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MAY 1979 Vol. 50 No. 5

ON THE COVER
A Time/Voltage Calibrator is a must if you have digital test equipment. It's the only way available to most of us to keep our test gear calibrated. Learn how to build your own calibrator. Story starts on page 35.

PACE 8117 is a computerized CB transceiver. For more data see our new Communications Corner on page 68.

TITANIUM DISULFIDE COMPOUND is used in new Exxon rechargeable lithium battery. Read the whole story starting on page 44.


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**AM stereo:** The battle for stereo on the standard broadcast band is taking some interesting new turns. Although the industry-wide National AM Stereo Radio Committee (NAMSRC) submitted field-test data to the FCC, the Commission seemed dissatisfied and asked for more broadcast testing and more information, with the indication that selection of a system would take longer than expected—if, indeed, the FCC decides to authorize AM stereo broadcasting at all. The second surprise was the choice by the ABC Radio Network of the Kahn-Hazeltine independent sideband (ISB) system as the one it feels “will best serve the interests of the broadcasters and the public.” The ISB system, which carries left-channel information on the left sideband, right-channel on the right sideband, was not one of the systems tested by NAMSRC, although it is the oldest proposed system. ABC is currently testing the system on its New York station.

**Teletext:** EIA has established a special committee to evaluate various home video data systems and eventually establish standards for their use in the U.S. Several European countries already are using these systems, which present graphic data on home TV screens. Teletext systems display data broadcast during the vertical interval of the television picture. A second basic system, viewdata, is transmitted on telephone lines and provides the home user with access to a wide variety of material. Both systems can provide information on demand—such as weather forecasts, news, sports, stock market reports, highway information, etc., while viewdata eventually can serve as the home display terminal for a central computer.

**Projection:** Henry Kloss, who as founder and president of Advent Corporation was the father of home color projection television, has re-entered the business with a new projection TV system (he quit Advent in 1976). The “Nova-beam” system, scheduled for marketing next fall, is based on a new Kloss-designed tube-and-lens system. Claims made for Novabeam are higher brightness, sharper resolution, lower cost than comparable three-tube two-piece television projectors now on the market.

**Electronic gamesmanship:** The toy business has discovered electronics with a vengeance, and things will never be quite the same. The major impact currently is in games, where even the familiar Scrabble is available in a handheld electronic version called Sensor. Although the first electronic games used the family TV set, toy manufacturers now have discovered they can accomplish many of the same effects without tying up the home video outlet. Many of the new handheld games were inspired by video games and include both visual displays and audio effects. While Mattel is the undisputed pioneer in the handheld game, the game that created the most talk at the recent New York Toy Fair was Milton Bradley’s Microvision. This $50 unit is programmable, like a sophisticated TV game—and it has a screen, a two-inch-square liquid-crystal panel with 16 X 16 resolution. It can be used to play all of the familiar “TV games” plus new ones to come. How big is the pocket electronic game business? Just ask Mattel. It sold more than 2,000,000 of them last year.

**Digital VTR:** Television broadcasters are in a bit of a tizzy these days about videotape recorders. The “standard” four-head quad VTR, first introduced by Ampex in 1956, is an expensive two-inch-tape-gobbling monster and current technology has made possible its replacement by a far more economical one-inch helical-scan type of recorder that is superior in virtually every way. So naturally, broadcasters are beginning to replace their big quad recorders with the new standard helical unit—or are they? There’s still a nagging worry that analog recording is obsolete and that digital VTR’s represent the true wave of the future.

This is a real problem for the VTR manufacturers, who want to sell recorders now without encouraging a wait-for-digital attitude but who still want to impress potential customers that they’re up to date on digital technology. Britain’s Independent Broadcasting Authority demonstrated a digital recorder at a recent industry conference, impressing broadcast engineers and putting pressure on VTR leader Ampex. So at a major digital recording seminar sponsored by the Society of Motion Picture and Television Engineers, Ampex felt it was necessary to present something concrete along with its technical papers, without discouraging broadcasters from buying the latest in analog recorders. What Ampex did was take one of its four-head broadcast recorders, modify it for eight heads (and about twice the tape usage) and demonstrate perhaps the best digitally recorded video pictures ever shown. At the same time, it warned broadcasters that a practical, commercial digital recorder was still five to seven years away. It remains to be seen whether broadcasters will buy the new generation of helical-scan analogs or patch up their old quad machines and hold out for the start of the digital age.

**Longitudinal scan:** The home videocassette recorder business is also faced with a problem in standards and formats, but digital recording doesn’t enter the picture. In the consumer field, the issue may become helical vs. longitudinal scan. Longitudinal recording, of the type used in audio, was attempted for video in the 1950’s and abandoned. Now it promises to make a comeback in portable recorders, thanks to new tape transport systems. BASF is building a factory in California to turn out its multitrack LVR (longitudinal video recorder) which uses 8-mm tape in a portable format. Eastman Kodak, which is actively developing video recorders, is believed to be working on a longitudinal format. Toshiba recently demonstrated a longitudinal-scan system using half-inch tape with 220 video tracks in an endless-loop cartridge. The company gave no indication of when it would produce the unit, if ever, but pointed out it has one-third fewer mechanical parts than the Sony-developed Beta format. The simplicity of longitudinal systems is based on the use of a fixed head instead of the revolving-head system used in helical-scan recorders.

David Lachenbruch
CONTRIBUTING EDITOR
How to listen to Moscow, Russia... Moscow, Idaho and your good buddy, Max Moscow.*

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RCA CELEBRATES ITS 50 MILLIONTH TV SET in 32 years. Here, Jack K. Sauter, RCA marketing vice president, displays on the left the 19-inch ColorTrak receiver produced in 1978 and costing $570. On the right is the first TV set produced by RCA 32 years ago—a 10-inch black-and-white model, which sold in 1946 for $375.

COMUS C-6 DIET COMPUTER is a microprocessor-based instrument used to determine an individual's proper caloric needs to keep in shape. Keyboard data entry uses the word "SHAPE" (Sex, Height, Age, Pounds and Exercise), to compute the correct daily caloric intake based on metabolism, daily exercise (in 5 code categories) and diet. The unit is handheld, portable and powered by a 9-volt battery; it also doubles as a 4-function calculator with floating decimal (so you can figure out cost-per-serving). The Comus C-6 comes in an off-white plastic case; it features an 8-digit red LED display and provides 2K bytes of ROM and 128 bytes of RAM. The entire package consists of the computer, instructions, calorie counter and exercise-level table. Selling for a suggested retail price of $34.95, and it is manufactured by Comus, Inc., 4550 Cascade Rd., Grand Rapids, MI 49506.

DUAL-VISION TV RECEIVER is manufactured by Sharp Electronics, who calls it the "TV of the Future." In the model 17D50, the 17-inch screen can display a 4-inch superimposed black-and-white picture in either the upper or lower corner of the screen, or it can eliminate it entirely. These pictures are also switchable, with the superimposed image becoming the main display and vice versa. The set also contains the following features: electronic varactor tuning; a 17-button/18-function capability; filter; a two-way/two-speaker system; a 75-ohm CATV connector; plus color-adjust, channel-hold and channel-lock controls. The picture tube used is Sharp's Lynatron Plus High Focus tube.
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The instrument's on-board microprocessor even calculates the wind chill factor at the touch of a button. It also stacks barometric pressure readings in memory, so it can compute the rate of rise or fall on command! The barometer readings are derived from a newly-developed piezo resistive silicon bridge transducer that senses the most minute changes in pressure. It's the first and only truly digital electronic barometer!

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The most commonly used communications equipment has electronic circuitry as its heart. It's a CB radio, a UHF/VHF radio, an amateur radio station, an all-wave receiver or a scanner and it is a hot item—an item many Radio-Electronics readers want to be kept up to date on.

Hearing this in your communications to us, we've added a new regular monthly column. It has been titled "Communications Corner." It will appear every month and is intended to be responsive to your needs. While no reader questions about communications will be answered directly, your comments about the column will be carefully considered as future columns are prepared.

I think you'll like it. Turn to page 68 now, and you can judge for yourself.

Larry Steckler
Editor
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BILL OWEN
Optoelectronics, Inc.
Fort Lauderdale, FL

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affords a whole new set of opportunities. A related issue, and maybe not one you're concerned about, is that designers needn't be so skilled as in the past. That's true for the same products, and that's progress of a sort. But the super-designers are still there—in as limited quantity as ever—although they're working on difficult problems that couldn't even be approached with the old technology and not on matters that technology made easy to cope with. That's important progress because it means that the pyramid of achievement and knowledge by which we tend to view civilized development is moving up another layer as far as technology is concerned.

Finally, I would like to mention that the feature article in the June 1975 issue was about a product designed with integrated components and that had sufficient design novelty to be awarded a U.S. patent!

DENNIS E. HAMILTON
Penfield, NY

If everyone uses the IC's, who's left to design them? Does this mean that the future of the electronics industry is at the mercy of the IC designer? Does this mean that if I need only one of something I may not be able to build it? Plain and simple—is all future electronic design going to become dependent on a handful of engineers working for IC manufacturers?—Editor

TV ADAPTER CORRECTIONS

I must make some corrections to my letter which appeared in the August 1978 issue of Radio-Electronics (page 16) regarding the TV-to-stereo adapter.

In paragraph 3 regarding the sound detector takeoff in solid-state sets, a sentence reads, "the volume control immediately follows the sound detector in most cases. This, in turn, varies the gain of an amplifier stage. If so, audio does not appear on the volume control." This should read: "The volume control follows the sound detector in most cases, but in some sets, the volume control merely varies a DC voltage, which, in turn, varies the gain of an amplifier stage. In these cases, audio does not appear on the volume control, and must be found elsewhere."

I might add that most American-made sets using this DC volume control system use an IC as the sound detector/IF/audio amplifier functions; and pin 8 of this IC is the best place to pick off the audio. However, this may not always be the case, so to be sure, check with a scope or a signal tracer. Also, since the pin 8 output has about 5 to 6 VDC on it, make sure to use a blocking capacitor.

My apologies to the TV networks regarding my comments on their narrowband telephone lines. Both my letters (in May and August 1978 issues) were written in late December, 1977, before the AT&T switchover to multiplexed video-audio transmission links.

MICHAEL KILEY
Palos Heights, IL

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MAY 1978
The Heath Company's Dept. 570-070, Benton Harbor, MI 49022) H17 floppy-disc system consists of a factory-assembled control board that plugs into the H8 bus and is connected via a ribbon cable to a Wangen model 82 5½-inch drive. The drive is housed in a cabinet that contains a power supply capable of powering a second drive. The cabinet also contains a cutout for an optional second drive.

Each 5½-inch hard-sector disc is divided into 40 tracks, and each track is subdivided into 10 sectors for a total storage capacity of 102,400 bytes-per-disc. The model 82 drives have a 30-ms track-to-track step-time specification, although some drives will operate much faster. Both drive units in my system operate reliably at a track-to-track step time of 8 ms. As Heath carefully points out, the track-to-track step time is not the same as the random-sector access time, which is the actual time required for the read/write head of the drive to get to a sector once it is requested. A track-to-track step time of 8 ms translates into an average track-to-track step time of 104 ms. Since the disc rotates (at 300 rpm), there is an additional average time of 100 ms for the sector to come under the read/write head. So, the average random-sector access time is 204 ms. Once a sector on the disc is accessed, data is transferred between the drive and the controller board one bit at a time at a serial rate of 16,000 bits-per-second. To reference this speed, the H17 will load Extended Benton Harbor BASIC in about 2 seconds. Heath's standard 1200 baud cassette interface requires about 2 minutes.

Software

Software is required for a floppy-disc system to function. This software is called an operating system, and Heath supplies its own brand called HDOS. The operating system handles such functions as controlling the drive motor, positioning the read/write head, locating specific data on the surface of the floppy disc, creating files, transferring data, etc. It also provides communication with the user via command instructions.

After initially applying power to the system, HDOS must be "booted." Booting is the process of loading only those segments of HDOS that will enable the system to function. For example, one such portion, called the monitor, decodes the various commands and transfers control to the appropriate software segment to carry out the command. After the command is executed control returns to the monitor. Various other segments of HDOS are loaded into the H8 when necessary.

When HDOS is booted, the monitor program is automatically loaded in the upper address space of the H8 memory and occupies 2.4K. The other segments of HDOS are located in the lower address space of memory and occupy approximately 9K. Therefore, HDOS requires a total of approximately 12K RAM to operate. If you plan on using a BASIC interpreter, then you will need additional memory to support the BASIC; plus whatever "user" memory you require for your programs.

To boot HDOS, simply set the H8 program counter to 030 000 using the octal keypad on the H8 front panel and execute CO. HDOS will respond by printing 'ACTION' (BOOT) on the CRT terminal. To boot HDOS, simply type B on the terminal keyboard. After HDOS is loaded it will respond by identifying itself. It will then ask for the current date by printing 'DATE (DD-MM-YY)' After entering the current date and hitting the carriage return, HDOS is up and running. From now on, HDOS responds with a prompt character to indicate that it is ready to accept commands. There is a wide variety of commands available with HDOS. Among these commands is SYSGEN, which permits you to copy the minimal operating system onto a blank disc. You can use the COPY TO-FROM command to copy additional programs to this disc and store the origi-

continued on page 26
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nal disc away for safekeeping. A PIP command (Peripheral Interchange Program) is included and is used to copy a file from one disc drive or peripheral device to another. Other commands include SYSHELP, which lists all the valid system commands; DELETE, which erases specified files; HELP, which changes the name of a specified file; CAT, which lists the files contained on the disc; and other commands.

Among the many commands and features of HDOS, one in particular struck me as being interesting and unusual. This is a diagnostic routine called TEST 17. After executing this command, you can check the rotational speed of the disc drives. The normalized drive speed is displayed on the LED’s on the front panel of the H8 as a decimal number, which should be as close to 1.000 as possible. Since the rotational speed tolerance is 1 percent, any number between 0.990 and 1.010 is acceptable. If it is out-of-tolerance, it can be trimmed by adjusting a pot on the drive assembly itself. Another test that can be performed under TEST 17 is a general checkout. Under this test, a specific bit pattern will be recorded on each sector of the disc and then read back. This test is automatically performed three times and is intended to check the read/write head and the track seek mechanism. There is also a media check that locates all the bad sectors on the disc (if there are any) and a routine for minimizing the track seek time of the drive being tested.

One important feature that is available and that are associated with the operation of the disc system. For example, if you have various BASIC programs already stored on cassette tape, you can use BASECON to convert these programs into files that can be stored on the disc. If you have text files stored on cassette tape, you can use TXTCON in a similar manner to convert these into disc files. A ONECOPY command is included that allows you to copy files from one disc to another in a system that has only one drive. In addition to HDOS, the software disc also contains BASIC, BUG-8, HASL-8 and TRED-8.

Overall, HDOS is a versatile operating system. The H17 disc system which sells for ($695.00 including software) will greatly increase the versatility of your H8 system. R-E

Sylvania Module Extension Cable Kits

CIRCLE 141 ON FREE INFORMATION CARD

Many years ago, when sets and circuits (and I) were much simpler, I used extension cables a good deal. These cables let me get the chassis out onto the bench where I could actually get at it. When I started troubleshooting my first modular TV set, I thought it would be great if we had a set of extension cables so that we could get each module out where we could get at it . . . since many of our repair such modules, especially larger ones.

Evidently, someone was listening! Sylvania has come up with module-extension cable sets; one of these fits Zenith modules, the other, RCA modules. The Zenith cable set is called the TV Module Extension Kit P/N KZ-2. It will fit 19 Zenith chassis, including the 17EC45, 19EC45, 23EC45, and several others. This set consists of six cables and two special brackets (plus pins) and can be used with 10 different Zenith modules.

The instructions state: "Each Zenith module listed has an even number of pins (8, 12 or 16) on one end and an odd number (7, 11 or 15) on the other. Each bracket has two four-conductor cables and a larger one. One with 7 conductors, the other with 8. By selecting the right cables and plugs, any of these modules can be hooked up correctly." A complete instruction sheet comes with each set, listing the modules and chassis with which it can be used. A special data sheet is also included showing the Sylvania ECG part number semiconductor for the original component used in each module.

The RCA extension cable set is the TV Module Extension Kit P/N KRX-5, with five separate cables for use with the RCA Accu-Color chassis from the model CTC-41 through the model CTC-76. Three of the cables have six contacts each, and the two remaining cables have 12 contacts. By choosing the right combination of contacts, any of the 15 modules listed in these chassis can be hooked up full. Full hookup data and instructions are provided, as well as a list of ECG replacement semiconductors.

Both extension cable sets use flat monoco-continued on page 32

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**ADVANCE ELECTRONICS**

**EQUIPMENT REPORTS**

continued from page 26

ductor cables, color-coded on one side and colored plain red on the other. This helps identify the position of the edge connector in the chassis socket. The terminal boards used for the socket end of these cables are made with what looks like a good grade of glass epoxy. Printed-circuit wiring on the other side of the board completes the circuit, and jumpers are added where used in the original socket that look as if they would stand up to hard use with no trouble.

I feel these extension module cable kits are a giant step forward in making our job just a little bit easier! The suggested retail prices for the extension cable sets are as follows: the Zenith model KZ-2, $49.50; the RCA model KRX-3, $54.50. The sets are available from Sylvanida dealers and distributors. "Try 'em, you'll like 'em!"

**Microproducts Apple II Assembler/Editor**

CIRCLE 142 ON FREE INFORMATION CARD

A **CORESIDENT ASSEMBLER/TEXT EDITOR** for the Apple II computer is now available from Microproducts (1024 17th Street, Hermosa Beach, CA 90254). This assembler is supplied on cassette tape, floppy-disc or EPROM, and features line renumbering, printer control and driver software for Microproducts' EPROM programmer. I used the disc-based assembler (Version 2.0), which also allows the program text files to be stored, retrieved and merged from the disc.

Writing in machine language yields fast and efficient programs. However, machine code is tedious and hard to debug. Even with a mini-assembler, such as the one in the Apple II, changing one line of a program usually necessitates a lot of machine code acrobatics. With a true assembler/editor such as the one described here, the program is written into a text file that can easily be read, documented, altered and debugged.

The Apple II assembler supports all standard 6502 mnemonics and address modes. Also included are six pseudo-op codes that allow you to originate variable codes as well as hexadecimial format or ASCII constants or tables. Labels can be 1 to 4 characters long, and the comment field handles up to 16 characters. Using this assembler makes writing machine-language programs almost as easy as using BASIC (well, maybe not quite). But with a little practice even the beginning computer user can break the "BASIC barrier."

I did find one bug that causes the assembler to generate false code — it does not always catch a **BRANCH OUT OF RANGE** error. Instead, it generates legitimate code, which can play havoc with your program and is very hard to debug. Fortunately, I also found the cure for this problem, and I notified Microproducts so that the company can correct any future units. (If anyone has an old version of this assembler and wishes to correct it, just send a self-addressed, stamped envelope to West Side Electronics, Dept. MP-P, P.O. Box 636, Chatsworth, CA 91311.)

The assembler on cassette tape (No. MP 78101-1) costs $19.95; on disc (No. MP 78101-3), $25.00; and on EPROM (No. MP 78101-2), $40.00 and you must supply the two 5-volt 2716 EPROM's.

---

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Time/Voltage Calibrator

Precision digital test equipment requires special test instruments to insure that calibrations are within specified tolerances. This calibrator supplies time and voltage references you'll need.

DOUG FARRAR

FOR YEARS LARGE COMPANIES HAVE ENJOYED the benefits of highly accurate digital test equipment because only they could afford the substantial initial capital outlay and the periodic maintenance and calibration required in using this equipment. Recently, however, advances in digital and linear-integrated-circuit technology have brought the cost of these test instruments down to a price affordable to even the hobbyist.

However, there is a side to this story that is never mentioned: How is a hobbyist going to keep his new gear calibrated? In the days of 1% to 5% accuracy, the known voltage of a battery or the approximate resonant frequency of a crystal were adequate enough for calibration standards. Nowadays, a 3½-digit digital voltmeter (DVM) needs a 0.1%-voltage standard; newer scopes need 1% (or better) time standards. And even inexpensive frequency meters need 0.1% time standards.

Of course, you can routinely send an instrument to a calibration lab (as the manuals tell you to do!), but this could easily become more expensive than the cost of the unit itself. Even if you’re willing to do that, you may not have such a lab near you. What’s the hobbyist to do?

The Time-Voltage Calibrator described in this article can be the answer to your calibration problems, and could pay for itself many times over. This instrument has two separate sections for time and voltage, each controlled by a standard 4-digit thumbwheel-switch network. When you dial in the desired voltage and press the LOAD VOLTS pushbutton, a DC-voltage output is produced that is accurate to better than 0.1%. Dialing in the desired time and pressing the LOAD TIME pushbutton produces two time outputs with 0.005% accuracy. The first output is a standard TTL output with a duty cycle within 5 ns of 50%. The second time output has slower rise and falltimes than the first, but its voltage swing is highly accurate. The time period is controlled from the front panel, while the voltage

<table>
<thead>
<tr>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VOLT SPECIFICATIONS</strong></td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Total error</td>
</tr>
<tr>
<td>Settling time</td>
</tr>
<tr>
<td>Trim range</td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Multiplier</td>
</tr>
<tr>
<td>Total error</td>
</tr>
<tr>
<td>Trim range</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>TTL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Output impedance</td>
</tr>
<tr>
<td>Rise/falltimes</td>
</tr>
<tr>
<td>Duty cycle</td>
</tr>
</tbody>
</table>

FIG. 1—MULTIPLE EXPOSURES of “time” outputs. At a programmed voltages are 4, 6, 8 and 10 with 2.0-µs period. At B we have 5-volt swings at 1, 2, 4 and 10 µs programmed periods.
swing is between ground and whatever is dialed into the volts section (± 10 mV). This last time output is very useful for calibrating oscilloscopes.

The maximum programmable output voltage is 10,000 mV. The time output is from 0.1 µs to 999.9 µs in 0.1-µs steps; but a multiplier switch can be used to multiply all these time increments by 10, 100, 1000, or 10,000, even while maintaining the 0.005% accuracy. This results in a maximum time output of 9,999 seconds. The scope photos in Fig. 1 show some of the waveforms obtainable with the Time and Voltage Calibrator.

