only tones generated by the telephone instrument are permitted to enter *IC6*. After processing by internal filters and converters, *IC6* outputs at D0 through D3 pins 11 through 14 the binary equivalent of the input tones. This is the data *IC1* reads and acts upon when the need arises.

Because of the way *IC6* is wired, data information is always at the data output of this chip, even when no button on the keypad of the telephone instrument is pressed. To surmount this, *IC6* is equipped with a STROBE line at pin 10, which is at logic 1 only when a valid tone pair are introduced at the input of this chip. Hence, *IC1* is programmed to accept the output from *IC6* only when pin 10 of *IC6* is high.

The 8031 has eight specially adaptable pins identified as PORT1 at pins 1 through 8 of *IC1*. Using this port, through program control, information can be read from and written to these pins. Operation is like the case with the data bus but with an exception: no enabling pulses are needed to turn on any specific chips.

By telling *IC1* to output a decimal number between 0 and 255, you can place any combination of 0s and 1s on the port pins. Also, under program control, the 8031 can be directed to read the binary code applied to these pins. Note that STROBE pin 10 of *IC6* is connected to PORT1 pin 1 (PORT1.1). In the Call Restrictor, the program in *IC5* tells *IC1* that a valid tone has been detected by *IC6* only when pin 1 of *IC1* is at logic 1. In contrast, if pin 1 of *IC1* is at logic 0, the 8031 refuses to acknowledge as usable information the binary data on the data bus.

Another section of the project that uses PORT1 is the base circuit of *Q1*. On initial start-up, pin 3 of *IC3* is at logic 1, This voltage is applied to the base of *Q1* through *R15*. At this time, *RY1* is energized and its contacts are closed. These now-closed contacts can be used as a telephone hookswitch. By wiring the contacts in series with the red-insulated telephone-line conductor, as shown in Fig. 3(D), any telephone instrument connected to the line is under control of *IC1*—not the caller.

If *IC1* senses that 1900, 976 or 0 are the first digits dialed when a call is being placed, the EPROM program instructs the 8031 to ground pin 3. This cuts off *Q1* and deenergizes *RY1*. When the relay contacts open, the telephone-line connection is automatically broken. After 2 seconds, *IC1* re-applies a logic 1 to pin 3 to reactivate the relay and restore dialtone.

Any number dialed to make an outgoing call that the project will permit is stored in memory in the Call

Restrictor. When you hang up, a means must be found to have *IC1* erase the current number before you can dial another number to avoid conflict. This is accomplished by Teltone line-sense relay *RY2* shown in Fig. 3(D) whose internal contacts close every time a telephone instrument is lifted off-hook.

By connecting one side of *RY2* to ground and the other side to PORT1 pin 2 of *IC1*, the 8031 can act upon the hang-up signal. If PORT1 senses a ground condition at pin 2, *IC1* is instructed to erase the current number from memory.

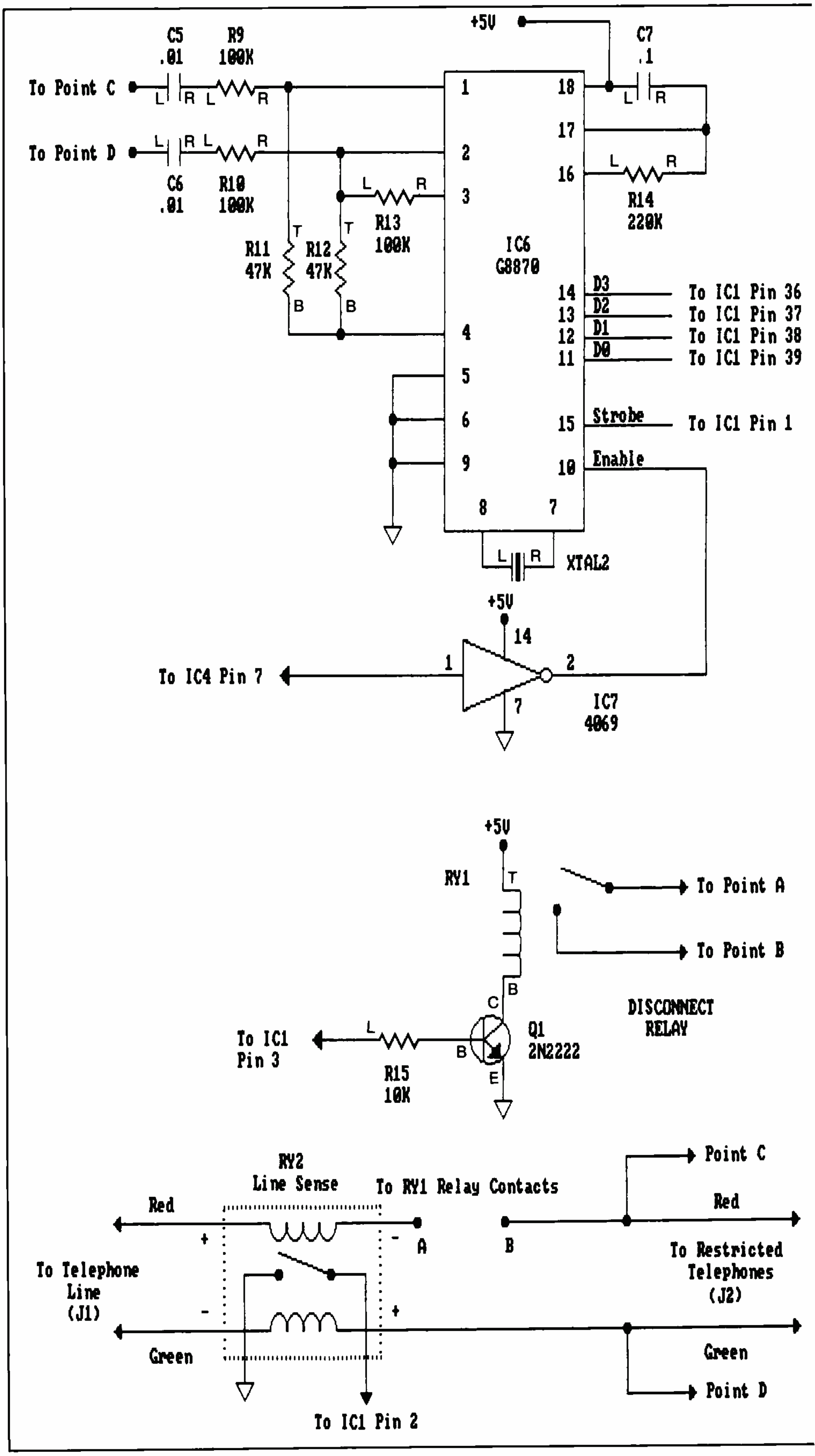
Operation of *RY2* is straightforward. This relay senses the current flow when the contacts of *RY1* are closed and the handset of the telephone instrument is taken off-hook. When both sets of contacts are closed, a conductive path is created for the dc voltage coming from the telephone line to flow. This causes *RY2* to energize and close its contacts just before a new number is dialed.

The Call Restrictor requires a 5-volt, 100-mA dc supply for operation. Circuit details for an ac-operated supply that meets these requirements are shown in Fig. 3(E). The power transformer for this supply circuit should be a plug-in wall-type unit to provide isolation between the 117-volt ac line and low-voltage circuits in the Call Restrictor.

In operation, the low-voltage ac output from the secondary side of *T1* is rectified to pulsating dc by the bridge rectifier made up of *D1* through *D4*. The pulsating dc is then filtered to pure dc by *C8*, after which it is regulated to +5 volts by *IC8* and further filtered by *C9* for delivery to the remaining circuits in the Call Restrictor.

Construction

As you can see from the multiple-section schematic diagram in Fig. 3, this is a fairly complex project. However, bear in mind that a lot of the circuitry shown represents repetitious wiring.



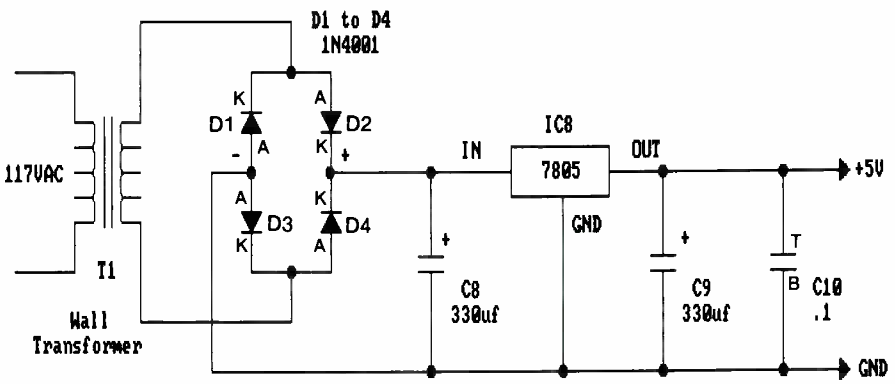


Fig. 3(E)

PARTS LIST

Semiconductors
D1 thru D4—1N4001 silicon rectifier diode
IC1—8031 microcontroller
IC2—74LS373 octal D-type latch
IC3—6264-15 SRAM memory
IC4—74LS138 3-to-8-line decoder
IC5—Programmed 2764 EPROM (see Note below)
IC6—G8870 DTMF decoder (see Note below)
IC7—CD4066 hex inverter
IC8—7805 fixed +5-volt regulator
Q1—2N2222 or similar general-purpose silicon transistor

Capacitors
C1,C2—30-pF ceramic disc
C3—2.2-μF, 16-volt electrolytic
C4,C7,C10—0.1-μF ceramic disc
C5,C6—0.01-μF ceramic disc
C8,C9—330-μF, 16-volt electrolytic

Resistors (¼-watt, 10% tolerance)
R1 thru R8,R15—10,000 ohms
R9,R10,R13—100,000 ohms
R11,R12—47,000 ohms
R14—220,000 ohms

Miscellaneous
RY1—5-volt dc spst reed relay
RY2—Teltone line-sense relay (see Note below)
T1—12.6-volt, 150-mA plug-in wall-type transformer
XTAL1—11.059200-MHz crystal
XTAL2—3.58-MHz crystal
Perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for all DIP ICs; suitable enclosure; machine hardware; hookup wire; solder; etc.

Note: The following items are available from Suncoast Technologies, P.O. Box 5835, Spring Hill, FL 34606: G8870, $10; Teltone line-sense relay, $5.75; programmed 2764 EPROM, $7; six-conductor telephone cord, $1.25; 11.059200-MHz crystal, $1.75. Add $2.50 ($3.50 in Canada) S&H per order. Florida residents, please add 6% state sales tax.

PARTS SUPPLIERS

B.G. Micro
P.O. Box 28209
Dallas, TX 75228
214-271-5546

Digi-Key Corp.
701 Brooks Ave. S.
Thief River Falls, MN 56701-0677
1-800-344-4539

JDR Microdevices
2233 Branham Lane
San Jose, CA 95124
1-800-538-5001

If you have any experience at all in building circuits, you should fairly easily build the Call Restrictor.

You can mount the components on perforated board that has holes on 0.1-inch centers, preferably with copper rings around each hole, and point-to-point wire them together with Wire Wrap or soldered connections. Your first step is to photocopy the schematic diagram sections so that you can strike off each wire run as you make it according to the Master Wiring List.

Begin construction by mounting the sockets for the various DIP ICs on the circuit board. If copper rings surround the holes on your board, solder only the four end pins into place. Use solder sparingly to avoid getting it on all but about ⅛ inch of the pin lengths. If your board does not have copper rings around each hole and the socket pins do not provide a friction fit, bend the four end pins slightly outward to hold each socket mechanically in place. Do *not* plug the ICs into the sockets until after preliminary voltage checks have been made and you are satisfied that your wiring is correct.

After mounting the IC sockets, mount the various components on the board. If you are using the Wire Wrap technique to wire the circuit, use Wire Wrap posts to hold these components (except the relays, which mount via their own pins) in place, soldering the component leads to the posts on the top of the board.

Once the components are in place, refer to the Master Wiring List and begin with the *IC1* socket to make your interconnections. As you make each wire run, trace its path on your photocopy of the schematic in a contrasting pencil or pen color. As you go, properly polarize your connections to the socket pins, electrolytic capacitors, relays and diodes.

Make sure your connections to the pins of *Q1* and *IC2* are correct. Note that the latter is the *only* IC that should be mounted on the board at

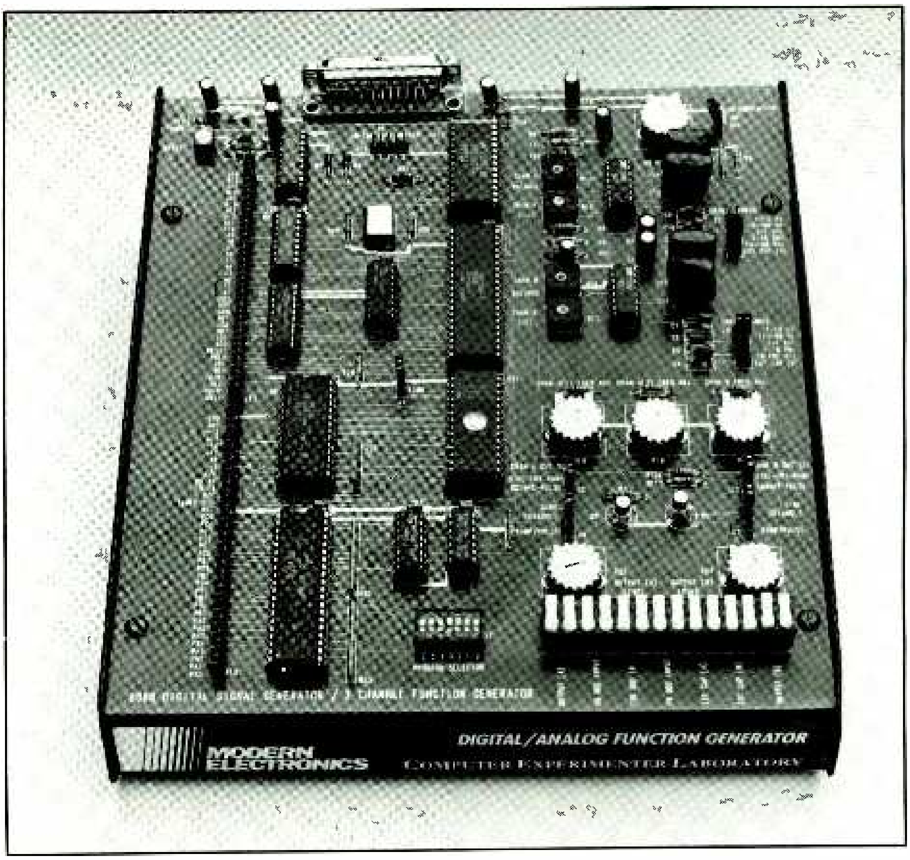
(Continued on page 71)

The Modern Electronics Computer Experimenter Lab

(Part 3)

Adding a combination Digital Signal Generator and 8088-microprocessor Computer Experimenter Platform to the Dual-Channel Function Generator

By Martin Meyer



Last month, we gave details for building and using an analog Dual-Channel Function Generator that had room on its pc board for adding a digital signal generator, which is the subject of this installment. This add-on is a continuation of a series begun in the January issue with a build-it-yourself low-cost Digital Storage Oscilloscope and optional eight-channel Logic Analyzer module.

This month's Digital Signal Generator add-on generates up to 23 simultaneous digital signal trains that will be used as signal inputs for upcoming digital experiments. A main feature of this project is that you will be able to start learning about programming the 8088-series microprocessor. A limited understanding of programming, though not necessary for these projects, will allow you to integrate digital parts that require software interfacing into your projects.

An 8088 microprocessor in the Digital Signal Generator comes supplies all the necessary bus signals, permitting the instrument to also be used as a platform to build, test and learn about peripherals and programming of the most popular series of microprocessors ever introduced. In future articles, we will present projects using the 8088 microprocessor in this project as the base processor. Figure 1 gives an overview on how the various experimenter Labs could be configured.

Next month, we will describe a Prototyping station that connects the equipment together and begin our discussion on theory, applications and experiments of interesting analog, digital and computer circuits.

System Overview

The Digital Signal Generator serves as the stimulus that allows you to examine experiments that involve digital circuits. You wire the circuits to be explored on a solderless breadboard or a Wire Wrap prototyping board, depending on personal preference and complexity and use the Oscilloscope or Logic Analyzer to observe both inputs and outputs.

The advantage of using a Logic Analyzer when working on digital circuits is that you can observe both inputs and outputs simultaneously. If you were to study the operation of a 74LS165 shift register, for example, you would find that you need eight data signals, a signal to load the data into the register and a clock to shift the data out of the registers. The Digital Signal Generator described here produces the needed signals, while the Oscilloscope lets you observe inputs and outputs.

Computer circuits like analog-to-digital (A/D) and digital-to-analog (D/A) converters, input and output ports, memory, ROMs, interrupt systems, displays and digital signal processors (DSPs) can be studied using the 8088 test platform included in this project. For example, A/D and D/A converters, wired on the Wire Wrap prototyping board, can be connected to the I/O ports. An analog signal, supplied by the Function Generator, connects to the ANALOG input.

The processor program can invert, filter and limit the range or simply turn the data around and out to the D/A circuit. You monitor circuit responses and actions using the analog and logic analyzer features included in the Digital Storage Scope.

Analog circuits like operational and power amplifiers, comparators, filters, sensors and power-control circuits can be wired on the prototyping station and evaluated using the Function Generator and the Digital Storage Scope. You can use the prototyping station to build hundreds of useful circuits that illustrate basic ac and dc circuit principles, magnetic and transformer principles, power supply operation, and to demonstrate how games, voice, video and ultrasonic circuits work, to name just a few of the may things you can do with this system.

The Digital Signal Generator/8088 Computer Experimenter Platform is built on the same circuit-board assembly you used to build last month's Dual Function Generator. This keeps the cost to less than $140 for the combination Dual Function Generator/Digital Signal Generator/8088 Computer Experimenter Platform system.

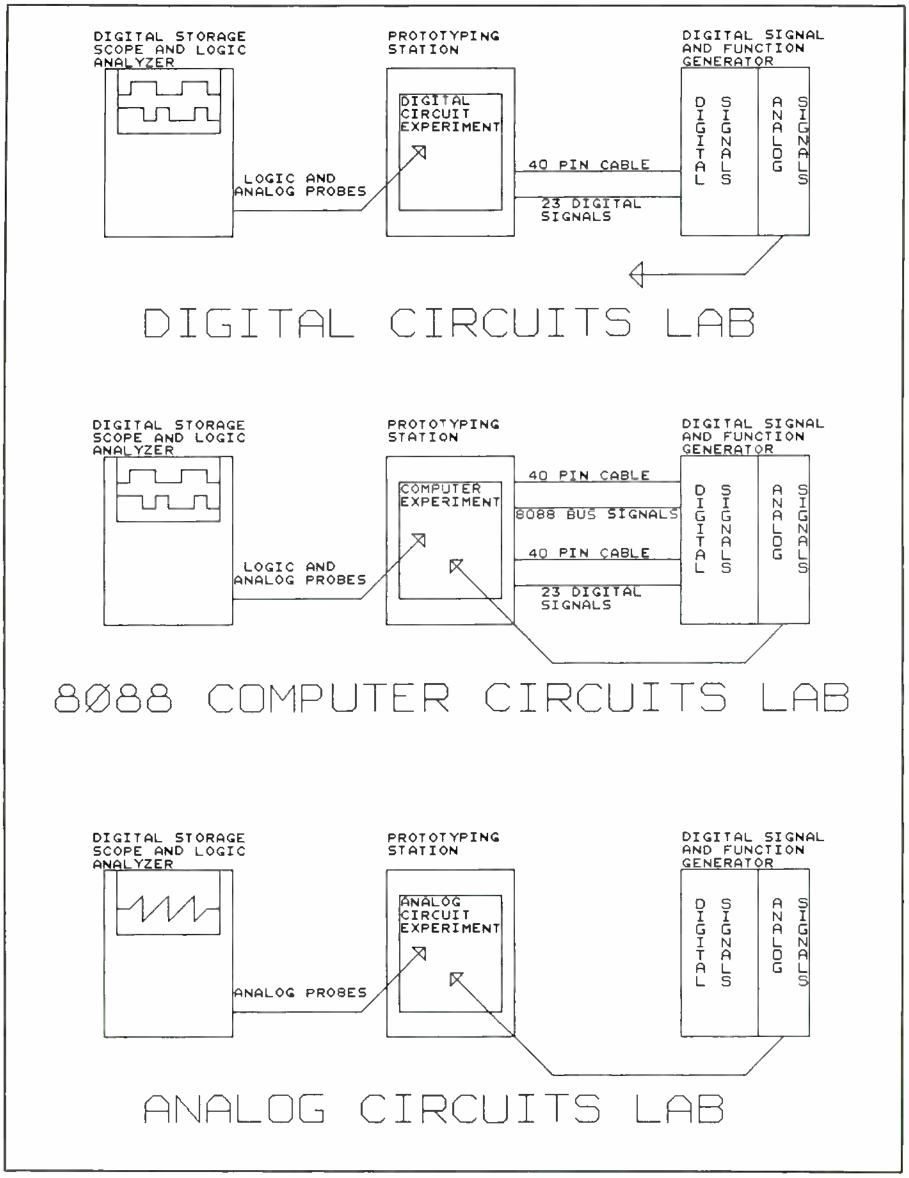
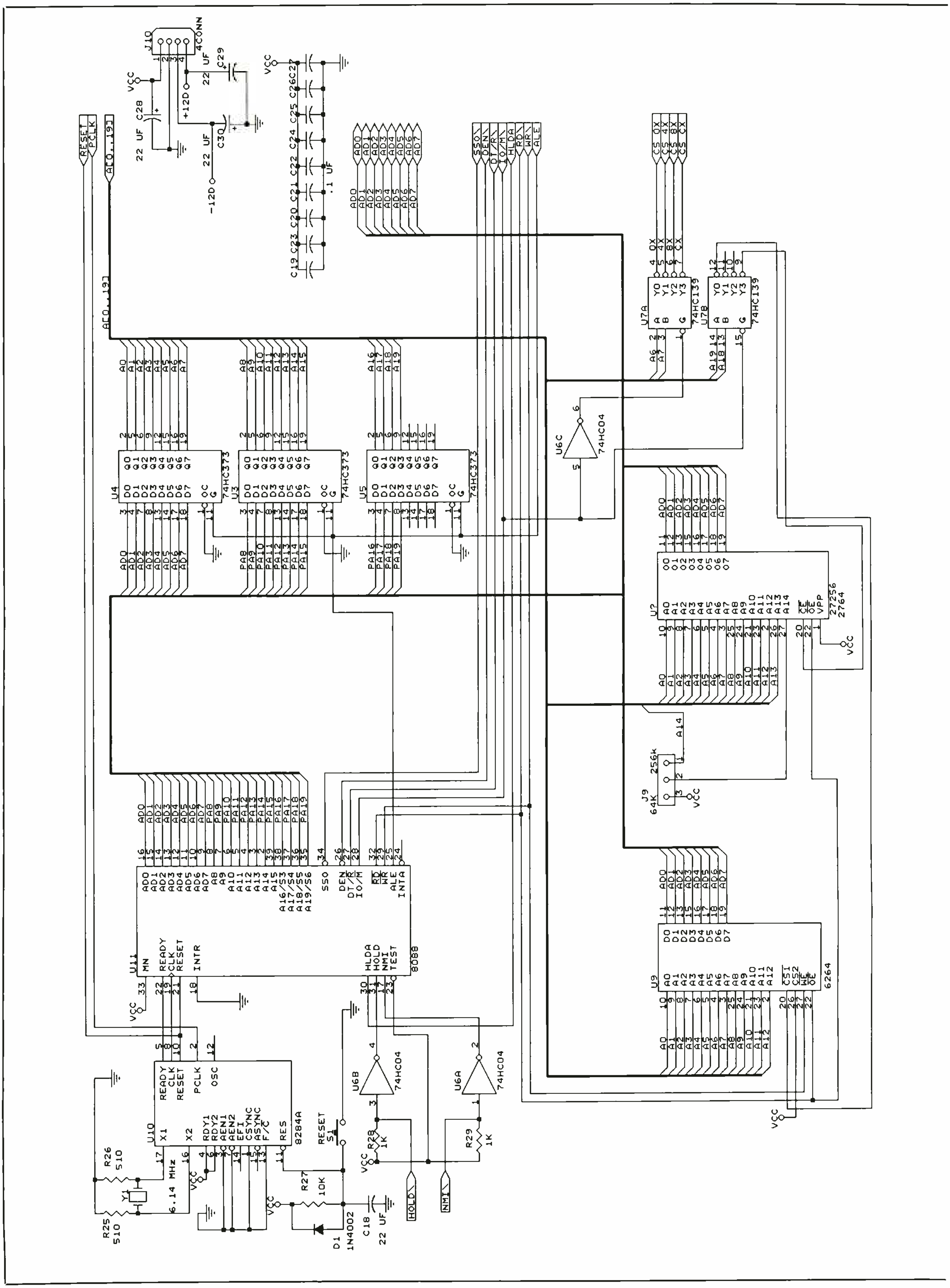


Fig. 1. Overview of how various Experimenter Labs can be configured.