The best part about the entire project is that it requires no calibration to meet these specifications! Using the components called out in the parts list, means you now have your own secondary time and voltage standards that are traceable to the National Bureau of Standards (NBS). But if you do have access to very accurate time- and voltage-measuring equipment, the calibrator can be trimmed to even tighter specs.

**How it works**

There are two almost separate sections to the calibrator: time (Fig. 2) and voltage (Fig. 3). Both sections are loaded with the thumbwheel-switch network, S1–S4 (Fig. 4). Two separate sets of latches (IC1–IC4 and IC5–IC8) latch the state of the thumbwheels when their respective load switches (load volts, S6 and load time, S7) are depressed and then released. So, after a value is loaded into either set of latches, the thumbwheels can be set to any other value.

Let's examine the time section first. The design goals for this circuitry were:

- Time increments of 0.1 µs;
- A squarewave output;
- A time range of 0.000 0 to 999.9 µs, with a time multiplier on top of this.

To accomplish the first two goals, a divide-by-n counter, where n is the thumbwheel-latch value, is clocked at a 20-MHz rate (50-ns time period), and

**FIG. 2—THE TIME SECTION** of the calibrator. Four thumbwheel switches select the time period of the waveforms at the time and TTL outputs when pushbutton S7 is depressed.
the counter output is divided by two to produce a squarewave with a time step of $2 \times 50 \text{ ns} = 100 \text{ ns}$ (or 0.1 $\mu$s). The third and last design goal requires a four-decade counter network. By reducing the counter's clock frequency by 10, 100, 1000 and 10,000, the time output can be multiplied by a similar number.

Decade up/down counters IC21–IC24 are wired in the down-count mode, with IC21 being the most significant stage and IC24 the least significant. These IC's form a divide-by-n counter stage, where the value of $n$ ranges from 2 to 9999. When the counter reaches a value of 0002, all inputs to NAND gate IC33 go high, forcing the gate's output to a logic low level. This output drives the data input of the D-type flip-flop, IC34-a. On the next clock, IC34-a's output (Q) goes low, while the counter decrements to 0001. The output of IC34-a is connected to all four counters' synchronous parallel load inputs, so the counters are now prepared for a synchronous load on the next clock cycle, and will load the latched value of $n$ from the thumbwheel switches at that time. The counter stage decrements in the following sequence:

$$n-(n-1)-(n-2)\ldots3-2-1+n\ldots$$

So loading the $n$-value produces a low output from IC34-a every $n$ clock cycles. Dividing this signal with a divide-by-two flip-flop (IC34-b) produces the desired squarewave output, and every step in $n$ is a 0.1 $\mu$s change in the resulting squarewave output.

Invariably, a value of 0000 or 0001 will be loaded into the time section. Since a divide-by-zero or a divide-by-one counter does not exist, the circuitry would produce an ambiguous output. To circum-
vent the problem, an open-collector exclusive-NOR network consisting of IC13–IC16 is used as a comparator to monitor the latches’ loaded value. When a 0000 or a 0001 is loaded, the or-tied output of the comparator gates goes high, signaling the logic that this special condition now exists. The comparator output drives IC35–e, IC35–d and IC36–b (IC35 is wired as a 1-of-2 multiplexer).

When the comparator output is low, the multiplexer selects the divide-by-n output to be applied to the clock input of divide-by-two flip-flop IC34–b, as discussed above. But when the comparator output is high, the multiplexer selects the downcounters’ clock input as the clocking signal to IC34–b. This produces a divide-by-2 squarewave of 20 MHz, or 10 MHz, which is a 0.1-μs period. But if a 0000 is loaded into the time thumbwheel latches, the input of NAND gate IC36–b is low, causing its output to go high. This means that both inputs to IC36–a are high, and the overriding asynchronous SET input to IC34–b is activated. The divide-by-two flip-flop output is now always low, regardless of the inputs on the synchronous inputs, producing a period of 0, as required.

The time-counter network can generate the correct squarewave for any value from 0 to 9999. All that remains to be done is to buffer the squarewave before applying the signal to the front panel. Buffer IC36–c inverts IC34–b’s output, and is a standard TTL output (i.e., it has a precise time but no amplitude control). Open-collector buffer IC37–a drives CMOS buffer network IC40. This output swings between ground and its VDD input (indicated as V HIGH on the schematic diagram), which is a DC signal coming from the volts section (to be discussed shortly). While the rise and falltimes from buffer IC40 are slower than that of a TTL output, the amplitude and period are very accurate. However, reliable operation below about 4.5 volts cannot be expected.

Getting the time-counter network to operate at 20 MHz is not easy and requires much complexity than a slower counter chain. Integrated circuit 31, IC32, IC33 and IC34 perform the necessary high-speed logic operations. It is important that these IC’s be Schottkytype IC’s, and not low-power Schottky or standard TTL types. Furthermore, if you believe in worst-case numbers, downcounters IC21–IC24 should be manufactured by either Fairchild, Motorola, or Raytheon, since the worst-case speed specifications of these companies are tighter than those of other makers. The “slower” devices may result in the counters not working with some n counts!

Up to this point, it has been assumed that the time counters work with a 20-MHz clock input. If a 2-MHz clock rate is used instead, each least-significant thumbwheel step would be 1.0 μs, rather than 0.1 μs. Furthermore, 200-kHz, 20-kHz and 2-kHz clock inputs would produce minimum steps of 10 μs, 0.1 ms and 1 ms, respectively. Generating these clock rates is a simple task, assuming that the 20-MHz frequency already exists.

Decade counters IC25–IC28 (Fig. 5) are hooked up to divide the 20-MHz clock by factors of 10 per-counter.

The 20-MHz signal and the four counter outputs are connected to multiplexer IC29. Use of the multiplexer and TIME MULTIPLIER switch S5 allows front panel “cold-switch” selection of a single clock to be applied to the time section. That is, a set of DC signals can select one AC signal to be applied to the time counters, thus avoiding the need to route the noise-producing AC signals to the chassis’s front panel. The output of the multiplexer is buffered by IC30–d before being applied to the time calibrator’s clock inputs. The NAND gates, IC30–a and IC30–b, are the amplifying components of the crystal oscillator, whose frequency is set by the 20.0-MHz crystal. The NAND gates introduce a small amount of loop delay that is compensated for by the paralleled capacitor combination of C35, trimmer C36, capacitor C37 and resistor R38. Resistors R21, R22, R36 and R37 bias the gates in their linear regions. The oscillator output is buffered by IC30–c before being applied to the multiplexer and countdown string.

The volts calibrator: how it works

Anyone who has designed an automobile dwellmeter will recognize the operational principle behind the programmable
So, with a duty-cycle of 0, the waveform never switches but remains at ground, and V_{AVG} = 0. A duty-cycle of 100 means that the waveform remains at V_{PEAK}, so V_{AVG} = V_{PEAK}. A duty-cycle at any point between the two extremes produces an average voltage between 0 and V_{PEAK}, as shown by the Fig. 6 equation.

How can this principle be used here? It's easy to generate an extremely accurate duty-cycle using standard digital technology. However, where do you obtain an accurate voltage source? Here comes linear IC technology to the rescue! National Semiconductor produces a linear IC voltage reference that is laser-trimmed to 10,000 volts. This IC comes in two accuracy grades: ±1H is 10,000 volts ±10 mV (±0.1%), while ±2H is ± 5 mV (±0.05%). The latter value is specified here for the ultimate in untrimmed accuracy.

How do you generate an AC rectangular waveform that swings accurately between 0 and 10,000 volts; does it with the desired duty-cycle; and exhibits insignificant rise and falltimes between the two voltages? The answer is surprisingly simple: All CMOS circuits switch their outputs between ground and their supply voltage, V_{DD}. Because FET's behave in a resistive manner, there is no offset voltage at the outputs to contend with, as in TTL logic circuits. Thus, by applying the 10,000-volt reference to V_{DD} of a CMOS gate, and applying the specified duty-cycle to the gate's input, the desired signal conditioning appears at the CMOS output. All that remains to be done is to continued on page 104

**PARTS LIST**

**Resistors** are 5%, 1/4 watt unless otherwise noted

- R1, R18 = 10,000 ohms
- R19, R20, R23, R24, R36, R37 = 1000 ohms
- R21, R22 = 510 ohms
- R25 = 1800 ohms
- R26, R28 = 1 megohm
- R29 = 15,000 ohms
- R30 = 5100 ohms
- R31, R33 = 22 ohms
- R34 = 25,000-ohm, PC-mount trimmer
- R35 = 10,000-ohm, PC-mount trimmer
- R36 = 100 ohms

**Capacitors**

- C1-C19 = 0.047 μF, 25 volts, ceramic disc
- C20, C21 = 1000 μF, 16 volts, radial electrolytic
- C22, C23 = 220 μF, 35 volts, radial electrolytic
- C24-C28 = 10 μF, 25 volts, radial electrolytic
- C29-C31 = 47 μF, 25 volts, radial electrolytic
- C32-C34 = 0.1 μF, 50 volts, Mylar
- C35 = 56 pF (or 91 pF), 50 volts, mica (see text)
- C36 = 15-60-pF trimmer (see text)
- C37 = 91 pF, 50 volts, mica

**Semiconductors**

- D1-D6 = 1N4002, 1A, 100-volt diode
- IC1-IC8 = 74LS175, quad D-type flip-flop
- IC9-IC16 = 74LS266, quad exclusive or gate
- IC17-IC20 = 74LS169, 4-bit up-down decade-counter
- IC21-IC26 = 74LS169 (Fairchild, Motorola or Raytheon, see text) 4-bit up-down counter
- IC45, IC46: LM340T-5
- IC47: LM320T-5

**ICs**

- IC29 = 74LS151, 8-input multiplexer
- IC30, IC35, IC36 = 74S00, quad 2-input NAND gate
- IC31 = 74S32, quad 2-input or gate
- IC32 = 74S04, hex inverter
- IC33 = 74S30, 8-input NAND gate
- IC34 = 74S74, dual D-type flip-flop
- IC37 = 7406, hex inverter, open-collector.
- IC38 = 74LS02, quad 2-input non gate
- IC39 = 74LS109, dual J-K flip-flop
- IC40 = IC41 = CD4001, quad 2-input CMOS NOR gate
- IC42 = LF355N (National) JFET op-amp
- IC43 = LM1458N (National) dual op-amp
- IC44 = LH0070-2H (National) 10-volt reference
- IC45 = LM340T-5 (National) 5V positive regulator
- IC46 = LM340T-15 (National) 15-volt positive regulator
- IC47 = LM320T-5 (National) 5V negative regulator

**Miscellaneous**

- S1-S4 = Thumbwheel switch, BCD-complement, Unimax SF-16 or equal (Unimax Switch Corp., Ives Rd., Wallingford, CT 06492)
- S5 = 2-pole, 5-position rotary switch (CTS T-206 or equal)
- S6 = SP-1 momentary, normally open switch
- S8 = SPDT, on-off-on switch
- S9 = SPST switch
- J1-J4 = 5-way binding post
- J5 = BNC female, panel-mount connector
- XTAL1 = 20.0-MHz quartz crystal, series-resonant, 0.005% or better tolerance, HC18/U holder

**Ref**

- 1C28: 15.5VCT, 0.75A
- 1C29: 32VCT, 0.25A
- 1C45, 46, 47: 74LS266, quad exclusive or gate

- 1N4002, 1A, 100-volt diode

- LM3201-5

- 1C41: 74SO4, hex inverter

- 74500, quad NOR

- 74532, quad AND

- 74LS151, 8-input multiplexer

- 74LS00, quad 2-input NAND gate

- 74S30, 8-input NAND gate

- 74S74, dual D-type flip-flop

- 7406, hex inverter, open-collector.

- 74LS02, quad 2-input non gate

- 74LS109, dual J-K flip-flop

- CD4001, quad 2-input CMOS NOR gate

- LF355N (National) JFET op-amp

- LM1458N (National) dual op-amp

- LH0070-2H (National) 10-volt reference

- LM340T-5 (National) 5V positive regulator

- LM340T-15 (National) 15-volt positive regulator

- LM320T-5 (National) 5V negative regulator

- Thumbwheel switch end plates; line cord; strain relief; case (LM64171); 4-40 X-1/4-inch; hardware; knob; 1/4-inch aluminum strips; wire and coax; BNC receptacle and ground lug; PCB board; and dry transfer letters.

**The following components are available postpaid from Noveltronics, P.O. Box 4044, Mountain View, CA 94040:**

- **CK-TVC:** Complete kit of parts and hardware—PC board, special 2-color dry transfer chassis lettering sheet, and unpunched chassis, $150.

- **PK-TVC:** Partial kit—complete thumbwheel switch assembly, LH0070-2H, transformer, crystal, case, special dry transfer lettering sheet, and PC board, $100.

- **PCB—Etched, drilled and silk-screened PC board, $25.**

**California residents add state and local taxes to the total order. Individual items are not available for sale. Orders paid by money order or bank-certified check can be discounted 5%, and guarantee shipment within 2 shipping days after receipt of order. Allow up to 2 weeks delay for personal check clearance time. No out-of-state P.O. boxes, please. Canadian and Mexican orders add 10% (non-discountable) of order, all other non-USA orders add 10% (non-discountable) to cover additional postage and handling. U.S. funds only.
BOWLING MAY BE ONE OF OUR EARLIEST sports, with origins dating back to the Egyptians of 5200 BC. Almost five million Americans bowl in sanctioned leagues, and over sixty million more bowl for recreation or exercise. However, it is hard to find a functional yet reasonably priced toy bowling game for the home. The game described in this article can be built to almost any size, uses materials that are easily obtainable and priced reasonably and is a faithful representation of the real thing.

Playing the game

Depending on the size of the alley you want to build, various objects can be selected as a “ball” or puck. I chose to size everything around a quarter (a twenty-five cent coin), but you could use a poker chip or any other circular opaque object. When the game is turned on and reset, all 10 display LED’s are dark. If the “ball” slides down the alley and passes over several of the “pin” spots the photo-Darlington transistors embedded in the lane are blocked from light. This change in state is remembered by the internal CMOS bistable latches, and the display LED’s indicate which pins would have been knocked down in a real game had the ball taken a similar path. For example, striking the 1 and 2 pins but missing the 3 pin is the same as hitting the “pocket” and it gives you a strike. Hitting the 1, 2 and 3 pins results in that nemesis of all bowlers, the 7–10 split. Other ball paths are similarly translated into the equivalent pin knockdown. If you get a “spare,” (i.e., less than 10 pins are knocked down), the second ball is then thrown. Again, the gating tells the display which pins have been knocked down. For more realism, all the spares can be picked up except for the 7–10 split, which is unmakeable. After a strike or the second ball, pressing the RESET pushbutton clears the display for the next bowler. Scoring is done exactly as in real bowling; you can obtain bowling score sheets from a local bowling establishment.

The circuit

The block diagram in Fig. 1 shows the sequence that occurs when a ball or puck such as a quarter passes over the pin area of the board. Each of the front seven pin locations has a photo-Darlington transistor inserted in a slot flush with the lane surface. Normal room lighting is sufficient to cause logic-level switching when the photosensitive area is covered by the ball. Each phototransistor (Fig. 2) is wired to its own bistable latch circuit, which “remembers” a pass of the ball by flipping states. These latches, in turn, feed a series of CMOS AND gates (Fig. 3), which are wired to detect various pin combinations. A total of 30 gates in 10 IC packages is connected to provide 21 separate and distinct outputs. While there is no way to show the effect of a hook ball or a pin bouncing off the side boards, every possibility of one or two balls going over the pin area is considered. See Table 1 for the various input combinations and the resultant displays.

Twenty-one of the outputs are diode-Or’ed into a diode matrix ROM (Read Only Memory) with seven horizontal-input lines and 10 vertical-output lines (see Fig. 4). The input lines each have connecting diodes at the appropriate junctions of the output lines to drive the 10 display LED’s.

The power supply for this circuit (Fig. 5) is noncritical since switching speed is not important. Any handy holder for 4 C or D batteries will suffice. I omitted the batteries and used a 6-volt calculator battery eliminator from my junk box instead. Diode D1, capacitor C1 and resistor R1 provide the needed rectification and protection against reverse polarity and power surges. Note that both supplies can be installed if a shorting-type jack is used; standard dry cells can leak or explode if charging is attempted. A battery eliminator of from 4.5 to 12 volts can be used if LED current-limiting resistors R20-R29 are changed in value; the CMOS IC’s will function on any DC supply between 3 and 15 volts.

Construction

Before starting construction, decide on the size of the ball. I chose a quarter, since the alley is a convenient size for table-top play and there is no danger of losing the ball and not easily finding another. The dimensions shown in Fig. 6 for constructing the lane, gutters and phototransistor holes are all determined by the diameter of a quarter. If a different size “ball,” such as a poker chip, is chosen, all these dimensions must be multiplied by the ratio of the diameter of connector.
the chosen ball to that of a quarter (this is approximately \( \frac{1}{4} \) inch). In addition, you must be careful to shape the circuit board (see Fig. 7) so that it fits under the alley.

While an etched PC board could have been developed for this project, the labor and cost involved would have exceeded that of the rest of the components combined. This game, with its low-cost IC's and relatively straightforward schematic diagram, is a natural for wire wrapping techniques. I went one step farther and used a modification of the IC bricklaying method (see "IC Bricklaying," Radio-Electronics, December 1977). The IC's were glued upside down to a sheet of \( \frac{1}{4} \) inch clear plastic, and the pins were direct-wired using a wiring pencil. Anyone trying this, however, must accept the risk of static damage to the sensitive CMOS IC's. A safer procedure is to use multilevel wire-wrap sockets on perforated board and connect the pins with several colors of 30-gauge Kynar-insulated wire.

First, insert the sockets in their relative locations, being careful to leave room for mounting the hardware and other components (see Fig. 7 for general guidelines and dimensions). At this point, it is generally easiest to wire the positive and ground leads on all IC's, using 22-gauge hookup wire and soldering them flush with the PC board. This both holds the sockets in place and provides a pin reference. Note the nonstandard connections of IC's 15 and 16. Now, install R1 and R2 through R8, C1, D1 and the 22-gauge wires that will later be connected to S1, J1 and B1 (if used). Finally, label each socket and mark the pin 1 locations on both sides of the board.

Wiring between the pins of IC's 1-14 will be easier to perform and trace if one wire-insulation color is used for all the number-designated pins (1, 1, 2, etc.) and another color is used for all lettered pins A through FF. Start by connecting all the pins of each designation together, as shown in Fig. 8. For example, I (which means "not one") is found at IC1 pins 2

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**TABLE 1—INPUT-OUTPUT CODES**

<table>
<thead>
<tr>
<th>Pin Code</th>
<th>Gate Combinations</th>
<th>Gate Output</th>
<th>Diode Matrix Input Lines</th>
<th>Diode Matrix Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3</td>
<td>B (1 2 3)</td>
<td>B</td>
<td>1, 11, 14, 16</td>
<td>1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>1 2 3</td>
<td>C (1 2 3)</td>
<td>C</td>
<td>1, 11, 14, 16</td>
<td>1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>1 2 3 4 6 7 10</td>
<td>A (1 2 3) &amp; E (4 6 7 10)</td>
<td>E</td>
<td>1, 11, 12, 14, 16</td>
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<td>U</td>
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<td>T</td>
<td>1, 13, 10, 11</td>
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<td>J (2 4 6 7) &amp; T</td>
<td>P</td>
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<tr>
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<td>H &amp; G</td>
<td>W</td>
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<tr>
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<td>A &amp; 10</td>
<td>X</td>
<td>1, 11, 14, 16</td>
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<tr>
<td>1 2 3 4 6 7 10</td>
<td>A &amp; 6</td>
<td>Y</td>
<td>1, 11, 14, 16</td>
<td>1 1 1 1 1 1 1</td>
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<tr>
<td>1 2 3 4 6 7 10</td>
<td>K (1 2 3) &amp; 3</td>
<td>Z</td>
<td>1, 12, 17</td>
<td>1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>1 2 3 4 6</td>
<td>J &amp; 3 6</td>
<td>Q</td>
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<tr>
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<td>H &amp; 3 7</td>
<td>R</td>
<td>1, 12, 16, 11, 11</td>
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<td>F (2 3 4 6)</td>
<td>F</td>
<td>1, 13, 17, 11, 11</td>
<td>0 0 0 0 1 1</td>
</tr>
<tr>
<td>1 2 3 4 6 7 10</td>
<td>J &amp; D (6 7 10)</td>
<td>AA</td>
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<tr>
<td>1 2 3 4 6</td>
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<td>BB</td>
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<tr>
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<td>J &amp; G &amp; 10</td>
<td>S</td>
<td>1, 14, 15</td>
<td>0 0 0 0 1 1</td>
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<tr>
<td>1 2 3 4</td>
<td>A &amp; 4</td>
<td>CC</td>
<td>1, 16, 11, 11, 11, 11</td>
<td>1 1 1 1 1 1</td>
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<td>A &amp; 7</td>
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<td>1 1 1 1 1 1</td>
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<tr>
<td>1 2 3 4 6 7 10</td>
<td>M (3 4 6) &amp; D</td>
<td>EE</td>
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<td>0 0 0 0 1 1</td>
</tr>
<tr>
<td>1 2 6 10</td>
<td>K &amp; L</td>
<td>FF</td>
<td>1, 17, 14</td>
<td>0 1 0 1 1 1</td>
</tr>
</tbody>
</table>

Note: All numbered inputs from Fig. 2. Outputs connect elsewhere in this Fig. or in Fig. 4.

---

**FIG. 2**—DARLINGTON phototransistors Q-07 are wired to bistable latches using xor gates.

**FIG. 3**—THIRTY AND GATES provide 21 outputs generated by input from the phototransistors.
Then, and Fig. 4 come next. Diodes D2 and resistors R2
are connected to invertersm. Insert additional small -signal diodes
IC's. However, few pieces of tempered Masonite or other smooth-surfaced board
and some pine strips. First, cut both of the lane base pieces to the dimensions
determined by the chosen ball size. Note that the T-shaped piece is the actual bowling surface and be careful not to mar
or gouge it. Carefully mark and drill the photo-Darlington transistor mounting holes.
Now, paint in a contrasting color the part of the bottom (rectangular)
board that will be exposed as the gutters. Use black paint if a light shade of board is
available, and white paint if you use dark Masonite or paneling. Do not paint the
entire board because the glue will adhere better to bare wood or fiber. Next, glue
the two pieces together.
When the lane is thoroughly dry, assemble it to the side boards using the 1/4-
inch or 1-inch-square corner braces and glue.
When all the gluing is complete and set, drill two very small holes (1/4 inch or
less) through the bottom lane piece near the edge of each of the front seven trans-
istor mounting holes. Snip off the base lead of photo-Darlington transistors

Now, turn the circuit board over and connect a wire up each of the 10 vertical
lines of diodes, starting at the resistor. Thread these leads through the board and
connect to their respective pins of IC's 15 and 16. Finally, connect the output pins
of IC's 15 and 16 to resistors R20–R29.

Building the cabinet
The construction of the alley is quite straightforward, requiring only simple
hand tools, a few pieces of tempered Masonite or other smooth-surfaced board
and some pine strips. First, cut both of the lane base pieces to the dimensions
determined by the chosen ball size. Note that the T-shaped piece is the actual bowling surface and be careful not to mar
or gouge it. Carefully mark and drill the photo-Darlington transistor mounting holes.
Now, paint in a contrasting color the part of the bottom (rectangular)
board that will be exposed as the gutters. Use black paint if a light shade of board is
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When all the gluing is complete and set, drill two very small holes (1/4 inch or
less) through the bottom lane piece near the edge of each of the front seven trans-
istor mounting holes. Snip off the base lead of photo-Darlington transistors

**NOTES:**

- **D2 - D66** = 1N914
- **R10 - R19** = 100K ohms
- **R20 - R29** = 220 ohm

**PARTS LIST**

<table>
<thead>
<tr>
<th>Resistors, ¥/watt, 10% unless otherwise noted</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1—10 ohms, 2 watts</td>
</tr>
<tr>
<td>R2—R8—15,000 ohms</td>
</tr>
<tr>
<td>R9—R19—100,000 ohms</td>
</tr>
<tr>
<td>R20—R29—220 ohms</td>
</tr>
<tr>
<td>C1—100 µF, 15 volts, electrolytic</td>
</tr>
<tr>
<td>D1—1N4001 or equal</td>
</tr>
<tr>
<td>D2—D66—1N914 small-signal diode</td>
</tr>
<tr>
<td>Q1—Q7—2N5777 photo-Darlington transistor</td>
</tr>
<tr>
<td>IC1—IC4—4001 quad 2-input non gate</td>
</tr>
<tr>
<td>IC5, IC10, IC12—4073 triple 3-input and</td>
</tr>
<tr>
<td>gate</td>
</tr>
<tr>
<td>IC6, IC7, IC11, IC13, IC14—quad 2-input</td>
</tr>
<tr>
<td>and gate</td>
</tr>
<tr>
<td>IC6, IC9—4082 dual 4-input and gate</td>
</tr>
<tr>
<td>IC15, IC16—4049 Inverting-type hex buffer/converters</td>
</tr>
<tr>
<td>LED1—LED10—Jumbo red LED, Radio Shack 276-041 or equal</td>
</tr>
<tr>
<td>S1—SPST toggle or push-on/push-off switch</td>
</tr>
<tr>
<td>S2—SPST momentary pushbutton switch</td>
</tr>
<tr>
<td>J1—shorting-type phone jack, see text</td>
</tr>
<tr>
<td>BATT1—BATT4—size-C or size-D dry</td>
</tr>
<tr>
<td>batteries, see text</td>
</tr>
<tr>
<td>Misc:</td>
</tr>
<tr>
<td>(14) 14-pin wire-wrap-type DIP sockets; (2)</td>
</tr>
<tr>
<td>16-pin DIP wire-wrap sockets; battery</td>
</tr>
<tr>
<td>holder; perforated board; 22-gauge and</td>
</tr>
<tr>
<td>30-gauge wire; pressed board or Masonite, etc.</td>
</tr>
</tbody>
</table>

**FIG. 4—DIODE OR GATES feed into a diode read-only-memory with seven horizontal input lines and ten vertical output lines. Ten inverters led by the output lines, control the LED indicators.**

**FIG. 5—THE POWER SUPPLY. A 6-volt battery or four flashlight cells can be used away from AC lines. See text on AC input voltages.**

*see text*
NOTE:
LED1-LED10 MOUNT IN PIN POSITIONS 1-10 RESPECTIVELY ON DISPLAY PANEL
PHOTOTRANSISTOR Q1 MOUNTS IN POSITION 1, Q2-P2, Q3-P3, Q4-P4, Q5-P5, Q6-P7, Q7-P10 ON ALLEY SURFACE

FIG. 6—SUGGESTED DIMENSIONS for the bowling alley. Pin hole spacings are for “ball” the size of a quarter. Alternate display mount has sloping “ball” return.

INPUTS FROM Q1-Q7

FIG. 7—HOW PARTS ARE POSITIONED on the circuit board. The transistors are cemented topside-down so the pins are convenient for point-to-point wiring.

Q1-Q7, carefully bend the other two leads as shown in Fig. 9, and insert them into the two small holes. Press down gently, making sure each transistor is slightly below the playing surface. Now, wire all the emitters in parallel and hook a separate lead to each collector. Leave these eight wires long enough so that they reach the eventual locations of R2-R8.

Constructing the display panel

The size of the display board is determined by the mounting method chosen. The simplest type of mounting is to attach the display panel to two vertical posts attached to the side frame pieces near the far end of the alley. In this case, the width of the panel will be the overall width of the alley plus the thicknesses of the vertical mounting posts (a ½-inch width is recommended). The actual display area is composed of two pieces of ½-inch or ¾-inch particle board or Masonite. Drill two small holes (a maximum of ½ inch) at the location of each LED in the front piece, then paint the panel flat black. Insert the LED leads, hold the LED’s flush and carefully bend the leads flat on the back of the panel. Wire all the anodes in parallel with a piece of 22-gauge hookup wire that is long enough to reach from the display to the circuit board. Then, connect a similar length of 30-gauge Kynar wire to each of the cathodes. Group all the wires together at a bottom corner of the panel, and bolt or screw the back-panel cover in place. This will both hide the wires and hold the LED’s in place. Now, carefully strip the necessary length of outer insulation off a piece of coax or other available wire of the proper size, and use it as a sheath for the eleven leads between the panel and the circuit board.

For a more professional look, drill the proper size holes in a piece of clear acrylic plastic and add it to the front of the panel. It will enhance the display brightness and give a finished appearance. I formed a convoluted shape out of clear plastic to form both a front panel and a sloping bulk return.

Installation and testing

First, insert all the IC’s into their proper sockets, observing polarity and CMOS-handling procedures. Then, screw the corners of the PC board to the mounting blocks and install power jack J1 and switches S1 and S2. If batteries are used, mount the battery holder. Finally, connect the display, power and switch leads. Be very careful to observe polarity at jack J1 and the battery holder. Unless the display wires are color-coded or tagged, they will have to be sorted out one continued on page 106
WHAT’S NEW IN RECHARGEABLE BATTERIES

If we wanted rechargeable batteries to supply power to electronic equipment, we generally selected a NiCad or special alkaline type. Now, we can choose Lithium too.

WALTER SALM

IF YOU USE BATTERIES (AND WHO doesn’t), you’re probably painfully aware of some of their limitations. Primary (nonrechargeable) batteries fill a definite need in our lives, but they have the distressing habit of becoming exhausted just when you need them the most.

The obvious answer to this has traditionally been the secondary (rechargeable) battery, and where electronic equipment is concerned, nickel-cadmium (NiCad) has been king for the last 10 to 15 years. But there are many forms of rechargeable batteries with specifications that vary widely. In addition to nickel-cadmium, there is the lead-acid type which is now being trimmed down from its large automobile size to small sealed units that are supposed to compete with nickel-cadmium. The sealed lead-acid type uses a sulfuric acid gel for its electrolyte, making it about as dry as other “dry” secondary batteries. It has the big advantage of a lower cost per watt-hour—less than ¼ as much as the nickel-cadmium type.

But the sealed lead-acid cell just hasn’t caught on all that well with consumers. For one thing, the cell’s nominal open-circuit potential of 2.0 volts means that it has little compatibility with the more traditional types of batteries used in consumer goods, such as appliances, radios, calculators and other devices. Remember, these devices were mainly designed to work with primary batteries that typically have a 1.5-volt open-circuit potential. The nickel-cadmium battery has been fairly interchangeable with them because of its 1.35 to 1.4-volt open-circuit rating. The slight difference in voltage is usually more than made up for by the NiCad’s higher current discharge rate.

A closer look at the nickel-cadmium cell shows that it has a lot of built-in safeguards—and some important variables. When most secondary batteries recharge, a certain amount of waste-product gas is produced by the charging process. The lead-acid batteries used in the family chariot vent this gas through the small holes in the water filler plugs. Periodically, this type of battery must have water added to offset normal evaporation and water lost during the recharging process. In the sealed nickel-cadmium battery, the gas produced is oxygen, which is handled by two techniques: providing enough internal air expansion space to accommodate this gas within the cell until it goes back into solution in the electrolyte during discharge; and by providing chemicals that would combine with and absorb excess oxygen to prevent pressure buildup. Generally though, as used by consumers, nickel-cadmium batteries do not vent gas when used with chargers recommended by the battery manufacturer.

Most people think nothing of leaving a set of batteries plugged into the charger long beyond their recommended maximum charging period. It’s quite familiar to notice the razor sitting on the shelf with red light still glowing a full 24 hours after it should have been unplugged. “Oh my gosh, how long has that been charging?” is the usual reaction.

Since one of the biggest abuses of NiCad’s is overcharging (and overdischarging), most manufacturers now provide some kind of exhaust vent to prevent the ultimate catastrophe—an explosion or rupture due to overcharging, an event that rarely happens with consumer batteries but can occur in heavy-use industrial and commercial applications. There are basically two types of such vents—oneshot deals that effectively take the battery out of useful service, but prevent the explosion; and resealable vents that relieve pressure but maintain the battery’s airtight integrity.

The secret of the resealable vent is that it opens only momentarily and then only when the internal gas pressure gets so high that the battery is in danger of rupturing. The vent opens, a puff of charging gas (oxygen) escapes, and the vent closes and reseals automatically. Actually, this vent can open and reseal many times during a heavy overcharge cycle, but
and its presence greatly extends the life of the battery.

The non-resealable vents, while they avoid possible battery rupture, stay open once they break their seal, and the battery's electrolyte then proceeds to dry out fairly quickly.

The resealable vent is especially important in batteries used with quick-charge systems of 15 minutes or so.

**Lead-acid in new dress**

While it's fairly common to compare other rechargeable batteries with the venerable open-vented wet automotive lead-acid type, this old-time combination of materials has taken on new dress in recent years. The dry, sealed lead-acid battery has been on the scene for a couple of years now, and is gaining ground in many areas. Unfortunately, it still hasn't been able to displace the nickel-cadmium battery yet in its many consumer power applications.

In its basic form, the dry lead-acid battery consists of two strips of lead separated by a porous glass-fiber strip. This sandwich is wound up into a cylindrical form and then baked to harden the lead paste. Once in the case, a very tiny amount of sulfuric acid is squirted in to become the electrolyte, and the whole thing is sealed up. There's no venting needed (except for instances of battery abuse), since the battery chemistry uses up free oxygen as soon as it forms during charging, and the battery will not overcharge.

Weight is somewhat of a problem when comparisons are made with NiCad types, but there is even more of an obstacle—the 2.0 volt open-circuit cell potential obviates any possible direct replacement use for conventional carbon-zinc or man-

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<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
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<tr>
<td>VOLTAGE</td>
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<td>2.0</td>
<td>1.8</td>
<td>1.6</td>
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<td>0.4</td>
<td>0.2</td>
<td>0.0</td>
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**DISCHARGE CURVE for a sealed lead-acid 2.5 amp-hour D-size cell with a 125 mA current drain.**

<table>
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<th>% RATED CAPACITY AVAILABLE</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
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<td>25</td>
<td>30</td>
<td></td>
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</table>

**SELF-DISCHARGE CURVE of sealed nickel-cadmium cells in dry air.**

- Positive and negative plates spirally-wound to yield high discharge capacity, even at high rates.
- Highly retentive separator that retains essentially all of the electrolyte.
- Pure lead grids give excellent corrosion resistance and low internal impedance.

**INTERNAL CONSTRUCTION of a typical sealed lead-acid cell.**

in certain applications. A favorite place for such batteries today is electric-start lawn mowers, motorcycles and other devices ordinarily started by handcranking.

Lead-acid batteries have also appeared as rechargeable lantern batteries (they're 6 volts, so the 2-volt nominal doesn't present a design problem) and in certain kinds of high-consumption power tools and appliances that are more conveniently used in a cordless version.

Lead-acid battery manufacturers state that these units can be recharged at least 200 times, and deliver full rated power each time. Full discharge doesn't shorten the battery life as it can do with some other types, and the battery doesn't leak off the charge as rapidly as NiCad's or conventional wet lead-acid batteries. NiCad's, on the other hand, are often guaranteed for at least 500 charge/discharge cycles, but can hold a full charge only for a week or so before leaking it off. As with
Lithium to the rescue

Remember the big splash over lithium primary batteries a couple of years ago? These batteries were going to be the power source of the future—they had such fantastic energy density. But as with many new technological developments, they had their design problems, which have been pretty much cleaned up by now.

Lithium's prodigious energy-storing properties have now come to the rechargeable battery. Two companies—Bell Laboratories and Exxon Research and Engineering Co.—have developed lithium secondary battery technologies that could well be the beginning of a minor revolution in energy sources. Bell's battery is called lithium-vanadium disulfide, while Exxon's is lithium-titanium disulfide. They both use certain special properties of metal-disulfide combinations to make the batteries work.

These materials belong to a class known as "layered compounds" and the compounds are typically only three molecules thick—two molecular thicknesses of sulfur bonded with a layer of metal molecules in between, sandwich-fashion. The next layer consists of another sulfur-metal-sulfur bond and so on.

These layers are loosely bonded together like the pages in a book—with free space in between. A familiar layered material that comes to mind is mica, whose "pages" can be peeled apart rather easily.

In these layered compounds, the space between the layers is filled with lithium (full discharge state). When the battery is charged, the lithium migrates out from between the layers and is plated out as lithium metal. There is no reason for the lithium to move back between the layers until current is drawn from the battery. Thus, the battery retains its full charge.

Since the charge/discharge cycle doesn't involve any kind of chemical reaction, just a migration of lithium ions from one free space to another, there's no opportunity for any kind of chemical deterioration to occur. One scientist at Bell Labs described it as something like a sponge taking up water. The sponge may increase slightly in volume when all the spaces are filled, but it hasn't changed at all. The lithium ion migration into the space between layers acts much the same way.

Plastic separator

A further difference between the Bell and Exxon batteries is the plastic sheet separator used by Exxon. Here, the layered titanium disulfide is separated from a layer of metallic lithium by a porous plastic film. Once again, lithium ions migrate through the electrolyte mix, in this case a solution that's as dry as the paste in most "dry" batteries. Unlike the Bell battery, in which the layered compound is pressed or molded into a sponge-like shape, Exxon physically layers the material on a substrate, covers it with the plastic sheet, then covers it with a layer of lithium.

The other big difference between the two companies' approaches: Bell is licensing the manufacturing to other companies instead of producing batteries itself; Exxon is already in pilot production in a spanning-new plant and expects to have full-scale production underway soon. The new manufacturing subsidiary is part of Exxon Enterprises, Inc.

The new lithium rechargeables have several important features:

- Once charged, they can be stored indefinitely without leaking off any of the charge.
- No matter how many times the battery is cycled through charge/discharge, there is no chemical deterioration.
- Energy density is significantly higher than for other battery types—typically about two to five times as much as for comparable size nickel-cadmium batteries.

But that unlimited lifetime does have some qualifications. As one Exxon scientists put it, "Deep charging and discharging could have some adverse effects on battery lifetime. Actually, you can wreck any battery if you abuse it badly enough."

The frosting on the cake is a very practical application in a mind-blowing desk ornament proudly displayed by Exxon officials. Sealed into an acrylic plastic paperweight is an LCD digital watch movement, a lithium cell about the same diameter as the watch movement, and a tiny string of solar cells. The solar cells trickle-charge the battery, which keeps the watch running—indefinitely. Exxon believes that new products will be tailored to use these new batteries wired in permanently—just like so many transistors, resistors and capacitors. Since the battery will probably outlast whatever device it's powering, this doesn't sound like such a bad idea.

The one hitch is that the lithium rechargeables aren't directly interchangeable with batteries that have a nominal voltage of 1.5 volts; they can be designed for full-charge potential ranging from 2.1 to 2.4 volts per cell. The LCD watch desk ornament uses a tiny voltage-dropping resistor as a regulator to suit the voltage to existing watch circuits. But such "regulators" won't be needed with many products since they'll be designed with the lithium batteries in mind.

On the horizon, we'll probably soon see a whole new class of devices with permanent batteries. Overnight charging will become normal, while fast-charge systems will also undoubtedly be developed. It will be a boon for the person who can't afford to have a single day of downtime on his timepiece. It will be a godsend for the hearing-impaired whose hearing aids eat up expensive mercury batteries at a prodigious clip. The money saved on batteries will pay for a second hearing aid, so while one is being worn, the other can be hooked up to the charger.

The timetable is still a little fuzzy. But Exxon feels that the first product to feature its battery—probably a timepiece in the over-$100 range—could be ready for the market in a year or less. From there, the sky's the limit for the new "Forever Battery."
BUYERS GUIDE TO HI-FI AMPLIFIERS

LEN FELDMAN
How To Select
The BEST Amplifier
For Your Hi-Fi

Although the fidelity and response of an audio system can be no better than that of its poorest component, the amplifier may be the very heart of the hi-fi setup. Use this guide to amplifier selection.

LEN FELDMAN
CONTRIBUTING HI-FI EDITOR

THE AMPLIFIER OF A COMPONENT HIGH-FIDELITY SYSTEM may well be thought of as the “heart” of that system. All program source signals—whether they are from AM or FM broadcasts, phonograph records, tapes or TV—all pass through the amplifier before they are applied to the loudspeakers (or stereo headphones) for conversion back into audible sound.

When this article refers to a high-fidelity amplifier, we mean all the required amplification circuits, from the so-called preamplifier stages right on through to the power-output stages. In terms of high fidelity components, therefore, we might find the audio amplifier sections of a system contained in a single unit (a so-called integrated amplifier containing a preamplifier and a power amplifier); a two-unit system (a separate preamplifier/control unit and a so-called “basic” power amplifier); or even a subsection of a more all-encompassing component known as a stereo receiver (which, in addition to containing amplifier elements, also contains the FM tuner circuitry). Which of these three amplifier alternatives you choose for your system will depend upon your budget (usually, separate components end up costing more than an all-in-one receiver), the amount of space you have available for your components, and the degree of control flexibility and number of operating features you require.

Receivers, because of their compact size, generally offer a lower power output and fewer switches and controls than separate components. However in recent years there has been a distinct tendency on the part of receiver manufacturers to offer higher and higher power outputs (the latest “standard” set by one manufacturer is 250 watts-per-channel) as well as many, if not all, of the controls and switches normally found on separate components.

No matter which form of amplifier you elect to purchase, its performance specifications and the operating features you should be aware of are common to all types and can be discussed in similar terms. So, as we examine those specifications and features, we will use the term “amplifier” regardless of whether the unit is an all-in-one receiver or a separate component.

Phono preamplifier and equalizer

Signals delivered by such program sources as an FM or AM tuner or a tape deck are generally much greater in amplitude than those produced by the tiny phono pickup, or cartridge, mounted in the pickup arm of your record changer or turntable. The latter signals may have an amplitude of just a few millivolts. Accordingly, the phono signals must be amplified to a greater extent than the other high-level signals. The phono preamplifier section of an amplifier performs this task, raising the signal-amplitude level produced by the phono cartridge from a couple of millivolts to perhaps one-half volt or more.

The phono preamplifier section performs another important task—that of equalization. Modern phonograph discs are recorded with anything but a flat frequency response. Low bass frequencies are deliberately attenuated, while high treble frequencies are boosted or pre-emphasized. These frequency-response modifications are made to accommodate a greater amount of music per-disc-side and to improve the signal-to-noise ratio of the resulting disc by decreasing the audible surface noise heard during playback. But, to play back a record properly, all frequencies must be restored to their correct relative intensities. This is done by introducing the converse frequency-response characteristic in the preamplifier section. The process is known as RIAA equalization (RIAA stands for Record Industry Association of America), and the same response curve is standard throughout the world. The RIAA playback response curve shown in Fig. 1 is the exact converse of the RIAA recording characteristic, so that the net effect of this two-part process is to restore flat response to the music we hear from phonograph records.

This response curve must be adhered to as accurately as possible, and, in quoting the frequency-response curve of a given preamplifier section, manufacturers generally use
the following statement: “Frequency response, Phono: RIAA ± so-many' dB.” The lower the dB value, the more precise the equalization. Thus, “RIAA ± 0.5 dB” represents a more accurate equalization (and, hence, a flatter playback response) than “RIAA ± 1.5 dB.”

Another phono-input specification is the input sensitivity. This specification, rather than being a measure of the quality of the preamplifier, is given to enable you to properly match the phonograph cartridge to the preamplifier. Stated in millivolts (mV), the specification indicates how much of a signal must be fed to the preamplifier’s phono inputs so that, with the volume control turned all the way up, the preamplifier delivers its rated output voltage (or, in the case of an integrated amplifier or receiver, delivers its full rated power output).

Obviously, if a preamplifier requires a signal input of 4 mV and a cartridge is connected to it that nominally delivers a signal of only 1 or 2 mV when tracing record grooves, the cartridge will have difficulty driving the amplifier or preamplifier to its rated output. Most state-of-the-art preamplifiers intended for use with magnetic cartridges (the type preferred for high-fidelity use) have input sensitivities ranging from 2 to 3 mV, a value that closely matches the typical output of most phon cartridges.