Circuit Description

To generate the digital signal trains in the Digital Signal Generator add-on, an 8088 microprocessor, 8K of RAM, 8K of ROM, an 8155 I/O port/timer and the required support circuits are used. The circuitry for all this is shown schematically in Fig. 2(A) and Fig. 2(B). With this arrangement, digital signal trains are generated by toggling the *U13* output port signals. The timer can be programmed to produce a variety of


U11
8088
U10
8284A
U4
74HC373
U3
74HC373
U5
74HC373
U7A
74HC139
U7B
74HC139
U6C
74HC04
U6B
74HC04
U6A
74HC04
27256
2764
U9
6264
J10
4CONN
J9
256K
64K
RESET
S1
HOLD\
NMI\
D1
1N4002
C18
22 UF
R27
10K
R28
1K
R29
1K
R25
510
R26
510
Y1
6.14 MHz
C28
22 UF
C29
22 UF
C30
22 UF
.1 UF
RESET
PCLK
A[0..19]

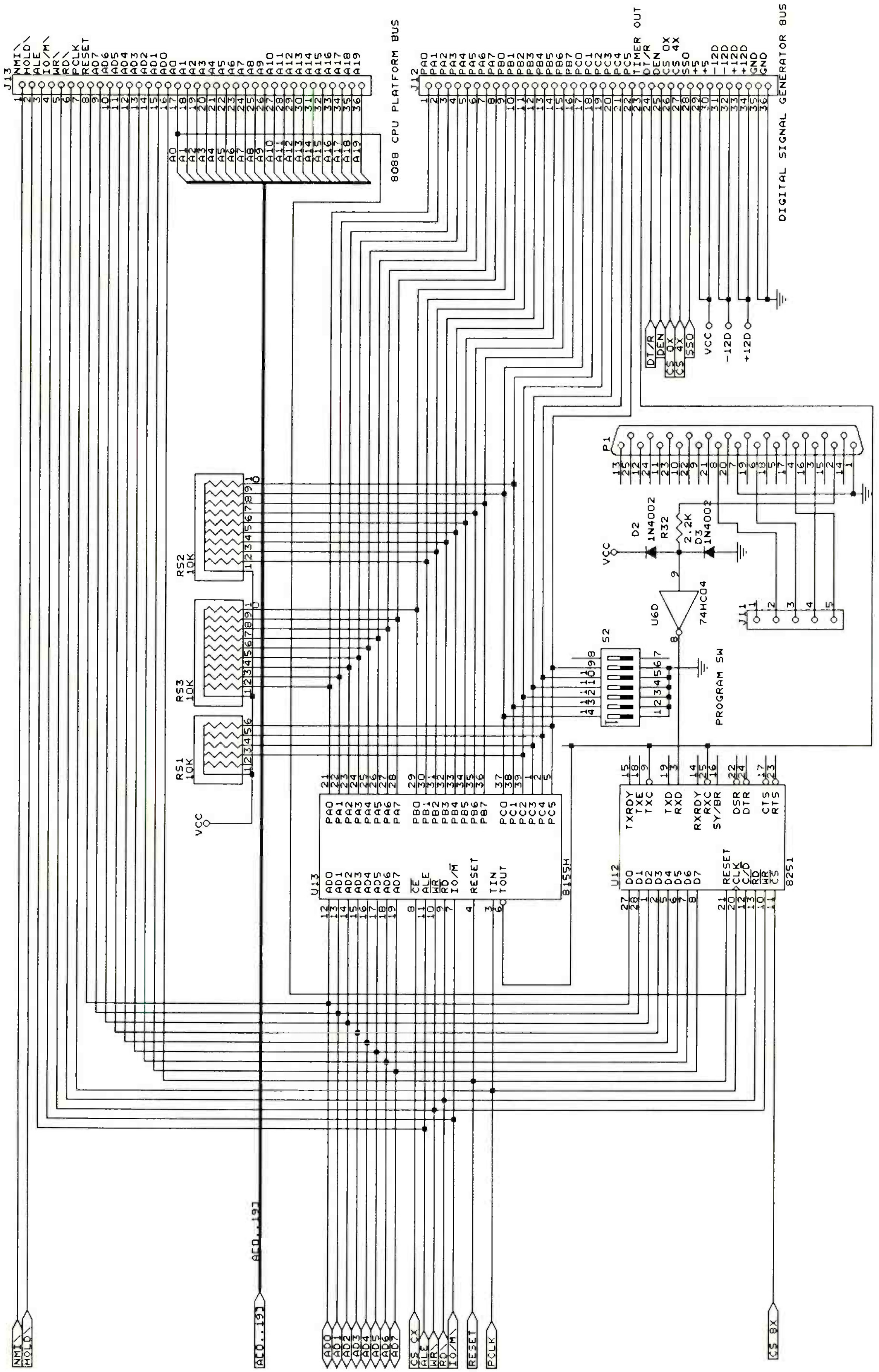


Fig. 2. Complete schematic diagram, minus dc power supply, for Digital Signal Generator add-on.

PARTS LIST

Semiconductors
U3,U4,U5—74HC373
U6—74HC04
U7—74HC139
U8—27C64
U9—6264
U10—8284A
U11—80C88
U12—82C51
U13—81C55H
D1,D2,D3—1N4002 diode
Y1—6.144 crystal
Capacitors
C19 thru C26—0.1-μF monolithic
C18,C28,C29,C30—22-μF, 16-volt radial
Resistors (¼-watt, 5% tolerance)
R25,R26—510 ohms
R27—10,000 ohms
R28,R29—1,000 ohms
RS1—Five-resistor 10,000-ohm resistor SIP
RS2,RS3—Nine-resistor 10,000-ohm SIP
Miscellaneous
S1—Spst normally-open momentary-action switch
S2—Seven-position DIP switch
J9—Three-position single in-line header
J10—Power connector
J11—five-position single in-line header
J12,J13—40-pin socket strip
P1—DP-25 connector
Printed-circuit board; suitable cabinet (see Note below); etc.

Note: The following items are available from Netronics R&D Ltd., 333 Litchfield Rd., New Milford, CT 06776 (tel. 203-355-2659)*:
For Digital Signal Generator:
Complete set of electronic components (mount on last month's Dual-Channel Function Generator pc board), $69.95 + P&H;
Optional +5- and ±12-volt power supply kit (one required for both Generators), $34.95 + $4 P&H;
Optional black steel cabinet (for combination Function/Digital Signal Generator), $37.50 + $4.50 P&H.
Also Available from Netronics R&D Ltd.:
For Digital Storage Oscilloscope (January 1991):
Complete set of electronic components, including pc board but *not* cabinet, power supply or probes, $199.95 + $6.50 P&H;
Optional eight-channel Logic Analyzer, $59.95 + $3 P&H;
Optional +5- and ±12-volt power supply kit, $34.95 + $4 P&H;
Optional IC socket kit (contains 33 sockets), $9.50 + $1 P&H;
Optional 100-MHz scope probe with 10:1 attenuator, $27.50 + $3.50 P&H.
For Dual-Channel Function Generator (February 1991):
Complete set of electronic components, including pc board but *not* power supply or cabinet, $69.95 + $4 P&H;
Optional +5- and ±12-volt power supply kit (one required for both Generators), $34.95 + $4 P&H;
Optional black steel cabinet (one required for combination Function/Digital Signal Generator), $37.50 + $4.50 P&H.
*MasterCard and VISA accepted on all orders.

pulses and square-wave trains.

Programs to produce the signal trains can be written on and downloaded from an IBM PC or compatible computer, or they can be run from fixed programs stored in ROM. The programming mode is selected via DIP switch *S2*. Simple user programs can be written using the Debug program supplied with DOS. No programming experience is needed for writing these simple programs.

• *The Microprocessor.* The 8088 CPU (*U11*) is a member of a family of devices that have become the world's most popular series of microprocessors. If you are going to study any microprocessor, this Lab series is an excellent place to start. Basic system architecture and the instruction set is compatible with all newer processors, except for memory width, address size and added instructions.

The 8088 microprocessor used in this project is set to operate in minimum mode. That is, special control and status signals that are necessary for large systems are not used here. The 8088 CPU is a relatively straightforward hardware device. Address/Data bus lines A0 through A7 are multiplexed so that they share this function with the eight-bit data bus without creating conflicts or collisions. Address pins PA16 through PA19 are also multiplexed with various status signals.

In both cases, the address information is presented on the output pins of the 8088 during the first part of each machine cycle and is latched into *U4* through *U6* when the CPU issues an ALE (Address Latch Enable) signal. During the remainder of the machine cycle time, the low-order address pins become the eight-bit bidirectional data bus, and address lines PA16 through PA19 become CPU status pins.

All 19 address bits are latched and are connected to the 8088 Platform bus. The bus includes all address, data and CPU control signals that are used as part of the 8088 Computer Experimenter Platform.

• *Clock Generator.* The 8088 requires the use of 8284A clock generator *U10*. This circuit supplies the 8088 with a special clock signal that has a 33% duty cycle and is half the crystal frequency. When power is turned on or the system is reset, the 8284 generates a master reset signal that is used to reset all peripherals and the CPU. A symmetrical system clock, labeled PCLK, is generated for the 8088 system bus. The 8284 also has provisions, via the RDY and AEN signals, that support multi-processor operation. These pins are not used in this application.

• *Address Decoders.* The 8088 can address 1M of memory. The ROM is positioned at the very top of memory, starting at F8000 if a 32K ROM is used or FE000 if an 8K ROM is used. System RAM is positioned at

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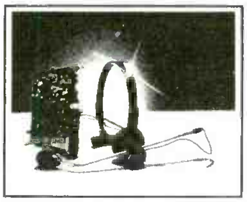

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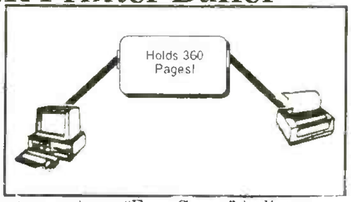

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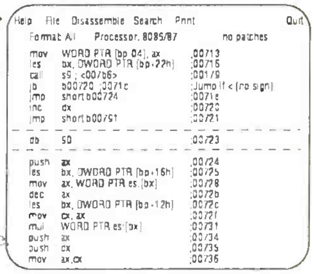

Snooper takes executable program code and turns it into assembly language source code. That's not so unique, but Snooper is intelligent. It automatically comments the source code and labels jump targets. Snooper even includes a patcher to make small changes to a program without time-consuming reassembly. For more extensive changes, Snooper is compatible with Microsoft and Borland assemblers.

Snooper gives you commented source code for almost any DOS file—including COM, EXE, SYS. Its pull-down menus and on-line help make disassembly fast and easy. So what's this good for? Well it's the best way around to learn assembly language and to make changes to software when you don't have the source code. **Cat. #SNPR $49.** Order today.

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00000 to permit use of interrupts if needed for Platform applications. Lines A18 and A19 are decoded by *U7B*. If A18 and A19 are high, the ROM is selected; otherwise RAM is addressed.

Chip *U7B* decodes the I/O addresses. Provisions have been made for four I/O devices by decoding addresses A6 and A7 when the IO/M pin 28 of *U11* is low. I/O decoder *U7B* generates chip-select lines at locations 0X, 4X, 8X and CX. The Digital Signal Generator uses Port CX for the *U13* and Port 8X for UART *U12*.

• *The 8155 I/O Port.* In this project, *U13* plays a key role. The 8155 device consists of two eight-bit and one six-bit I/O ports that can be configured to be either inputs or outputs. The six-bit port can be programmed to be status pins, the eight-bit ports operate in a handshaking mode.

Also included is a 14-bit timer/counter that provides either a square wave or terminal count pulse outputs. The six-bit port is used as an input port to read the program selector. If the download mode is selected, the six-bit port is available to produce digital signals or to act as an I/O port. The program toggles the ports to produce the digital signal trains.

The programs simply initialize the 8155 to configure the ports and timer operation. Outputs are then set to the value desired at the beginning of the digital signal train. The system loops until the next change is required, at which time, the ports are changed. This process is duplicated, changing the loop time and the output data to produce the desired signal train.

The counter/timer can also be used to produce digital signals. In square-wave mode, the timer can be turned on and off to produce a predetermined set of pulses. The program then jumps to the beginning or waits for a system reset to begin again.

• *Program ROM.* The program ROM is mapped at FE000. Unlike other processors, the 8088 series looks for the first instruction at location FFFFO, which is 16 bytes from the top of the 1M address space. The program starts with a jump to the base address of ROM. After running some housekeeping routines, the program checks program selector switch *S2* to determine if you want to use a built-in program or download a custom program from an IBM com-

An Example of a Digital Experiment Using the 74LS165

When clocked, the 74LS165 eight-bit serial shift register shifts data toward the serial output pin (QH \). Parallel data is entered directly into registers that are enabled by a low level at the SH/LD \ (shift/load) input. (Note: reverse slash symbol \ indicates that the load input is active low.) The 74LS165 also features a clock inhibit and a complemented (inverted) serial output. Clocking or shifting data that has been entered into the registers is accomplished via a low-to-high transition of the clock input while SH/LD \ is high. Parallel loading is inhibited when the SH/LD \ pin is held high. The logic level at the serial input is present at the output after the first eight shifts, provided no additional parallel data has been loaded.

Applications

The 74LS165 is used to convert an eight-bit parallel data format into a serial format, which is desirable when sending data over a two-conductor link or when shifting parallel data into serial inputs. This device was used in the Digital Storage Oscilloscope to transfer the data from the eight-bit parallel display memory to the serial display registers inside the LCD. These registers require the data be in serial format.

The 8251A USART used in this project has this type of register embedded in a relatively complex device to transmit eight-bit parallel data to the serial RS-232 output pins. Other shift registers convert serial data to the parallel format, which is required at the receiving end of serial data if data is to be entered into an eight-bit parallel port.

Lab Experiments

The object of this experiment is to generate eight-bit parallel data, a shift clock, clock inhibit and shift/load logic signals to stimulate the 74LS165 and then view the inputs and outputs on an oscilloscope or logic analyzer.

Signals necessary for this experiment are stored in the Digital Signal Generator (Digital Experiments) ROM. Let us look at how simple it is to generate the signals if the program that generates the signals is downloaded from an IBM PC or compatible computer.

The first signal to be generated is a shift clock. The 8155 timer/counter is ideally suited for this task. There is no need to get into the actual programming steps at this time. What follows is a flow chart that indicates the simplicity of the process. Refer to Fig. A as you go along.

(1) Initialize the 8155 ports as outputs

(2) Initialize the timer to produce a square wave

(3) Load the timer divider to divide the 3-MHz timer input to produce a 10-kHz square wave

(4) Output AA hex to Port A to make it the parallel data input to the 74LS165

(5) Output C0 hex to Port B to set clock inhibit and SH/LD \ high

(6) Output 80 hex to Port B to set SH/LD \ low

(7) Output 50 hex to Port B to set clock inhibit low and SH/LD \ high

(8) Turn on timer for 9 counts

(9) Turn off timer off

(10) Jump to step 4

Connect the signals to the 74LS165 as detailed in Fig. A and start the program. Verify the results shown in the timing diagram with either your scope or logic analyzer.

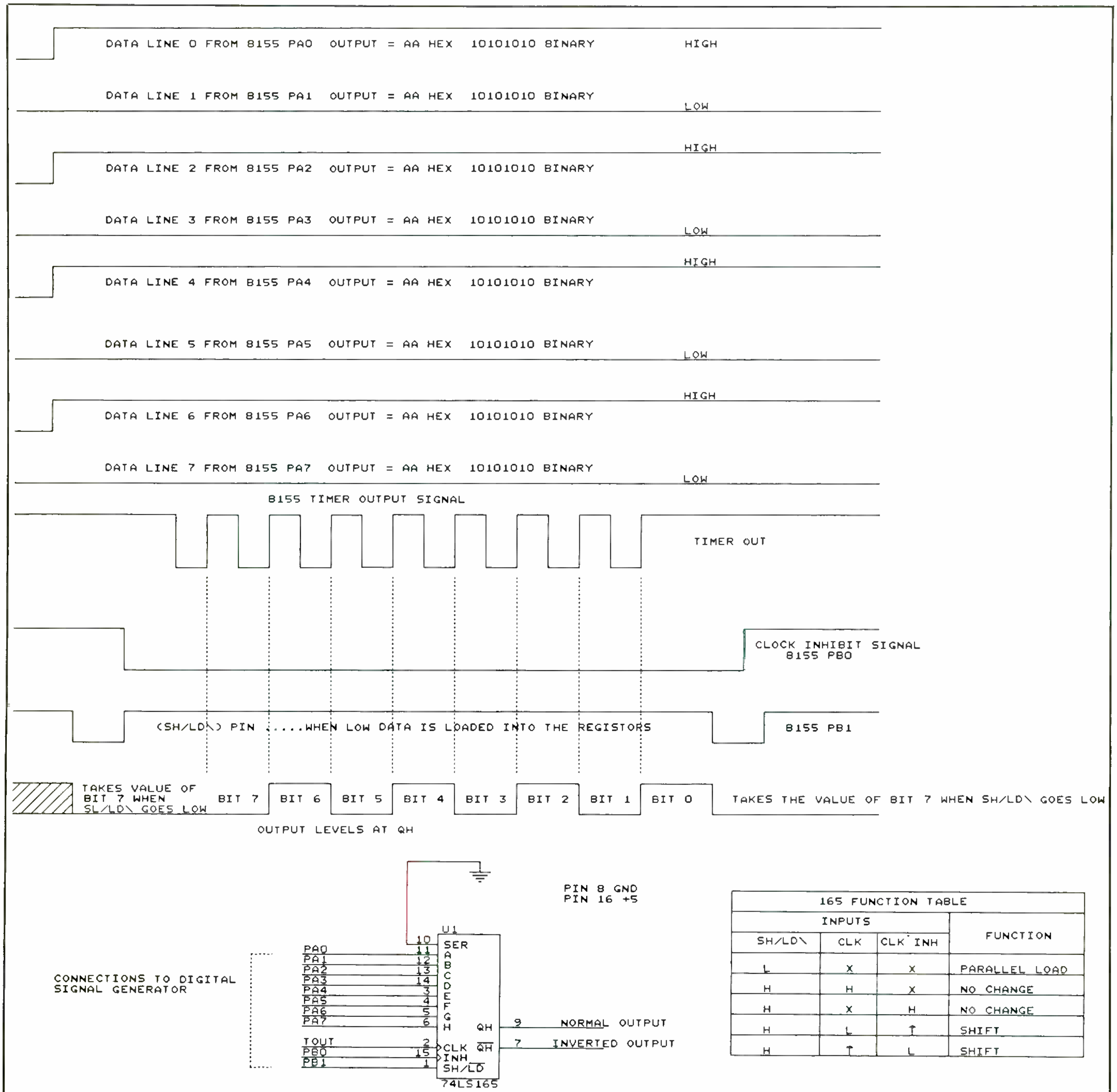
The program includes some additional code to determine the delay between operations. Other than this, you can see that programming is not complicated and could even be fun to do on your own.

Try changing the data at step 4 and note the results. Check that QH \ is the inverted or complemented QH.

patible. If you select a custom program, the program jumps to the one selected and begins generating digital signals as required. It then loops until you press the RESET button.

• *RAM.* RAM is principally used to store the programs you download from a PC or compatible computer. After the UART receives the custom program, the system ROM transfers control to the RAM-based program.

Used in the system is 8251A programmable communication interface *U12.* This device permits downloading of custom programs into the



165 FUNCTION TABLE

INPUTS			FUNCTION
SH/LD\	CLK	CLK INH	
L	X	X	PARALLEL LOAD
H	H	X	NO CHANGE
H	X	H	NO CHANGE
H	L	↑	SHIFT
H	↑	L	SHIFT

Fig. A. Timing details; pinouts for address, timer out, normal out and inverted out; and function table for 74LS165.

Digital Signal Generator/8088 Computer Experimenter Platform. The ROM program initializes the 8251, setting it up to wait for data from the computer. The data format selected is 9,600 baud, eight data bits and one stop bit. The receiver clock signal is generated in the 8155 counter/timer, which is cleared and reset for user applications after downloading.

Downloading of custom programs is another good example of the need to develop basic programming skills. It requires that all operating parameters be set via software initialization. The only way data is removed and tested is via a polled or interrupt program. The system waits for the data stream to begin and then jumps to the downloaded program when the transmission has been completed.

Various jumpers must be connected to meet the requirements of a standard IBM COM format (pins 4, 5, 6 and 20 of *P1* must be connected together). This is easily accomplished by strapping *J1*. Data output signals from the computer swing between +12 and −12 volts. Resistor *R32*, diodes *D2* and *D3* and IC *U6D* condition the input signal so that it is TTL-compatible, which is a requirement of the 8251A.

• *Generator Bus.* The Digital Signal Generator bus consists of a 40-pin header that accepts 25-mil (0.025-inch) diameter wires. These wires connect directly to your prototyping station, as shown in Fig. 2(B).

Next month, we will describe a prototyping station in which two ribbon connectors connect all signals available in the Digital Signal Generator directly to a prototyping station that utilizes popular plug-in breadboards and a Wire Wrap system.

The Digital Signal Generator bus consists of the 22 I/O lines plus the timer and clock signals from the 8155. The power supply is also available to the prototyping station to be used with experiments that draw less than 100 milliamperes of current. You can add a separate power supply to the prototyping station when building projects that draw more than 100 milliamperes.

• *Computer Platform Bus.* When you conduct experimental computer projects, you want all 8088 CPU signals, plus the 8155 I/O signals, at the prototyping station. The second 40-pin connector ties the address, data, control and chip-select signals to your prototyping station. This permits you to perform experiments using the 8088 microprocessor and its RAM, ROM and 8155 I/O as the host. All you must add is the experiment components and the program.

• *Power Supply.* This project requires a power supply capable of delivering +5 volts at 1 ampere and ±12 volts at 100 milliamperes. ME

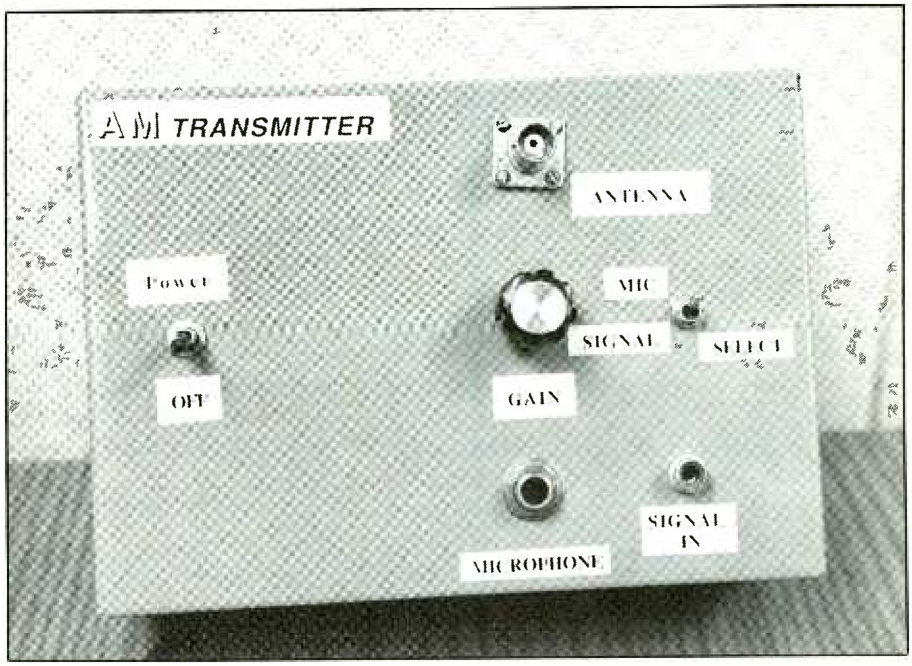
AM Radio Transmission

How AM radio transmission works and a mini-power AM transmitter you can build and use for experimenting

By Bob Mostafapour

You may have wondered how radio waves are transmitted or why transmission is done in a certain way. Or perhaps you shied away from building a radio transmitter because you thought such a project would be difficult, requires a special FCC license and requires hard-to-find costly components. Actually, a radio transmitter—especially an amplitude-modulated one—is one of the easiest circuits to build, using only readily available low-cost components. In fact, building an AM transmitter is a major focus of this article. And you don't need a license for this one!

We begin here with a discussion of AM radio transmission in all its guises. Then we present full details for building a low-power, license-free AM transmitter that broadcasts a signal that can be received with any AM broadcast-band radio. Because the transmitter radiates less than 1 milliwatt of power from its short antenna, no FCC license is required to build and operate it. You can voice-modulate the transmitter through a microphone or from a higher-level source like a tape deck or compact disc player simply by flipping a switch.



AM Transmission

Amplitude modulation, or AM, is a means by which two signals are combined so that one modulates the other. The signal to be modulated, called a carrier, is usually constant and much greater frequency than the modulating signal. The modulating signal can also be fixed in frequency, though it's usually variable and in the audio range so that voice, music and other sounds can be heard after demodulation at the receiving location.