![Figure 1: RIAA Playback Curve](image)

**FIG. 1—RIAA Playback Curve** is the converse of the curve used during the recording process.

Recently, the Institute of High Fidelity (IHF), an American-based trade organization of high-fidelity component manufacturers, devised a new set of amplifier measurement standards. The new Standards (IHF-A202, 1978) are an attempt to make amplifier measurement more uniform among manufacturers, so that when prospective purchasers compare specifications they can be sure that all the manufacturers’ measurements are based upon the same reference points and can therefore be meaningfully compared.

One of the changes incorporated in these Standards concerns the measurement of input sensitivity of preamplifiers and amplifiers. The IHF felt that referencing phono-input sensitivity to the full rated output of an amplifier was not the best way to arrive at this specification. The reason will be clear if you consider the following example:

Suppose there are two amplifiers, one having a power-output rating of 10 watts-per-channel, the other with a power-output rating of 100 watts-per-channel. Suppose also that each manufacturer rates the phono sensitivity of these amplifiers as 2.0 mV (the voltage needed to drive the amplifier to its rated output). Clearly, the 100-watt-per-channel amplifier will sound much louder when driven with a 2-mV signal than the 10-watt-per-channel amplifier.

The IHF decided that it would be better to specify phono-input sensitivity (as well as the input sensitivity of other amplifier inputs) with reference to a constant, fixed output level of 1 watt, regardless of the amplifier’s power rating.

Under these test conditions, the “new IHF” phono sensitivity of the 10-watt-per-channel amplifier would become 0.63 mV, while the phono sensitivity of the 100-watt-per-channel amplifier would be 0.20 mV. These results clearly indicate that if the same level of phono signal is applied to each amplifier, the 100-watt-per-channel amplifier will sound much louder, which is indeed the actual case.

Another important specification related to the preamplifier’s phono input is known as “phono overload” or maximum phono-input level. Also stated in millivolts, this specification gives the maximum phono-input signal level that can be applied to the preamplifier before it produces audible distortion.

While average music signals imbedded in record grooves may cause a phono cartridge to produce a 2- or 3-mV signal, modern records have a great dynamic range and, during loud musical passages, cartridges may deliver much more voltage. Therefore, it is important that the preamplifier be able to handle higher signal levels without introducing distortion.

**Phono S/N ratios**

All electronic circuits generate some noise of their own. If the noise is very low compared with the signal being processed by the circuit, when the signal is finally reproduced with its added noise, the noise may be inaudible since it is so much lower in amplitude than the desired audio signal. In the case of very small phono-cartridge signals, the preamplifier stages must generate far less internal noise if that noise is to be inaudible after the extra phono-signal amplification. An all-important specification relating to the phono section is, therefore, the signal-to-noise (S/N) ratio.

Unfortunately, because not all manufacturers quote the S/N ratio in the same way, S/N specifications vary and cannot be easily compared with each other. The most conservative phono S/N specification references the residual hum and noise to the rated input sensitivity—i.e., how much lower the amplified noise and hum is compared with the amplified 2.0- or 3.0-mV phono-input signal.

On the other hand, some manufacturers refer the S/N figure to 10-mV input (a voltage value rarely produced by a cartridge tracing standard test record grooves). Clearly, the same amount of noise will be further removed or lower with respect to a 10-mV amplified phono signal than with a 2-mV or 3-mV signal, and the resulting S/N figure, quoted in dB (the higher the better), comes out anywhere from 10 dB to 14 dB higher than would be the case if it were referenced to the lower input signal level.

Often, certain weighting curves are inserted during phono hum-and-noise measurements. These curves tend to downplay the “hum” components of the resulting noise output, as well as the higher hiss frequencies of noise, on the theory that human hearing is less susceptible to these extreme frequencies than to middle-range musical frequencies. True as this theory may be, it nevertheless leads to still higher, or better, S/N figures when applied to amplifiers. Manufacturers who use this measurement technique will, at least, say so in quoting the results. Thus, the notation, “S/N, Phono (IHF “A” Weighted).”
means that such weighting networks have been used in making the measurement, and these weighted measurements should not be compared with unweighted measurements quoted for another product.

The new IHF Amplifier Measurement Standard addresses the problem of the many ways in which amplifier manufacturers have been specifying S/N ratio (and the attendant confusion this creates in the mind of the prospective consumer). The audio engineers who devised and wrote the new standard reasoned that, in the first place, users are not likely to listen to amplifiers with the volume control turned all the way up (the setting of this control normally used to measure S/N ratios). A standard phono cartridge output level of 5 mV was set as the reference level against which signal-to-noise should be measured for all amplifiers.

The procedure, therefore, is to apply a fixed 5-mV signal to the phono inputs and to reduce the volume control on the amplifier until the output at the speaker terminals is equal to 1 watt (0.5 volt for separate preamplifiers that do not include power-amplifier circuitry). Next, the 5-mV signal is removed, a dummy load equivalent to the impedance of a phono cartridge is inserted into the phono-input jacks, and the noise level is measured on a meter and expressed in dB below the new input and output reference levels. The “A” weighting measurement is also used in the new technique.

There is no direct way to correlate the new IHF S/N measurements with older methods. On the one hand, the 5-mV input level will tend to make the dB values look higher, compared with readings obtained when lower input levels (such as 2 mV) were used, but the values will be lower if a manufacturer had previously used a 10-mV input level as a reference signal. On the other hand, the 1-watt output reference to which the volume control must now be set tends to make the dB values lower. The use of an “A” weighting network (if none was used in earlier S/N measurements) further complicates the relationship between the old and new readings. As soon as all manufacturers begin to use this new measurement technique, however, comparisons of the S/N ratio between competing amplifiers will be more meaningful in terms of actual perceived noise and hum; the higher dB values will, as usual, mean a better specification. During the transition period, some manufacturers may continue to quote their old S/N ratios as well as the new IHF measurements.

The final specification usually associated with the phono-input section of an amplifier is the input impedance. Usually, the input impedance will be 47,000 ohms or 50,000 ohms, a figure that is most nearly ideal for most phono cartridges. Some preamplifier sections may be equipped with a switch selector that permits you to choose other input impedances to match the specific cartridge requirements, such as those for playing quadrophonic (CD-4) records, which generally perform optimally with a 100,000-ohm impedance.

Amplifier control section

Figure 2 is a block diagram that shows the various sections of a complete audio amplifier. Earlier this article discussed the phono-preamplifier section. Only a single stereo amplifier channel is shown in Fig. 2, since the opposite channel of the stereo pair is identical. Note that connection points for high-level tuner or tape signals bypass the preamplifier section and go directly to the program selector switch. The signal selected by this switch is then fed to one or more tape monitor circuits that are nothing more than switchable circuit-interruption points in the signal chain.

![Block Diagram of an Amplifier](image)

Input and output jacks were originally devised as a connection point for tape decks—by connecting the amplifier’s tape-out jack to the tape recorder input, and the tape-in or tape-play jack to the recorder’s output, you can monitor the recorded results from three-headed tape machines a fraction of a second after the recording itself has been made. These input/output jacks are also useful as connection points for such audio accessories as graphic equalizers (they offer better tone control than more common bass and treble controls); noise reducers (Dolby decoders, or those using different noise-reduction designs); dynamic range expanders (they process music signals to restore an otherwise compressed dynamic music range); and even four-channel decoders. If you plan to expand your high-fidelity system to include a tape recorder and any of the above accessories, you should look for at least two separate tape-monitoring circuits on the amplifier you’re considering.

Amplifier power

The most important question you will face in choosing an appropriate audio amplifier for your hi-fi system is: how much power output should the amplifier be able to produce? Much has been written about power requirements for audio systems, but here is a general guideline:

The louder you like your music, the more power you need. The larger the listening room, the greater the power requirement. The lower the efficiency of the speaker you select, the more power needed from the amplifier. The greatest variable of all is speaker efficiency. One type of speaker may require ten times as much power as another to deliver the same apparent loudness level. In fact, it is a good idea to choose speakers before any other component in your system. Then you can audition different amplifiers (or receivers) by hooking them up to your previously selected speakers to determine if the amplifier has sufficient power reserve to produce undistorted sound at your highest preferred listening levels.

Prior to November, 1974, many amplifier manufacturers specified the power-output ratings of their products in a variety of different ways, leading to all sorts of confusion regarding amplifier power ratings that was even worse than that associated with signal-to-noise ratios. After November, 1974, all amplifier manufacturers were required to state power ratings in very specific terms, as

![Block Diagram of an Amplifier](image)
AMPLIFIER CLASSES

As you read through the brochures supplied by various amplifier manufacturers, you will probably come across terms such as "Class A," "Class AB," "Class B," etc. These terms all refer to the type of circuits used in the final power-output stages of audio amplifiers. There are many ways in which to arrange an amplifier's output stages, and these are identified by the "power" nomenclature. While it is possible to design good-sounding amplifiers in all classes, let's examine the difference between them.

In a Class-A amplifier, the transistor or transistors that supply power to the speaker load continuously conduct current, and that current value is essentially constant. In the absence of an audio signal, all the current (and power) is dissipated within the transistors themselves. When a signal appears, part of the power developed by the output stage is transferred to the speaker load. This arrangement is, therefore, highly inefficient, in that the same amount of power is drawn from the amplifier's power supply regardless of whether the amplifier is producing its maximum rated power, no power at all, or anything in between.

Class-A amplifiers (what few exist these days) are therefore generally noted for their lower power-output ratings and require unusually large heatsink devices to dissipate the heat generated by the always fully on transistors. Class-A amplifiers are, however, capable of producing extremely low-distortion sound and are favored by those listeners to whom the unusual large energy consumption is of secondary importance.

A Class-B amplifier requires at least two output transistors. Each transistor is designed to amplify one-half of the alternating waveforms that constitute an audio signal. One transistor amplifies the positive-going wave, while the other transistor amplifies the negative-going half-cycle of each alternating transmission. In the absence of all audio input signals, each transistor draws almost no current, and a Class-B amplifier, in the absence of input signals, runs extremely cool. As signal levels increase, current drawn from the power supply increases until maximum power-output levels are reached. Thus, a Class-B amplifier is much more efficient than a Class-A unit.

Class-B efficiency (at full power output) can reach as high as 65% or so (it is less than that at lower power levels), as opposed to the typically low 20% to 25% for a Class-A design.

While Class-B amplifiers can be designed to produce equally low distortion, special care must be taken in their design to make sure that no discontinuities in output take place as the signal is switched from one transistor to the other. Failure to observe proper design techniques can result in "notch distortion," or "crossover distortion," which is particularly annoying at low listening levels.

Class-C amplifiers are not normally used in audio amplifier circuits, but are reserved for radio receivers and transmitters. A Class-C amplifier conducts for less than one-half of each cycle, and depends upon the flywheel action of an associated resonant circuit to fill in the missing portion of the waveform. A Class-C amplifier is therefore practical to use where the same single frequency is to be amplified continuously, but is impractical for amplifying constantly varying complex audio signals.

The so-called Class-D amplifier is also known as a "switching amplifier," or "pulse-width modulation" amplifier. One or two manufacturers offer limited quantities of Class-D amplifiers, and a great deal of experimentation with this type of amplifier continues.

In a Class-D amplifier, a very high-frequency series of pulses are modulated in their width by the audio signal. The output stages need to conduct for a short interval only to amplify the tips of these pulses, and when they do conduct, they are highly efficient—conducting as much as 90% to 95%. The high-frequency pulses associated with Class-D amplifiers (500 kHz or more) present special problems in the transistor switching speed and suitable transistor availability.

The recently developed Class-G amplifier uses a minimum of two pairs of output transistors. One pair is powered by a lower voltage supply than the other. When signal levels are relatively low, only the low-powered pair of transistors does the amplifying. When signals exceed the low-voltage supply amplitude, the other transistor pair, which operates from the higher voltage supply, takes over, while the first pair is simultaneously turned off. In this way, each pair of transistors is always operating over its most efficient range, and overall amplifier efficiency is greater with a Class-B design. Thus, less massive heatsinks are needed for the output transistors, and the complete amplifier or receiver is lighter in weight.

Somewhat similar to Class-G operation is the new and tentatively labeled Class-H amplifier. Only one set of output transistors is used, but these transistors are connected to two different power-supply voltages. The lower voltage powers the output devices for low-level signals, while the higher voltage takes over when the input signal amplitudes exceed the limits of the low-voltage supply. As in Class-G, this approach results in a more efficient use of the output transistors, and the audio signals themselves do not have to be switched from one device to another during the process.

Thus, a typical power-output specification might read:

"Power Output: 50 watts minimum continuous power into 8-ohm loads, at any frequency from 20 Hz to 20,000 Hz, with no more than 0.5% total harmonic distortion."

Since the rule simply states that all these facts must be given (but does not specify minimum acceptable numbers), some degree of care is still required. For example, suppose amplifier A has a power rating of 100 watts-per-channel, 8-ohm loads, from 20 Hz to 20 kHz at no more than 1.0% distortion, while amplifier B is rated at the same 100 watts-per-channel, 8-ohm loads, 20 Hz to 20 kHz at no more than 0.3% distortion. Clearly, amplifier B is the better of the two. Or, suppose amplifier A is rated at 100 watts-per-channel, 8-ohm loads, from 20 Hz to 20 kHz, with no more than 0.2% distortion; amplifier B also carries a 100-watt rating, 8-ohm loads, from 40 Hz to 15 kHz at no more than 0.2% distortion. In this case,
amplifier A is superior to amplifier B.

We have been using the word "distortion" without truly defining it. In fact, there are many forms of distortion that an amplifier can generate. Distortion is defined as any difference between the nature and composition of the signal input to the amplifier and the resulting output signal. The most common distortion is harmonic distortion. If, for example, a 400-Hz pure tone is fed to an amplifier, the output signal should contain an equally pure 400-Hz tone and nothing else. If multiples of that frequency show up in the output signal, such as 800 Hz, 1,200 Hz, 1,600 Hz, etc., the signal is said to contain harmonic distortion. While musical instruments produce complex harmonics or overtones, all of which should be faithfully reproduced by an amplifier, the amplifier should not generate its own harmonics, for these would change the overall musical timbre or coloration. Figures 3 and 4 show examples of amplifier-generated harmonic distortion. The upper trace of Fig. 3 shows that a single frequency or tone is reproduced by an amplifier with little or no distortion. The lower trace is a highly magnified representation of only the distortion components contained in the upper trace and appears as a virtual straight line (no distortion is present). If the same amplifier is driven beyond its power-output rating, the pure sinewave form will be clipped, as shown in Fig. 4. Under those circumstances, the distortion components (see the lower trace) are quite evident, and consist largely of third harmonic components. Harmonic distortion is specified in percent (%); and the lower the figure the better the amplification.

Another form of distortion that is usually specified is called IM (Intermodulation Distortion). This type of distortion arises when a complex of frequencies is fed to the amplifier instead of a single tone. In a poorly designed amplifier, high and low frequencies may beat against each other, causing sum-and-difference frequencies between the two to appear in the output of the amplifier. Since such musically unrelated frequency components were not present in the original signal, their presence at the amplifier's output, even in small percentages, can be quite disturbing to a listener. The IM distortion is also specified in percent, and the lower the figure the better.

More subtle forms of amplifier distortion have recently been discovered, but since accepted measurement standards for measuring them have not yet been agreed upon, harmonic and IM distortion are the two types most commonly found in the specifications sheets.

Figure 5 shows the IM and harmonic distortion-versus-power-output characteristics for a typical high-quality amplifier. Note that both forms of distortion remain quite low until the maximum power output is reached, at which time they tend to climb rapidly. That is why it is important to operate an amplifier within its power rating. To try to pump more power from an amplifier into a speaker that requires more than the amplifier can deliver leads to horrendous distortion levels.

We mentioned earlier that frequency response is cited for the preamplifier section in adherence to the prescribed RIAA equalization curve. In the case of the high-level sections of the amplifier, frequency response is quoted directly in hertz, and a tolerance or maximum deviation from flat response is included. The specification, "Frequency response: 20 Hz to 20 kHz" has no real meaning unless we also know the ±dB-tolerance associated with the response over that frequency range. A proper response statement would read: Frequency response: flat from 20 Hz to 20,000 Hz, ±0.5 dB, and this would be superior to one that stated: Frequency response: flat from 20 Hz to 20,000 Hz, ±2.0 dB.

Signal-to-noise ratios relative to the high-level inputs also appear in the specifications and are quoted in dB (with the higher values being better), and are ordinarily higher than those listed for the phono section.

The specification called damping factor is a measure of an amplifier's ability to control or suppress unwanted residual motion of the speaker cone caused by the mechanical inertia or by forces other than the driving audio signal itself. Stated as a simple number, higher damping factor values are better, although damping factors higher than 40 to 50 contribute no audible improvement to an amplifier's performance.
Front-Panel Controls and Features

Unlike low-fidelity "table radios," most high-fidelity amplifiers are equipped with separate power on/off switches. This arrangement permits setting the volume control at preferred points when turning the unit on and off. The balance control adjusts right- and left-channel listening levels so that they are equal (or, if you must sit closer to one speaker system than to another, the balance control can be used to adjust for that situation).

The need for tone controls, whether simple bass and treble controls or more elaborate types, often puzzles audio neophytes. If all the components in an audio system produce a uniform or flat frequency response, why do you require tone controls, which, after all, are designed to provide adjustments that alter the overall system response from that flat quality? It is true that amplifiers can be made to have a frequency response which is "ruler flat"; however, this does not necessarily apply to the loudspeaker system or even to the listening room (which, in a very real sense, is a system component). For this reason, and because different people prefer different tonal balance, tone controls are a very necessary feature.

Some amplifiers, in an attempt to cater to the audio purist who prefers not to use tone controls, offer a tone defeat switch or pushbutton that bypasses the tone control circuits completely. The standard bass and treble controls offer a wide range of adjustment, usually beginning above or below mid-frequencies (around 400 Hz to 1 kHz), as shown in Fig. 6. One disadvantage to this control range is the fact that when you want to boost extreme low or high frequencies (to compensate for deficient speaker bass or ultra-high treble) you necessarily also affect the response of frequencies that are closer to the middle of the audio range. To counteract this effect, some manufacturers offer tone controls having multiple turnover (or pivot) points, as shown in Fig. 7. Still other amplifiers offer main- and sub-tone controls; the former effecting a wide frequency range, the latter boosting or attenuating only the extreme bass or treble range. Recently, some amplifiers have begun to include a mid-range tone control that acts upon the mid-frequency range similar to the way the bass and treble controls affect those frequencies. Fig. 8 shows the range typical of many mid-range tone controls.

A loudness switch is another control usually found on amplifier front panels. Studies of human hearing long ago confirmed that when we listen to music at lower-than-lifelike loudness levels, our hearing is less sensitive to extreme bass and treble frequencies than to mid-frequencies. Since in a home listening environment we often listen to music at "background" levels, reproduced music tends to sound thin and lacking in brilliance. To compensate for this effect, actuating the loudness control switch causes the amplifier to automatically boost the bass (and sometimes the treble) by an amount commensurate with the main volume-control setting. At high settings (where listening levels are presumably loud and therefore do not require compensation), no compensation is inserted, but as the volume is lowered, increased amounts of compensation are added automatically. Figure 9 shows the action of a volume/loudness control for different volume-control settings. This compensates for the fact that the loudness of any tone is a function, not only of its intensity, but also of its frequency.

![Fig. 6—Typical Range of the bass and treble tone controls.](image)

![Fig. 7—Elaborate Tone Control circuitry include multiple user-selectable turnover frequencies.](image)

![Fig. 8—Midrange Tone Control offers additional flexibility over standard bass and treble controls.](image)

![Fig. 9—Loudness Compensation decreases as the volume level is raised.](image)
Another form of tone-altering control is the filter circuit. Low- and high-cut filter switches, often found on the front panels of amplifiers, attenuate frequencies above or below their respective cutoff points more steeply than regular bass and treble controls. Figure 10 shows a comparison between the action of tone controls and steep-cutoff filters. Such filters, if properly designed, are effective in reducing high-frequency hiss or noise, and in lessening the audible effect of lower-frequency turntable rumble without impinging too severely on the music.

The final decision

Up to this point, a great many amplifier specifications have been examined and, indeed, published specs are important parameters for choosing this important hi-fi component. We would never suggest, however, that published specifications tell the whole story. There are still a great many audio amplifier characteristics that cannot be defined or measured—at least not with state-of-the-art instruments and techniques.

There is one ultrasensitive instrument you should use in making a final choice—your own ears. Compare specifications and pricing, of course, but in the last analysis let your ears serve as the final judge. Listen to several amplifiers in the price and power category which you seek. Use a wide variety of musical programs to make these subjective sound quality judgments. Listen at low and high levels—until you are sure that you have chosen the right amplifier for your own selected high-fidelity system.

As a final aid, a brief summary of the specifications we have discussed appear in Table I. The values shown in the table can serve as a general guide only and may not conform in all cases to what is available in the audio marketplace. We hope, however, that this summary helps get you started and wish you good listening.