Though an audio-frequency signal can be transmitted directly, economics (among other reasons) dictate that it be impressed on a carrier. This is because transmission and reception of a signal depend on antenna length. The lower the frequency to be transmitted, the longer the antenna needed at both ends. If an audio signal of, say, 5 kHz were to be transmitted directly, the antenna would be an impractical length. Its length is calculated using the wavelength formula:

$$\lambda = c/f$$

where λ is wavelength in meters, c is the speed of light (considered to be a constant 300,000,000 meters per second) and f is frequency in Hertz (Hz). Since we already know two of the unknowns for this formula—the speed of light and frequency—antenna wavelength is calculated as follows:

$$\lambda = c/f$$
$$\lambda = 300{,}000{,}000/5{,}000$$
$$\lambda = 60{,}000 \text{ meters}$$

As you can see, 60,000 meters (60 km) is an exceedingly long antenna length. The cost of building such an antenna would be prohibitive, as would be installing it.

Using a high carrier frequency, such as 1.5 MHz, to convey the 50-kHz signal considerably shortens the effective length of the antenna needed to transmit it. This reduces both cost and real estate on which to mount the antenna. When a carrier signal of a considerably greater frequency than that of the modulating signal is used, only the frequency of the carrier need be considered in the wavelength formula used to calculate antenna length.

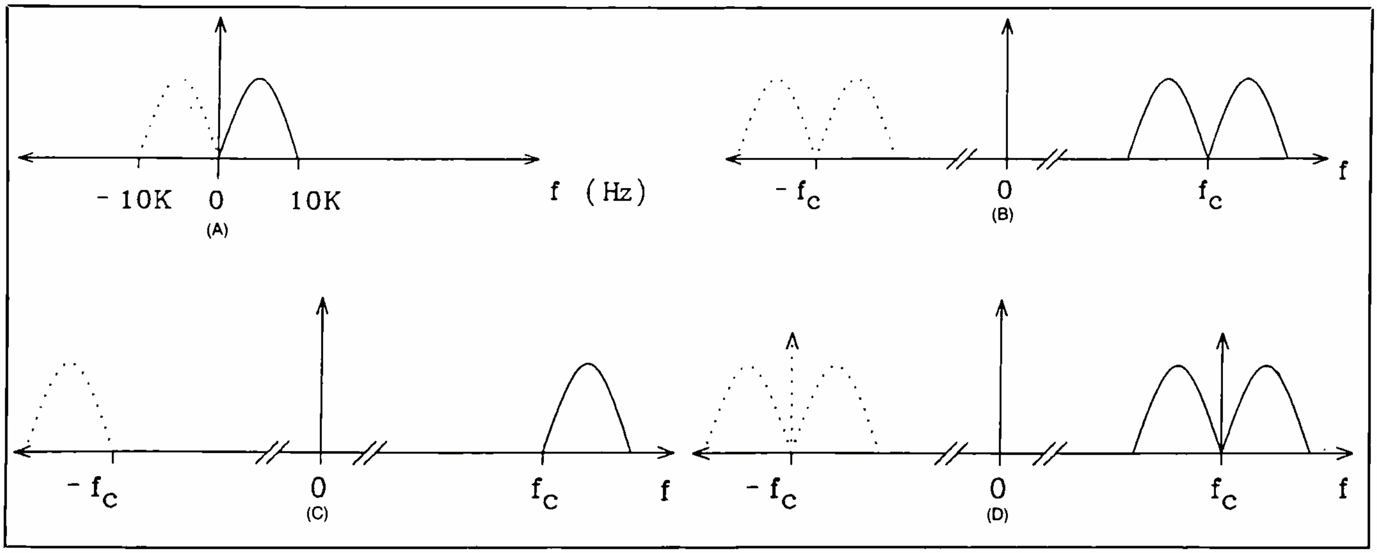


Fig. 1. Frequency distribution details for: (A) speech range profile; (B) modulated spectrum showing both negative and positive frequency components; (C) SSB spectrum; and (D) DSB-C (standard AM) spectrum.

Thus, for a 1.5-MHz (1,500,000-Hz) carrier, effective antenna length is calculated as follows:

λ = c/f
λ = 300,000,000/1,500,000
λ = 200 meters

At 200 meters in length, this a considerable improvement over the 60,000-meter antenna length needed to transmit the 5-kHz signal directly. If the carrier frequency is further increased to 30 MHz, only a 10-meter-long antenna would be needed for transmission and reception of the signal.

Modulation is the key to transmitting useful low-frequency information on a high-frequency carrier. This is done by electronically combining the two frequencies so that they produce a composite signal that's then radiated from the transmitting antenna.

Amplitude Modulation

Many forms of modulation are currently used for transmission and reception of radio waves, including amplitude modulation (AM), frequency modulation (FM), pulse modulation (PM), pulse-code modulation (PCM), etc. Our focus here is on AM, which includes such techniques as single sideband (SSB), double sideband (DSB), and double sideband with carrier (DSB-C). Each technique has its advantages to recommend it as well as its unique drawbacks. To understand the differences between these techniques, we'll discuss each in turn.

• Single Sideband. SSB is a type of signal that's transmitted with only one of its "side bands" present. To understand what is meant by sidebands, visualize the audio spectrum in terms of frequency. This can be represented in a graphic manner in much the same way as audio equipment frequency-response curves are presented.

Speech can be simplified into a frequency curve that has a "hump" centered around 5 kHz, as in Fig. 1. Although the hump appears to be symmetrical in Fig. 1(A), it isn't. It's shown like this for simplicity. As shown, speech consists of a range of frequencies, with greatest concentration in the middle of the range and a tapering off at both ends of the curve.

A phantom curve that depicts *negative* frequency is also shown in Fig. 1(A). Negative frequency is an important concept in gaining understanding of the modulation and transmission process.

A spectrum analysis of the human speech reveals a range of frequencies that can be divided into fundamental

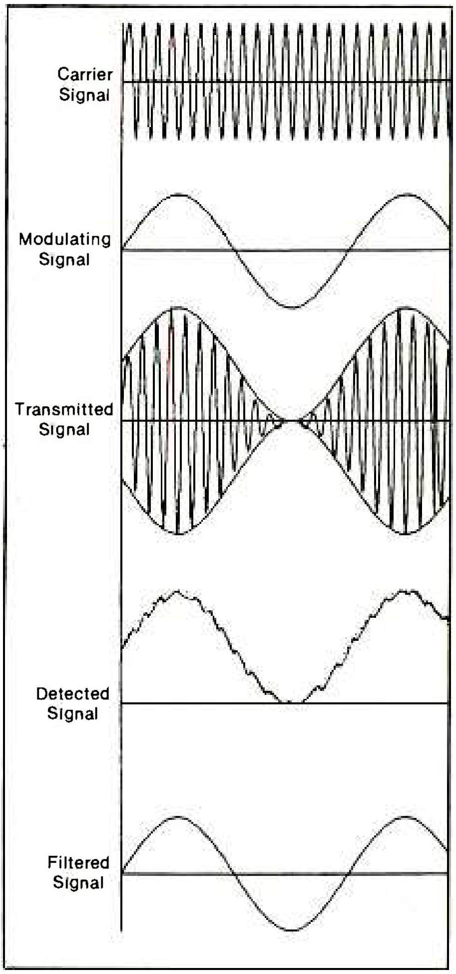


Fig. 2. Representations of modulation, transmission, detection and filtering of a signal.

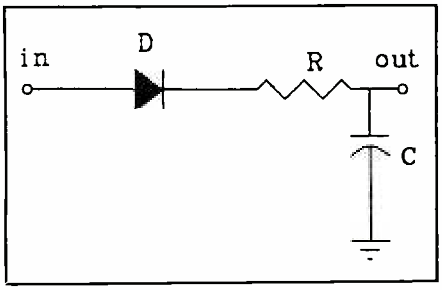


Fig. 3. A simple AM detector circuit arrangement.

parts as a summation of sinusoids. Mathematician Fourier hypothesized that any continuous function can be represented as a summation of sine waves, starting at a fundamental frequency and adding to it higher frequencies (harmonics, which are multiples of the fundamental). These frequencies have phase relationships that can be shown, through trigonometric identities, to be "negative" frequencies.

When the desired signal that contains the information to be transmitted is multiplied by a high-frequency carrier, modulation is the result. During modulation, the baseband signal being shifted up in frequency, centered at the carrier frequency (f_c). Modulation also creates a copy of this signal, shifting it in the negative direction as a negative frequency, as shown in Fig. 1(B).

Notice that the modulated signal at f_c contains both upper and lower sidebands. Recall that the shifted spectrum at f_c has what was once the negative and positive profiles of the speech spectrum. Consequently, it contains redundant information, since only one profile is needed to convey the desired information. Therefore, filtering out one of these humps won't diminish the transmitted information.

The process of filtering out one of the humps is where single sideband gets its name from. After filtering is accomplished, only one sideband remains to be transmitted, as illustrated in Fig. 1(C).

• *Double Sideband.* As its name indicates, DSB transmits both sidebands intact, as in Fig. 1(B). Although the transmitted signal contains redundant information, the design of the DSB transmitter is simpler than the SSB transmitter. Without sideband filtering, the transmitter is less costly and easier to build. At the destination, though, the receivers for DSB and SSB are fairly complex.

• *Double Sideband With Carrier.* DSB-C is the technical designation for standard AM, which is what commercial AM broadcasters use to deliver music, news, weather, sports, etc. to their audiences. The frequency spectrum of DSB-C looks much like that of DSB, except that it contains a spike at carrier frequency f_c, with both bands along for the ride, as in Fig. 1(D).

The tradeoff between these AM modulation techniques is a matter of efficiency *versus* ease of implementation and cost of demodulation. Because consumers want low-cost receivers, the sacrifice made is lower efficiency. Greater efficiency is realized in SSB and DSB systems, but cost is much greater for receivers because a synchronous modulator is needed for reception and demodulation of DSB and SSB signals.

To be able to hear the information contained in an incoming signal, the receiver must use circuitry that multiplies the incoming signal by a sine-wave signal of exactly the same frequency as the carrier. Multiplying the incoming signal again shifts the spectrum. But now the negative-going spectrum falls into the place it started from but is at twice the original carrier frequency, making it easy to filter out. The spectrum shifted to the original position allows you to hear the information. The circuitry required to achieve this is expensive and requires many components to implement.

AM Radio Detection

Graphic examination of DSB-C transmission and reception demonstrates the economy of this format. Referring to Fig. 2, carrier signal (A)

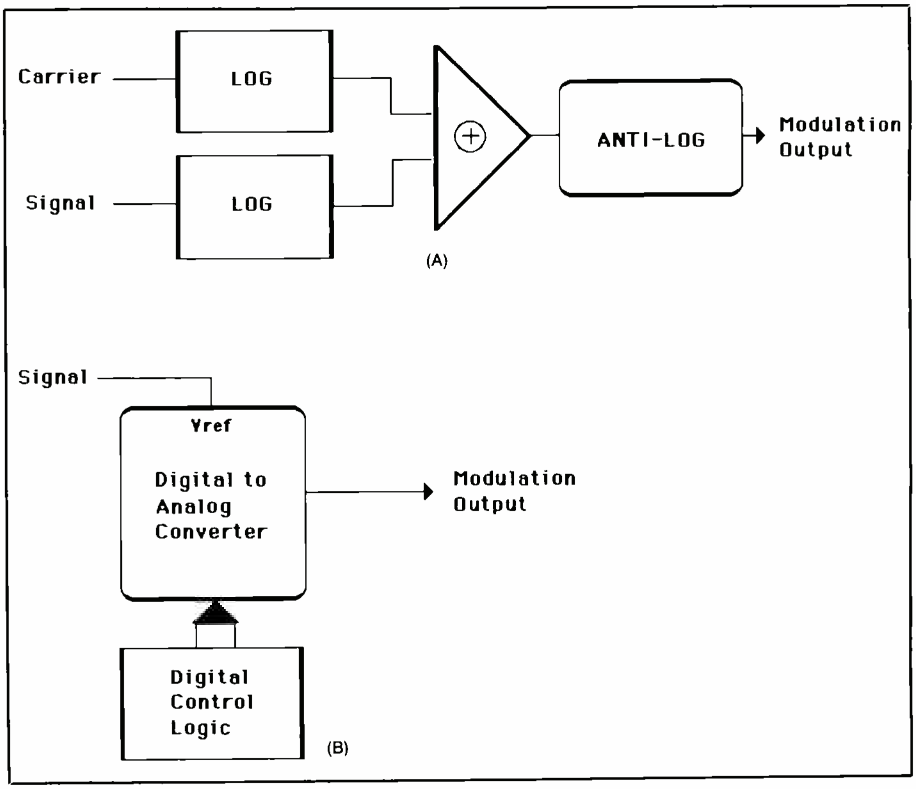


Fig. 4. Ways of achieving amplitude modulation by the (A) logarithmic method and (B) the analog-to-digital method.

is multiplied by dc-offset modulating signal (B) to yield transmitted composite (modulated) signal (C). Signal (C) is received and input to the detector arrangement shown in Fig. 3. The simple diode/resistor/capacitor circuit shown is all that's needed to retrieve the transmitted signal. Of course, a receiver would also contain a preceding r-f amplifier and an amplifier to drive a speaker.

The demodulated signal exiting the detector is usually ragged, as shown in Fig. 2(D). After final filtering, raggedness is removed, producing a clean signal like that in Fig. 2(E).

Recall that the double sidebands contain the same information. Hence, efficiency can be measured as the ratio of the power of one sideband to total transmitted power. From this, it's easy to see that SSB is most efficient and DSB-C is least efficient. The DSB-C transmitter uses power to transmit both sidebands *and* the carrier. This being the case, efficiency is a maximum of only 33 percent.

Modulation Methods

To build an AM transmitter, you need a modulator to multiply a carrier frequency by a modulating signal that contains useful information. You can do this electronically with logarithmic conversion and addition, use of digital-to-analog (D/A) converters, etc. Because it's readily available, low in cost and easy to implement, the project to be described employs the D/A circuit for its modulator.

Operational amplifiers can be configured to integrate, differentiate and amplify signals, each function implemented by feedback elements. An integrator, for example, requires a capacitor in the feedback loop. If the feedback element is a nonlinear device like a diode or transistor, you can design a logarithmic converter like that depicted in Fig. 4(A). With such a circuit, adding the log of two signals and then taking the antilog produces the equivalent multiplied signal. In theory, this would work, but putting it into practice can be a real nightmare. The bandwidth consideration of the op amps would make this implementation prohibitively expensive, and a large number of op amps would be needed to implement such an arrangement.

With support circuitry, D/A converters can be used for modulation, as in Fig. 4(B). A D/A converter can be used as a programmable attenuator by feeding the signal into its voltage-reference pin. Digital control logic switches the attenuation of the signal at a high rate (creating the carrier) to produce modulation. This implementation is limited by the bandwidth of the D/A converter and requires extensive support logic.

Balanced Modulator Chip

The versatile low-cost and readily available LM1496 balanced modulator IC can be used for DSB-C, SSB and DSB modulation. Choice of modulation depends on how you bias this chip. In operation, the LM1496 circuit modulates two signals by chopping the modulated signal at the rate of the carrier frequency, in effect using the chopping operation as a multiplier (see Fig. 5).

Internally, the LM1496 uses two sets of transistors configured as differential pairs and only a small voltage to switch at the carrier frequency. The differential pairs are fed by constant-current sources biased by external resistors and the modulating signal. Therefore, the dc offsets applied to the input determine the type of transmitter configured.

Close examination of Fig. 5 reveals that chopping is, indeed, multiplying. For example, look at the input signal at the top of the illustration at any time along the axis when in its

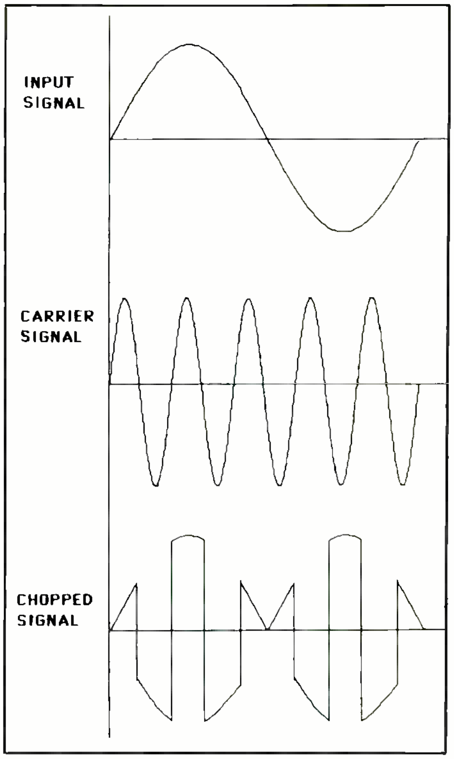


Fig. 5. How signal chopping results in amplitude modulation.

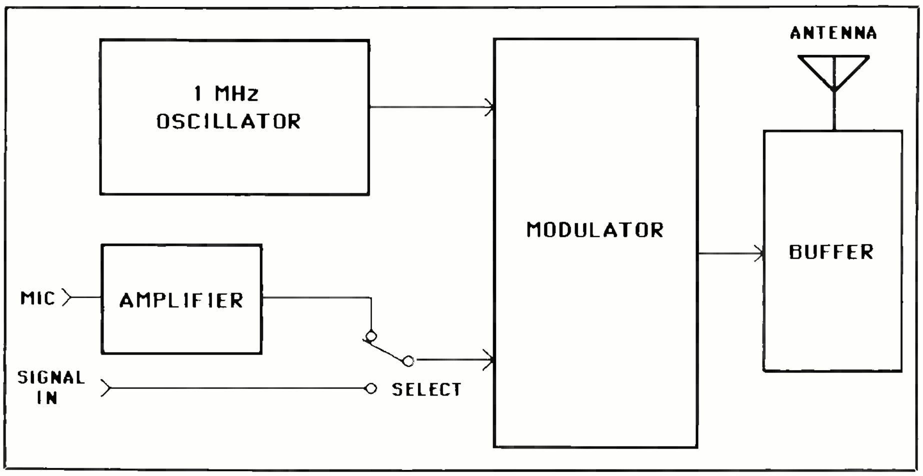
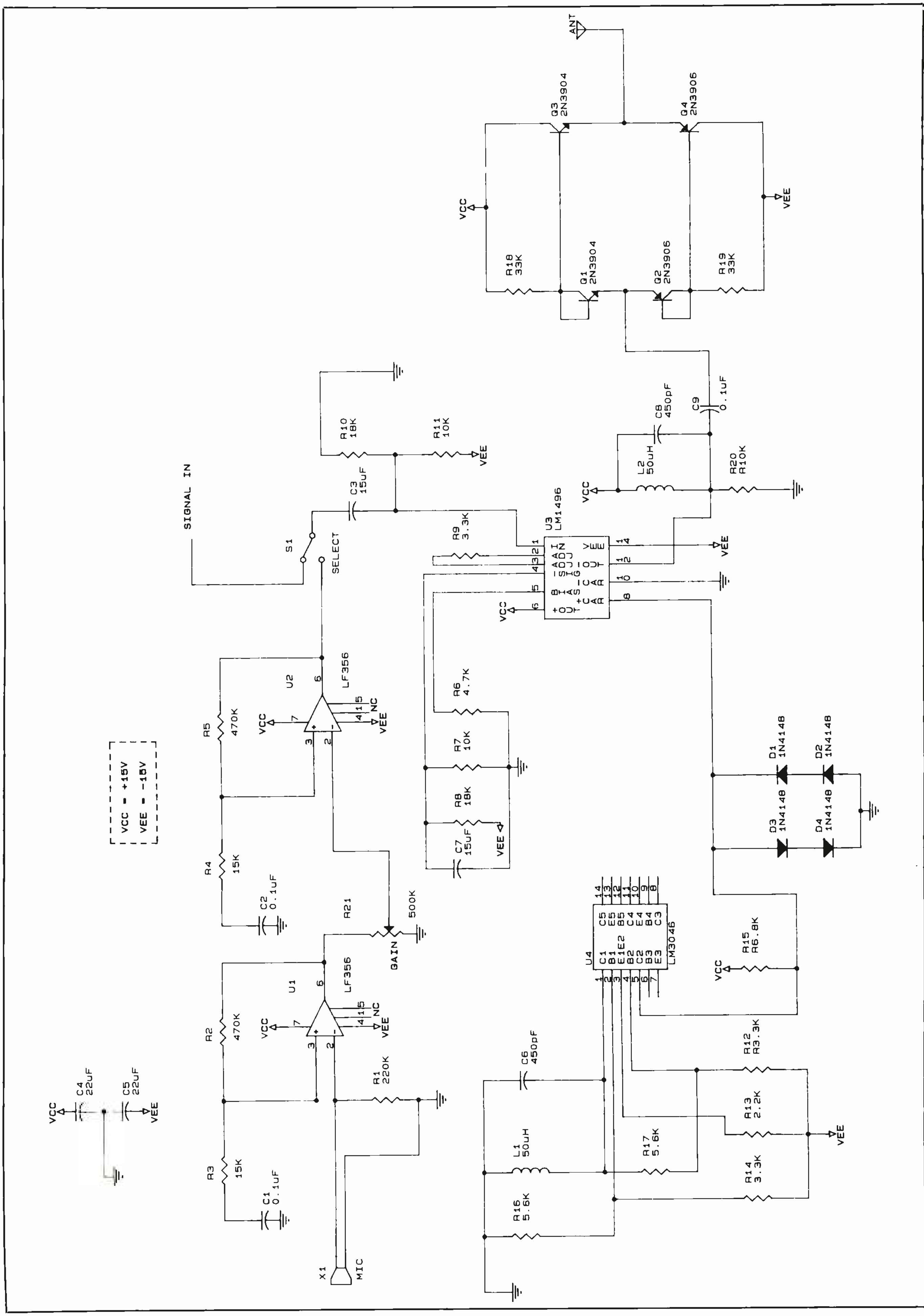


Fig. 6. Block diagram of the circuitry used in the AM Transmitter project.



ANT
Q3 2N3904
Q4 2N3906
VCC
VEE
R18 33K
Q1 2N3904
Q2 2N3906
R19 33K
C8 450pF
C9 0.1uF
R10 18K
R11 10K
SIGNAL IN
C3 15uF
L2 50uH
R20 R10K
S1
SELECT
R9 3.3K
U3 LM1496
U2 LF356
NC
R5 470K
R6 4.7K
R7 10K
R8 18K
C7 15uF
D1 1N4148
D2 1N4148
D3 1N4148
D4 1N4148
VCC = +15V
VEE = -15V
R4 15K
C2 0.1uF
R21 500K
GAIN
U1 LF356
R2 470K
U4 LM3046
R15 R6.8K
C6 450pF
R12 R3.3K
R13 2.2K
R17 5.6K
L1 50uH
R14 3.3K
R16 5.6K
R1 220K
C4 22uF
C5 22uF
R3 15K
C1 0.1uF
X1
MIC

Fig. 7. Schematic diagram of basic AM Transmitter circuitry.

PARTS LIST

Semiconductors
BR1—200-volt, 1-ampere bridge-rectifier module
D1 thru D4—1N4148 or similar small-signal diode
Q1,Q3—2N3904 silicon npn transistor
Q2,Q4—2N3906 silicon pnp transistor
U1,U2—LF356 operational amplifier
U3—LM1496 balanced modulator
U4—LM3046 transistor array
U5—LM7816 +15-volt fixed regulator
U6—LM7915 −15-volt fixed regulator
Capacitors
C1,C2,C9—0.1-µF ceramic disc
C3,C7—15-µF, 25-volt electrolytic
C4,C5—22-µF, 25-volt electrolytic
C6,C8—450-pF ceramic disc
C10,C11—2,200-µF, 25-volt electrolytic
C12,C13—0.1-µF tantalum
C14,C15—0.22-µF tantalum
Resistors (¼-watt, 5% tolerance)
R1—220,000 ohms
R2,R5—470,000 ohms
R3,R4—15,000 ohms
R6—4,700 ohms
R7,R11,R20—10,000 ohms
R8,R10—18,000 ohms
R9,R12,R14—3,300 ohms
R13—2,200 ohms
R15—6,800 ohms
R16,R17—5,600 ohms
R18,R19—33,000 ohms
R21—500,000-ohm panel-mount linear-taper potentiometer
Miscellaneous
F1—0.5-ampere slow-blow fuse
L1,L2—50-µH inductor
S1—Spdt toggle or slide switch
S2—Spst toggle or slide switch
T1—24-volt, 300-mA center-tapped power transformer
Perforated board with holes on 0.1 inch centers and suitable soldering hardware (see text); suitable enclosure (see text); sockets for all DIP ICs; fuse holder; ac line cord with plug; microphone; panel-mount connectors; lettering kit; clear acrylic spray; ½-inch spacers; machine hardware; hookup wire; solder; etc.

positive excursion. Select a point and draw an imaginary line down to the carrier signal. You'll notice that if the carrier signal is positive, the chopped signal is also positive, and *vice-versa*. In essence, the carrier signal is multiplying the chopped signal by +1 and −1. To create true multiplication, the chopped signal must be fed through a filter to smooth out sharp edges. This is accomplished in the final circuit.

Project Circuitry

Shown in Fig. 6 is the block diagram of a transmitter circuit you can build and use for experimental purposes. A microphone, the low-level signal from which is amplified by an on-board preamplifier stage, or a high-level signal that doesn't undergo preamplification can be used as the modulating signal source. The carrier signal comes from a 1-MHz oscillator for easy tuning of the transmitted signal on a standard AM broadcast-band radio.

The modulator in this transmitter chops and filters the carrier and modulating-source signals. The final stage buffers the modulator and delivers the output from the transmitter to the antenna.

As shown in Fig. 7, the preamplifier section is the straightforward two-stage (*U1* and *U2*) noninverting op-amp circuit. It's selected by setting *S1* to the alternate position shown. The purpose of the preamplifier section is to match the impedance of the microphone to the impedance of the *U3* balanced modulator. The gain of each stage in the preamplifier is 30, yielding an overall gain of 900 (30 × 30). Two stages were used in the preamplifier because of the limited gain bandwidth product of inexpensive op amps. Though extremely high gain is possible with one op amp, a narrower bandwidth would have resulted.

Capacitors *C1* and *C2* in the noninverting amplifier configuration limits dc gain to about 1. This eliminates the possibility of saturation of either amplifier at dc. The JFET op amps provide immunity to noise at high input impedance.

The *U4* oscillator section is the familiar Colpitts configuration. It's simply a differential pair with an LC tank and feedback to provide regeneration. The modulating frequency can be changed here with ease. The values of capacitor *C6* and inductor *L1* in parallel determine carrier frequency using the formula: $f_c = 1/(2\pi\sqrt{LC})$.

With values of 50 µH and 450 pF for *L1* and *C6*, respectively, f_c factors out to 1,060 kHz, or 1.06 MHz. This frequency is in the middle of the AM broadcast band. If you use a different transmit frequency, recalculate the values of *C6* and *L1* using the above formula.

LM3046 *U4* is simply four npn transistors on the same piece of silicon inside the chip. The oscillator could be built using discrete components, but the LM3046 approach is better because its matched transistors are on the same substrate and withstand the same processing parameters. The transistors also heat and cool together for more stability.

LM1496 *U3* is configured for DSB-C transmission by offsetting the dc component applied to the input using *R10* and *R11*. The potential at the junction of these two resistors is −9.6 volts. The values of *R8* and *R9* are the same as those of *R11* and *R10* but their arrangement provides a potential of −5.4 volts that's applied to pin 3 of *U3*. These dc offsets create the envelope needed for DSB-C transmission.

The output of the oscillator at pin 12 of *U3* is clamped at two diode drops of approximately 1.2 volts by *D1* through *D4*.

The switching mechanism inside *U3* is a differential transistor pair that requires only a small voltage to switch states. The smoothing filter that rounds out the sharp edges created by the chopping action is made up of *C8* and *L2*. Without this filter, the transmitter would be less efficient because it would waste power on harmonic frequencies. If you change the carrier frequency, you must also recalculate the values of *C8* and *L2*.

Capacitor *C3* buffers the dc applied to pin 1 of *U3* and prevents back feeding to *U2*. Capacitor *C7* shorts to

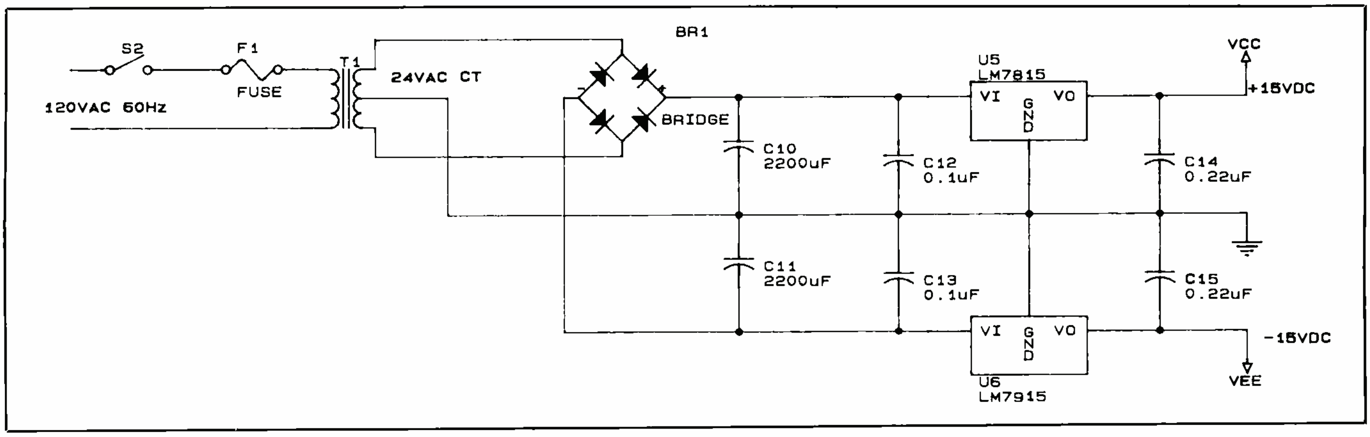


Fig. 8. Schematic diagram of power supply for the AM Transmitter.

ground high frequencies at pin 4 of *U3*, allowing proper bias to be applied to this pin. Bridging resistor *R9* sets the internal bias for *U3*. Internally, the two emitters of the differential transistor pair meet at *R9*. Thus, the modulating voltage creates a current through *R9* and, consequently, a voltage across this resistor.

The output of *U3* is a current that's fed through *R20* to obtain a voltage for transmission. The high output impedance of *U3* requires a buffering stage to accomplish transmission. The buffering stage is a straightforward emitter-follower arrangement that has a gain of 1.

Since ±15 volts is available, a class-AB circuit was devised. Front-end transistors *Q1* and *Q2* are connected as diodes that bias output transistors *Q3* and *Q4*.

An antenna not longer than 2 to 3 feet must be used with this transmitter to assure the broadcasting range is limited to the immediate area.

Power for the transmitter is provided from the 117-volt ac line by the circuit shown schematically in Fig. 8. This circuit arrangement provides regulated ±15 volts. Regulators *U5* and *U6* reduce the incoming dc voltages and regulate them to +15 and −15 volts because the biasing voltages in various stages is based on ±15 volts dc. Center-tapped power transformer *T1* provides outputs for the positive and negative voltages required by the transmitter circuitry.

Construction

The simplest approach to construction is to wire together the components on perforated board that has holes on 0.1-inch centers using soldering hardware. Use sockets for *U1* through *U4*. Two points to keep in mind when building the transmitter: keep all wire runs and component leads as short as possible and mount the power supply on a separate board.

A suggested layout for the main board is shown in Fig. 9. The *U1/U2* preamp is on the end, the *U3* modulator is in the center and the *U4* oscillator is on the left. The output section (*Q1* through *Q4*, *D1* through *D4* and their support components) are at the far left and along the top of the board. The modulator is fed from both sides, and the output is at a corner of the board away from the microphone preamplifier circuit.

Begin assembly by mounting into place the four IC sockets. Do *not* plug the ICs into the sockets until you're directed to do so. Then mount the other components in the locations shown for them. Some resistors and the diodes mount on-end to conserve board space.

Refer to Fig. 7. Wire together the components. Take care in making connections to the IC sockets, elec-

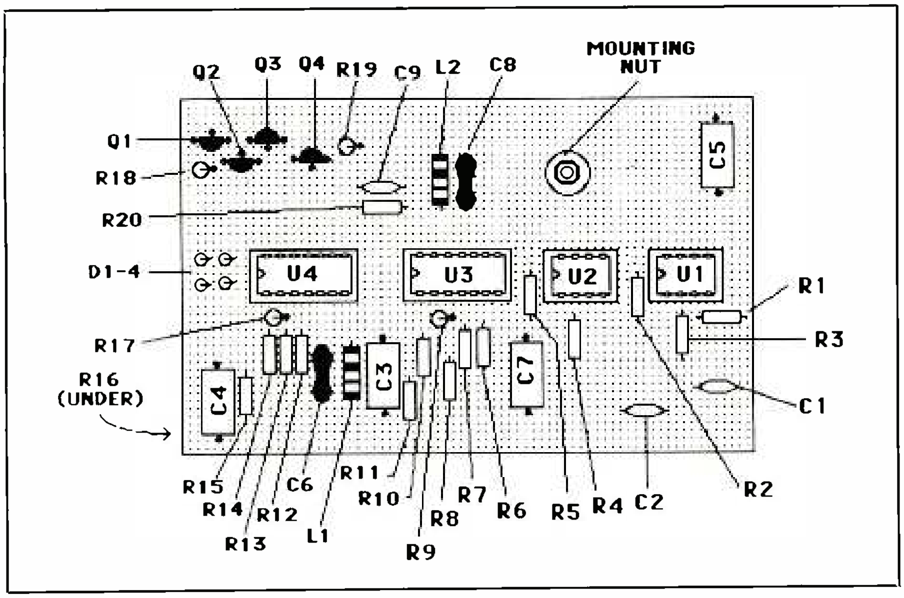


Fig. 9. Suggested component layout for main transmitter circuitry on perforated board.

trolytic capacitors, diodes and transistors. The microphone and signal inputs, antenna output, GAIN control *R21* and MIC/SIGNAL selector switch *S1* mount off the board.

Provide solder-post pins on the board for circuit ground, +15 and −15 volts, the microphone and signal inputs, antenna output, MIC/SIGNAL selector switch and GAIN control. These will be connected later, during the final assembly stages. Temporarily set aside the main transmitter circuit-board assembly.

As shown in Fig. 10, the power supply is best wired on two small pieces of perforated board. Mount the power transformer, bridge rectifier and filter capacitors on the larger of the two boards, the remainder of the power-supply circuitry on the smaller board. Refer to Fig. 9 to wire the power-supply circuit, making sure to observe correct capacitor polarities and regulator and bridge-rectifier pin identifications.

Use solder posts with which to make interconnections between all three boards and the primary circuitry of *T1*. Label each pin on all circuit-board assemblies according to its function for easy identification.

Use any size metal enclosure that accommodates the circuitry and provides sufficient panel space on which to mount the connectors and controls (see lead photo for a suggested layout for the panel). Drill mounting holes for the circuit-board assemblies and fuse holder and an entry hole for the ac line cord through the rear panel. Then drill mounting holes for the connectors and controls through the front panel. When done, deburr all holes to remove sharp edges.

Use a dry-transfer lettering kit or tape labeler to apply appropriate legends on the front panel. If you use dry-transfer lettering, spray two or more light coats of clear acrylic over them. Allow each coat to dry before spraying on the next.

Line the ac cord entry hole with a rubber grommet. Then mount the fuse holder and circuit-board assemblies in place, using suitable machine hardware and ½-inch spacers for the boards. Referring to Fig. 7 and Fig. 8, wire together the circuit boards.

Route the ac power cord into the enclosure through its grommet-lined entry hole and tie a knot in it about 10 inches from the end inside the enclo-

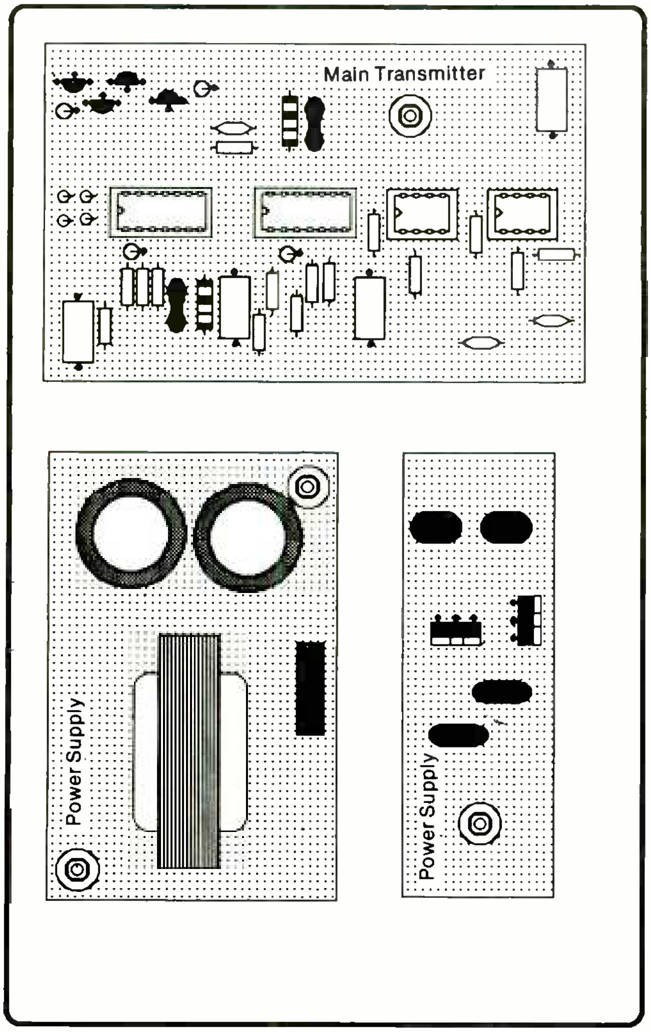
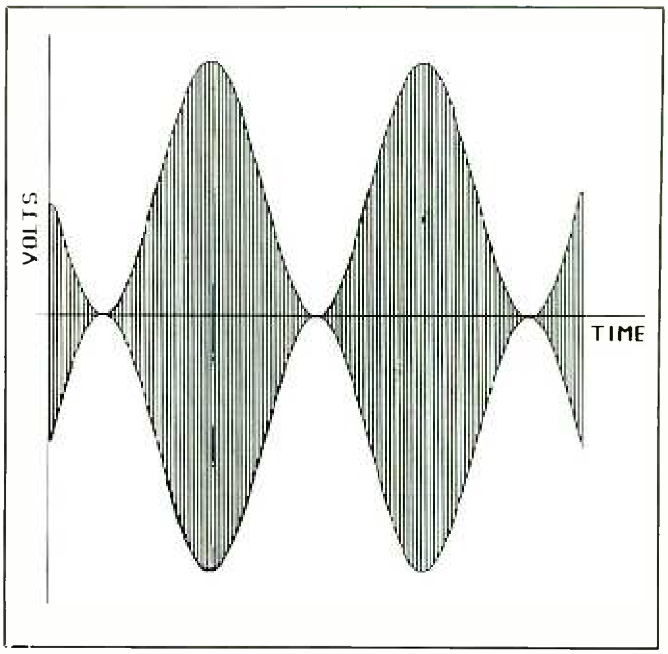


Fig. 10. Layout details for circuit-board assemblies inside enclosure. Large board at top is main transmitter circuitry. Power supply circuitry is on two smaller boards shown at bottom.

Fig. 11. Typical DSB-C AM-modulated signal as displayed on the CRT screen of an oscilloscope.



sure. Tightly twist together the fine wires in one conductor and sparingly tin with solder. Determine how long the other conductor must be to reach one of the solder posts connected to the power transformer primary, leaving some slack. Cut this conductor to length, strip ⅜ inch of insulation from it, tightly twist together the fine wires and sparingly tin with solder. Connect this conductor to either transformer primary solder post.

Mount the GAIN control, POWER and MIC/SIGNAL switches and ANTENNA, MICROPHONE and SIGNAL IN connectors in their respective locations. Place a control knob on the shaft of the GAIN control.

Crimp and solder the free end of the other ac line cord conductor to one lug of the POWER switch. Then use hookup wire to bridge from the other lug of the switch to one lug of the fuse holder and another wire to bridge from the other lug of the fuse holder to the unused transformer primary solder post. Place a fuse in the fuse holder.

Interconnect the circuit assemblies and components mounted on the front panel as needed, using hookup wire. Make sure each connection goes to the proper pins on the circuit-board assemblies.

Checkout & Use

Make sure *U1* through *U4* are not plugged into their sockets. Connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to any convenient point in the circuit that is supposed to be at ground potential. Plug the line cord of the transmitter into an ac outlet and set the POWER switch to "on."

Touching the "hot" probe of the meter to pin 7 of the *U1* and *U2* sockets and pin 6 of the *U3* socket should yield a reading of + 15 volts. Similarly, touching the "hot" probe to pin 4 of the *U1* and *U2* sockets and pins and pins 4 and 14 of the *U3* should yield a reading of − 15 volts.

When you're certain that your wiring is correct, power down the Transmitter and plug the ICs into their respective sockets on the main board.

Temporarily disconnect the links between the oscillator, microphone preamplifier, modulator and output buffer sections. Power up the Transmitter and check the input section with a low-level signal from a signal generator. Use an oscilloscope to verify that proper gain is obtained at pin 6 of *U2*. If you observe saturation (flattening of the signal waveform peaks), you may have to install a voltage divider to correct for this.

After verifying that the preamp circuit is working properly, power down the Transmitter and generator. Disconnect the latter and plug into the MICROPHONE jack a microphone. Power up the Transmitter once again and speak into the microphone as you observe the scope display. You should see a variable amplitude/frequency waveform displayed with peak-to-peak excursions amounting to a few volts.

Next, check out the oscillator section. Touch the input probe of your scope to the anode of *D3* and note that there should be at this point a square waveform of approximately 1.06 MHz (unless you chose a different frequency for the carrier). Peak excursion of this signal should be approximately 1.2 volts. If the signal obtained is considerably off-frequency, change the value of *C6* to bring it in line. Tolerance here may affect frequency.

Restore the links between the microphone preamp, oscillator and modulator circuits, but don't restore the link between the modulator and output buffer circuits just yet. Check the output of *C9* while feeding a low-level signal from your signal generator into the MICROPHONE input jack. Set the panel switch to MIC during this test. The scope should display a waveform similar to Fig. 11.

If you fail to obtain a modulated-signal display, check the connections to *U3*. Use your meter to check the dc bias at pins 1 and 4 for presence of − 9.6 volts and − 5.4 volts, respectively. If you obtain different readings, resistor connections are incorrect.

When the output signal from the modulator looks okay, power down the Transmitter and restore the link between it and the buffer section. Powering up the Transmitter, there should be no difference in signal at the input and output of the buffer.

Now plug your antenna into the connector on the Transmitter. You should observe no change in the signal displayed on your scope. If everything works as described, you're ready to go on the air.

Plug the output cable from a tape deck or CD player into the SIGNAL IN and a 2- to 3-foot length of solid hookup wire (strip ⅜ inch of insulation from one end first) ANTENNA jacks. Turn on your transmitter, a nearby table or portable AM radio and tape deck or CD player and start a tape or disc playing. Set the SELECT switch on the panel to SIGNAL. Then carefully tune through the middle of the band on the radio until you hear the program being played on the tape deck or CD player from the radio.

Having verified that the high-level input works, power down the transmitter and unplug the tape deck or CD player from it. Plug your microphone into the MICROPHONE jack and set the SELECT switch to MIC. Power up the transmitter and speak into the microphone. If you fail to hear your voice coming from the AM radio or the signal sounds distorted, adjust the GAIN control until the signal sounds clean.

Experimenting

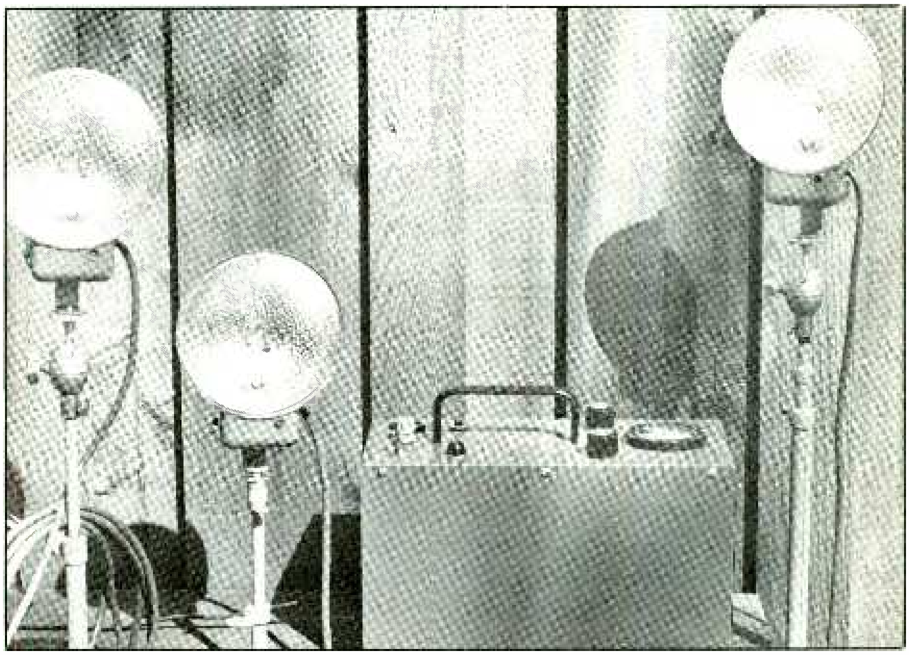
This Transmitter project serves well as a basis for studying DSB-C amplitude modulation. The LM1496 balanced modulator can easily be configured for DSB and SSB modulation, though additional filtering is needed to complete the design. However, the buffer, oscillator and input stages remain as they are shown. Implementation of SSB and DSB also requires a suitable receiver to pick up and demodulate the transmitted signal.

DSB-C modulation simplifies things because just about everyone already has a standard AM broadcast-band radio to receive its transmissions. If you have a shortwave receiver that can tune SSB transmissions, you can experiment with the SSB and DSB transmission. ME

Triple-Head Photo Flash System

Gives the amateur photographer the advantages of multiple-source studio lighting systems for shooting professional-quality portraits

By Maurice P. Johnson



Regardless of the camera you use, if the flash is mounted on it, you get very restrictive illumination because light aimed at your subject from the same axis as the lens can produce flattening and very unflattering front light. This flash-on-camera arrangement is also the cause of "red eye" commonly seen in color photos of people. For effective photography lighting, you need more than one light source in locations that are off-camera.

Though use of a flash gun with a flash head that can be tilted upward to bounce light onto the subject provides a bit of improvement, it isn't a good solution. Light reflected (bounced) off the ceiling onto your subject from a direction may be more flattering, but the intensity of the light that reaches your subject is considerably reduced when compared to direct-flash intensity. Consequently, unless you use a fairly powerful flash gun, the light falling on your subject may be too weak to provide adequate exposure without a fast lens.

For effective portrait photos, what you really need is a multiple-head flash system like the triple-head design described here. Our Triple-Head Flash System is designed to meet three important criteria for good indoor studio-quality photos. One is the modeling light, which is the dominant light that establishes the direction of principal illumination and is seldom located at the lens axis. It defines butterfly, Rembrandt, 45°, etc. type light. Next is fill-in light that you use to illuminate the shadows created by the main light. This light can be located near the lens axis but is subordinate to the main light. The third and final criterion is independent background lighting that acts as a "hair" light for a degree of background lighting to separate the subject from the background. It can be used as a "rim" light or side light.

We offer here two different but similar multiple-head flash system designs. One provides 300 watt-seconds of power and features a bevy of bells and whistles. The other, more conservative system provides 100 watt-seconds of power and omits some convenience features. The version you build will almost certainly be determined by availability of certain components.

Design Considerations

A convenient per-tube power level for a home studio system lies in the 100-Ws (watt-second) range. Such a unit requires power packs that supply 450 to 500 volts dc. This is a feasible voltage for home construction and provides a very useful light level.

There's no need for miniaturization or powering from a source other than the 117-volt ac line for a studio setup. The flash heads are intended to mount on light stands, the power pack to rest on the floor.

The flash heads consist of flash tubes with reflectors and a minimum of electronics. Trigger transformers and trigger capacitors are the only trigger components in the flash heads. The remaining triggering circuitry is housed inside the power pack, which is the major element in the system, since it encompasses the storage capacitors, charging power source, control and monitor elements, and triggering circuitry.

To obtain effective energy/light conversion, a full amount of energy should be supplied to each flash tube in a multiple-head system. To achieve this, the applied potential must be at least 400 volts but not more than 550 volts for reliable firing. You must take care to avoid subjecting the flash tube to greater than 550 volts, or the tube will be irreparably damaged. From the foregoing, you can see that there's a very definite voltage "window" between 400 and 550 volts that defines power pack voltage levels. The power pack must, therefore, be designed to load the tube to a 100-Ws energy level within these voltage limits. Also, *each* flash tube should be loaded to this energy level, whether one, two or all three flash heads are in use for a particular photo session. This is accomplished with a separate storage capacitor in each flash head. These capacitors charge in parallel from a single source, but they're electrically isolated from each other for independent discharge into their respective flash tubes.

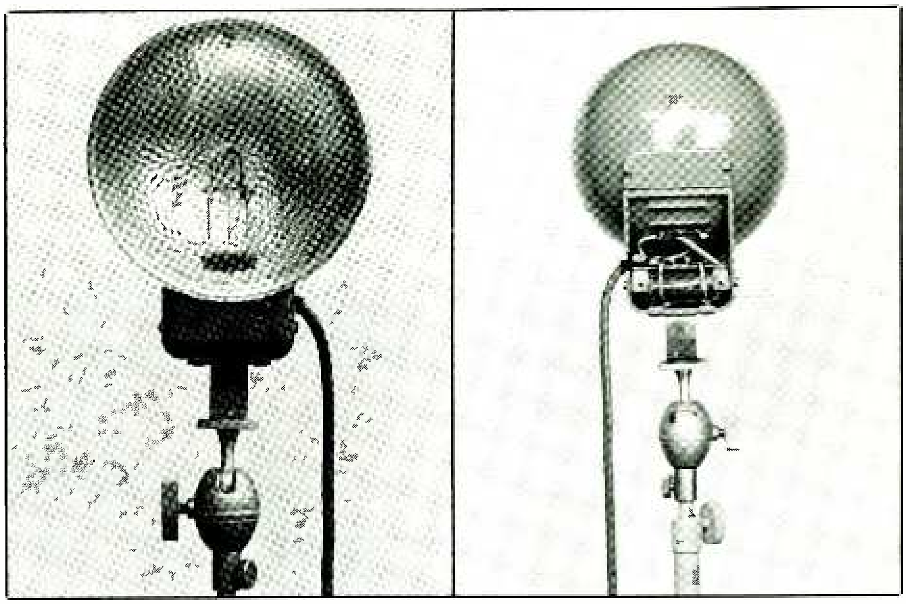


Fig. 1. Flash heads selected should have built-in flash tubes and trigger transformers. They should also be able to mount on tripods or other supports. Being able to tilt is also a plus.