---

**TABLE I**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Low-cost</th>
<th>Mid-cost</th>
<th>High-priced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonic distortion at rated output (%)</td>
<td>0.8-1.5</td>
<td>0.3-0.5</td>
<td>Less than 0.3</td>
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<tr>
<td>Harmonic distortion at 1-watt output (%)</td>
<td>0.2-0.5</td>
<td>0.05-0.1</td>
<td>Under 0.95</td>
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<tr>
<td>IM distortion at rated output (%)</td>
<td>1.0-2.0</td>
<td>0.3-1.0</td>
<td>Under 0.3</td>
</tr>
<tr>
<td>IM distortion at 1-watt output (%)</td>
<td>0.5-1.0</td>
<td>0.2-0.5</td>
<td>Under 0.2</td>
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<tr>
<td>Power bandwidth (full power Hz-kHz)</td>
<td>40-10</td>
<td>20-20</td>
<td>20-20 or better</td>
</tr>
<tr>
<td>Damping factor</td>
<td>10-15</td>
<td>15-30</td>
<td>30 or higher</td>
</tr>
<tr>
<td>Phono S/N, unweighted referred to Input sensitivity (dB)</td>
<td>50-60</td>
<td>60-68</td>
<td>Above '68</td>
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<tr>
<td>Phono S/N, &quot;A&quot;-weighted, referred to 5-mV input &amp; 1-watt (or 0.5 volt for preamplifiers) output, per new IHF Standards (dB)</td>
<td>60-65</td>
<td>65-75</td>
<td>Above 75</td>
</tr>
<tr>
<td>High-level input S/N, unweighted, referenced to full rated output (dB)</td>
<td>65-75</td>
<td>75-80</td>
<td>Above 80</td>
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<tr>
<td>High-level input S/N, &quot;A&quot;-weighted, referenced to 0.5-volt input and 1.0-watt (or 0.5-volt, for preamplifiers) output, per new IHF Standards (dB)</td>
<td>60-70</td>
<td>70-75</td>
<td>Above 75</td>
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<tr>
<td>Residual hum and noise referred to full output, unweighted (dB)</td>
<td>75-85</td>
<td>85-95</td>
<td>Above 95</td>
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<tr>
<td>Residual hum-and noise, &quot;A&quot;-weighted, referred to 1-watt (or 0.5-volt for preamplifiers) output (dB)</td>
<td>70-80</td>
<td>80-90</td>
<td>Above 90</td>
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<td>Phono frequency response (RIAA—dB)</td>
<td>±1.0-2.0</td>
<td>±0.5-1.0</td>
<td>±0.3 or less</td>
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<tr>
<td>High-level Input frequency response (Hz-kHz, dB)</td>
<td>20-20, ±2.0</td>
<td>15 Hz-25 kHz, ±1</td>
<td>10-30, ±0.5 or better</td>
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<tr>
<td>Phono overload (mV)</td>
<td>50-70</td>
<td>80-100</td>
<td>Greater than 100</td>
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</table>

(NOTE: The power output of an amplifier is not an indication of its quality, but is dictated by price and design objectives.)
## STEREO-AMPLIFIER ROUNDPUP

<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>MODEL</th>
<th>PRICE</th>
<th>POWER OUTPUT CAPABILITY</th>
<th>DISTORTION</th>
<th>PHONO PREAMPLIFIER</th>
<th>HIGH-LEVEL INPUT</th>
<th>COMPONENT MATCHING</th>
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<td>8(\Omega) @ 20kHz (W)</td>
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<td>IM &amp; MW (W)</td>
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<td>&lt;0.1 &lt;0.25 &lt;0.1</td>
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<td>$749.00</td>
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CIRCLE NUMBER 120 ON FREE INFORMATION CARD FOR LIST OF ADDRESSES.
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<th>INPUT SENSITIVITY</th>
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*NEW ACOUSTIC DIMENSION:
3000        2200        1900        1530        1360        1300        1200        1000        800        480
1300        1000        800        480
*POWER OUTPUT CAPABILITY:
25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW

*POWER OUTPUT CAPABILITY:
25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW        25mW
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<th>$2 @ 500H (W)</th>
<th>$2 @ 1000H (W)</th>
<th>FREQUENCY LIMITS FOR PEAKED OUTPUT</th>
<th>DYNAMIC RANGE (dB)</th>
<th>NO. @ RATED OUTPUT (mW)</th>
<th>% NO. @ RATED OUTPUT (%)</th>
<th>DAMPING FACTOR (dB)</th>
<th>PHONO PREAMPLIFIER</th>
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CIRCLE NUMBER 120 ON FREE INFORMATION CARD FOR LIST OF ADDRESSES.
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<th>MANUFACTURER</th>
<th>MODEL</th>
<th>PRICE</th>
<th>6Ω @ 2W, 1KΩ (W)</th>
<th>6Ω @ 2W, 8Ω (W)</th>
<th>6Ω @ 20W, 1KΩ (W)</th>
<th>6Ω @ 20W, 8Ω (W)</th>
<th>FREQUENCY Response (10Hz-20kHz)</th>
<th>DYNAMIC RANGE (dB)</th>
<th>MAX. RATED OUTPUT (W)</th>
<th>IN @ 1KΩ, 10KΩ, 0.1%(THD)</th>
<th>IN @ 100Ω, IN, 0.1%(THD)</th>
<th>DISTORTION</th>
<th>PHONO PREAMPLIFIER</th>
<th>HIGH-LEVEL INPUT</th>
<th>COMPONENT MATCHING</th>
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NOTES:
1. AT 20Hz~20kHz
2. AT 1kHz
3. UNWEIGHTED
4. FOR 25W OUT
5. FOR 100W OUT
6. S/N RATIO
7. FOR RATED POWER
8. FOR PHONO INPUT
9. 10mV IN
10. RATED POWER
11. 20Hz~20kHz
12. MINIMUM
13. REFERENCE TO 2.5mV
14. RE, 150mV INPUT
15. REF 120W, 20V/m IN
16. THD AT RATED OUTPUT, 2W TO 20kHz
17. THD AT 1% POWER, 1kHz
18. DAMPING FACTOR AT 1kHz ACROSS 8 OHMS
19. S/N RATIO ("A" WEIGHED WITH 5mV INPUT
20. "A" WEIGHTED S/N RATIO AT RATED POWER
21. RESIDUAL NOISE, "A" WEIGHTED, IN mV
22. HIGH-LEVEL INPUT SENSITIVITY FOR RATED
23. THE SAME FIGURE APPLIES TO AUX, TUNER AND TAPE POSITIONS
24. AT 30 WATTS
25. AT 50 WATTS

CIRCLE NUMBER 120 ON FREE INFORMATION CARD FOR LIST OF ADDRESSES.
Part 4—This month we discuss in detail the theory of operation and the construction of the voltmeter and digital frequency meter that are essential to maximum usage of this audio test station.

RAY DAVISON

THIS MONTH, WE CONCLUDE THE CONSTRUCTION DETAILS OF THE AUDIO TEST STATION WITH THE VOLTOMETER AND FREQUENCY COUNTER SECTIONS.

VOLTMETER SECTION

The voltmeter circuit shown in Fig. 10 has two separate inputs. One is labelled EXT INPUT, which is a high-impedance low-gain input for line-level signals and the other is labelled MIKE INPUT, which is a low-impedance, high-gain input for low-level low-impedance signals. The front panel connector for the MIKE INPUT (J6) is a standard XLR type. The mike input circuitry consists of IC601 and its associated components, which form a balanced-line receiver. Resistor R601 terminates the line and R603 and R602 set the gain of IC601. The gain as seen from pin 3 of J6 is 16. The gain of the + input of IC601 is 16 + 1 or 17. Therefore, R603 and R604 are added to form a voltage divider so the overall gain of a signal applied at J6 pin 2 is the same as for a signal applied at J6 pin 3. This satisfies the basic purpose for having a balanced transmission line, namely common-mode rejection.

The balanced transmission line reduces the effect of stray signals picked up by interconnecting cables. The most susceptible stray pickup point in sound systems is a microphone cable. It is not that the mike cable itself is more susceptible, but rather that the microphone supplies such a low-level signal that it is relatively easy to pick up enough of a stray signal to be audible when mixed and amplified with the mike signal. The stray signal is often induced into a mike cable when the cable is in the presence of an electric or magnetic field.

The mike input circuitry inverts the signal applied to J6 pin 3, while the signal applied to pin 2 is not inverted. The actual mike signal that is applied to J6 pin 3 is of equal magnitude and opposite polarity of that which is applied to pin 2. Op-amp IC601 inverts the negative signal at pin 3, and adds this to the positive signal at pin 2.

When stray signals that are induced into the cable arrive at J6 pins 2 and 3 in phase, the signal at pin 3 is inverted and added to that at pin 2. However, this is subtraction. The result is what is known as common-mode rejection. A signal that was common to both inputs is rejected.

This circuit is normally shown with the four resistors of high precision and fixed value. In this circuit the common-mode rejection is simply trimmed by R604. To do this, connect a signal simultaneously at J6 pins 2 and 3. A mid-frequency sine wave at about a half a volt peak-to-peak is suitable. Set S17 to −72 dB, adjust R604 for minimum output from IC603. The signal at the output of IC603 should be about the same magnitude as the input signal. Note that the same signal applied to either input alone would have been amplified by about 4,000 or 72 dB. Therefore, since the signal was passed with a gain of approximately 1, the common-mode rejection ratio is the 72 dB that the signal would ordinarily have been amplified by.

We have used this type of mike preamp in sound systems with mike cable lengths of well over 100 feet without any apparent extraneous pickup. However, for sound system use, the 748 is much too noisy. This can be easily remedied though by replacing the 748 with something like TI's TL071. The two parts are pin-compatible, and the 5-PE compensation capacitors used for the 748 can even be left in place when switching to the TL071. The difference in noise levels is dramatic.

A second-stage preamp consisting of IC602 is included. Having the preamp in two stages accomplishes a couple of things. First, the supply voltages are rather close to the maximum output voltage. A single amplifier with 48-dB gain and with an attenuator at the output would clip at signal amplitudes intended for the low-gain attenuator setting. In fact a signal which yields full scale on the −30-dB setting causes IC602 to clip.

Another reason for cascading is that the overall bandwidth is increased. This allows two common op-amps to be used in place of a single high-frequency unit.

Switch S16 selects one of three high-level inputs. The sweep generator and timebase pickup points are on the inboard side of the fuse that is used in conjunction with the output overvoltage sensors. Therefore, if there is no output from the sweep generator or timebase but its level can be read on the meter, it indicates a blown fuse. Capacitor C603 blocks any DC component present at S16. Resistors R610 through R615 form the actual input attenuator. Consider for the moment just this resistor string and S17. There is stray capacitance between every node of that resistor string and every other node. The result is a very complex R-C filter. At low frequencies, it is a simple voltage divider whose transfer function can be easily determined by simple arithmetic. Higher frequencies, however, travel from node to node in a manner that is quite difficult to predict accurately.

Capacitors C604 through C609 are added as an attempt to swamp out the internodal stray capacitance. This is
called attenuator compensation. For purposes of simple compensation, the absolute capacitance values are relatively unimportant except that they must properly relate proportionately to the resistors that they are parallel with and the stray capacitances they are combining with. However, it is generally desirable to keep these capacitors small so as to minimize the total capacitance seen from the input.

If this were the input attenuator to an oscilloscope where waveform purity is of great importance, a low capacitance switch would be necessary. This is typically a large open-frame type with relatively large intercontact spacing. In this system, the problem is somewhat intensified by the use of a miniature switch where all nodes are in very close proximity. However, it is quite satisfactory up to at least 100 kHz, which should satisfy the needs of the system.

To adjust the compensating capacitors, monitor the output of IC603 with a scope. Apply a 10-15 kHz squarewave to the input and move S17 through each of the relevant positions. Adjust the capacitor immediately below the selected switch position for best squarewave response. Initial calibration of the attenuator will require several trials to bring the trimmers into proper relationship with each other. Once the adjustment is made with a squarewave input, a sinewave can be applied and swept from 10 kHz to 100 kHz to verify the overall response. Some fine tuning may be helpful at this time.

Assuming the sinewave from the time-base would be used for this last check, recall that the timebase begins a noticeable rolloff around 100 kHz. So be sure that any compensation adjustments made with the sinewave input are not compensating for timebase rolloff.

An additional gain stage and attenuator buffer consisting of IC603 is provided. Diodes D605 through D608 provide protection against excessive voltage applied to the external input. With S17 in the -24 dB position, IC603 is connected essentially straight to the external input. The diodes conduct at about 1 volt and are capable of 50 milliamp. Resistor R616 is intended to limit the diode current to a safe level. However, R616 cannot be arbitrarily large since it combines with the capacitance at the input of IC603 to form a low-pass filter. Since the diodes can handle 50 milliamp, 500V can be applied without damaging them. However, the power-handling capability of R616 must be considered at a fraction of that voltage level. If R616 is a half-watt resistor, it will tolerate 70 volts. The resistor can tolerate larger voltage levels than that for short periods of time. Since even a much smaller level will cause the meter to peg, if the operator is attentive, a 10K half-watt resistor should be adequate.

However, for insured safety R16 can be replaced with a positive temperature coefficient thermistor of approximately 10,000 ohms cold resistance. Such a device is a self-protecting resistor, since as excessive power causes it to heat, its resistance increases, which decreases the power and hence the heating effect. Also, keep in mind that R616 is of no-particular value and need only be large enough to protect the diodes and small enough not to degrade high-frequency performance.

IC610 is a comparator with hysteresis. A zero-crossing dejector is formed by applying a signal through an isolation resistor to the negative input. Applying positive feedback causes the detection point to shift, which results in a circuit that ignores signals smaller than the detection levels.

This circuit preconditions the voltmeter signal before it is applied to the counter. For the circuit shown, the overall result is that the counter will count an input whose magnitude is 10% of the full-scale setting selected by S17.

IC604 through IC607 form the AC-to-DC converter. IC604 and IC605 are a full-wave rectifier. One-half of an applied waveform is inverted and added to the noninverted half. Resistor R630 adjusts the relative gain of the inverted and noninverted parts of this waveform. Trimmer R625 adjusts the overall gain of the rectified waveform.

Components D611, C615 and IC606 form a peak detector. When the signal from IC605 goes positive, diode D611 conducts charging C615. Capacitor C615 is small and hence charges as fast as the voltage from IC605 rises. When the output of IC605 passes a peak and starts to decrease, diode D611 cuts off and IC606 is left with charged C615 on its input.
Capacitor C615 discharges through the input of IC606. The rate at which C615 discharges is called the droop rate. Note that when D611 is cut off, IC606 has no DC bias on the + input. This results in a negative offset from IC606 equal to 1 diode-drop. Trimmer R622 shifts the output of IC605 enough to compensate for this and hence zero the output of IC606.

Note that the three diodes in the circuit do not exhibit the 1/2-uV-volt threshold normally associated with a diode. The threshold is reduced to a negligible level by the active circuitry with which the diodes are associated.

The result so far then is a full-wave peak detector that will track an increasing amplitude instantaneously and track a decreasing amplitude at a slower rate, this rate being determined by the capacitor, and hence the droop rate is rather arbitrary and is based on the system under test.

If the acoustics of a large reverberant room are being analyzed, standing waves can cause wide fluctuation in amplitude. Tracing these rapid fluctuations requires a fast droop rate and hence a small capacitor. On the other hand, a fast droop rate will tend to track individual waveforms of a low-frequency signal. Therefore, to provide for difference response time requirements, S18 is provided to switch in a parallel capacitor, C616.

Also recall from the generator sections that there is a blanking mode that switches off the output of the audio generator at the end of a sweep. The same trigger that switches off the output of the audio generator turns on Q601, which rapidly discharges the capacitor at the input of IC606. Therefore, a clean cutoff is provided at the end of a plot.

The same signal that is applied to the peak detector is also applied to IC607. This is a true RMS-to-DC converter. Capacitor C617 controls the amount of filtering of the DC output. Unlike the peak detector, the response of IC607 is equal regarding both increasing and decreasing signal levels. Again S18 provides for a variable response time by adding C618 in parallel. Also the blanking trigger turns on Q602 to rapidly zero the output at the end of a sweep.

IC607 is a linear-to-log converter. Voltage gain in dB is defined as 20 times the log of the square voltage gain. There is a linear voltage at S19 that is zero for a zero level input and ranges up to 4 volts for either a 4-volt peak or RMS input. Since a true log function cannot be physically implemented because it is of infinite length, a decision must be made to use only part of the function and eliminate the region that extends below some practical limit.

To help select an appropriate range, note the effect of a log converter on a linear input signal. Input variations slightly above zero produce very large output variations. Therefore, such things as ripple from the peak detector would be greatly magnified at low levels. Eliminating the lower portion of the function produces a dead zone, for any input voltage below the cutoff point is ignored. The cutoff-point trade off is between low-level excessive sensitivity and total dynamic range, which is the remaining portion of the function. Thus, it was rather arbitrarily decided to cut off the function at minus 40 dB.

VOLTMETER PARTS LIST

Resistors, 1/4 watt, 5% or better
R601, R603, R617, R641—1000 ohms
R604, R620, R622, R625, R631, R633, R634, R640—50,000 ohms, trimmer
R605, R624—15,000 ohms
R606—R608—30,000 ohms, 1/4 watt, 1%
R607, R609—10,000 ohms, 1/4 watt, 1%
R610—768,000 ohms, 1/4 watt, 1%
R611—192,000 ohms, 1/4 watt, 1%
R612—48,000 ohms, 1/4 watt, 1%
R613—12,000 ohms, 1/4 watt, 1%
R614—3000 ohms, 1/4 watt, 1%
R615—1000 ohms, 1/4 watt, 1%
R616, R628, R629, R632, R637, R638—10,000 ohms, 1/4 watt
R618, R621—30,000 ohms
R623, R627—1 megohm
R616—100,000 ohms
R630—820 ohms
R635, R636—1000 ohms, trimmer
R639—330,000 ohms
R642—2200 ohms
R643—1500 ohms

Capacitors
C601, C602, C613, C614—5 pF disc ceramic
C603—0.1 pF disc ceramic
C604—5—15 pF trimmer
C605—7—40 pF trimmer
C606, C608—100—400 pF trimmer
C607—680 pF disc ceramic
C609—0.005 µF disc ceramic
C610—100 µF electrolytic, 16 volts or higher
C611, C612—33 µF, electrolytic, 16 volts or higher
C615—0.001 µF disc ceramic
C616—0.01 µF disc ceramic
C617—2.2 µF electrolytic or tantalum
C618—22 µF electrolytic, 16 volts or higher
C619—C622—10 µF electrolytic, 16 volts or higher
C623—10 pF disc ceramic
C624—2.5—10 pF disc ceramic
C625—100 pF disc ceramic
C626—10 pF disc ceramic

Semiconductors
IC601, IC602, IC605—748
IC603, IC604, IC610—310
IC606—LH0991 (National)
IC607—7048 (Intersil)
IC608, IC609—741
D601—D604—1N4001
D609—D611—1N4148
Q601, Q602—T1597

Miscellaneous
S15, S16—DPDT toggle switch
S16—SP3-position toggle switch
S17—SP10-position rotary switch
S19, S20—SPDT toggle switch
J6—3-terminal microphone connector
J7—BNC connector
M601—1-mA DC meter
OV601—LA10 overvoltage limiter (MCG Electronics)
F601—0.5-amp fuse
The next task is to physically eliminate the lower portion of the function. To accomplish this, R631 applies a negative voltage to the inverting input of the output stage of IC607. This drives the log waveform up against a positive supply rail, which limits the transition or deflection. IC608 and its associated components provide proper polarity as well as gain and zero set.

Switch S20 selects the log signal, which was just described, or the linear signal, which is simply a bypass of the log converter. Resistor R635 converts the voltage signal to a current signal to drive the meter. A one-milliamp movement is quite satisfactory. Since audio measurements can sometimes be quite dynamic, it is preferable that the movement be critically damped.

IC609 is a very low-impedance output buffer. When connected in this manner, the impedance, looking back into the device, is that of the negative input, which is a virtual ground. IC609 is not really necessary but it does provide lower output impedance, isolation of the signal to the meter and better output protection than the circuit would have without it.

Overvoltage limiter OV601 limits the effect of the application of an external voltage; the same type optional unit is recommended here as was recommended for the other sections. Fuse F601 protects the overvoltage protector from excessive dissipation.

Assembly of this section is straightforward. Figure 11 shows the location of the voltmeter section with respect to the entire PC board and Fig. 12 shows the location of the components.

Counter section

The schematic diagram of the frequency counter is shown in Fig. 13. Section b of S21 is the counter power switch; switch S21-a selects the signal to be counted. In one position the counter counts whatever signal is applied to the voltmeter. The voltmeter signal, however, can possibly be very low amplitude or altered in some way by the system under test so that it does not provide true and stable triggering of the counter. Therefore, S21-b can alternately select an internal signal from the audio sweep generator section. Stable counting of the sweep generator signal is thus always assured regardless of what happens to that signal as it is processed by the system under test.

The counter timebase establishes the counting period or window. The counting circuit counts each cycle of the input waveform that occurs during the time the window is open. If the counting window is 1 second, the total number of cycles counted is the average frequency of the input signal during that second in Hz.

This system uses both 1-second and 1/4-second counting windows. The one-half second window is more useful for tracking a swept frequency.

The timebase, which establishes a counting window, is derived from the power line and selected by switch S22. Resistor R702 is a pull-down resistor for the input of counter IC702. With pin 11 connected to ground, IC702 divides by 60. With pin 11 connected to V+ (which for the counter section is 12V), it divides by 50. On the circuit board, pin 11 is connected to ground. To convert the unit to a 50-cycle power line, it is only necessary to cut a circuit on the back side of the board and install a short bus wire jumper between two pads, which are provided for this purpose. Cutting the circuit disconnects pin 11 from ground. Adding the jumper connects pin 11 to V+. The output of IC702 then is a pulse train whose frequency is either 1 or 2 times the power-line frequency.

IC703 is a dual one-shot. For each input pulse, IC703 provides a negative going store pulse. This store pulse is about 10-µs wide. This time is determined by C703 and R703. As the store pulse terminates, it triggers the second one-shot, which produces a positive going clear pulse. The width of the clear pulse is determined by C704 and R704 and is also about 10 µs. The counting window then is from the end of the clear pulse to the beginning of the next store pulse. These two pulses shorten the counting window by about 25 µs, inducing an error of 25 parts-per-million for a one-second update time or 50 parts-per-million for a half-second update. This error is insignificant in comparison to the normal power-line frequency variation. Line frequency er-
**COUNTER PARTS LIST**

- R701 — 100 ohms, ¼ watt, 5% or better
- R702 — 100,000 ohms, ¼ watt, 5% or better
- R703, R704 — 22,000 ohms, ¼ watt, 5% or better
- R705–R711 — 330 ohms, 1 watt, 5% or better
- C701 — 1 μF electrolytic, 16 volts or higher
- C702 — 0.005 μF disc ceramic
- C703–C705 — 0.001 μF disc ceramic
- IC701 — 4030 or 4070
- IC702 — 4556
- IC703 — 4528
- IC704 — MK50395N
- IC705 — UDN2982A (Sprague)
- IC706 — ULN2004A (Sprague)
- DIS1–DIS6—MAN72 7-segment display
- S21—DP3-position toggle switch
- S22—DPDT toggle switch

The following are available from FSI, 1894 Commercenter W., No. 105, San Bernardino, CA 92408: Complete Kit, $495.00; cabinet and circuit board, $115.00. Set of semiconductors, $195.00; seven slide pots with knobs, $17.00; set of trimmers including four multiturn pots, $17.00.