When searching for suitable flash tubes, look for ones intended for 450 to 500 volts across them (GE No. FT-118 and similar types). Try to obtain heads that include tubes, trigger transformers and suitable reflectors to minimize any modifications needed to adapt them for light-stand use.

Suitable capacitor values are in the 500- to 800-μF range. These capacitors should be rated to handle 500 working volts, but in a pinch you can get away with capacitors rated at 450 volts. You can parallel-connect smaller-value capacitors to obtain the desired value if need be.

You also need a power transformer of the type used to power tube-type TV receivers, amplifiers or radios. The transformer should have a secondary winding rated at 650 to 700 volts and a center tap to drive a full-wave power-supply circuit. A transformer with no tap on the secondary winding and capable of delivering 325 to 350 volts can be substituted for a half-wave power-supply circuit. Select a transformer rated at not less than 50 mA. The greater the current rating, the faster the charging cycle for the flash-head storage capacitors and the shorter the cycle interval between shooting pictures.

To avoid confusion, we'll deal with the elements that make up this project one at a time, discussing how each works and giving construction details before proceeding to the next.

• *Flash Heads.* Only a minimum of circuitry is included inside a flash head (see Fig. 1). A three-conductor cable terminated in a plug connects each flash head to the power pack through a mating jack. This cable should be wired directly to the components in the flash head, not through a plug/jack arrangement.

Flash-tube leads shouldn't be subjected to strain. They're best secured to solder lugs or support terminals at the points the cable conductors or trigger transformer leads attach. Connect the high-voltage secondary of the trigger transformer directly to the trigger band on the flash tube. (Each flash head must be equipped with a separate trigger transformer and trigger capacitor.) One side of the trigger capacitor connects to the primary of the trigger transformer, while the opposite (input) end of the capacitor is brought back through the cable to the power pack, where it's accessible to the firing circuits.

In essence, the trigger capacitor simply connects back to the opposite end of the trigger transformer when the flash is to be fired. The primary circuit is completed so that the capacitor discharges through the transformer in only a few microseconds to generate a high-voltage firing pulse at the transformer secondary. Applied to the tube, this trigger pulse ionizes the internal xenon gas so that the capacitor, in turn, discharges through the very-low resistance of the ionized gas and produces a light pulse of very-short duration.

Nearly 500 volts dc appears across the flash tube and cable conductors when the storage capacitor is charged. The trigger capacitor charges to about 150 volts, which also appears on the third cable conductor. Within the head housing, when the tube is fired, the voltage at the secondary of the trigger transformer is a pulse with a magnitude of at least 4,000 volts and may even approach 10,000 volts with certain transformers. Consequently, component layout and cable type should be selected with these voltages in mind.

Fit the flash head with adequate hardware to permit it to be attached to a standard light stand. A tilt head is particularly useful for aiming the flash to direct light in a specific direction during use.

• *Power Pack*. This part of the system requires construction from scratch. Here we give you a choice between two versions of power pack to build—"bare-bones" and a more elaborate design, both of which can power up to three flash heads. The major difference between the two designs is the amount of loading each applies to each flash tube when the tubes are fired in parallel.

When using multiple flash heads powered by a common power pack, each flash tube should have its own trigger transformer and capacitor to ensure reliable triggering. Parallel-connected flash tubes should be of the same type if a common stored energy source is to divide equally among the tubes. Make sure that the energy discharged into any one tube never exceeds the energy (watt-second) rating of that tube.

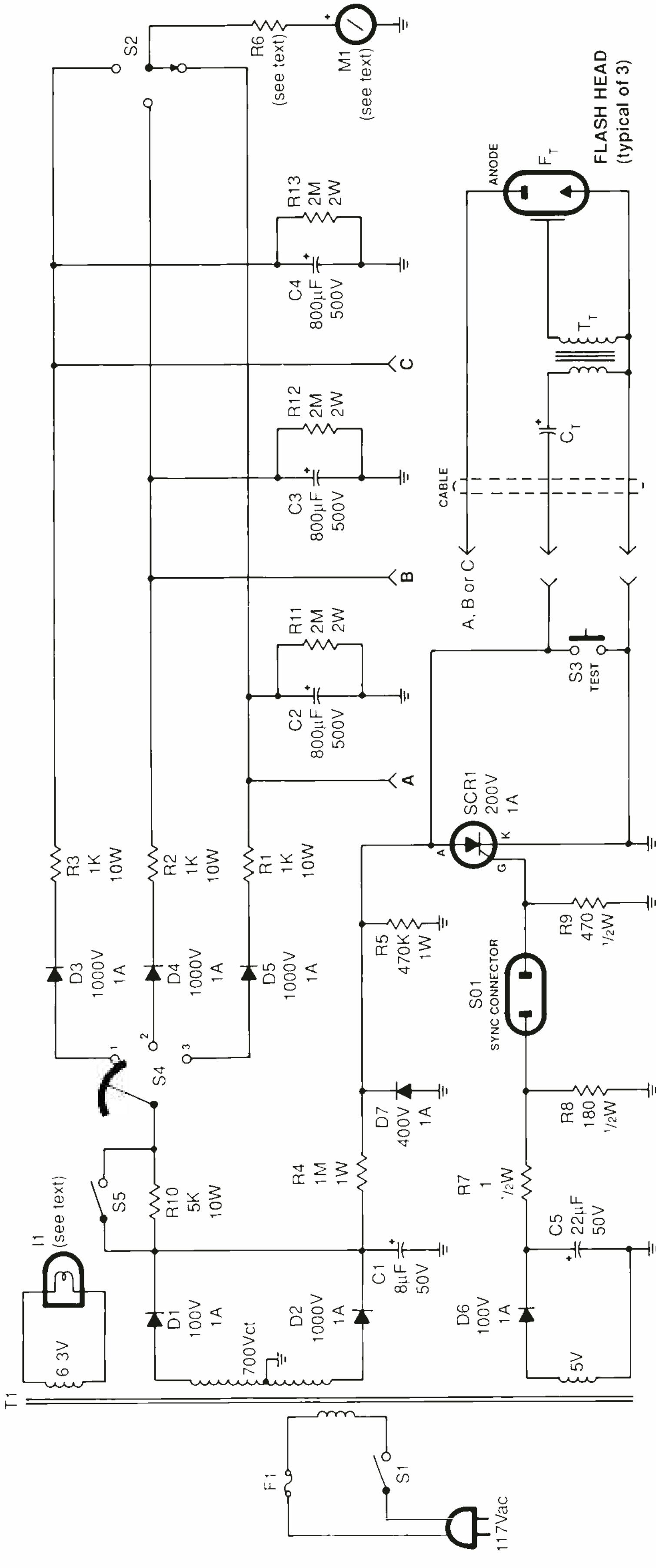
The more-elaborate power pack contains a storage capacitor for each flash tube in the setup, each of which charges to the energy rating of a single tube. Thus, each storage capacitor charges to a 100-Ws energy level. To ensure that no tube becomes overloaded, which could happen if one tube receives the charge of more than one energy capacitor, each tube and its energy capacitor is isolated from the others via "steering" diodes. This makes for a bit more elaborate power pack and permits loading each parallel-connected tube to its full energy rating, with attendant greater total light output.

It makes little difference whether you use half-wave or full-wave rectification, except that the full-wave supply has a higher ripple frequency that's a bit more efficient in charging the storage capacitor(s). Availability of a specific transformer can be the guiding factor in your choice between half- or full-wave rectifier circuit. In any case, transformer voltage must be selected according to the

300-WS PARTS LIST

Semiconductors
D1 thru D5—1,000-volt, 1-ampere silicon rectifier diode
D6—100-volt, 1-ampere silicon rectifier diode
D7—400-volt, 1-ampere silicon rectifier diode
SCR1—200-volt, 1-ampere or more silicon-controlled rectifier
Capacitors
C1—8-μF, 500-volt electrolytic
C2,C3,C4—600- or 800-μF, 500-volt computer-grade electrolytic
C5—22-μF, 50-volt electrolytic
C_T—0.22-μF, 400-volt paper*
Resistors (10% tolerance)
R1,R2,R3—1,000 ohms, 10-watt wire-wound
R4—1 megohm, 1-watt carbon
R5—470,000 ohms, 1-watt carbon
R6—533,000 ohms for 1-mA meter movement; 5.3 megohms for 100-μA movement
R7—10 ohms, ½-watt carbon
R8—180 ohms, ½-watt carbon
R9—470 ohms, ½-watt carbon
R10—5,000 ohms, 10-watt wire-wound
R11,R12,R13—2 megohms, 2-watt carbon
Miscellaneous
F1—3-ampere slow-blow fuse
F_T—100-watt-second, 450-volt flash tube with suitable reflector and housing (GE-FT118 or similar)*
I1—6.3-volt ac panel lamp
M1—1-mA or 100-μA meter movement (see R6 above)
S1,S5—Spst toggle or slide switch
S2—Sp3t non-shorting rotary switch
S3—Spst normally-open pushbutton switch
S4—Sp3t shorting rotary switch
SO1—Polarized jack
T1—700-volt, center-tapped power transformer with 6.3- and 5-volt windings (see text)
T_T—4-to-10,000-bolt trigger transformer*
Suitable enclosure (see text); bayonet fuse holder; pointer-type control knobs for S2 and S4; C clamps for mounting storage capacitors; bayonet panel-lamp holder; sockets for flash-head cables; flash-head cables; flash heads (see text); tripods or stands for flash heads; ac line cord with plug; spacers; terminal boards (see text); dry-transfer lettering kit; spray paint and clear acrylic spray (see text); stand(s) for flash tube(s)*; suitable wire (see text); machine hardware; hookup wire; solder; etc.

*These items are for the flash-head assemblies. You need one of each per assembly.



voltage rating of the storage capacitor(s) and flash tube(s).

There are some interesting aspects to the interrelationship between the power supply and flash head. The power pack charges the storage capacitors between flashes fairly rapidly so that you can snap another photo again quickly. A time constant related to the charge time involves the value of the storage capacitor and series resistance in the charge path: T = kRC. From this, you can see that larger-value capacitors take longer to charge through a given resistance. A smaller resistance speeds up charging but results in heavier current flow. However, current flow must be limited for safe repetitive delivery without excessive heating.

Similarly, discharge of the storage capacitor through the flash tube (which has been ionized by the trigger pulse) may see a low-resistance path of, say, 3 to 6 ohms or so. Discharge can then occur in only a few milliseconds, depending on the value of the capacitor. A large-capacity storage capacitor takes longer than a small one to discharge. Flash units with electrolytic capacitor values in the hundreds of microfarads produce a flash that lasts a few milliseconds.

Since the power supply generally runs continuously during a photo session, the charging circuit constantly attempts to charge the storage capacitors, even during the flash discharge period. Therefore, the series charging resistance must also keep the power supply from attempting to keep the flash tube alive by supplying current directly to the tube. If this occurred, the tube would quickly be destroyed. Hence, the series charging resistance assures that discharge current comes from only the storage capacitor and *not* directly from the power supply.

Fig. 2. Complete diagram of more-elaborate power-pack circuit design.

The time required to recharge the storage capacitor is a determining factor in the rate at which flashes can be repeated. Another factor is the need to limit the number of flashes per unit time that the flash tube experiences because each discharge generates heat in the tube that must be dissipated between flashes. However, the charge time of the power pack is more of a limitation than the allowable repetition rate of the flash tube. So the power supply itself will be the determining factor for flash repetition rate.

• *Storage Capacitors.* Having established that a transformer secondary potential of 350-volt rms (or a full-wave 700-volt center-tapped secondary winding) will provide a peak potential near 500 volts, the next step is to select suitable storage capacitors. So-called computer-grade electrolytic capacitors of good quality (low internal series impedance) are suitable. Your objective is to operate the flash tube near its full watt-second rating for maximum energy-to-light output efficiency.

Loading is related to the voltage across the capacitor and its value in microfarads by the equation Ws = ½ CV, where *Ws* is the energy in watt-seconds, *C* is capacitance in microfarads and *V* is the charge voltage in kilovolts (kV). With 500 volts available, Ws = 0.125 C. Thus, 500 μF delivers 62.5 Ws; 600 μF provides 75 Ws, and 800 μF supplies 100 Ws. A 1,000-μF capacitor is a bit large, delivering 125 Ws, which is the absolute maximum rating of the tube. However, 1,000 μF capacitor could be effectively used if the power pack voltage turns out to be a bit lower than the 500-volt peak being discussed.

300-Watt-Second Design

The power-pack circuitry for the more-elaborate design is shown schematically in Fig. 2. This version has a center-tapped transformer and two diodes for full-wave rectification.

In addition to the impedance of power transformer *T1*, series resistors limit the charging current. Independent storage capacitors are used, one per flash head, to permit each flash tube to be fired at maximum energy. Yet, any tube will never be over-stressed, since steering diodes *D3*, *D4* and *D5* isolate the capacitors from each other. If one flash tube fails to fire, its associated capacitor doesn't discharge. The other capacitors won't be effected, nor will the unfired capacitor "dump" into those that do discharge. This keeps any flash head from ever being over-stressed, while full energy is supplied to each tube.

For convenience, shorting switch *S4* permits one or two of the storage capacitors to be disconnected from the charging path if only two or one flash heads are needed during a photo session. Doing this can speed up charging time, resulting in shorter cycling intervals between shots.

Meter *M1* monitors the voltage on any selected storage capacitor. You can select the storage capacitor to be monitored with *S2*. The series resistance of the meter was selected so that a reading 90% of full-scale represents full capacitor charge. The slight overvoltage scale allowance can be useful if high line voltage is ever encountered.

Momentary-action pushbutton TEST switch *S3* permits firing the charged flash heads to test the system. Pressing *S3* grounds the trigger capacitors of all connected flash heads to fire the tubes. The current that flows in this trigger line is a bit high for camera shutter sync contacts, especially when several flash heads are fired with a common sync switch. A simple way to upgrade the firing circuit is to use an SCR to complete the discharge path of the trigger capacitor(s). With *SCR1* connected as shown, its anode-to-cathode circuit absorbs the current that flows through the very-low resistance trigger-capacitor return path when firing the system. In turn, *SCR1* is triggered by the much lower voltage delivered to its gate from the camera shutter contacts.

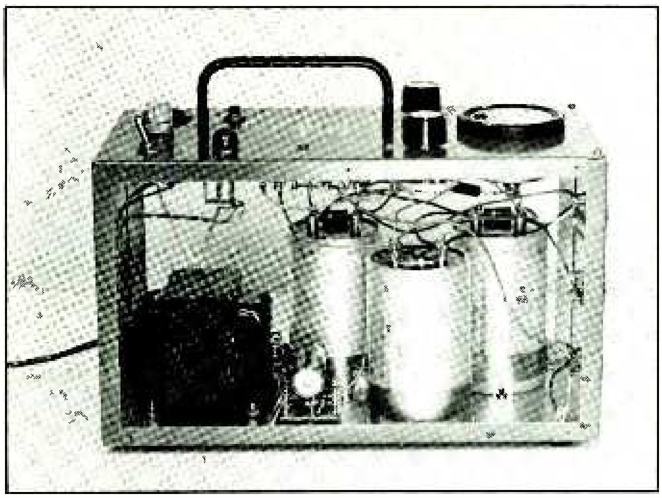
SYNC CONNECTOR *SO1* can be any polarized socket for connection from the camera to the power-pack trigger interface. One side of the sync cable goes to the gate voltage source, the other to the gate of *SCR1*. Because the amount of current flowing in this path is very low, no arcing or sparking will occur. Therefore, no significant wear of the camera sync contacts will result.

Power transformer *T1* selected for this version of the project has two additional secondary windings. The 6.3-volt winding permits use of POWER indicator *I1*, while the 5-volt winding is the source for the SCR gate voltage. Transformers that don't have these secondary windings can be used, but you must obtain the voltages for the POWER indicator and SCR trigger from the main secondary winding (we'll show you how this is done later, when we discuss the minimal power-pack circuitry).

Construction

Before you can decide on what size enclosure to use for the power-pack circuitry, collect the major components that must go into it and from their physical sizes determine the dimensions of the enclosure you need. Typical computer-grade capacitors measure 2½ inches in diameter by 5 inches high. The power transformer may occupy a similar volume. These components dictate enclosure size, especially since three storage capacitors are involved.

The prototype of this power pack, shown in the lead photo, was built into a 12 × 7 × 6-inch aluminum utility box, which nicely accommodated the power-pack circuitry. Note that this enclosure provides ample volume for the components and a satisfactory control-panel layout. Removable 7 × 12-inch panels serve as the sides of the enclosure, and all



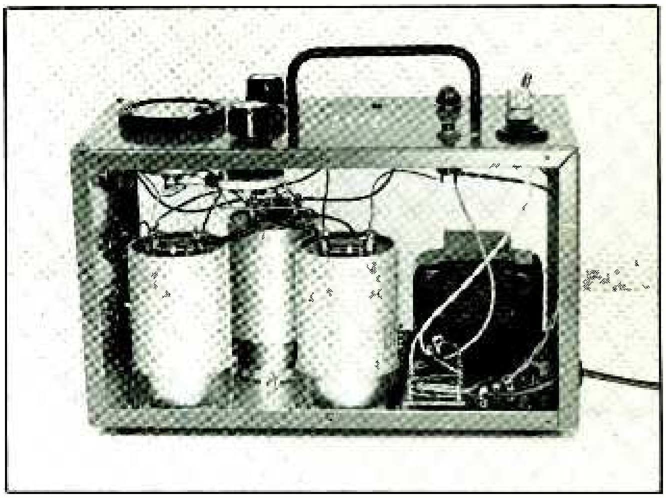


Fig. 3. These two views of author's prototype of the 300-Ws unit show the zig-zag pattern you should use to fit the power transformer and storage capacitors on a minimum of enclosure real estate.

components attach to the box itself.

One side wall (*not* removable side panel) accommodates the controls and indicators for the project and serves as the top panel of the enclosure. Most major components mount on the other side wall, which also serves as the floor of the enclosure. On one end of the enclosure should go the sockets for the cables that connect the flash heads to the power pack. No actual chassis is needed, since all components mount to either the enclosure walls or on small terminal boards.

If you use the utility box described above, position the storage capacitors and power transformer in a zig-zag pattern (see Fig. 3) to fit the available area on the bottom panel. Plan on using ring clamps for mounting the capacitors and ½-inch spacers to support the transformer so that its leads can fan out under the transformer and obviate the need for drilling extra holes.

Plan your layout so that two small terminal boards mount near enough to the power transformer so that its leads reach the appropriate points on the boards without requiring you to extend them with wires.

Mount on one terminal board the components associated with the high-voltage rectification section, namely the rectifier diodes, filter capacitor *C1* and resistors *R4* and *R5*. On a second terminal board that will mount near the transformer, mount *D6*, *C5*, *R7* and *R8*, with *SCR1*, *R9* and *D7* at one end of the board. Mount on a third terminal board *D3*, *D4*, *D5*, *R1*, *R2* and *R3*. The resistors on this last board are 10-watt units that operate at nearly 500 volts. Use a high-quality board material and leave ¼ inch of space between the resistors and the surface of the board.

Machine the enclosure as needed, including drilling a hole for entry of the ac line cord. Plan on mounting a carrying handle on the top control panel near the center of gravity. Don't drill the holes for the handle until after you've assembled the power pack and can better judge where this point will be. Because the power transformer is a bit heavier than the storage capacitors, this point will be a bit to the rear of enclosure center. Arrange the holes for the POWER indicator, POWER switch and fuse holder at one end of the control panel and those for the sync cable socket and TEST switch in the other corner.

The third terminal board will mount on the underside of the panel, beneath the carrying handle. This makes for short leads between capacitors, steering components and output sockets. The two rotary switches and meter movement holes should be drilled and punched through the top control panel.

Switch *S5* should mount under the top panel on a small L bracket. This switch isn't an operating control. You open it only to insert *R10* into the charge path during initial forming of the storage capacitors. You then close it to short out *R10* for normal power-pack operation.

By mounting components on the three terminal boards, you can use point-to-point wiring to make all interconnections when you're ready to wire together the components and assemblies. Since the currents involved in charging average less than 1 ampere, ordinary hookup wire will do for these portions of the circuit. However, the discharge path from storage capacitors to sockets to flash heads carry current pulses of 75 to 100 amperes for a few milliseconds, necessitating use of heavier wire—No. 18 or heavier-duty and well-insulated, at the minimum.

Locate the holes for the three sockets into which the flash-head cables plug in one end wall of the enclosure.

When you finish machining the enclosure, deburr all holes drilled and punched to remove sharp edges. Thoroughly clean all exterior surfaces of the enclosure with scouring powder and fine steel wool. Then thoroughly rinse the enclosure and dry it. The scouring powder and steel wool will have left behind a fine "tooth" to which paint will adhere.

Spray a *light* base coat of enamel paint in your choice of color on all exterior surfaces and allow it to completely dry, preferably two or more days. Then lightly rub the painted surface with dry steel wool and wipe away all dust. Spray onto the first two or more light coats of the paint, allowing each coat to thoroughly dry before spraying on the next.

When the paint has completely dried, use a dry-transfer lettering kit to label appropriate legends at the control, connector and indicator locations. Follow up with two or three *light* coats of clear spray acrylic to protect the legends. Again, allow each coat to dry before spraying on the next coat.

Mount the various components and subassemblies in their respective location. Then refer back to Fig. 2 to wire together the circuit. Take care when doing this to properly polarize the electrolytic capacitors and diodes and properly base the SCR. Make certain that the connections to the sockets into which the flash-head cables plug are properly polarized.

Wire the ground and trigger-capacitor feeds in parallel. Be sure to feed the high-voltage leads independently to each storage capacitor, since each flash head has its own separate storage capacitor.

A word of caution: Electrolytic capacitors that have been sitting around unused for a long time have a tendency to lose storage capacity and must be re-formed before they behave properly. An unformed capacitor won't fully charge and may heat internally if excess current is applied to it. Forming isn't difficult, but it must be performed *before* you try to put the power pack into service.

Your wired power pack includes everything you need to form the storage capacitors as follows. Resistor *R10* at the input of switch *S4* is included just for the forming procedure. Opening *S5* inserts *R10* into the charge path to limit charging current when forming the capacitors.

Forming is a straightforward process. With the flash heads disconnected from the power pack, open *S5*, plug the line cord of the power pack into an ac outlet and set the POWER switch to "on." You can set *S4* so that all three capacitors are connected to the charge line. Monitor the voltage across each of the switched-in capacitors in turn and note that one or more may not charge to more than, say, 200 or so volts after a minute or more of charging time. This is characteristic of unformed capacitors.

Turn off ac power to the power pack and allow the capacitors to discharge through their bleeder resistors. You can accelerate discharge by shunting a 500-ohm, 10-watt power resistor from the + terminal to ground. *Don't* just short the capacitors to ground with a screwdriver or other very-low-resistance path. Remember to observe all applicable safety precautions when working around the storage capacitors and voltages involved!

Repeat this charge/discharge several times and you'll notice that each time you do the capacitors should charge a bit faster to a slightly greater voltage. Depending on the history of the capacitors, it should be possible to reach a charge of about 400 volts on each capacitor. A capacitor may need more cycles before it charges to this voltage. If so, continue the process until all capacitors reach this level or more.

You can now connect the flash heads to the power pack to continue the forming process. It's now possible to discharge the capacitors by firing the flash heads as the discharge load. Close *S5* and continue to charge and fire the heads until the capacitors can be charged to at least 450 volts in a reasonable amount of time (20 to 30 seconds). The capacitors have now been formed and should accept full charge.

It's a good idea to cycle capacitors of the electrolytic type, even if unused, by charging and firing a few times every month or so. This keeps the capacitors fully formed and obviates having to go through the re-forming process again. To form capacitors from scratch or after unknown periods of time on the shelf may take hours to accomplish if internal heating is to be minimized. This is the reason for using at least 5,000 ohms of charging resistance in the initial forming steps. The operating circuit uses only 1,000-ohm values for charging resistors *R1*, *R2* and *R3*. These resistors limit the charging currents applied to fully formed capacitors. They also limit the maximum current drawn from the power supply and keep the flash tubes from suffering "hangover" from current coming directly from the power supply instead of from only the storage capacitor.

After you secure the side panels to the enclosure, there's little chance for electric shock from the power supply or flash system. Of course, completely enclose the flash heads, since high voltages appear at the tube terminals. The interconnecting sockets for attachment of the heads to the power pack are polarized to be female on the power pack and male on the flash head cable. The trigger circuit, as brought to the camera, carries only 3 or 4 volts and, thus, avoids any problems in camera handling relative to the higher pack voltages.

100-Watt-Second Design

The elaborate power pack discussed above includes operating convenience features and maximizes the energy directed to each flash head,

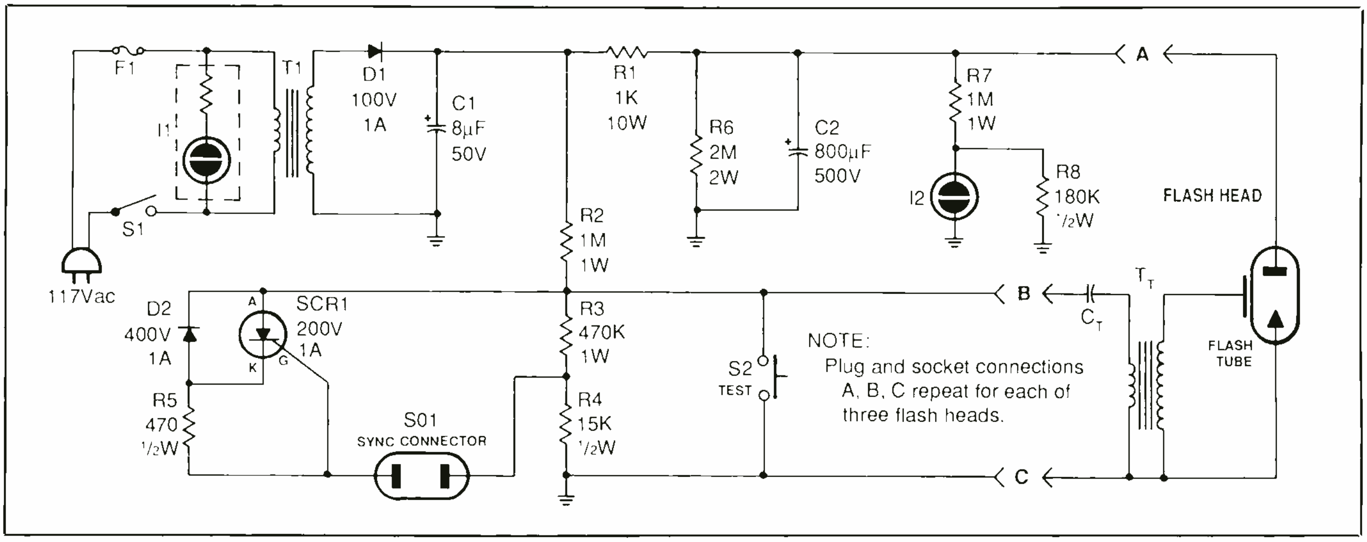


Fig. 4. Complete schematic diagram of minimal power pack circuit design.

whether one, two or three heads are used for a photo session. The minimal power pack, shown schematically in Fig. 4, is less versatile but still useful. It can apply 100 Ws total energy to flash heads and can fire two or three heads, provided the charge energy is divided among the heads for a *total* of 100 Ws. With this arrangement, one head could be fully loaded, two heads fire with 50 Ws each and three heads share the charge at 33 Ws each.

Many simplifications are made in the Fig. 4 circuit, though some features of the Fig. 2 300-Ws power pack can be included, if desired. For example, you might add a voltmeter circuit to monitor charge status, as in the more-elaborate design.

In Fig. 4, power transformer *T1* has a single untapped secondary winding that drives half-wave rectifier *D1*. Because a 6.3-volt winding isn't available for a pilot light, neon lamp *I1* and its series resistor connect across the ac-line after POWER switch *S1* and fuse *F1* to serve as a POWER indicator.

Also note that the 150 volts for charging trigger capacitor C_T is taken from bleeder resistor *R2*, as is done in the Fig. 2 circuit. However, an additional voltage tap is made in this divider, between *R2* and *R3*, to supply gate bias to *SCR1*.

The SCR trigger circuit is included in this minimal power pack to avoid having 150 volts and high trigger currents appear at the camera shutter contacts, as would occur if the camera shutter was directly used to short the trigger capacitor(s).

The half-wave rectifier circuit charges storage capacitor C_T to 100 Ws, somewhere beyond 450 volts. READY lamp *I2* shunted across part of the resistive voltage divider made up of *R7* and *R8* indicates when C_T is charged but doesn't indicate voltage as charge progresses. It lights only when a preset charge is reached.

TEST switch *S2* across the 150-volt trigger bus lets you test the flash system, as in the Fig. 1 circuit. Three output sockets are included in this design to permit you to connect multiple flash heads to the power pack, with the same head circuit as used in the more-elaborate design. However, the total 100-Ws charge on a single storage capacitor is all the en-

100-WS PARTS LIST

Semiconductors
D1—1,000-volt, 1-ampere silicon rectifier diode
D2—400-volt, 1-ampere silicon rectifier diode
SCR1—200-volt, 1-ampere or greater silicon-controlled rectifier

Capacitors
C1—8-μF, 500-volt electrolytic
C2—600- to 800-μF, 500-volt computer-grade electrolytic

Resistors (10% tolerance)
R1—1,000 ohms, 10-watt wire-wound
R2,R7—1 megohm, 1-watt carbon
R3—470,000-ohms, 1-watt carbon
R4—15,000 ohms, ½-watt carbon
R5—470 ohms, ½-watt carbon
R6—2 megohms, 1-watt carbon
R8—180,000 ohms, ½-watt carbon

Miscellaneous
I1—Neon panel-lamp assembly with built-in limiting resistor
I2—Neon lamp
S1—Spst toggle or slide switch
S2—Spst normally-open pushbutton switch
SO1—Polarized jack
T1—350-volt power transformer
Suitable enclosure; ring clamps for capacitors; terminal boards; bayonet fuse holder; ac line cord with plug; materials for flash heads (see 300-WS Parts List); carrying handle; spacers; machine hardware; hookup wire; solder; etc.

ergy available and is divided between flash heads. Hence, there's no need for steering diodes. This supply could be implemented with a full-wave rectifier circuit, with a bit better charging efficiency.

Construction

The minimal-design power pack can be built into a much smaller enclosure than was recommended above. A "double-U" shaped utility box measuring 8 × 6 × 3½ inches is suitable. Again, you should collect all the components to be used before settling on a given-size enclosure.

No chassis as such is needed for building the power pack. The top of the enclosure serves as the control panel on which you mount the POWER switch, POWER indicator lamp, READY indicator lamp, fuse holder, SYNC connector and a handle.

One of the 6 × 3½-inch ends of the enclosure accommodates the three sockets for connecting the flash heads to the power pack. Secure the power transformer to the underside of the control panel, and attach the single energy-storage capacitor to the other end of the box with a ring clamp. Use terminal strips to mount the few circuit components, and wire together the components using the point-to-point scheme.

Compared to the more-elaborate design, this minimal-design power pack is much simplified. Nevertheless, it's an easy and inexpensive way to get involved with multiple-head lighting setups. If you go this route and later wish to upgrade to the more-elaborate design, the components can be directly salvaged and re-used in it.

Using the Project

Operating either of the flash units is almost instinctive. The flash heads plug into the power pack and a sync cable attaches between the camera and the pack. Two of the flash-head units should have 10- to 15-foot-long cables and be fitted with tilt heads for use as modeling light and background/rim/hair light. Locate these flash units at a distance from the camera. Tilt heads let you aim light at a subject from various angles.

The third flash head gets a 6-foot-long cable. Positioned close to the camera, this flash head provides fill-in light. It doesn't need a tilt head, because you'll usually direct its light straight onto your subject from essentially camera position. If you wish, you can fit to this flash head a normally-open pushbutton switch that can be used to short across the trigger capacitor line so that you can test fire the heads from camera position instead of having to reach for the TEST switch on the power pack.

Whenever you connect and disconnect the flash heads to and from the power pack, always power down the power pack. A flash head may fire on its own when being connected if its capacitor is already charged.

It's a good practice to energize the system and make a few test firings before actually starting to take pictures. This will assure you that the capacitors charge properly and even do minor reforming before a shoot-

Cautionary Notes

Storage capacitors must be able to hold a high-energy charge and not leak or discharge over long periods of time. Internal losses must be very low. These desirable factors for a good storage capacitor also contribute to making it a potentially lethal device! Even a computer-grade electrolytic capacitor can hold its charge for many hours, even days. Another mark of a good capacitor is low internal resistance, which means that there's nothing internal to limit the discharge current if the terminals are shorted together.

The factors that go into making a good storage capacitor in its intended application can also make it dangerous. A capacitor charged to 75 to 100 joules (watt-seconds) contains considerable energy. When discharged in the normal manner into a flash tube you'll hear a very audible "snap" as the tube fires, and a very noticeable amount of heat will be radiated from the flash tube. This is because the 100 joules of energy are being "dumped" into about 6 ohms of tube resistance at a current of 75 to 100 amperes for a few milliseconds.

The discharge current can vaporize the tip of a screwdriver if a charged capacitor were to short it with such an essentially zero-resistance shunt. Shorting the capacitor with zero resistance can tear it apart internally and create destructive internal heating. Don't *ever* attempt to discharge a capacitor in this manner.

The proper way to discharge a capacitor is to shunt its terminals with a power resistor, carefully avoiding personal contact with the leads or terminals. Experienced personnel who work around high voltages, keep one hand in a pocket or behind their backs to avoid injury and death when working around high-voltage, high-energy storage capacitors. You should adopt this as a working rule as well.

When discharging capacitors, use well-insulated clip leads attached to a 10-watt resistor of, say, 500 ohms resistance. Attach one clip to one terminal of the capacitor. Then carefully touch and hold the other clip to the remaining terminal for several seconds. Repeat the procedure several times to make sure the capacitor is fully discharged, even if you're working on a circuit that hasn't been powered for hours or several days. Work with one hand only (remove any rings and watches before you start) and an alert appreciation of what charge can do. And always handle any capacitor as if it's fully charged to a lethal voltage!

ing session. Test fire the system with the TEST button on the power pack or on the fill-in light head, before starting to trigger the system with the camera sync contacts.

When you're done taking pictures, always fire the heads to discharge the capacitors and trigger circuits before stowing your gear. Do this by firing the system with the TEST button and immediately switch off ac power.

If at any time you must gain access to the interior of the power pack, exercise extreme caution. Bear in mind that the storage capacitors may have potentially injurious charges on them. So exercise care when the unit is open. Discharge all capacitors *before* you do any internal testing.

An integrating flash meter is a very useful accessory and is highly recommended when using this project. Place the meter at the location of your subject and aim it toward the camera while you test fire the system. The meter will indicate the correct f-stop for proper exposure as a function of film speed. It will result in correct exposures, saving you time and film. Shutter speed doesn't have any effect on exposure because the flash is only about a millisecond in duration. With focal plane shutters, however, speeds must be slow enough to ensure that the curtains are fully open when the flash does fire. This means you must use "X" sync, usually at $1/60$ second or slower. **ME**

Electronic Strain Gages

By Forrest M. Mims III

The strain gage is an electronic transducer that senses physical expansion, compression or bending of a surface. A strain gage is usually bonded directly to the surface it's designed to monitor. Additionally, some strain gages can monitor the displacement of a surface from a short distance away.

Many types of strain gages are used for dozens of different applications. Before we discuss several ways you can make strain gages of your own, let's find out how they're used and examine some typical kinds of commercial strain gages.

Applications

Among the most important applications for strain gages is continual monitoring of mechanical structures subject to compression, expansion, flexing and torsion. Shown in Fig. 1 is a pictorial representation of each of these kinds of strain. Depending on their location in the structure, steel girders in a highway bridge may be subject to either compression or expansion. Airplane wings are subjected to flexing. Shafts and axles are subjected to torsion. Many structures can experience more than one kind of strain, and the direction of maximum strain can vary over a period of time.

Strain gages permit the strain experienced by these structures to be continually monitored over their lifetime. Strain gages can also provide a warning when excessive strain occurs.

The ability of a strain gage to detect strain makes possible many kinds of sensors. For example, a strain gage can be attached to a pedestal that supports a weight to form an accelerometer. When the object to which the accelerometer is mounted moves, the weight tends to remain at rest. This causes the pedestal to bend, thereby distorting the strain gage.

A strain gage can be bonded to a flexible diaphragm and used to detect pressure changes in sealed vessels. When bonded to a shaft, a strain gage can detect torque when the shaft is rotated. A displacement sensor can be made by mounting a strain gage on a flexible arm that's moved by flowing gas or liquid or a mechanical force.

Commercial Strain Gages

Most commercial strain gages have a sensing element made from a thin metal wire or a foil pattern with an electrical resistance that changes when the element is compressed, expanded or bent. Some strain gages have a silicon sensing element. Figure 2 shows a simplified outline view of all three kinds.

Foil gages are by far the most common. They resemble tiny etched circuit boards. A film of copper-nickel alloy or similar metallic foil several micrometers thick is laminated onto a thin, flexible substrate. The foil is then etched to produce a grid or whatever pattern is desired. Overall resistance of a typical foil strain gage may range from around 30 to as much as 3,000 ohms. Gages with a resistance of a few hundred ohms are most commonly used. When the gage is distorted, the resistance of the foil changes.

An important feature of foil strain gages is that they can be made with very uniform characteristics. They're also durable and light in weight. Still another important advantage is that multiple strain gages can be easily made on the same substrate. This means a single very thin, compact sensor can detect the direction of expansion, compression and rotation of a substrate being monitored.

Wire strain gages are no longer as important as they once were. Their operation is dependent on the well-known fact that the resistance of a wire increases as the wire is stretched. The wires used to make strain gages vary in diameter from around 12 to 25 micrometers.

Silicon strain gages employ a bar of silicon with a thickness of around a 0.25 millimeter. Their resistance is considerably greater than that of foil and wire gages. While they produce a much greater resistance change for the same strain than do foil and wire gages, silicon strain gages can't be used to measure large strains since the silicon element is very brittle.

Other electronic sensors can measure strain, but for various reasons they aren't used nearly as much as resistive devices. They include inductors and capacitors whose electrical parameters are changed by movement of one part of the component with respect to another. They also include piezoelectric devices that generate a voltage when strained.

Configurations

Two basic kinds of strain gages are shown in Fig. 3. The single-element gage is designed to detect strain along a single axis. While strain often occurs only along a single axis, some structures are subjected to twisting (torsion) and bending, as well as stretching and compression. It's possi-

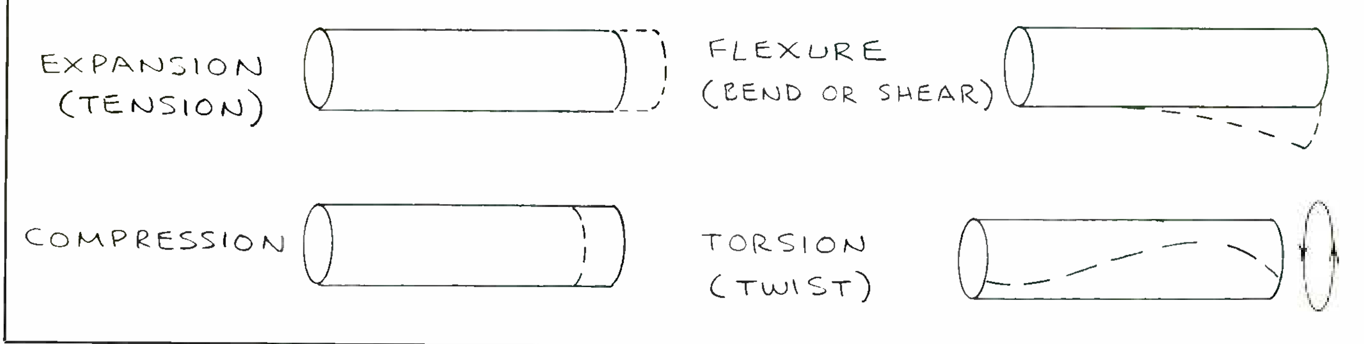


Fig. 1. Important types of mechanical strain.

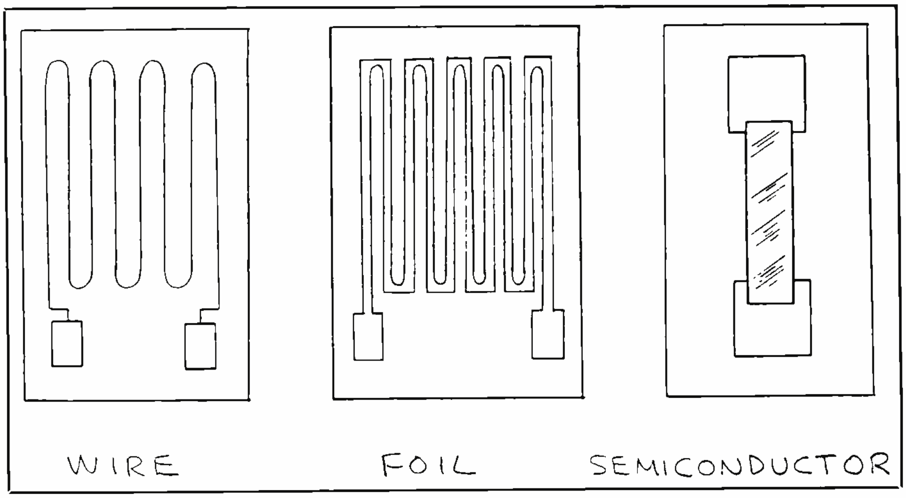


Fig. 2. The most-important types of strain gages.

ble to detect strains along more than one axis by using two or more gages that are aligned in different directions. One way this is accomplished is to stack two or more gages on top of each other, as shown in Fig. 3.

Another way to detect the direction of strain is to form several gages, each aligned in a different direction, on the same substrate. The result is known as a strain gage rosette. The principal direction of strain can then be calculated by in-

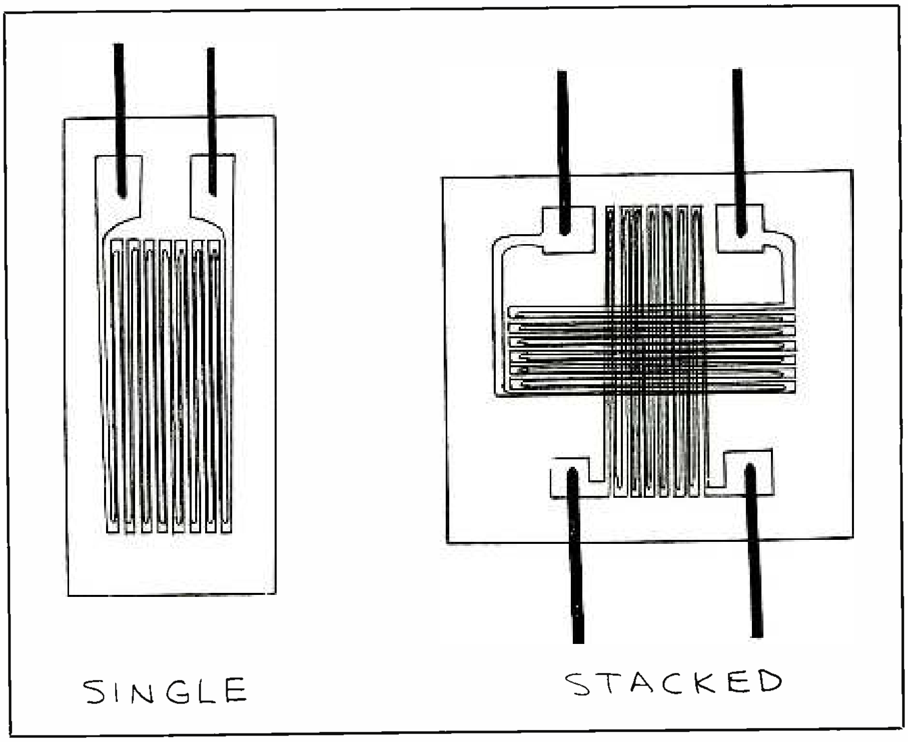


Fig. 3. Single-axis (left) and stacked (right) strain gages.

serting the resistance changes of each gage into an equation whose derivation is given in *Experimental Stress Analysis and Motion Measurement* by R.C. Dove and P.H. Adams (Charles E. Merrill Books, 1964). The same equation is given in *Experimental Methods for Engineers* by J.P. Holman (McGraw-Hill, 1984).

Figure 4 shows one kind of strain gage rosette. A more common kind incorporates a circular pattern of three strain gages arranged 120 degrees apart.

Bonding Strain Gages

Strain gages are usually cemented to surfaces to be monitored. If you don't properly bond a strain gage to the surface, it may not respond to the strain you want to monitor. Both the strain gage and the surface must be absolutely clean to insure a uniform, stable bond. It may be necessary to first buff the surface with emery paper and to then scrub with a cleaning solvent for best results.

Various kinds of cement can be used to bond strain gages. Duco cement can be used with paper-base gages. Cyanoacrylate adhesives are often used with foil gages on resin substrates. Whichever you use, it's important that the cement be completely dry or cured before readings from the strain gage can be considered reliable. Even though the cement around the edges of the gage might be cured, the cement under the central portion of the gage might still be wet. For detailed information about bonding commercial strain gages, see the literature supplied by the various manufacturers.

Temperature Problems

Foil and wire strain gage performance is affected by temperature in at least two ways. Since the resistance of the metal foil or wire that forms the element of the gage varies with temperature, changes in temperature can cause erroneous signals. Another temperature effect can result when the coefficient of expansion of the strain gage differs from that of the surface to which it is bonded. Changes in temperature can also cause uneven expansion of either the surface or the gage, thereby giving rise to an erroneous indication of strain.

The easiest way to solve both these pro-

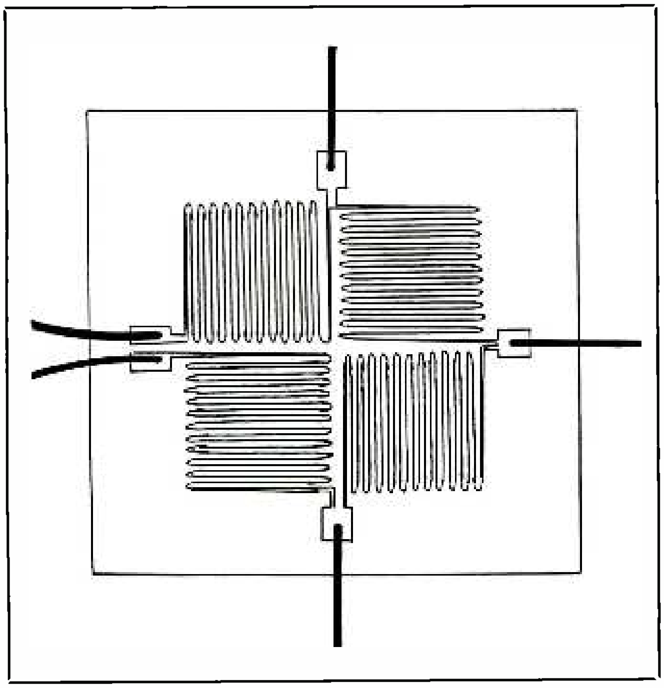


Fig. 4. Full bridge rosette strain-gage configuration.

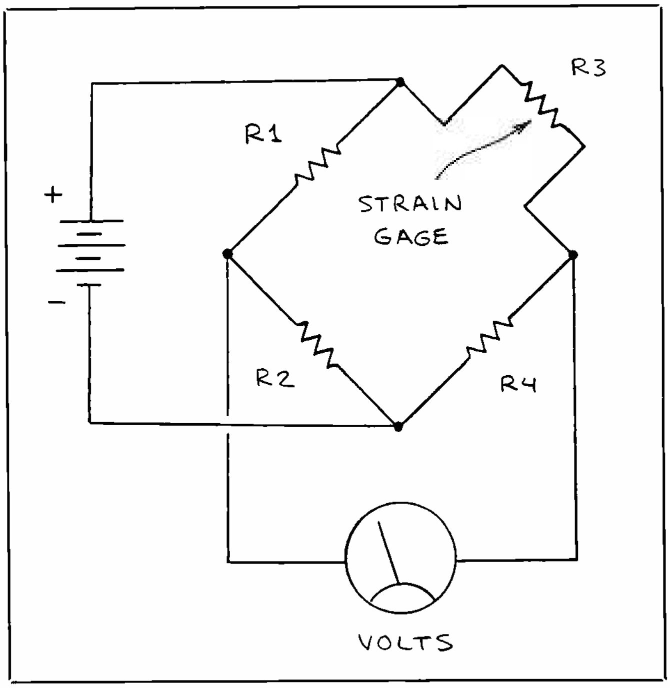


Fig. 5. How to connect a strain gage to a Wheatstone bridge.

blems is to connect two identical gages in a Wheatstone bridge, as shown in Fig. 5. One gage, the sensor (*R3*), is bonded to the surface to be monitored. The second gage, the reference or compensation gage (*R1*), is installed on a nearby surface that's identical to the first but not subject to strain. As long as both gages are installed in the same way, both will remain at the same temperature. The bridge remains balanced, and no current flows. Only when the sensor gage is strained will the bridge become unbalanced.

Noise Problems

Strain gages exhibit such tiny changes in resistance that it's usually important to guard against electrical noise that might interfere with the measurement of the resistance change. Noise can enter the strain gage directly if its exposed wire leads touch the metal structure to which the gage is bonded. Noise can also be induced into the strain gage's wire leads, particularly if they're long. These problems can be prevented by using shielded cable and by carefully insulating any exposed wire leads and connections.

Amplifiers

You can use a digital multimeter to measure the very small changes in a strain gage's resistance. In most applications, however, an amplifier is used to beef up the very tiny voltage or current changes caused by strain.