California residents add state and local taxes as applicable.

*To test display add jumper. Display shows all 8's.*

FIG. 13 (above)—THE SCHEMATIC of the digital frequency meter. FIG. 14 (left)—THE AREA OCCUPIED by the frequency meter. FIG. 15 (lower left)—LAYOUT OF PARTS in the frequency counter. IC105 at top center is a voltage regulator that is a part of the power supply.

The errors are a fraction of a percent. The overall result is a timebase-caused error in the fourth or fifth significant figure of the displayed frequency.

IC701 is a quad exclusive OR gate connected as a frequency doubler. Gate continued on page 105
COMMUNICATIONS

TROUBLESHOOTING CB Receivers

The receiver circuits in Citizens band transceivers can develop defects that affect range and performance. Here's a look at basic circuits and suitable test equipment.

FOREST BELT

THE SIGNALS NEEDED FOR CB RECEIVER servicing are not drastically different from those for FM two-way radios. Yet, because they are simpler, CB signal generators typically cost less than those designed for FM communications. Citizens band involves only a limited range of VHF signals—from 26.965 MHz to 27.405 MHz. You need IF (or high-IF) signals, usually, from 4 MHz to 12 MHz. Certain noise blankers take 21-MHz, 23-MHz and 25-MHz signals for correct alignment. And of course there's the 455-kHz IF that seems standard almost everywhere.

A CB generator uses AM modulation; and that's easy. However, there is one tricky concern: checking out the single-sideband function of AM/SSB receivers. Ordinary amplitude modulation doesn't suffice for that job. So, for SSB tests, you'll want your CB generator to have a frequency-offset feature. Various generators include this capability, but in different formats.

Basically, an overall alignment procedure follows the pattern for other communications receivers. There's no demodulator calibration for AM, nor any limiter stages. The first steps in an alignment procedure takes care of the 455-kHz IF stages.

The AM detector is a good—and usually convenient—place to connect your DC voltmeter as an alignment indicator. As the signal reaches the AM detector, the diode (or diodes) develops (by rectification) a DC component that is proportional to the carrier strength. This is often the same DC voltage used for the automatic gain control (AGC) of RF and IF stages, and in many CB receivers to control the squelch system.

Find the AM detector. Three common versions are shown in Fig. 1. Identify the detector output side on the circuit board; usually it's at the anode end of the series diode. This orientation makes the rectified DC negative with respect to ground. So the negative or black lead of your DC voltmeter clips to the detector output. The other (red) voltmeter lead goes to the negative power bus (note—only in a few chassis is this bus the same as chassis ground). If the diodes are wired with the cathode to the output side (Fig. 1-c), you'll have to reverse the voltmeter leads.

If a receiver has an S-meter, you can usually depend on it as an alignment indicator. Just make sure (using the schematic as a guide) that the S-meter senses signal strength after the last IF stage and not before. A few S-meters are driven directly by the AM detector or by a DC-driven AGC system; either of these systems is OK for alignment.

Set the signal generator for 455 kHz. Although accuracy is not so critical as for FM demodulator alignment; the frequency should be relatively close. And it must be stable—free of any significant drift. If you have any doubts, monitor the generator output with a frequency counter.

Feed the 455-kHz signal into the base of the mixer transistor just preceding the 455-kHz IF stages. Turn up the generator output just enough to show a noticeable DC meter reading at the AM detector. Do not turn it high enough to flatten out the indication. That is, if more input

![Fig. 1—MOST AM DETECTORS have diodes oriented for negative-going input, as shown in a and b. A few doubler detectors have diodes wired so that output is positive-going as in c.](image-url)
signal causes hardly any additional meter deflection, you've turned the generator output level too high.

Now adjust the mixer output coils and the 455-kHz IF transformers for a maximum DC reading. Where any core adjustment does not show a sharp peak, suspect trouble. The most likely culprits are: (1) a generator set for too much output; (2) a defective coil or slug; (3) an open decoupling capacitor for that winding; or (4) too much leakage from a transistor junction either before or after that coil. The cure for each should be obvious.

High-IF section

Some CB receivers do not have a 455-kHz IF. They use only one single-conversion mixer. The IF is in the megahertz range, just as it would be for a double-conversion mixer. In this case, however, the high-IF signal feeds the AM detector directly.

This design is most often found in AM/SSB receivers. The block diagram of Fig. 2 shows why. Signal insertion for SSB demodulation takes place at the same frequency used for SSB signal generation in the transmitter, so that the same oscillator is used. Hence, the receiver high-IF is chosen to match.

During AM operation, the same IF signal feeds an AM detector, with no need to heterodyne down to 455 kHz. The main advantage of the second conversion, which would be useless during SSB reception anyway, would be greater AM selectivity. However, today's crystal filters for high-IF stages have very steep skirts. Further bandwidth filtering is not absolutely necessary. A designer can choose an exceptionally sharp-sided high-IF filter, and get by without the extra mixer and extra IF section.

If you're dealing with a single-conversion receiver that has only the high-IF section, alignment procedure starts the same as for low-IF. Clip your DC voltmeter to the AM detector. (Never try to align in the SSB mode.) Feed the base of the mixer transistor with an accurate high-IF signal. Common frequencies are 7.8 MHz, 10.7 MHz and 12 MHz. Check the schematic or the service notes for the set you are aligning. The high-IF filter may have the frequency stamped on it. (This filter often does double duty as the SSB filter.)

Adjust the generator output as already described—enough for a DC reading at the AM detector, but not enough to saturate the RF or IF stages. Peak all the mixer and IF adjustments. As a trouble-finding aid, note any adjustments that peak too broadly.

In double-conversion sets, align the high-IF section after making sure the low-IF stages are OK. However, first verify that the second receive oscillator feeds the right frequency to the second mixer. The schematic usually gives the crystal frequency, but not always to fine enough accuracy. For example, a 7.8-MHz high-IF requires a 7.345-MHz crystal in the second conversion oscillator. The diagram could indicate only a 7.3-MHz frequency. Use your knowledge of heterodyning and a calculator to determine the exact frequency. Then, using your frequency counter, measure this frequency at the output of the oscillator.

You can use an alternative approach if your signal generator has digital dial-up accuracy. Use the high-accuracy generator for the 455-kHz alignment, as already described. Then, without changing the feed point, move the generator frequency to the high-IF. Keeping an eye on the DC voltmeter, raise and lower the frequency in 100-hertz steps. The highest DC voltmeter reading should coincide exactly with the high-IF design frequency.

If it doesn't, the crystal probably has
TABLE 1—CB SIGNAL GENERATORS

<table>
<thead>
<tr>
<th>Mfr Brand</th>
<th>Model</th>
<th>Output (mV)</th>
<th>Accuracy (ppm)</th>
<th>PLL</th>
<th>SSB offset</th>
<th>IF Signals</th>
<th>Low (kHz)</th>
<th>High (MHz)</th>
<th>EIA NB test</th>
</tr>
</thead>
<tbody>
<tr>
<td>B&amp;K/</td>
<td>2040</td>
<td>100</td>
<td>5</td>
<td>✓</td>
<td>Var</td>
<td></td>
<td>455</td>
<td>—</td>
<td>Yes</td>
</tr>
<tr>
<td>Precision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Com-Ser²</td>
<td>CB-2700</td>
<td>1</td>
<td>5</td>
<td>✓</td>
<td>—</td>
<td>±1 kHz</td>
<td>30 up to 12</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Hickok</td>
<td>266</td>
<td>100</td>
<td>5</td>
<td>✓</td>
<td>Var &amp;</td>
<td>±1 kHz</td>
<td>455</td>
<td>1-20³</td>
<td>Yes</td>
</tr>
<tr>
<td>Leader</td>
<td>LSG-227</td>
<td>100</td>
<td>5</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logi-Metrics</td>
<td>981²</td>
<td>20</td>
<td>2</td>
<td></td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sencore</td>
<td>CB4²</td>
<td>100</td>
<td>5</td>
<td>✓</td>
<td></td>
<td>±1 kHz</td>
<td>375 up to 12</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Time &amp;</td>
<td>CBW</td>
<td>300</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>Technology</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Var = Variable.
1. ppm = parts per million. 5 ppm equals 0.00005 percent.
2. Has features in addition to signal generator.
3. Needs external crystal for each high-IF frequency.

shifted frequency. The second oscillator circuit may contain a frequency adjustment, but many do not. A shift in frequency of more than 300 Hz from the center can degrade reception enough to justify replacing the crystal. Besides, the error will only grow worse.

A quick trick

The crystal-controlled nature of a CB receiver offers an excellent opportunity to save some alignment time. This time-saving procedure works best for single-conversion, whether the IF is 455 kHz or several megahertz. It also—usually—works OK for double-conversion, if you follow the procedure carefully.

You need a highly accurate signal generator, any of the phase-locked models (see Table 1) will have sufficient accuracy and stability. Once you're familiar with the CB models you work on most, you may like this shortcut.

Follow the procedure shown in the block diagram of Fig. 3. Coils have been added to show the adjustments you may encounter; some sets have fewer, some have more.

First thing you do is jump in with your frequency counter and verify the frequencies generated by the phase-locked loop (PLL) or use a frequency synthesizer if the CB is an older model. Keep the transceiver's RF input connected to a dummy load during these measurements. This is to avoid any stray inputs that might confuse the frequency counter. A test point is usually provided for the counter near the mixer input. Check all channels.

Next, measure the frequency of the receive oscillator. It may be adjustable, so you can set the frequency precisely. If the set is a single-sideband model, look for another oscillator or two in the same vicinity. Set these oscillators while you're at it. A test point or test points nearby accommodate the frequency counter. Certain elaborate CB models have three or four oscillators, for various modes. Measure the frequencies of them all, switching to the appropriate modes of transceiver operation. Correct any that are adjustable. Install a new crystal anywhere the error exceeds a couple of hundred kilohertz.

Feed an accurate generator signal right into the front end (remove the dummy load). Set the generator for Channel 21. (Use Channel 13 in 23-channel sets.) No modulation is needed from the generator. Connect your DC voltmeter at the AM detector, as already described. Set the receiver for Channel 21, and select the AM mode. Turn up the generator output so that a reading is obtained on the meter.

Since you've already determined that all conversion oscillators and the phase-locked loop (or synthesizer) are of frequency, you can now peak all the IF and RF adjustments for maximum DC at the AM detector. If the reading goes too high with the peaks too broad, reduce the generator output somewhat.

The beauty of this procedure, once you know where to find the oscillator and PLL (or synthesizer) test points, is its simplicity and speed. It is also thorough. If there's a problem in the oscillator or the PLL, it appears during your frequency-counter tests. (Note—of course, the frequency counter must have enough sensitivity to measure oscillators directly. Oscillators in CB sets usually have an output range from 20 mV to 50 mV RMS.)

You complete RF and IF alignment both with one connection of your signal generator, which saves time. And, naturally, any weaknesses or oscillations in those stages become evident as you adjust.

Unwanted oscillations in the RF or IF stages appear generally as an uncontrollably high DC reading at the AM detector. Often, this appears as you peak an adjustment, and is usually because somebody detuned the stages to cure the squawk or distortion. The true cure is substituting a new decoupling capacitor, a new coil assembly, or (rarely) a transistor with less inter-element capacitance.

Selectivity filters

You can check the bandwidth filters in CB sets in much the same way as in FM
two-way receivers. But there is a handy evaluation, using the same test setup as for RF alignment.

The generator signal feeds into the antenna jack. The receiver and generator both operate on Channel 21 (or Channel 13). Keep the DC voltmeter at the detector output. However, here are two differences. Turn the generator output up to 50,000 µV, and add 30 percent modulation. Yes, the RF and IF stages will be saturated, the AGC will be fully operative, and the DC meter reading will be at its peak. Set the volume for comfortable listening.

Leaving the receiver set to Channel 21, change the generator frequency to Channel 20, which is 27.205 MHz. You'll note a drastic reduction in sound from the speaker, and in the DC meter reading. Turn up the volume enough to hear some sound, even if it's just noise with very little demodulated sound. Adjust the generator output, if there's enough, for a measurable DC meter reading.

Next, switch the generator frequency to Channel 22, or 27.225 MHz. The DC meter reading and the recovered sound should be the same as they were when you fed in Channel 20. If there is much difference, the alignment is faulty or the filter is off-center. Since a complete alignment procedure was performed before you made this test and you made sure all coils peak properly, the defect is likely to be in the filter.

You probably recognize what you're doing in this quick test—assessing adjacent-channel rejection. You can measure actual decibels of rejection. This test gives only an approximation. In a properly operating CB receiver, sound recovered under adjacent-channel conditions should drop to weak sound with some noise in the speaker. That signal drop represents about 50 dB of rejection, which is roughly equivalent to reducing the generator signal from 50 mV to 0.5 µV (on-channel).

Measuring adjacent-channel rejection takes only enough (or more) time to connect an audio voltmeter across the speaker. Set the generator to Channel 21, the output to 1 µV and modulation to 30 percent. Set the receiver to Channel 21, and adjust the volume control to give an audio output of 1.5 volts RMS. That's your reference audio level.

Switch the generator to Channel 20. Increase the generator RF signal, in decade steps, until the audio output meter reads 1.5 volts RMS or close to it. Each RF increase by a factor of 10 represents 10 dB of adjacent-channel rejection. For example, if the adjacent-channel audio output comes up to 1.5 volts RMS again when the RF signal from the generator is increased from 1 µV to 1000 µV, the adjacent-channel rejection is 30 dB. If it takes 10,000 µV, the rejection is 40 dB. A 100,000-µV signal means 50 dB of rejection. The average modern CB receiver shows a rejection of 40 dB or so.

With this approach, you can assume the selectivity filter is faulty if (1) adjacent-channel rejection is less than 20 dB, or (2) if rejection values above and below the receiver channel are more than 10 dB apart. This judgment presumes that you have finished troubleshooting and aligning the RF and IF sections before testing adjacent-channel rejection.

The cure for a faulty filter is usually a new filter. If adjacent-channel rejection is balanced but poor, check carefully the input and output loading of the suspected filter. This includes the transistor preceding the filter and following it, plus the decoupling capacitors in the base or collector circuits of those transistors. New filters are somewhat expensive in some models, so you want to be as sure as you can.

Noise blankers

Manufacturers of specialized CB generators seem to have overlooked noise-blanker adjustments. They provide no signal for aligning the RF input coils. Inexpensive CB receivers of course have no noise blanker to consider. Some blankers sense pulse noise after the first mixer; any input coils tune to the high-IF. Others have untuned inputs, but several still incorporate a system similar to the one shown by the block diagram of Fig. 4, in which the coils are included to indicate their positions. An IC chip contains most of the blanker stages in newer CB receivers.

For alignment purposes, what concerns you mainly are the input coils. In Fig. 4, these coils are shown to peak at 21 MHz. However, some set designers choose 23 MHz or 25 MHz. A significant part of the objective is rejection of 27-MHz signals. But the blanker system needs the gain these stages afford at their own RF frequencies. This gain assures efficient diode output; an IC usually has a test point for this connection. Feed just enough signal into the antenna jack (at the listed blanker-coil frequency) to cause a meter reading, and peak the RF coils.

That's all there is to it. Accuracy isn't critical, but you use a stable signal source because even small frequency changes could lead to a broadening of blanker response.

SSB tests

When you've aligned and tested a CB receiver for AM operation, you've already covered almost everything in the RF and IF stages that could interfere with SSB reception. Any symptom present in SSB only indicates a demodulator or mode-switching fault. The SSB demodulator normally is the same circuit as the SSB modulator. Servicing it as a transmit function proves easier than troubleshooting its receive function. So, if the complaint is an SSB "receive-only" symptom, mode-switching seems about all that's left.

To corroborate your evaluations of receiver operation after you've finished all AM alignment and assessment, you can test SSB reception with your CB signal generator. Here's the way to do it, quick and easy if your generator has the right controls.

What does "right controls" mean? It means you must be able to offset the channel carrier by 1 kHz (1000 Hz), accurately. You see this easiest in a generator with digital frequency knobs. For example, for CB Channel 21 at 27.215 MHz, the frequency reading on a 500-MHz signal generator that has a 7-digit dial would be 027.2150 MHz. To raise the frequency (the upper sideband) by 1 kHz, change the dial to read 027.2160 MHz. For the lower sideband, set the dial at 027.2140 MHz. Use no pickup of ignition-noise pulses, because automotive-noise RF energy is strong in the 20–30-MHz frequency range.

In the absence of noise pulses, such as when an unmodulated RF test signal is used, the pulse-detector diode acs similar to an AM detector. That is, it produces a DC voltage that is proportional to RF signal strength.

Connect your DC voltmeter at the modulation, just RF.

Set the receiver for AM at first. With the generator frequency set to channel center (027.2150 MHz), you should hear no sound in the speaker. Set the receiver for LSB operation, and set the signal generator for 027.2140 MHz. You should hear a 1000-Hz tone, and a frequency counter across the speaker should have no
A new monthly column devoted to the latest developments in
the communications field.

HERB FRIEDMAN, COMMUNICATIONS EDITOR

WELCOME TO "COMMUNICATIONS CORNER," a new monthly column devoted exclusively to the latest developments in the field of communications as they affect CB, SWL, VHF/UHF radio, amateur radio—and whatever else comes along as a result of new technologies.

Just a few short years ago, each of these individual branches in the field of communications would have been considered separately and covered by separate articles and feature stories. But because of the "crossover" factor, whereby a modern technological development for one branch finds instant application to other branches under the umbrella labelled "communications," a better picture of what's happening today and what will happen tomorrow is attained by combining all aspects of consumer communications into a single column.

We will try to describe not only the latest developments in general and specific communications, but how they are actually applied to the various pieces of equipment the average consumer, hobbyist and technician will find.

In many instances, we will introduce you to the "leading edge of the state of the art," although this leading edge could often be nothing more than a 30-year-old idea updated with modern devices, (such as the substitution of transistors for vacuum tubes). We plan (with cooperation from the manufacturers) to introduce you to new uses for old ideas, old uses for new ideas, and, of course, new uses for new ideas as they affect the world of communications.

To give you an idea of what to expect in future months, we're now going to touch all the bases with some of the very latest developments in all fields of consumer communications. Later columns will go into the nitty-gritty of individual circuits.

Computerized CB

Heading the list in terms of interest (or at least my own interest) is computerized CB transceivers. We've all been hearing about computerized CB for at least the past 12 months. Originally, the BIG NEWS was that "the biggie" company in computers and calculators was on the verge of introducing a computerized CB. Many months (and a poor year for sales) later, the "biggie" has yet to introduce their model; but computerized CB has now been introduced by Robyn and Pathcom (among others), with more to follow.

Actually, the computerization of CB is really receiver-oriented. There are variations, of course, but the basic idea is a microprocessor that permits the user to program a specific group of channels to be scanned for activity (busy channel) or lack of activity (clear channel). Alternatively, the computer can be programmed to scan all channels, or it could be programmed for operation on one channel with frequent checks of an alternate channel. (For example, Pathcom's Pace 8117 can be programmed to monitor a second channel once every 10 seconds for 1/2 second.)

While you cannot scan with the transmitter keyed, the transmitter usually follows the receiver in a computerized transceiver; so if the receiver stops on a channel during a scan, the transmitter is similarly tuned to the same channel. One main feature of the computer is that it prevents operation on unauthorized frequencies. For example, if you attempted to program the Pace 8117 for Channel 51 or even a 3-digit channel, as for example Channel 123, the computer says "tilt" to itself and defaults to Channel 19.

The Pace 8117's touch-pad, used for both channel entry and microprocessor programming, is shown in Fig. 1. This touch-pad is more or less typical of a computerized CB keyboard, and in later columns we'll cover touch-pad programming.

VHF/UHF

For several years, the more expensive VHF/UHF scanning monitor radios have allowed the user to digitally program a group of desired frequencies. Although somewhat more expensive then crystal-controlled scanners, the programmable scanners permitted the user to easily follow the special services—in particular the police—as they moved around the public-service bands. Usually, it took a not-very-accurate frequency list or handbook and some local undercover work to discover where the local safety services were moving as they hopsscotched around the low VHF (30–50 MHz), high VHF (146–174 MHz), UHF (450–500 MHz) and the "T" (Television—unassigned low UHF television channels) bands. But for every need there's an invention, and this year's is the "searching scanner." Microprocessor-controlled searching scanners, such as those manufactured by Radio Shack and Bearcat, allow you to program high- and low-frequency limits, which are then continuously scanned until an active frequency is located. Some of the more sophisticated models, such as the Bearcat model 250, keep a running count of each active frequency; and at the end of a given time period, you can read back total activity to determine which frequencies in your immediate locality are most used.

And, finally, there's a searching scanner for the aviation enthusiast, the Regency model ACT-T-720A Digital Flight Scan. This scanner covers airport and aviation frequencies from 108 MHz to 136 MHz. Like the VHF/UHF monitor radios, the model ACT-T-720A can be directly programmed to a desired frequency, or can be programmed to search a selected range of frequencies.

Amateur radio

After having spent many years in the doldrums in terms of both membership and equipment, amateur radio, the oldest of electronically oriented hobbies, has been given new life by modern technology. From new all-band VHF mobile antennas, to broadband-tuned transmitters and receivers, to an ever-expanding two-meter FM band, and, finally, to digi-
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#D-146 Same as above
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COMMUNICATIONS CORNER
continued from page 68

tal readout and synthesis of VHF and UHF equipment, probably more technological excitement is going on in ham radio now than in all other electronic hobbies combined, other than personal computing. We'll cover many of the latest ham radio developments in detail in the coming months. Right now, let's look at digital-frequency readouts.