Figure 6 shows how to connect an operational amplifier to a strain gage that forms part of a Wheatstone bridge. The bridge circuit permits the output to be set to any desired level simply by adjusting *R4*. The resistance of *R4* should be somewhat greater than the maximum expected resistance of the strain gage.

Automatic temperature compensation can be provided by using identical strain gages for *R1* and *R3*. Increasing *R5* increases the circuit's gain and, hence, its sensitivity to strain.

The output voltage of the circuit in Fig. 6 decreases as the resistance of *R3* increases. In other words, an increase in strain causes the output voltage to decrease. This operating mode can be reversed by transposing the positions of *R3* and *R4*.

The 741 op amp is readily available and inexpensive. Much better op amps are available, and these should be used for precision applications. Many other strain gage amplifier circuits are available as well. You can find them in application notes published by strain gage makers and manufacturers of op amps.

Do-It-Yourself Strain Gages

It's possible to make strain gages using commonly available materials and supplies. Years ago, I was studying the movements of a small guided rocket in a homemade wind tunnel that was strapped to the side of my car. I needed a way to measure the displacement of the rocket in response to guidance commands. The rocket was mounted on a stiff length of piano wire that flexed when the rocket moved. The obvious solution was to attach a strain gage to the piano wire. But I didn't have a strain gage!

The solution to this measurement problem was deceptively easy. First, I coated all but the ends of the wire with a layer of insulating paint. After this layer of paint dried, I applied a coat of conductive paint over the insulating paint and the exposed end of the wire to which the rocket was attached. I then attached wires to the unpainted end of the piano wire and to the conductive paint. The completed strain gage is illustrated in Fig. 7.

When the wire was flexed, the electrical resistance between the particles of copper in the paint changed. It was, therefore, possible to monitor the movements of the rocket simply by connecting an ohmmeter to the piano wire-conductive paint strain gage.

Conductive paints and inks can be used to make many kinds of strain gages. The paint can be applied as a thin zig-zag, curved or straight line. It might even be possible to make a template so that strain gages with similar dimensions can be made. Whether or not two such strain gages with the same appearance also have the same resistance is another matter, though. Variations in the thickness of the conductive paint can make significant differences in the resulting resistance.

In any case, of course, the paint must be applied over an insulating surface. And there must be a means for attaching leads to opposite ends of the painted region. Often, leads can be bonded directly to conductive paint. It's also possible to solder leads to some conductive paints. A better approach is to apply the paint to a very thin, flexible etched circuit substrate on which a pair of electrodes have been formed. You can then solder leads to the copper foil electrode. Flexible copper-clad substrate is available from some electronics parts suppliers and surplus dealers among others.

A very simple strain gage can be made by cementing a length of conductive foam plastic to an object that is subject to bending, compression or expansion. The resistance of the conductive foam will increase when the foam is stretched and decrease when it's compressed. For repeatable results, it's essential that connections to the foam be stable.

Optical Strain Gages

Many types of strain gages can be made with the help of optoelectronic components and optical fibers. For example, simple displacement sensors can be made by placing between the arms of a slot-type optoisolator a vane attached to the object in which strain is to be detected. If the vane has an angular profile and if it's carefully positioned, the slightest move-

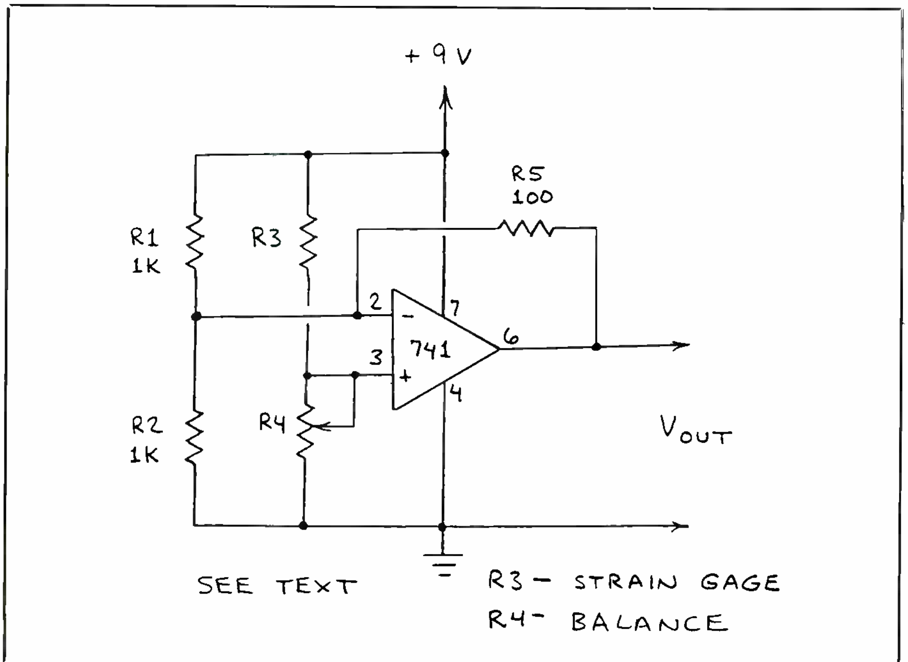


Fig. 6. Schematic details of a strain-gage amplifier circuit.

ELECTRONICS NOTEBOOK...

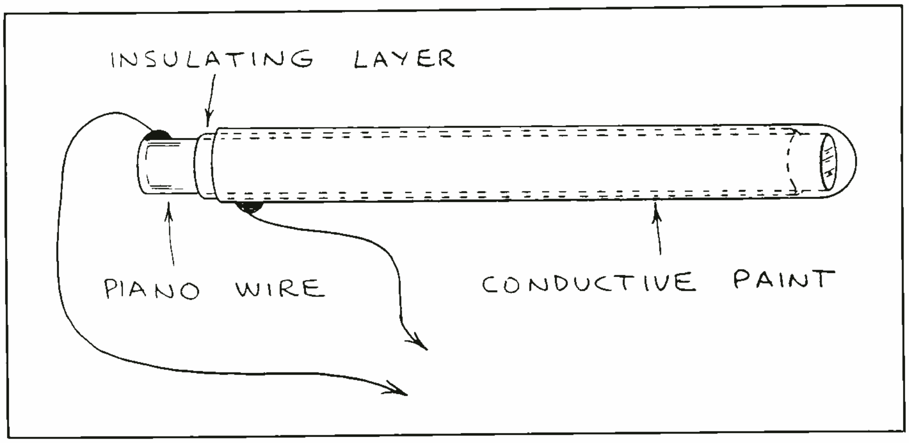


Fig. 7. Details for fabricating a piano-wire strain gage.

ment of the object to which it's attached will change the photocurrent through the phototransistor of the optoisolator.

Another very sensitive approach is to point the beam from a small laser at a tiny mirror cemented to the surface of the object being monitored. The reflected beam should form a spot of light on a fixed white surface some distance away. The slightest movement of the object will cause the reflected beam to move noticeably. This method is particularly good for detecting torsional strain.

Optical fibers can be used to make very sensitive strain gages. You can quickly demonstrate the sensitivity of an optical fiber as a strain gage simply by injecting the light from a helium-neon or diode laser into one end of the fiber. The light emerging from the opposite end of the fiber should strike a photodetector connected to an audio amplifier. When the fiber is still, the only sound from the amplifier will be a gentle rushing noise, which is always present. Depending on the kind of fiber and the coherence of the laser, when the fiber is slightly disturbed, the amplifier will emit sounds ranging from thumps and clicks to musical chirps.

You can use an optical-fiber strain detector to trigger an alarm or counter when the strain exceeds a certain threshold. For this purpose, a level detector should be connected to the detector amplifier's output. The level detector switches a logic circuit when the amplitude of the signal changes sufficiently. The simplest way to accomplish this is to couple the signal from the amplifier into one input of a comparator. A voltage divider connected to the comparator's second input can be used to set the trigger level. The output of the comparator can go to a one-shot if it's necessary to stretch the pulse long enough to trigger an alarm.

Additional Information

A brief but good introduction to strain gage principles is given in *Experimental Methods for Engineers* by J.P. Holman (McGraw-Hill, 1984). Manufacturers of strain gages publish applications information that provides valuable information on how to select, install and use various kinds of strain gages. You can find the names and addresses of strain gage manufacturers in various trade directories available at libraries and engineering companies.

One of the best sources of applications information is *Pressure, Strain and Force*, an annual publication available to serious inquirers from Omega Engineering, Inc. (Box 4047, Stamford, CT 06907). Omega also sells a wide variety of metal-foil strain gages, adhesives and strain-gage amplifiers and other instruments. **ME**

BOOKS

Electronic Projects

Books on how to build interesting and entertaining projects occupy a favored niche among electronics enthusiasts. This month brings us a bevy of books in this category, all of which should pique your interest if you like to build projects.

We begin with an interesting book by Rudolf F. Graf & William Sheets, *Video, Stereo and Optoelectronics* (Tab Books Inc.; soft cover; 355 pages; $18.95). It offers 18 projects, including printed-circuit techniques and materials; multi-purpose video-link transmitter; video-effects generator; low-frequency active antenna converter; wireless headphones and speakers; and ultra-sensitive picoammeter/electrometer. Circuit descriptions and construction information, schematics, parts lists, pc guides and component-placement diagrams are given. Photos of the projects and, in some cases, of visual effects enhance presentations.

Next, Gordon McComb's *Gadgeteer's Goldmine* (Tab books; soft cover; 406 pages; $18.95) should interest science-fair enthusiasts and "mad-scientist" experimenters, not to mention the ordinary hobbyist/experimenter in its diversity of topics. Among its 55 space-age projects, you will find: a plasma sphere, Van de Graff generator, Tesla coil and Kirlian photography; He-Ne and solid-state laser experiments and projects; optical data link; variable-rate xenon strobe; see-in-the-dark viewer; experimenting with superconductors and biometal materials; espionage devices; robotics; and more. Operating details, schematics, parts lists, construction hints and where to obtain unusual parts are provided. The only shortcoming is that no pc guides are provided, but a big plus is an appendix that gives full names and addresses of sources of supply and further reading.

No less than three offerings come from Delton T. Horn (all published by Tab Books and all soft cover). *The Comparator Book* (185 pages; $15.95) offers 49 projects: a comparator generator; light and dark detectors; window comparator; two-bit flash converter; temperature-range detector; and more.

The Thyristor Book (205 pages; $16.95) offers: four-layer diode and laser circuits; alternative dc power controller; triac demo circuit; triac light dimmer; light cross-fader; self-activated night light; digitally controlled ac switch and light dimmer; and wide-range timer.

49 Easy Electronic Projects (216 pages; $16.95) focuses on uses for transconductance and Norton op amps. OTA projects include: direct-coupled differential amplifier; agc amplifier; low-power Schmitt trigger; four-quadrant multiplier; random music maker. Norton amplifier projects include: wide-bandwidth/high-gain amplifier; under-voltage detector; low- and high-temperature alarms; function generator; etc.

All three books provide schematics and operating details for circuits discussed. Though no pc guides are given, the projects presented are basically simple and can easily be built using traditional point-to-point wiring techniques.

From *Modern Electronics* author Steve Sokolowski comes *The Talking Telephone* (Tab Books; soft cover; 337 pages; $17.95), a book sure to excite the telephone-project enthusiast. Its title is also the name of the main featured project, and 14 other interesting projects are provided as well, some of which appeared in the pages of *Modern Electronics* as construction projects. Among the other projects featured are: English-style, two-tone and melody ringers; high-tech music-on-hold adapter; dialed-digit displays; digital telephone lock; talking telephone ringer; and synthesized speech for your telephone. How-it-works, schematics, parts lists, construction (including pc and component-placement guides), and installation details are given.

NEW LITERATURE

DSO Application Guide. An Application Guide titled "EBR: The Truth About Effective Bits" from John Fluke Mfg. Co., Inc. demystifies effective bit resolution (EBR) in digital storage oscilloscopes. EBR has been the cause of much confusion in the test and measurement community. This new Guide chronicles the migration of the DSO from its parent, the oscilloscope, and reviews sampling, bandwidth and rise time, accuracy versus resolution, bits and effective bits and factors that affect accuracy and resolution. In addition, it provides insight on how EBR is measured, how bandwidth relates to EBR, how S/N and EBR are related to each other and details of error sources.

CIRCLE NO. 33 ON FREE INFORMATION CARD

Calendar Creator Plus and Top Priority Personal Information Manager Software from Power Up!

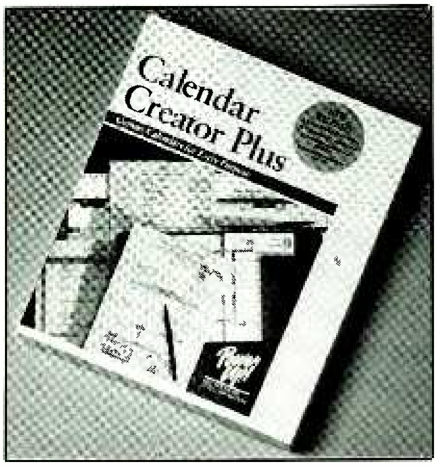
By Ted Needleman

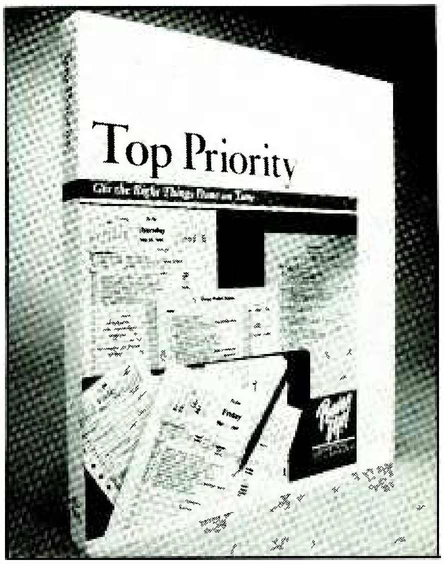
I hate to admit it, but I'm just not the world's most-organized person. In fact, my idea of organization is to have lots of rather neat piles. And my idea of filing is to know, within two or three piles in either direction, which pile has the information I need. My position as a mid-level manager usually requires me to juggle several tasks at once. And where they drop is where they stay, at least until the next time I need to access the task again.

It's not that I don't have the tools to do the job. There's a powerful 386 PC on the desk in my office. It has 4MB of RAM and 110-MB hard disk. I try not to leave it on very much, though. While the view from my office window is spectacular (I can see most of lower Manhattan, including the twin towers of the World Trade Center and the Statue of Liberty), the air-conditioning tends to be somewhat less than effective. Winter or summer, it's about 90° by the time I leave in the evening. And if my PC and laser printer have been on for more than a very few hours, I go home medium-rare. Needless to say, if I don't have to use the PC, it stays off.

Over the years, I've also tried other methods to get me on the straight and narrow. I've had a variety of electronic organizers, including the Atari Portfolio I reviewed a while back, a Casio Boss and a Sharp Wizard. Most of these are gathering dust on a shelf or have been returned to the vendor. They're all effective, but they're also very time consuming to set up and use. *Personal Information Manager* (PIM) software is another good organizing system, but like the electronic organizers, it's time consuming to set up and use and must be used conscientiously to be effective. Most of the time I've relied on the popular DayTimer notebooks, though this last year I've been using a "clone" of the almost ubiquitous Filo-Fax. It may not be state of the art in technology, but for the $12 or so it cost, it does let me keep track of appointments and other commitments.

For the past several months, however, I've been using a couple of packages from Power Up! that let me have the best of both worlds. *Calendar Creator Plus* and *Top Priority* can operate in conjunction with each other on the PC (or Macintosh), but they're also a very useful adjunct to my manual organizer, which is the way I usually use them.





Calendar Creator Plus *(left) and* Top Priority *(right) from Power Up! Software Corp.*

Both Power Up! programs are similar in packaging and documentation. They come with both 5.25- and 3.5-inch diskettes and a booklet-style manual of about 50 pages or so. Each separate manual is organized along the same lines, explaining what the program does and taking you through set-up and use of the package. The manuals are well written and have lots of illustrations, both containing screens you'll encounter and reports that you can generate.

Calendar Creator Plus (CCP), as its name implies, allows you to print custom calendars that reflect your appointments, deadlines and other events of importance. Version 3.0, which is the version I've been using, doesn't have the fancy clip-art libraries that some of the other calendar-management programs I've seen provide, but Power Up! says that Version 4.0, due out about the same time as this review, will have clip-art. I haven't found the inability to mark Halloween with a little jack-o-lantern or Thanksgiving with a turkey to be much of a detriment, but tastes (and needs) vary.

What *CCP* does allow you to do, however, is generate a very complete variety of calendars in numerous formats. Depending upon which printer you're using, *Calendar Creator Plus* can generate calendars of up to 11 by 17 inches. Most of your calendars, however, will be printed on letter or legal-size paper, or the special paper Power Up! offers for several sizes of organizers. The sharpest and most attractive calendars are generated on a laser or Hewlett-Packard DeskJet printer, but the software does support almost any dot-matrix printer that can emulate Epson or IBM graphics.

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Data entry, which can be the most time-consuming part of using a program such as this, is facilitated by features such as wildcards (using the asterisk in repeating fields) and the "Overlay Utilities" that let you delete, rename, copy and merge overlays.

Once you've finished with your overlay, just select PRINT from the main menu. The software will let you choose a size and style and then print your custom calendar. If you run into any problems, the manual has a short but to-the-point troubleshooting section, and context sensitive on-line help is available by pressing the F1 key.

Top Priority installs in a similar manner and is just as easy to use. However, instead of calendar-oriented events, it lets you maintain complex and complete to-do lists. Although I use only a single list with everything I can think of on it, you can create different lists for different purposes. *Top Priority* lets you enter a task with a set due date or deadline or an event like an appointment that has both a date and time. When used together with *Calendar Creator Plus*, you can enter data in either of the packages and export and import deadlines and appointments back and forth. When used in this manner, the two pieces of software operate somewhat synergistically.

Top Priority also offers a host of features that I don't use much but can considerably extend its power. You can prioritize tasks using the letters A through Z (with A having the highest priority). This places priority tasks at the top of your lists and also reminds you that you've assigned a priority to a particular task.

You can also use *Top Priority* for a simplified project tracking and management system. The software allows you to define a task as a "subtask." These subtasks are components of a larger overall task, which then becomes a "goal." For example, the "goal" of writing this column could be broken down into a number of subtasks, such as "decide what to write about this month," "obtain packages," "install packages," "use packages," etc. This lets you break large tasks down into smaller tasks, which are simpler to track.

You can also use the field provided for "Category." When you enter something into this field, you can filter your lists and print only those categories you're interested in. *Top Priority* even has a "note pad" that allows you to append up to 630 characters to an entry. Accessed by pressing the F4 key, this feature is useful for leaving yourself a reminder. I generally use it when I schedule a follow-up call for several weeks in the future.

You can run *Top Priority* in TSR (terminate and stay resident) or stand-alone mode. When installed as a TSR, the LT-T key combination brings up the program. You can then add to your lists or edit them. You can also view the To-Do Today screen.

Because I don't like to leave my office PC running, I generally use the software in stand-alone mode and print the reports. The most frequently used report, at least for me, is the Daily To-Do list, which is the printed version of the To-Do Today screen mentioned above. It lists the tasks (Priority tasks first) that are either past deadline without having been completed or that have the current (or no) date entered as the due date. The Daily To-Do list also has a list of completed tasks that haven't been wiped from the system as well as room for penciled-in additions as the day progresses.

Other reports include files listings, category listings, a completion report (by due date), a weekly check-off report (which shows an entire week's events) and goal cards that list all subtasks assigned to a particular goal. As with *Calendar Creator Plus*, you can print these reports in a wide variety of sizes, including several organizer sizes to fit popular systems, such as DayTimers and FiloFax (and even my $12 knock-off).

Calendar Creator Plus and *Top Priority* aren't miracle solutions. How effective they are depends on how they're used and how often. I'm still not all that organized, and the piles are still being built (and toppled). But I'm a lot more organized with these two programs than I was before I started using them. At $59.95 for *Calendar Creator Plus* and $99.95 for *Top Priority*, I think they're well worth the money. ME

Products Mentioned

Calendar Creator Plus & Top Priority
Power Up! Software Corp.
2929 Campus Dr.
San Mateo, CA 94403
415-345-5900

A SCSI-II Adapter, Ruggedized SRAM and BurstRAM

By Joseph Desposito

In this column, I cover two products that use specialized devices, rather than the devices themselves. One is a SCSI-II controller and another is a ruggedized SRAM card. New memory devices for high-speed processors finishes it off.

32-Bit Caching SCSI-II Adapter

ALWAYS Technology Corp. (31336 Via Colinas, Suite 101, Westlake Village, CA 91362) announced an ultra-high-speed Extended Industry Standard Architecture (EISA) SCSI host adapter. This AL-4000 board provides very fast data transfer rates—up to 33 megabytes/second (MB/s)—and operates in caching and non-caching modes. The adapter is for 32-bit 386 and 486 EISA computers.

The AL-4000 features a very-large cache memory—up to 32 MB—and is equipped with an 80286 microprocessor that serves as a data manager and cache controller (Fig. 1). The microprocessor utilizes a separate bus with 128KB of SRAM and two EPROMs. This separate control bus allows the AL-4000 to achieve very-high transfer rates and facilitates its use as a non-caching adapter.

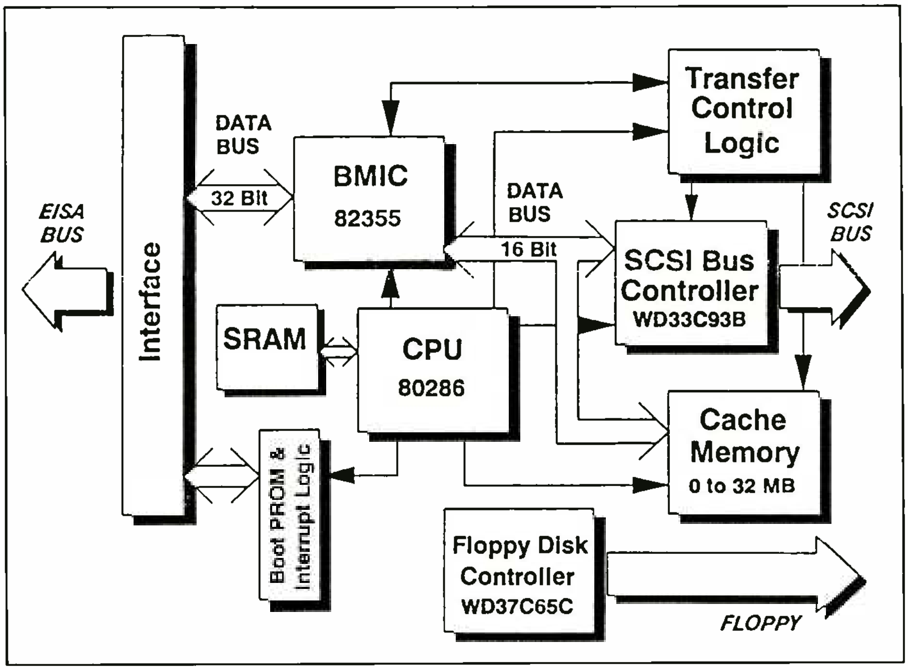

Fig. 1. ALWAYS Technology's AL-4000 EISA SCSI host adapter features a very-large cache memory and is equipped with an 80286 microprocessor that serves as a data manager and cache controller.

The AL-4000 utilizes a unique technology called "burst mode transfer." This feature of EISA offers ultra-high-speed transfer rates by allowing data to be buffered or held in the cache and then transferred across the 32-bit bus at minicomputer speeds.

Burst-mode-transfer technology requires large amounts of memory; so ALWAYS equipped the AL-4000 with eight SIMM sockets that accommodate up to 32MB of user-installed page-mode cache memory. Either 256KB, 1MB or 4MB memory chips can be installed.

To ensure continued EISA compatibility, the ALWAYS host adapter uses an Intel 82355 Bus Master Interface Controller (BMIC) to provide the interface with the EISA bus.

The AL-4000 supports systems that incorporate additional disk drives and multiple peripherals. Configuration of the hardware is automatically performed via a software utility provided with the standard product. An on-board floppy controller operates as a standard AT-style controller or as a secondary controller for a third and fourth drive. An external connector provides easy access for tape drives, CD ROMs, optical disks and other SCSI devices.

The AL-4000 architecture has features aimed at maximizing performance in cache and non-cache environments. Both read and write transfers are cached. Unlike cache programs that reside in system main memory and generally work with DOS, the AL-4000 cache is independent of the operating system. Certain operating systems and applications discourage caching outside control of the operating system software. The AL-4000 was specially designed to offer cache memory and operate as a non-cache adapter. This was accomplished by creating a control bus equipped with its own SRAM memory and dual EPROMs.

In addition to providing impressive performance across the EISA bus, the AL-4000 has high performance on the SCSI bus as well. The AL-4000 incorporates a new SCSI-II protocol chip. Although most disk drives today have raw transfer rates below the SCSI-I 5-MB/s limit, many of the drives entering the market include cache memory. With 256K of cache and "look-ahead" schemes, drives will soon be able to transfer in synchronous mode at above SCSI-I rates. The AL-4000 can accommodate the highest-performance disk drives.

The AL-4000 carries a lifetime warranty. Initial small quantity and evaluation boards are being sold for $895 each, which includes 2MB of cache memory.

Rugged SRAM Card

Dallas Semiconductor (4401 S. Beltwood Pkwy., Dallas TX 75244) has developed a nonvolatile, four-million-bit SRAM in a credit card-size package that is ruggedized for industrial environments. Developed in conjunction with AMP, Inc., the DS6417 CyberCard EV 4-megabit memory withstands 50,000 insertions and withdrawals. This superior durability is a result of new chip development and a new metal alloy used for the contact pins.

According to the company, existing memory cards require gold-plated contact pins for extended use. But because gold is soft and the coating is typically 30 micro-inches thick, the plating wears away quickly, exposing the base metal beneath. When the base metal—such as nickel plating over copper—is exposed for any length of time, oxidation occurs and the connection is no longer reliable. Solid-gold contacts would work, but they would be too expensive and too soft.

CyberCard has no plating. Instead, it uses a new solid metal that is 2,000 times thicker than gold plating and withstands insertions until the metal disintegrates. That metal—a new alloy specially designed for this contact arrangement—was developed in conjunction with AMP, Inc.'s Advanced Development Laboratory and is much harder than gold.

Each pin is six thousandths of an inch of solid, usable metal. Each time CyberCard is inserted, any oxidation or debris build-up on the pins is wiped clean because of the connector's 250-gram normal force, which further increases the card's dependability.

The reliability of a card also depends on the number of contacts, each of which is a potential failure point. CyberCard reduces the number of contacts from the typical 68 to just five, which greatly improves reliability.

This reduction is made with a special chip, the DS1280 3-Wire to Bytewide Converter, that supports up to 4 megabits of memory using only three input signals —clock, data and reset—in addition to power and ground.

JEDEC-standard bytewide SRAM inside the card is adapted to a three-wire, 1 megabit-per-second serial interface with the D51280. With Cyclic Redundancy Check (CRC) circuitry, the chip also monitors serial data transmission through the connector, detecting any connection problems. This ensures integrity of the card's data transfers.

Since memory cards can be subjected to harsh environments and handling by the user, CyberCard has special provisions to keep internal chips safe. CyberCard's ground contact pin is extended to ensure that it makes first and breaks last. Thus, power is applied and removed in the same sequence every time the card is inserted and withdrawn, affording an extra margin of safety to stored data. Static electricity discharges through the ground pin before the signal pins make contact, safeguarding the integrated circuits internal to the card from electrostatic discharge (ESD).

In addition, all contacts are recessed to keep away other sources of static electricity, such as finger contact.

Intended for use in rugged industrial environments, CyberCard is ultrasonically welded to form a rigid enclosure. With the number of contacts reduced to just five and the gold plating removed, normal pressure on the contacts was increased to break through dirt and films found in the industrial environment. In contrast, a card with 68 high-pressure contacts would have intolerable insertion/withdrawal force and quickly wear away the gold plating.

SOLID-STATE DEVICES...

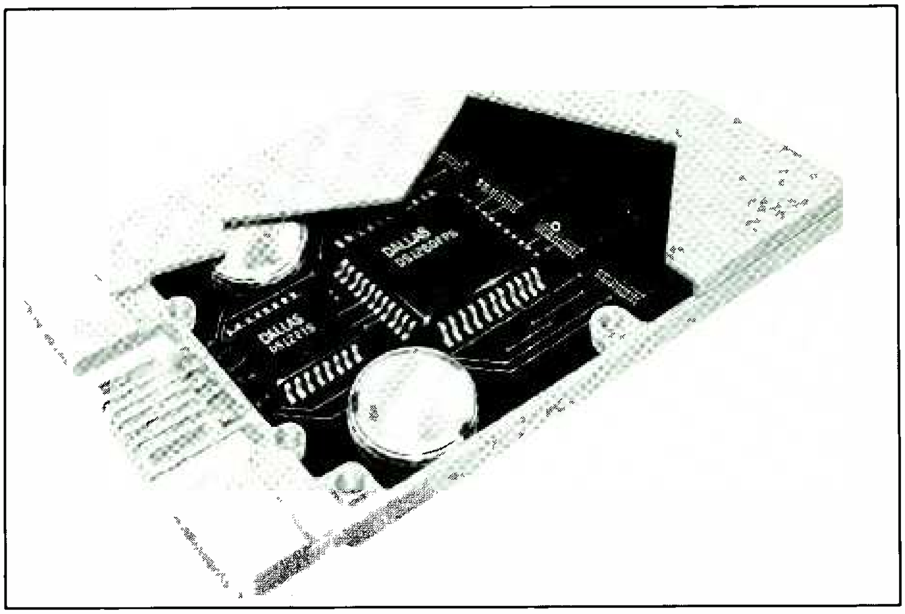

Fig. 2. Dallas Semiconductor's Cyber products includes the DS6400EV Extra Volume version of CyberCard pack to cram in more electronics.

CyberCard comes with up to 4 megabits of memory. Because of a built-in, lithium energy source and low-leakage CMOS circuitry, the memory is nonvolatile for over 10 years in the absence of external power.

Dallas Semiconductor offers three families of Cyber products with identical contact interfaces. The DS6200 series, called CyberKey, is shaped and sized for a key chain (2.375 × 1.120 inches). The DS6300 CyberCards, the size of credit cards except for thickness, measures 3.370 × 2.125 inches. The DS6400EV is an Extra Volume version of CyberCard to pack more electronics (see Fig. 2).

Prices of these Cyber products, in 100-piece quantity, range from $3.50 for a DS6200 CyberKey with a 64-bit read-only memory to $250 for a CyberCard EV with 4 megabits of memory. Receptacles for the Cyber series start at $3.90 in 100-piece quantity.

Protocol-Specific Memories

Motorola (MOS Memory Products Div., P.O. Box 6000, Austin, TX 78762) introduced a family of synchronous 32K × 9 fast static RAMs tailored for the Motorola, Intel, and Sparc microprocessors.

For the 68040 microprocessor, the MCM62940 BurstRAM utilizes the burst-memory protocol of the processor. The 68040 itself initiates three bursts. However, subsequent burst addresses are generated internally by the MCM62940 in the same sequence as by the 68040.

For the i486 microprocessor, the MCM62486 BurstRAM provides a similar solution. The processor or the cache controller initiates the burst mode, but BurstRAM generates subsequent burst addresses, imitating the burst sequence of the i486 processor.

With burst-memory protocols, processors can quickly transfer a succession, or burst, of consecutive memory words per bus cycle, rather than a single memory word per cycle. Since these burstRAMs are designed to support 50-MHz clock rates, they can keep up with even enhanced versions of the 68040 and i486 yet to come.

The MCM62960 synchronous RAM provides cache memory for memory address protocols specific to Sparc microprocessor applications.

The MCM62940 and MCM62486 BurstRAMs and the MCM62960 synchronous static RAM are packaged in a 44-pin plastic leaded chip carrier (PLCC).

Master Wiring List

From		To
IC1 pin	1	IC6(15)
	2	RY2(R)
	3	R15(L)
	9	C3(−)
	16	IC3(27)
	17	IC3(22)
	18	C1(T),XTAL1(T)
	19	C2(T),XTAL1(B)
	20	IC1(31),C1(B),C2(B), R42(L),GND
	21	IC3(25)
	22	IC3(24)
	23	IC3(21)
	24	IC3(23)
	25	IC3(2)
	26	IC4(1)
	27	IC4(2)
	28	IC4(3)
	29	IC5(22)
	30	IC2(11)
	32	IC2(18),IC3(19)
	33	IC2(17),IC3(18)
	34	IC2(14),IC3(17)
	35	IC2(13),IC3(16)
	36	IC2(8),IC3(15),IC6(14)
	37	IC2(7),IC3(13),IC6(13)
	38	IC2(4),IC3(12),IC6(12)
	39	IC2(3),IC3(11),IC6(11)
	40	C3+, +5V
IC2 pin	1	IC2(10),C4(B),GND
	2	IC3(10)
	5	IC3(9)
	6	IC3(8)
	9	IC3(7)
	12	IC3(6)
	15	IC3(5)
	16	IC3(4)
	19	IC3(3)
	20	C4(T), +5V

From		To
IC3 pin	2	IC5(2)
	3	IC5(3)
	4	IC5(4)
	5	IC5(5)
	6	IC5(6)
	7	IC5(7)
	8	IC5(8)
	9	IC5(9)
	10	IC5(10)
	11	IC5(11),R8(B)
	12	IC5(12),R7(B)
	13	IC5(13),R6(B)
	14	GND
	15	IC5(15),R5(B)
	16	IC5(16),R4(B)
	17	IC5(17),R3(B)
	18	IC5(18),R2(B)
	19	IC5(17),R1(B)
	20	IC4(11)
	21	IC5(21)
	23	IC5(23)
	24	IC5(24)
	25	IC5(25)
	26	IC3(28), +5v
IC4 pin	4	IC4(5,8),GND
	6	IC4(16), +5V
	7	IC1(7)
	15	IC5(20)
IC5 pin	1	R1 thru R8(T),IC5(27, 28), +5V
	14	GND
IC6 pin	1	R9(R),R11(T)
	2	R10(R),R12(T),R13(L)
	3	R13(R)
	4	R11(B),R12(B)
	5	IC6(6,9),GND

From		To
	7	XTAL2(R)
	8	XTAL2(L)
	10	IC7(2)
	16	R14(L)
	17	R14(R),C7(R)
	18	C7(L), +5V
IC7 pin	7	GND
	14	+5V
IC8	IN	C8+,D2(K),D4(K)
	COM	C8−,C9−,C10(B), D1(A),D3(A),GND bus
	OUT	C9+,C10(T), + bus
Q1	Collector	RY1 coil(B)
	Base	R15(R)
	Emitter	GND
RY1	coil(T)	+5V
	contact 1	RY2 coil(T−)
	contact 2	C5(L),red instrument line
RY2		
	coil(T+)	Red telephone line
	coil(B−)	Green telephone line
	coil(B+)	C6(L), green instrument line
	contact 1	GND
C5		R9(L)
C6	R10(L)	

Note: Numbers in parentheses are pin designations for IC specified, and letters in parentheses indicate: A—anode (diodes only), K—cathode (diodes only), L—left, R—right, T—top and B—bottom. IC pins to which no connections are made are not listed.

this time. Include on the circuit-board assembly six extra solder-posts for wiring the telephone line, the line to the telephone instrument(s) to be monitored and the cord from the power transformer.

When you finish wiring the circuit-board assembly, including making connections to the six extra solder posts, carefully go over all your wiring, checking off the runs on the Master Wiring List. (Note: mark the function and polarity of the six extra solder posts on the board for reference later.) If you made any wiring errors, correct them now.

House the circuit-board assembly inside any enclosure that accommodates it. The enclosure can be metal, all plastic or metal and plastic. Machine the enclosure for mounting the circuit-board assembly. Then drill an entry hole for the cable the wall-mount transformer cable through one end panel and a pair of entry holes through opposite ends of the enclosure for the telephone line and the cable that goes to the telephone instrument(s) to be monitored. Finally, drill a small hole near the telephone-line and instrument cable entry holes. If you drilled any holes through metal, deburr them to remove sharp edges, and line the entry/exit holes with rubber grommets.

Mount the circuit-board assembly

Dual-Tone Multi-Frequency

Tone-dial telephones produce a special kind of DTMF—an acronym for Dual-Tone Multi-Frequency—signal developed by Bell Laboratories more than 25 years ago. DTMF uses pairs of eight specially selected audio tones that are generated by the telephone instrument. These tones are further divided into groups of four low tones and four high tones. A DTMF tone is the algebraic sum of one low-tone and one high-tone frequency.

An example of the basic tones and the combined tone is shown in Fig. A. The top waveform is the row 3 825-Hz DTMF tone, the center waveform the column 2 1,336-Hz DTMF signal, and the bottom waveform the combined row 3 and column 2 waveform as it is transmitted over the telephone line. Rows and columns refer to the conventional Touch Tone keypad layout. Rows are numbered horizontally in consecutive order from top to bottom, while columns are numbered consecutively from left to right, as illustrated in Fig. B. Note that for special communication functions, tone dials can include additional keys labeled with the letters A through D and the symbols * and #.

Each keypad key occupies a unique position in a 4 × 4 matrix. With this arrangement, the 5 button is located at the juncture of row 2 and column 5 in the matrix, the 7 button at the juncture of row 3 column 1, and so on.

Pressing any given button on the Touch Tone keypad results in generation of the algebraic sum of the tones represented by the row and column at that juncture. For the 5 button, the tone generated would be the algebraic sum of 770 Hz (low-tone group) and 1,366 (high-tone group), and for the 7 button the algebraic sum of 852 and 1,209 Hz.

When DTMF dialing was introduced in the 1960s, comparatively large capacitors and inductors were used for generation of pure sine-wave frequencies. Today, DTMF keypads use ICs that are under crystal control to generate synthesized stair-step waveforms. DTMF equipment, like the G8870 DTMF decoder used in the project described in the accompanying article, can receive and decodes these stair-step signals into its corresponding binary output, as listed in the table. It is the binary output given in the last column of the table that is directly coupled over a four-bit data bus to the 8031 microcontroller used in the project.

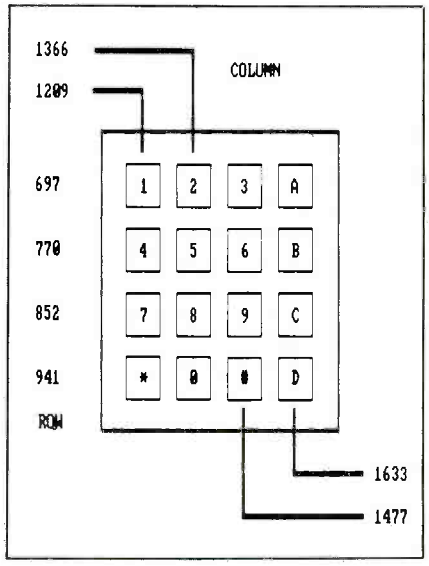

*Fig. B. Standard Touch Tone-type keypad keys can consist of a matrix of four rows and up to four (typically three) columns. Keys labeled A through D and * and # are for special-purpose communication applications. Each key generates one tone from the low and high groups to output their algebraically combined waveform.*

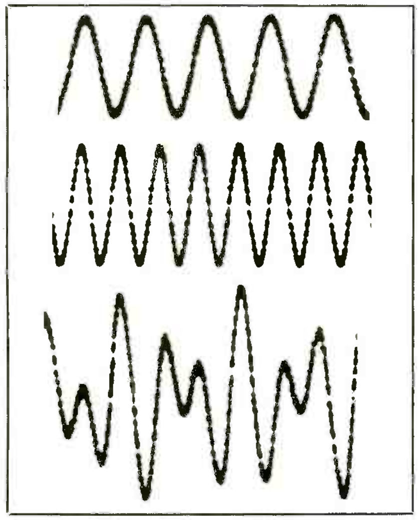

Fig. A. DTMF tone pairs generated when button 8 on a Touch Tone keypad is pressed include a row 3 852-Hz low-group (top), column 2 1,336-Hz high-group (center) and algebraically combined (bottom) tones.

Touch Tone Keypad Key Tone Frequencies and Hex Outputs

Key ID	High-Frequency Tone in Hz	Low-Frequency Tone in Hz	Output Format* 3	2	1	0
1	697	1,209	0	0	0	1
2	697	1,336	0	0	1	0
3	697	1,477	0	0	1	1
4	770	1,209	0	1	0	0
5	770	1,336	0	1	0	1
6	770	1,477	0	1	1	0
7	852	1,209	0	1	1	1
8	852	1,336	1	0	0	0
9	852	1,477	1	0	0	1
0	942	1,336	1	0	1	0
*	941	1,209	1	0	1	1
-	941	1,477	1	1	0	0
A	697	1,633	1	1	0	1
B	770	1,633	1	1	1	0
C	852	1,633	1	1	1	1
D	941	1,633	0	0	0	0

*In hexadecimal

(Continued on page 76)

Telephone Call Restrictor *(from page 71)*

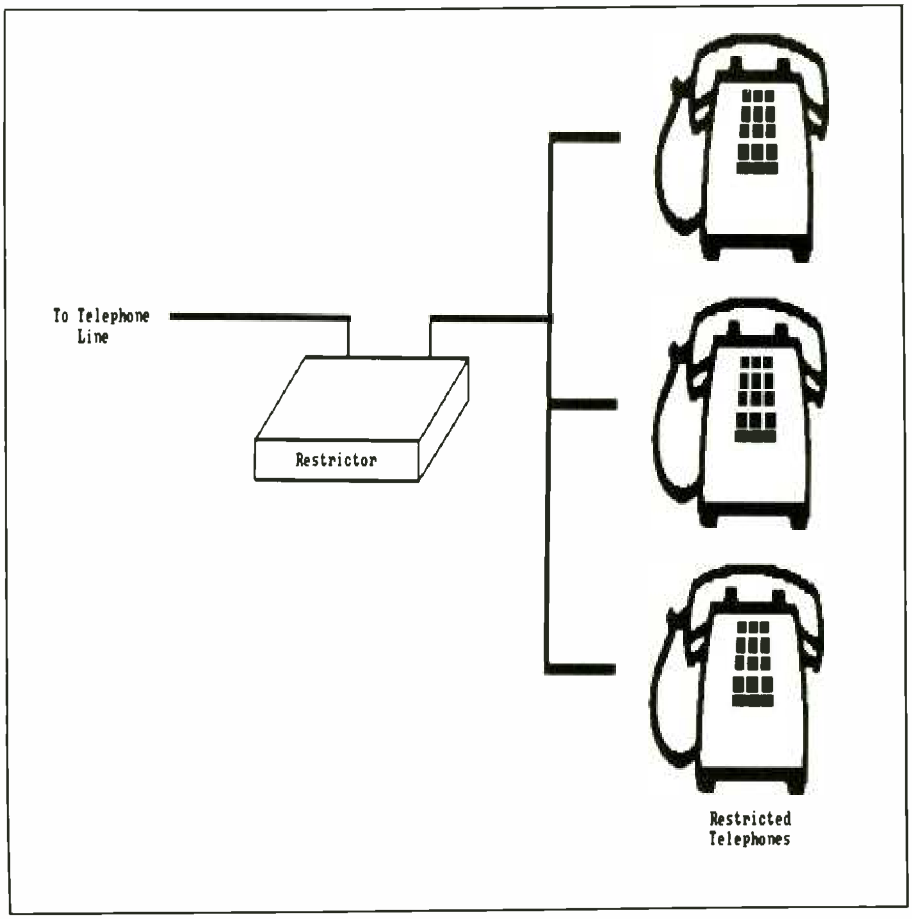

Fig. 4. Details for installing Call Restrictor into your telephone system.

in place, using suitable length spacers and machine hardware. If the cord coming from the wall-mount transformer has a plug on it, cut off and discard it. Separate the conductors of the cord a distance of 1½ inches. Strip ¼ inch of insulation from both conductors. Tightly twist together the fine wires in each conductor and sparingly tin with solder. Route this cable through one entry hole in the enclosure and tie a strain-relieving knot in it about 5 inches from the unfinished end inside the enclosure. Connect and solder the two conductors to the appropriate solder posts.

Determine where you will mount the project. Select a secure location, such as your basement, where the project is not likely to be discovered. This location must be near an ac outlet and between the incoming telephone line and any telephone instruments that are to be monitored (see Fig. 4). Cut the telephone line at the selected location. If necessary, use a telephone extension cord to effect installation.

Remove 1½ inch of outer plastic jacket from both cut ends of the telephone line. The only conductors you need for this project are those that have red and green insulation on them. If there are other conductors, clip them away close to the beginning of the remaining outer plastic jacket. Strip ¼ inch of insulation from the ends of the red- and black-insulated conductors.

Route these conductors through their respective entry holes in the enclosure and solder the free ends of the conductors to the appropriate solder posts. Make certain your connections are properly polarized. This done, use plastic cable ties to secure the cables to the enclosure with suitable machine hardware. Leave a bit of slack in the cables inside the enclosure. The ties will prevent the cables from being torn loose.

Checkout & Use

Before putting the Call Restrictor into service, it is a good idea to perform preliminary voltage checks to ascertain that you wired it correctly. For this test, you need a dc voltmeter or a multimeter set to dc volts.

Clip the common lead of the meter to a point on the circuit-board assembly that is normally supposed to be at ground potential. Convenient points for this connection are the negative (−) leads of *C8* and *C9* in the power-supply section. Make sure that the only IC on the circuit-board assembly is three-pin regulator *IC8*.

Plug the wall-mount transformer into its ac outlet. Then touch the "hot" probe of your meter to pin 40 of the *IC1* socket; pin 20 of the *IC2* socket; pins 26 and 28 of the *IC3* socket; pins 6 and 16 of the *IC4* socket; pins 1, 27 and 28 of the *IC5* socket; pin 18 of the *IC6* socket; and pin 14 of the *IC7* socket. At all locations, your reading should be +5 volts.

If you fail to obtain the proper reading at any indicated point, power down the project by unplugging its transformer from the ac outlet. Correct the problem before proceeding.

When you are certain that everything is okay with your wiring, power down the project and wait a minute or so for the charges to bleed off the electrolytic capacitors in the power supply. Then plug the DIP ICs into their respective sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets.

If you have an oscilloscope, you can make an operational check of the Call Restrictor as follows. Clip the common (ground) lead of the scope to circuit ground in the project and the "signal" lead of the scope to pin 11 of *IC1*. Power up the project by plugging its transformer into an ac outlet, and observe the scope display. If everything is okay, you should observe pulses appear on the CRT screen. These pulses last for only about 0.5 second, their presence informing you that the program data in the EPROM is being read by *IC1*.

If you fail to observe pulse activity on the screen of your oscilloscope, power down the Call Restrictor and correct the problem.

Even if you do not have access to an oscilloscope, you can test operation of the Call Restrictor. You do this simply by plugging its transformer into an ac outlet, lifting the handset from any telephone instrument connected to the line through the project and key the numbers 9, 7 and 6. As the last digit is dialed, the Call Restrictor should interrupt the line and you should hear dead silence. Then, 2 seconds later, you should hear a dialtone. Repeat this test by dialing 1900 and then 0. The line should go dead after each is dialed, and you should hear a dialtone 2 seconds or so later.

So far you have learned that the Call Restrictor will block the calls you do not want to get through. Now dial a "legitimate" number. This time, there should be no disconnect, and the call should go through as it normally would.

As an added security measure, the Call Restrictor is designed to prevent *any* call from being dialed out in the event someone accidentally or purposely unplugs the power transformer from the ac line.

The Call Restrictor will now silently stand guard over your telephone line, preventing unauthorized calls from being made to those toll services that have been inflating your monthly telephone bill. If you have been plagued by high bills for use of these services, the Call Restrictor should pay for itself in short order.

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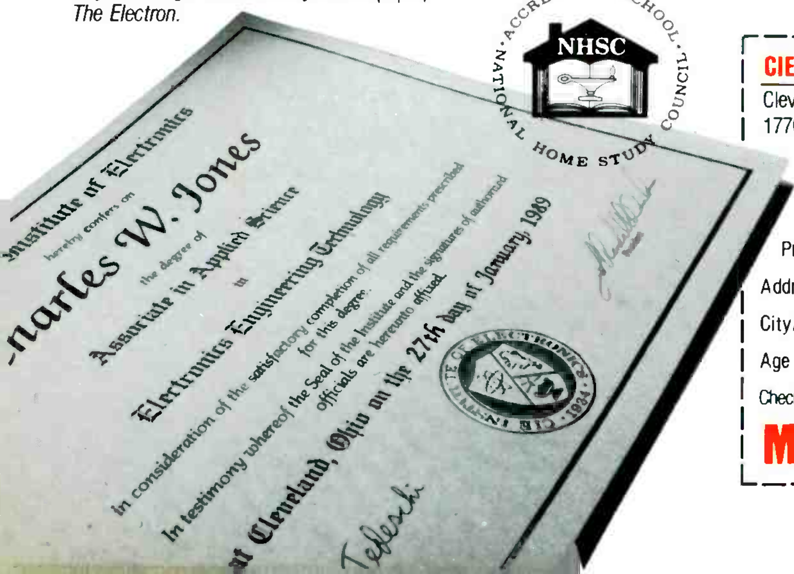

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Optional Accessories

R-2000:

- **VC-10** VHF converter
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R-5000:

• **VC-20** VHF converter • **VS-1** Voice module • **DCK-2** for 12 volt DC operation • **YK-88A-1** AM filter • **YK-88SN** SSB filter • **YK-88C** CW filter • **MB-430** Mounting bracket.

Other Accessories:

• **SP-430** External speaker • **SP-41** Compact mobile speaker • **SP-50B** Mobile speaker • **HS-5** Deluxe head-phones • **HS-6** Lightweight headphones

RZ-1
Wide-band scanning receiver

The RZ-1 wide-band, scanning receiver covers 500 kHz-905 MHz, in AM, and narrow or wideband FM. The automatic mode selection function makes listening easier. One hundred memory channels with message and band marker, direct keyboard or VFO frequency entry, and versatile scanning functions, such as memory channel and band scan, with four types of scan stop. The RZ-1 is a 12 volt DC operated, compact unit, with built-in speaker, front-mounted phones jack, switchable AGC, squelch for narrow FM, illuminated keys, and a "beeper" to confirm keyboard operation.

Optional Accessory
• **PG-2N** Extra DC cable

Specifications, features, and prices are subject to change without notice or obligation.

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