Digital readout
The price of a digital readout has decreased drastically. Everything from bathroom scales to set-back home thermostats has a counter-driven digital readout. It's, therefore, not surprising that much of the recently introduced Ham gear also contains digital readouts. No more interpolating the position of cursors, or "in-between" 1-kHz calibrations, a digital readout now indicates precisely—usually by 100 Hz—the center frequency of a receiver or transmitter. Actually, the procedure isn't difficult since all it involves is a frequency counter connected to the local oscillator or VCO. An offset applied to the counter programs it to display the frequency directly, for example, 21.2753 MHz. This is a lot easier than the digitally synthesized tuning (programmable frequency selection) used in some gold-plated-special receivers.

We'll cover both digital readout and synthesized tuning in amateur gear in greater detail in future columns.

SWL
Finally, let's see what's happening in shortwave listening (SWL). For almost the entire history of broadcasting, SWL receiver dial calibration was a hit-or-miss affair. With very rare exceptions, the dial calibrations barely came near the correct frequency, let alone right on it.

Those SWL enthusiasts who were fortunate to know about the Barlow-Wadley receiver (and parted with several hundred dollars for it) were fortunate to end up with one of the very few noncommercial, nonmilitary receivers that could be preset to a frequency and actually be on the button when the power switch was turned on.

The Barlow-Wadley circuit is unique. It uses two VHF crystal-referenced oscillators—one fixed, the other variable. Because the operating frequency is around 50 MHz and because the reference frequency is 1 MHz an unswitched tuning knob can step the tuning in quartz-referenced (drift-free), 1-MHz steps from almost 0 Hz to any desired frequency, usually 30 MHz. The output of the two oscillators (in the 1-MHz–3 MHz range, depending on design) is then tuned by a dial calibrated from 0–1 MHz in 1-kHz or 5-kHz increments. In short, this is a beautiful system with a drift-free dial calibration that provides accurate tuning on the first try.

The original Barlow-Wadley receiver was a small battery-portable unit that outperformed many of the "gold-plated boat anchors" we then called communications receivers.

If you wonder what a Barlow-Wadley circuit would be like using the latest digital readout, you can see for yourself at your local Radio Shack store in the form of the DX-300 Quartz-Synthesized Communications Receiver (see front-view photograph Fig. 2).

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FIG. 2

Using the Barlow-Wadley conversion format in a triple-conversion receiver, the model DX-300 features a digital readout directly in MHz and kHz, to a 1-kHz dial accuracy. The rated frequency range continued on page 76
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COMMUNICATIONS CORNER continued from page 74

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ELF II is the model DX-300 receiver wraps up the first column. In the months ahead we hope to keep you up to date on the very latest developments in consumer communications. Sometimes we'll just give you the highlights of several items; other times we'll provide more in-depth coverage.

Unless we hear from you, we certainly won't be guilty of making decisions about what subjects and equipment meet your particular needs. So take a few moments out to drop us a note on the back page, and let us know exactly what interests you most about consumer communications.
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VIDEOTAPE MAGAZINE. The Videophile, is a bi-monthly magazine containing information and articles on what's new in the world of VCR's and videotape. In addition to the feature articles, the departments include videotape and book reviews, VCR news and views, a humor section, letters to the editor, and many more. Subscription rates: 6 issues/year, $10 (Third Class); $16 (First Class).—The Videophile, 2003 Apalachee Parkway, Tallahassee, FL 32301.

CIRCLE 149 ON FREE INFORMATION CARD

WIRE AND CABLE CATALOG provides 96 pages of information on complete wire and cable line, including audio, CATV, intercom, mike, power and TV cables. The following new types of cable are described: computer, control, Teflon covered coax, booster and ribbon cables. The catalog also includes conduit-capacity charts, a metric conversion chart and technical data on solid and stranded copper wire.—Columbia Electronic Cables, 11 Cove St., New Bedford, MA 02744.

CIRCLE 150 ON FREE INFORMATION CARD

ELECTRONICS CATALOG, 99 pages describing hundreds of discounted items—from adapters to wire-wrap accessories. Includes such equipment as analyzers and testers; meters; color-bar generators; breadboarding materials; transistors; electronic tools; hi-fi equipment; CB's and accessories; service manuals; and troubleshooting guides. A handy order form and postal rate chart are contained in the back. Catalog price: $1.—Eddie Electronics, Inc., 2700 Hempstead Turnpike, Levittown, NY 11756.

TEST INSTRUMENTS/BREADBOARDS. Professional Products Catalog. Catalog contains 32 pages of solderless breadboard equipment and test instruments, ranging from simple sockets and IC clips to lab-quality pulse and function generators, and CSC logical analysis test kits plus accessories. All products are illustrated and come with complete specifications.—Continental Specialties Corp., 70 Fulton Terrace, New Haven, CT 06590.

CIRCLE 151 ON FREE INFORMATION CARD

CATV COAX CABLE GUIDE, EL-10-78, lists 20 pages of 59V/U-type and 6/U-type drop cable plus converter and accessory cable. Several shielding methods are described, including using Duobond and Duobond II bonded foil, Duofoil/foil/film laminate and copper and aluminum braid. Physical and electrical specs are provided along with attenuation ratings. The catalog also contains a description of the SEED (Shielding Effectiveness Evaluation Device) for analyzing shield efficiency. Other sections include procedures in braid-coverage calculation, plus a comparison of the performance of bonded versus laminated shielding.—Belden Corp., 2000 S. Batavia Ave., Geneva, IL 60134.

CIRCLE 152 ON FREE INFORMATION CARD
read 1000 Hz. Set the receiver for USB operation, and the signal generator for 027.2160 MHz. Again, the frequency counter should indicate 1000 Hz. Any imbalance signifies trouble, probably in the SSB demodulator.

Some CB signal generators make this procedure easy. The USB/LSB switches accomplish an exact 1-kHz frequency shift on whatever channel the generator has been set for.

Other models have a frequency-shift control for sideband tests, but it may not be precisely calibrated for 1-kHz offset. In these sets, upper and lower directions are usually switched, so that one setting of the variable knob still gives equal offsets. You adjust one sideband, either upper or lower, for a 1000-Hz count at the speaker, then switch to the other to verify demodulator balance.

As you may have guessed by now, you can use almost any communications service generator for CB alignment and diagnosis. Special CB test generators such as those described in this article simplify many procedures. In addition, certain generators contain features that widen their versatility. Consider all the features, plus all your needs, before you buy one.

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CB RECEIVERS continued from page 67

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CIRCLE 8 ON FREE INFORMATION CARD

MAY 1979

79
Here's a BFO circuit for shortwave receivers that helps clarify reception.

EARL "DOC" SAVAGE, K4SDS, HOBBY EDITOR

THE MAILBAG HAS BEEN VERY INTERESTING LATELY. THERE ARE A NUMBER OF READER QUESTIONS THAT I WILL SHARE WITH YOU JUST AS SOON AS WE FINISH DISCUSSING OUR NEW SUBJECT FIRST.

**Beat-frequency oscillator (BFO)**

Have you ever wondered about that "duck talk" you run into on your SWL receiver (that's single-sideband of course)? And what about the puffing sounds you hear when receiving continuous-wave (CW) code?

If you want to make sense out of those sounds, you will have to add a beat-frequency oscillator (BFO) to your receiver. Both SSB and CW require a steady signal in the receiver in order to be intelligible. The BFO described this month can be used with the shortwave receiver on your desk or your multiband portable receiver.

Several months ago we discussed crystal-controlled oscillators; and we stated that these could be used as a BFO with the proper crystal installed. This month's BFO circuit has several advantages over the crystal circuit. First, its components are less costly. Second, the device is smaller. Third, it can be tuned for maximum effectiveness.

This BFO is designed for use with any receiver having an intermediate frequency (IF) range of from about 400 kHz to 500 kHz. As the most common IF is 455 kHz, this BFO will work with most receivers. If your receiver has a different IF simply use an appropriate IF transformer in the BFO circuit.

NPN switching transistors will oscillate well, but if you use something other than the Radio Shack RS2001 shown in the diagram, you may have to vary the bias resistor. The applied voltage can vary over a wide range but it should be stable.

In order to save space, use a subminiature IF transformer (buy it or "steal" it from an old radio). The impedance is not critical, since we tried several in this circuit and all worked equally well. Just be sure that the one you use has a built-in capacitor on the primary side because the transistor has to have a tuned circuit or nothing will happen. Subminiature oscillator coils come in the same kind of containers but they have no internal capacitor.

If your BFO does not oscillate, exchange either the input or output leads of the transformer; do not change both sides. Capacitor C1 provides feedback to sustain the oscillation. You may want to experiment with its value.

Capacitor C2 serves two functions: It isolates the BFO operating voltage (+5 volts) from the receiver yet allows the 455-kHz signal to pass. Changes in its value will vary the strength of the signal applied to the receiver.

The BFO is built on a small (2 cm × 4 cm) piece of perforated board. The operating voltage can be supplied by a couple of flashlight batteries. However, when the BFO is installed in a receiver, the best practice is to use one of the circuits shown in Fig. 2 to obtain power from the receiver and save battery space.

The values for R1, R2 and R3 will depend upon the value of the voltage "stolen" from the receiver. You can compute the necessary values using Ohm's law (E = I × R). However, trial-and-error experimentation will also do the job. In any case, use larger resistor values in order to draw just a few milliamperes from the receiver. You should install a switch in the power line so that you can disable the BFO when you want to listen to AM stations.

Connecting the BFO to the receiver will undoubtedly require some manipulation for it to reach maximum effectiveness. Of course, we can't give exact instructions for all radios, but here are some general guidelines.

Getting the BFO to "inject" the right amount of signal into the receiver's IF is quite important. Too much BFO signal swamps or even blocks out incoming signals. Too little BFO signal won't do the job either. The amount of injection or signal BFO will be determined by the size of the coupling capacitor (C2 in Fig. 1), and by where in the IF chain you make the connection. Vary both of these if necessary to get the right amount of signal.

With the BFO connected but turned off, tune in a moderately strong broadcast station. Use the S-meter, tuning indicator and/or the quality and volume of sound to be sure that the receiver is tuned to the exact station frequency. Now, turn the BFO on, and you should hear a beat note or whistle. If not, turn the slug in the BFO transformer until you do hear one.

Next, adjust the slug to give a beat-note frequency of about 800 Hz. Then, adjust the coupling capacitor and/or the connection point until the note or whistle sounds about as loud as the broadcast-station signal.

That is all you have to do if you are interested only in CW (code) reception. However, if you also want to receive SSB signals, you must make additional adjustments. Single-sideband transmissions come in two varieties—upper and lower.

With the present BFO adjustment, upper SSB signals may be strong and readable but lower SSB signals will be weaker and not readable (or vice versa).

In order to improve reception with stations using the weaker sideband transmission, you must turn the BFO slug to give a lower note, passing through zero and back up the other side. This is inconvenient when you are receiving different.
stations, so you must do one of two things:
The first option is to build a second BFO and tune it to the other side of zero beat. Then, you could simply switch from one BFO to the other. The second option is a compromise.

Oversimplification
In the November 1978 issue, we discussed parts substitution. At that time, I showed how to change the value of a potentiometer—specifically, how to make a 175K pot out of a 500K pot and a 270K resistor (see Fig. 3).

Bill Clements, K4GMR, has pointed out to me that this is not always possible. It depends upon how the device is used. If it is used as a voltage divider (using all three terminals), the combination works like a single pot. Because most applications involve this type of use, you may never have noticed the exception.

However, when the combination is used as a two-terminal device, it does not function as a simple variable resistor. Place it into an audio tone-control circuit or into the R-C control circuit of a 555 timer, for example, and strange things may happen.

In two-terminal use, with some values the resistance does not increase from zero to maximum as the arm is turned. The value may go from zero to a maximum, and then down to the value of the parallel combination!

Bill enclosed a complete mathematical analysis to show that the example given above varies from zero up to 193K and then back down to 175K. Space won’t permit including his analysis, but to check out his conclusion, you can give it the old breadboard test. The results will be something like those shown in Fig. 4.

I’ll have to admit that a pot acting like continued on page 84
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that could produce very confusing results in some circuits. I sincerely hope no one has pulled out his hair over one since last November! Many thanks to Bill Clements for calling this to our attention.

Reader circuit

Bill Cikas, Rockford, Ill., sent in the very interesting circuit shown in Fig. 5. He calls it a “dual LED CMOS flasher,” and suggests that it can be used as a crossing light on model railroad layouts. I am sure many other uses will occur to you as you watch the LED’s light up alternately.

In this circuit, inverters IC1-a and IC1-b form a multivibrator and IC1-c is a buffer. Inverter IC1-d is connected so that its output is opposite that of IC1-c—when pin 6 is high, then pin 8 is low and vice versa. Because pins 6 and 8 are constantly changing state, first one LED and then the other is on since they are connected in reverse. The light seems to jump back and forth between the LED’s.

The 470-ohm resistor protects the LED’s by limiting the current through them. Depending upon the actual supply voltage used, the value of the resistor may have to be changed to obtain maximum light output without blowing the LED’s. You can change the switching rate by changing the value of the capacitor. However, don’t make the rate too fast, or it will appear that both LED’s are on all the time.

Thanks, Bill, for sharing your circuit with us.

Readers need help

Once again, readers are having problems. Most of you did very well answering the last questions, so put on the old thinking cap again and see what you can devise. Send along your answers and we’ll share the best ones. Here are the problems:

Mr. Taggart of California wants to have wireless control of his TV sound from his chair across the room. He is willing to use a flashlight beam to do so. How would you turn the sound on and off or up and down?

Here are some suggestions: The pickup might be a photoresistor, a phototransistor, a light-activated SCR, etc. The switch could be a relay, a triac, etc. The circuit could operate only when the light is on, or go on and off with alternate light flashes. How about controlling the circuit with sound instead of light?

Mr. Taggart doesn’t tell us exactly what he has in mind. Perhaps he wants quiet when the telephone rings. Or perhaps he objects when commercials seem too loud. If he wants to turn the sound down or off, there may be a better way to do this.

Can you devise something that modulates the sound automatically? How about running audio through an amplifier, then a rectifier and using that voltage to operate a relay when it reaches a preset level?

Here’s another challenge for you: Mr. Prado (also of California) wants a circuit that will produce a sound (or whatever) to keep mosquitos away. (Now, just a minute—I thought there wasn’t enough rain in sunny California to grow mosquitos!)

Mr. Cantley in Michigan wants a squelch circuit. He has one of those CB converters on his car radio, and says the CB comes in very well, but when no one is talking, the noise is driving him crazy.

Well, how about it? Can you help these readers? If so, send along the information to Radio-Electronics and you may see your circuit in a future issue.

HOBBY CORNER
continued from page 81

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CIRCLE 127 ON FREE INFORMATION CARD
Direct Memory Access—a look at what it is and how it's used.

D. LARSEN, P. RONY, J. TITUS AND C. TITUS

Direct Memory Access (DMA) is a technique that allows a computer user to have direct access to individual memory locations without first having to go through the computer's central processing unit (CPU). The DMA interfacing technique has a number of uses, but few computer users completely understand it, and even fewer have fully implemented it for scientific data acquisition or control purposes.

A fairly elementary calculation shows that a simple software routine that inputs an 8-bit word and transfers it to a memory location will take many microseconds. Furthermore, if additional 8-bit words are to be taken and stored in some sort of a sequential file, additional software steps are needed for such "housekeeping" tasks as counting the number of words, incrementing the address pointer, etc. When these additional software steps are introduced into the test program, an 8-bit data word may only be acquired every 30 to 40 \( \mu s \). In many cases, however, higher data-acquisition or data-transfer rates are required. Providing a direct access to the memory section of the computer is not a new idea. A DMA scheme was incorporated in Digital Equipment Corporation's popular PDP-8 minicomputer series. Additional hardware was required and interfacing was not particularly easy to do.

Most current microcomputers have a built-in DMA capability that is rarely considered. This capability allows microcomputers to be used in high-speed data-acquisition systems where the data-transfer rates are higher than those that can be achieved under program control. How is this possible?

Most microprocessor IC's, such as the 8080, Z-80 and 8085, have data-bus and address-bus outputs that are three-state. Three-state devices can pass normal logic 1 or logic 0 levels, and they can also be forced into a third logic state, in which their outputs appear to be very high-impedance loads on the bus. Thus, they no longer sink or source current and they are, in effect, disconnected from the bus. This third logic state allows external devices to obtain the use of the address and data bus lines when the computer's operations are suspended, and its outputs are removed from the bus lines. It is easy to control the microcomputer's bus signals to force them into this third state. The 8080 has a HOLD input. When this input is driven to a logic 1, it forces the 8080 to complete its current operation and then place its data-bus and address-bus outputs in their third state. A hand-shaking hold-acknowledge (HLDA) signal is output by the 8080 to indicate that it has actually placed these signals in the high-impedance state.

External devices that wish to make use of the address and data-bus lines are synchronized so that they will not attempt to use the bus lines until they receive the hold-acknowledge signal from the 8080. In general, these same devices have generated the bus-use request signal or hold signal that indicates to the 8080 that they want to use the buses. In many microcomputer systems, additional buffers are used between external devices and the address-bus and data-bus connections to the microprocessor IC itself. If this is the case, it is very important to make sure that these buffers sense the hold-acknowledge signal and place their respective outputs in the third state also. In the HOLD state, the CPU and its associated buffer circuitry must all be disconnected from the address and data buses.

External devices that are configured for DMA transfers generally have their own registers that provide address data, usually in 16-bit format. These address registers also have three-state outputs, which are normally disabled. They are enabled (or turned on) only when the 8080 is in the HOLD state. Then, they can use the address bus to address the particular memory location to or from which they wish to transfer data. The data path between the external device and the memory IC's has also been placed in the third state, so it also can be used for transferring data—in this case, the 8-bit value that will be transferred between the external device and the location being addressed by the external three-state address registers.

One other important detail must be discussed before the actual data transfer can take place. In most microcomputer systems, the reading-from and writing-to operations are controlled by two signals, memory-read (MEMR or MR) and memory-write (MEMW or MW). These signals may, or may not, be available with three-state outputs. In some systems, where a control-logic section has been constructed with discrete IC's, these two signals probably will not have three-state outputs. When a system controller IC has been used, the outputs are probably three-state devices. In either case, it is easy to gate an 8080-generated read or write pulse with the corresponding pulse generated by the microprocessor IC. In this way, either the external hardware, or the microprocessor can generate a read or.
a write signal. Since the 8080 processor does not operate or execute program steps while it is in the HOLD mode, it cannot generate a read or a write signal. By using the HLDA signal to enable the read and write signals generated by the external device, the proper signals will be generated by either the 8080 in the normal mode and by the external device in the HOLD mode.

While the DMA interface described thus far does not seem to be very useful, since it transfers only one 8-bit data word to a single location, it does illustrate the simplicity with which a DMA interface can be constructed. In most situations, however, a block of data will be transferred between the memory and an external device. Note that the transfer may be in either direction—i.e., from a high-speed data-acquisition device to the computer memory, or from the computer's memory to a high-speed data-storage device, such as a floppy disc.

In one application, a series of SN74193 programmable up-down counters were used to provide the 16-bit address information during the DMA transfer, and a first-in/first-out (FIFO) buffer memory was used to provide a block of data to the microcomputer's memory. Some simple control logic generated a write pulse (MEMW) and then incremented the address (count) present at the SN74193.

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**COMPUTER CORNER**

continued from page 87

counters. A series of switches allowed presetting the starting address at which the block of data was to be stored. Once a complete block of data was accumulated in the 256-byte long FIFO memory, external circuitry was used to detect the FIFO FULL condition, and to initiate the request for the use of the bus, asserting the HOLD line to the 8080. When the 8080 acknowledged the HOLD mode with the HLDA signal, the data was transferred from the FIFO memory to the microcomputer's main read/write memory at a rate of 500K bytes-per-second, or one byte every 2 µs. This data-transfer rate could have been increased at least fourfold, but it was unnecessary in this particular case.

Figure 1 is the block diagram of the interface that was used to control the DMA data transfers. The DMA interfacing technique is also used in front-panel control circuits. Control panels are often provided on microcomputers so that memory locations can be addressed and the user can examine their content. The user may elect to "deposit" new data in one or more memory locations, again through a front panel. A simple front-panel control system is easily constructed using the DMA technique, continued on page 96.
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CIRCLE 20 ON FREE INFORMATION CARD

MAY 1979

93
The mysterious FLS logic process revealed. Plus new semiconductor announcements. KARL SAVON, SEMICONDUCTOR EDITOR

As new integrated-circuit techniques evolve, terms are invented to go with them. Integrated Injection Logic (FLL) is one such term that, at first hearing, is enough to frighten anyone off. But FLL turns out to be not as ominous as it sounds, and, in fact, is a neat, valuable technique that leads to compact, moderate-speed logic applications. Another attraction of FLL is that the injector voltage (the highest voltage with the IC) is only about 0.75. The result is a very low power dissipation per gate.

The processing steps leading to a finished FLL circuit are nearly identical to those used to build conventional monolithic bipolar IC's, even to the extent that bipolar and FLL circuitry can be combined on the same monolithic substrate. Therefore, let's start by reviewing the conventional bipolar IC process.

Figure 1 shows the cross-section of a conventional integrated NPN transistor. The process of building this transistor starts with slicing a thin wafer of silicon from an ingot. After the wafer has been polished to a mirror finish, a layer of silicon dioxide is formed by heat and oxygen on the wafer surface. Throughout the process, windows are etched through the oxide layer to allow the selective diffusing of defined areas. Photomasks are used to superimpose a pattern of photoresist material on top of the oxide. The areas that are not covered with resist are unprotected and are removed by acid. The initial wafer material forms the P-type substrate shown at the bottom of Fig. 1.

The next series of steps involves diffusing N+ pockets. These low-resistance pockets are covered by the layer described in the next step, which is also referred to as the buried layer.

An epitaxial layer is grown on top of the substrate into which the remaining diffusions will go. To isolate the transistors from each other, their epi (or collector) areas must be separated. The P-+-isolation regions are diffused into the epi layer, dividing it into islands.

The transistor bases are then formed with a P-diffusion into the subregions of the collectors. This identical diffusion step also forms resistors, with their characteristic resistivity of around 200 ohms-per-square. Then, N+ emitter and collector contacts are added and openings are formed for contacting the aluminum interconnecting metal that follows in the next step.

Metalization is formed by wiring that connects the various IC devices in their predetermined pattern. It is deposited on the surface and alloyed to the semiconductor material under the contact openings.

Finishing the passivation, bonding and packaging steps complete the multistep procedure.

Figure 1 shows that NPN bipolar transistors have two semiconductor junctions—the base-to-emitter junction between the emitter N+ and base P-regions, and the collector-base junction between the P-base and N-collector regions. In normal transistor operation, the base-to-emitter junction is forward-biased and the base-collector junction is reverse-biased.

The junction between the N collector and P substrate is reverse-biased and forms a nonconductive diode that is the actual isolation mechanism between transistors. The substrate is usually grounded, and the transistor elements are biased at or above ground, thus inhibiting the substrate-collector diodes.

What happens if the collector and emitter functions are reversed? If the collector is connected in place of the emitter in a circuit and vice versa, this inverted transistor still acts as a transistor. However, the nonsymmetrical geometrical layout causes the inverted beta (current-gain) to be lower than the noninverted beta, as well as some other parameter differences. However, especially configured digital circuits, the inverted transistor performs satisfactorily.

The inverted transistor is the "trick" to FLL. If the noninverted N+ emitter regions are used as collectors and the N-collector region is grounded, many transistors can be built into a single isolated
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between the injector emitter and the N region, and the junction between the N region and the base of the NPN. The current sources serve as high impedances to the driving collectors. This very efficient arrangement allows compact use of the IC area because of the numerous devices contained in a single N-isolated area compared with the noninverted single transistor-per-collector isolation ratio. In addition, because of the injector PNP current sources, there is a complete absence of resistors in this logic scheme.

The deep N+ region shown at the extreme right of Fig. 2 does not have a counterpart in the conventional transistor shown in Fig. 1. This area is a guard band that prevents parasitic currents from flowing to the wrong places. We can now see how inverted transistors are used to implement a typical logic function. Figure 4 shows how output currents from several collectors are summed by simply connecting them together at the base of a transistor. Along with the inverter transistor, this connection creates a wired NAND gate. If currents $i_1$, $i_2$ and $i_3$ are all 0, current source $i_1$ turns on $Q_4$ and its output voltage is 0.

If any of the three input currents is nonzero, $Q_4$ is turned off and its collector swings high. In other words, current $i_1$, $i_2$ or $i_3$ switches $Q_4$'s collector low. Using inverter transistors $Q_1$, $Q_2$ and $Q_3$ creates an AND function. Assume the inputs to the transistors are $A$, $B$ and $C$. Their collector currents are summed at the base of $Q_4$, which swings high only when the three driving transistors are off—this is the AND function. You'll also observe that the NAND function, $ABC$, is equivalent to $A + B + C$.

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**Computer corner**

continued from page 92

since a 16-bit three-state buffer can be used to supply the address and eight indicators can be used to show the state of each bit in the memory location addressed. Eight logic switches are used to load new data into a location and two control switches, EXAMINE and DEPOSIT, are configured to generate the memory-read and memory-write control pulses, respectively. Additional features can be added to such a simple control circuit to automatically increment or decrement the 16-bit memory address, etc.

There are, however, some words of caution that must be noted when considering the use of DMA. The 8080 microprocessors are locked out of performing any program steps while they are in the HOLD state.

Some microprocessors such as the MC6800 series require that DMA-based devices regularly relinquish control of the bus. The three-state control (TSC) line in 6800-based systems can only be asserted for periods of 5 µs at a time. Similarly, in systems that use dynamic read/write memory devices, the address and data buses cannot be used continuously by DMA-based devices for more than 1 ms or so.
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Fast-recovery diodes and DC power supplies can cause many troubleshooting headaches. **JACK DARR, SERVICE EDITOR**

I'VE USED THE MATERIAL IN THIS COLUMN before. This concerns two items that have been discussed at length. Still, I keep getting far too many letters from technicians who obviously have not gotten the word. So, I'm going to run it by again and hope that we will be able to reach a few more people who can use the information.

Fast-recovery diodes

The first item concerns the fast-recovery diode. This diode is a special type that turns off very rapidly. So, this is the type we must **always** use as a replacement in any kind of DC power supply that is fed by horizontal-frequency pulses (i.e., a flyback-derived DC supply). Conventional silicon diodes are sinusoidal diodes and work fine for a 60-Hz sine wave or pulse. However, when these standard types are used in a flyback-derived power supply, the input is a very sharp high-frequency pulse, and conventional diodes simply will not turn off fast enough. So they draw a very high reverse current. If you've changed a diode and the new one blows up in about 25 to 30 seconds, look out! This is the typical symptom of using the wrong type of diode.

Use a fast-acting diode in **all sets** using flyback-derived power supplies even the Quasar Electronic Power Supply that operates at 15,750 Hz, and is synchronized by flyback pulses. Unless you are absolutely **sure** that the AC power supply to the diode is a 60-Hz sine wave, it is best to use a fast-recovery diode. Incidentally, a fast-recovery diode works on a 60-Hz supply, but not the reverse—It's a one-way street.

In checking any transistor replacement guide, you'll find lots of fast-recovery diode types listed. Every manufacturer has at least one, and some have five or six types. Typical specs for these diodes show a recovery time of 0.5 μs. Even on a very sharp pulse, a fast-recovery diode turns off completely and does not draw reverse current.

DC power supplies

The second item for discussion is a kind of dual problem in itself that has also drawn a lot of mail. For many years, I (along with many others) have been hollering "Check the B+!" (And this goes back as far as radio days!) It's still the **very first step** that should be taken in any kind of electronic troubleshooting. The reasoning is simple: If the B+ DC voltage supply is off, nothing will work until that is fixed. Also, statistically speaking, DC power supplies cause the most trouble of any section of the TV set.

So, when starting your analysis of a problem, make sure that all the DC power supplies are in the ballpark. In a solid-state color TV set, there may be four or five such supplies and they are all critical. Any trouble in here can cause all kinds of problems.

Secondly, there are two circuits in solid-state TV sets that interact—the DC voltage regulators, of which there may be several; and (linked with these) the numerous shut-down circuits. These circuits can kill everything if the high voltage or the low DC voltages exceed normal levels. If a voltage regulator is not working properly, the DC voltage rises, the shutdown fires and out it goes.

So, voltage regulators should always be checked for correct output. Most regulators are held to very tight tolerances. If the schematic calls for +69.5 volts, your'd better not get a reading less than +69 volts or more than +70 volts. If the regulators are using a pass transistor that is either leaky or shorted, the output voltage will rise to the supply level. Instead of +69.5 volts, you may read +90 volts or more. This voltage will trigger the shutdown circuit. If it doesn't the high voltage can go up to amazing levels, and a perfectly good horizontal-output transistor can be destroyed.

A simple test for this is to plug the set into a Variac. Monitor the DC voltage supply at a key point. Bring the line voltage up until the DC voltage reads exactly what it is supposed to---+69.5 volts or whatever the schematic calls for. In a lot of cases, you may find that the set starts working very well, I have. If this happens and the input voltage is quite a bit **below** normal, this is a very good hint that one of the voltage regulators is not working. If so, the problem is in the DC voltage regulator and nowhere else.

Ordinarily, these circuits are fairly simple to check. Look for shorted or leaky pass transistors, shorted or leaky drivers, error amps, and especially in one of the Zener diodes that are used as clamps in the regulator circuits. If the voltage across a Zener diode is not correct to within ±5%, check it or change it.

I hope that this reminder will get the message across to some who didn't get it the first time around. It saves a lot of time and trouble!

---

**HIGH VOLTAGE DOWN**

A model TAC-3310 Toshiba has turned into a tough nut. A couple of new tubes, including a new horizontal output, cured the original problems, but the picture is still too dark, and the high voltage is only 11 to 13 kilovolts depending on the brightness-control setting. Nothing is smoking. The boost is low. I'm checking it on a test rig. The grid waveform on hot is OK; so is the analyst plate drive.—R. T., Louisville, KY.

My reply to this problem began with some general suggestions. Then I wrote him, "Something's nudging me! You're using this on a test rig; your boost is low, etc. Maybe the horizontal yoke winding of the test rig doesn't quite match this set! If so, you would get these kinds of symptoms."

(Feedback: "Bingo! That was a good nudge. I used extension cables, hooked the Toshiba set to its own yoke/CRT, and everything fell into place. The high voltage and boost went up, the brightness was OK, and so on. I happened to notice that when the 21JZ6 screen went up to +105 volts, on the test jig it was also quite a bit lower.")

**ODD COLOR PROBLEM**

I get good color bars and a good vectorscope pattern on this Zenith model 25MC30. But... if I hook the set up to an antenna, there's no color at all I thought of using alignment, but this seems unnecessary with the good color bars and vectorscope output. What goes?—J. U., Beaverton, OR.
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I hate to say it but there's only one thing left that could be causing this. With the results you're getting from test signals, it could be there are problems in the color-killer. Check the grid voltage on the second bandpass amplifier; the schematic shows this as -30 volts, which signifies no signal or “killed” bias.

One thing used to cause us some odd problems—the 6JU8 quad-diode tube. This is used as the automatic frequency phase control and the killer detector. These tubes developed odd-ball leakages that upset things for three feet in all directions. Try a new 6JU8 first. (You're right. In no way is this an alignment problem.)

**RADIO WITH A GEIGER COUNTER?**

I've got something I'll bet you never heard of before. It's an old portable Sylvania radio, but it also has a built-in Geiger counter! The set is working but I can't get anything out of the counter. There is high voltage on the G/M tube, though. —J. D., Charleston, WV.

You're right, I have never heard of this one before. However, I do have a schematic on it (Sams Photofact 345-17). The partial schematic shows how it works.

When switch M7 closes, a pulse of current flows through the transformer. This charges up C8-C9 to a high voltage for the counter tube. When the tube fires, the “clock” seems to be coupled back through C11 to the bottom end of the volume-control circuit. The neon lamp may be used as a charge indicator or as a peak limiter to keep excessively high pulses from damaging the output tube.

**HORIZONTAL SYNC**

I can't stop the picture from sliding sideways in this Admiral 11H chassis. Checking the AFC circuit, tubes (including AFC diodes), etc. didn't help. The hold control can stop the picture momentarily, but when it is stopped a vertical white line appears in the center of the picture. The vertical hold is good. Any help would be appreciated! —J. T., Ocala, FL.

Normally I'd say there's no sync getting to the AFC diodes, but you've got that white line in the picture. You may have some feedback through the B+ line due to a bad filter capacitor. Scope all the B+ lines for any signals; these cause feedback and all kindS of weird problems.

(Feedback: “Thanks! Capacitor C2A, the 80-µF section of a multiple filter, was leaky. I replaced it and now it works.”)

**CATHODE CURRENT RUNS HOT**

The 6K76 horizontal-output tube cathode current in this RCA chassis CTC-27XAD runs 450 mA and there's no output. The grid voltage reads -25, and the screen grid voltage reads +185. I can't get that current down. —H. J., New York, NY.

I can tell you one thing: a +185 voltage on the screen grid is much too high and can cause the cathode current to go way up. Find out why this happens. I have seen sets where the screen-dropping resistor had burned up and dropped in value. The only other thing that could cause the screen voltage to go so high would be an open contact on the screen in the socket. If this is the case, however, the cathode current drops to about 45 or 50 mA. Your drive seems to be normal, but the high screen voltage is not.

**MORE BRADFORD FLYBACKS**

Like a lot of Service Clinic readers, I also need a Bradford flyback transformer for a 1143B31 chassis and the part number is 33AP03402. Can your crystal ball help? —D. B., FPO, NY.

The crystal ball didn't help, but after looking in some catalogs for similar part numbers, I dug up what certainly looks good. At least, the part number is exactly the same—it's a Mitsubishi (MGA). Look up an MGA CH-120 chassis in Sams Photofact 1176. You can probably order one from MGA Melco Sales, Inc., 3030 N. Victoria, Compton, CA 90221.

**SLOW WARMUP**

This Zenith model 14N28 takes about 1 to 2 minutes to reach full height. The width is OK, but the picture lacks about 3 inches at the bottom of the screen; it then slowly builds up until the screen is full. I've checked out everything I can think of in the vertical circuits, and the waveforms look normal. I tried coolant spray on the circuit; no luck. I'm overlooking something, but don't know what. —J. S., Prospect Heights, IL.

If your picture comes on in-sync and it remains stable, the chances are this is not a problem in the vertical circuitry itself. It is probably something in the supply voltage to it.

There is a small thermistor in the deflection yoke that is supposed to be 1.0-megohm cold and drop to an unknown value. In any case, this thermistor feeds the boost voltage to the plate of the input half of the vertical oscillator. Take the back cover of the deflection yoke off and look for this; it's a small disc-type component. You can replace it with a Workman GM 1-meg thermistor.
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DIGITAL MULTIMETER, model RMS-350 Voltmeter, is a battery-operated, 4-digit instrument designed to fit into a tool box. It measures true RMS AC from 1 mV to 750 volts; resistance from 1 ohm to 10 megohms; DC from 1 mV to 1000 volts and AC/DC current from 1 µA to 1 A.

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Features include LCD readout, automatic polarity, overload indication and overload protection, plus a 10-megohm input impedance. The model RMS-350 measures 1.9 H x 2.7 W x 4-inches D. Optional accessories available include batteries and charger, a probe, carrying case and tiltstand case. Price: $189.—Non-Linear Systems, Inc., Box N, Del Mar, CA 92014.

CCTV SURVEILLANCE CAMERA, model ITC-44, is available with choice of pickup tubes, including vidicon, separate-mesh vidicon, or silicon-target vidicon. With a 0.5-inch vidicon tube, only 12 foot-candles are needed from a standard 89% reflectance object; with the silicon-target vidicon tube, ABS plastic case, with internal RF shielding, weighs 5 lb., and carries a suggested retail price of $250.—Ikegami Electronics (USA) Inc., 37 Brook Ave., Maywood, NJ 07607.

WIRE-WRAP TOOL, model P184-4T, uses high abrasion-resistant polyurethane nylon Tefzel insulated wire to eliminate measuring. The tool uses the model P184 Silt-N-Wrap bit to feed wire from a spool on the shaft. This permits continuous wire-routing in a daisy-chain fashion. The Silt-N-Wrap bit can also be used with the model P184-4T NiCad-powered pencil-type motor. The Tefzel wire is available in 50-foot spools, with red, green, white or yellow insulation. Also available are 120-foot spools of uninsulated copper wire.

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the minimum sensitivity is 0.01 foot-candle. The response range is 1000:1, and it can provide a horizontal resolution of 550 lines (with separate mesh vidicon). With gamma correction off, the S/N ratio is better than 44 dB; the video bandwidth, 6 MHz or better; and the deflection distortion, less than 2%. The model ITC 44 operates from 117 VAC line, the economy model ITC-44A operates from 24 VAC. The unit is housed in an

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Suggested retail prices: model P184-4T1, $89; model P184-4T, $80; model P184 bit, $28.50; Tefzel-insulated wire, $4.18/package of two 50-foot spools.—Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, CA 91342. R-E

DIGITAL AUTOMOTIVE INSTRUMENTS, Indicators model DC-17301 clock/timer, model DC-17304 MPG computer and model DC-17306 tachometer, all feature 4-digit fluorescent display, require only 3-wire connection (hardware included). The model DC-17301 (shown) clock/timer shows time of day in hours/minutes to 12 hours, or can be used as an elapsed-time counter to read minutes/seconds to 59:59, or hours/minutes to 99:59. Operates on 10-17 VDC and draws only nominal 2 watts. The model DC-17304 MPG computer displays average miles-per-gallon since first fillup, total miles driven, total gallons purchased and total miles-per-gallon between fillups. Model DC-17301 tachometer features continuous RPM count, with 1% accuracy full-scale, and automatic memory feature to display preset RPM number. Price: $39.95.—Digital Concepts Corp., 249 Route 46, Saddle Brook, NJ 07662.

100-WATT REFLECTOR LAMP, model 1300 Cre- melite, can be bench- or table-mounted for do-it-yourself projects and hobbies. Offers 360° rotation angle and a 45-inch arm reach. Addition

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al features include insulator reflector and porcelain socket. The model 1500 is available in white-only, baked enamel finish, and operates from a 100-115-volt, 60-Hz AC source. Options include adjustable clamps and screwdown mounts for additional mounting angles. Suggested retail price, $39.95.—Dremel, Div. Emerson Electric Co., 4915 21st St., Racine, WI 53406.

SOLDER SPOOL HOLDER, Solder Mate, prevents solder wire from unraveling. Portable metal

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holder permits easy withdrawal of solder; holder is loaded by dropping spool into place and feeding solder through dispenser hole. Suggested retail price, $4.95.—Efficiency Products Corp., 2 Kennedy Dr., North Chelmsford, MA 01863. R-E
More information on stereo products is available from manufacturers of items identified by a Free Information number. Free Information Card is inside the back cover.

AM/FM STEREO RECEIVER, model CR-220, provides 15 watts-per-channel RMS into 8 ohms from 20 Hz to 20 kHz, with no more than 0.05% THD. Front-panel controls include power on-off switch, bass and treble switches, variable-loudness switch, tuning switch, and phone jack. Performance specifications for the model CR-220 are:

- For the amplifier—phono input sensitivity: 2 mV at 1 kHz; phono S/N ratio, 90 dB.
- For the FM section—alternate channel selectivity, 60 dB; capture ratio, 1.5 dB; 50-dB quieting, 17.3 dB (mono), 39.2 dB (stereo); frequency response, 30 Hz-15 kHz ±1, -3 dB; S/N ratio, 70 dB (mono), 65 dB (stereo; AM suppression, 52 dB. The AM section provides an alternate channel selectivity of 20 dB and an IHF sensitivity of 18 µV/m. The model CR-220 measures 435 X 144 X 326.5 mm and weighs 7.6 kg. Suggested retail price: $220—Yamaha International Corp., 6600 Orange Circle, Buena Park, CA 90622.

STEREO COMPONENTS, the model AA-1600 amplifier and the model AD-1701 graphic output indicator, are rack-mountable components. The model AA-1600 delivers 125 watts-per-channel (minimum RMS) into 8 ohms, 20 Hz through 20 kHz, at less than 0.05% THD. Other features include a delay switch, thermal circuit breaker and high-temperature LED indicator. The amplifier can also be installed in optional oak-finish model AEA-1800-1 case. The model AD-1701 output indicator has two rows of fifteen LED's for graphic output display, peak-hold circuit and peak/average switch.

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TIME/VOLTAGE CALIBRATOR continued from page 39

apply the waveform to a low-pass filter to generate the average DC voltage and then buffer it.

The voltage-calibrator section (Fig. 3) resembles the time section somewhat, but the two circuits are different. Thumbwheel-switch latches IC1–IC4 feed exclusive-NOR inputs. Again, the exclusive-NOR network IC9–IC12 is used as a comparator, but this time it compares the thumbwheel-latch contents to the counter output. When both values agree, the output is pulled high by resistor R19. Decade-counters IC17–IC20 are wired as up-counters. For this application, they free-run, starting from 0000, count to 9999, then start over again. Although the clock frequency's accuracy is unimportant in this application, a rather exact 1-MHz signal that is tapped from the 20-MHz timebase count-down section (IC26 pin 14) is used as the volts section's counter clock.

The TTL portion of the volts section must provide a programmable duty-cycle from 0 to 100%, inclusive, in 0.1 increments (with a 4-decade total). If a flip-flop can be set to 0 when the four decade-counters are at 0000 and then flipped back to 1 when the counter reaches the desired thumbwheel value, this achieves a programmable duty-cycle; the higher the thumbwheel setting the longer the flip-flop stays at 0. Since the counter-clock frequency is 1 MHz, the programmable duty-cycle output has a frequency of 100 Hz.

The duty-cycle flip-flop described above is JK flip-flop IC39-b. When the counter network reaches 9999, the outputs of counters IC17 and IC20 are low, forcing the output of NOR gate IC38-a high. On the next clock pulse, the counters advance to 0000, and the output of J-K flip-flop IC39-a goes low for one clock cycle. Assuming that the exclusive-NOR comparator output is low at this time (that is, the thumbwheel latches are loaded with a nonzero value), the output of inverter IC38-b is high, forcing the output of IC38-c low. Therefore, inputs J and K to IC39-b are high, so on the next clock input, the duty-cycle flip-flop's output Q goes low and the counter network increments to 0001. This is the first step of the duty-cycle generation.

The J and K inputs of IC39-b are held low and high, respectively, when there is no comparator equal output, or when the counter state is nonzero. This is the hold mode, so the duty-cycle flip-flop maintains its state until there is a change on its inputs.

When the counters and the thumbwheel latches agree in value, the comparator output goes high and the output of inverter IC38-b goes low. The output of IC39-a is high for all counts except .0000, so both the J and K inputs to IC39-b are low. On the next clock cycle, the flip-flop output is set back to a 1 and remains there until the counters again reach 0000, when the cycle repeats.

The counter sequence and the duty-cycle flip-flop's output proceed as follows:

Counter:
9999-0-1-2 ... n(n + 1) ... 9999-0-1

Duty-Cycle Flip-Flop (IC39-b pin 9)
1-0-0-0 ... 0-1-1-0

Thus, the output stays low for (n + 1) - 1 = n times out of 10,000 counts, so the thumbwheel setting directly loads the correct duty-cycle.

In the event that the thumbwheel latches contain 0000, the outputs of IC38-b and IC39-a go low simultaneously. This forces the output of IC38-c high, which, in turn, forces the output of IC38-d low. Then, IC39-b is constantly loading and then holding a 1 (i.e., the flip-flop output is a DC voltage, with a level corresponding to a 0% duty-cycle, as required).

By using the asynchronous SET and RESET inputs of flip-flop IC39-b, the duty-cycle logic can be overridden. The SET input forces the flip-flop output low (duty-cycle = 100%), and the RESET input forces a high output (duty-cycle = 0%). Switch S8 provides the logic signal. When switch S8 is in its center OFF position, the duty-cycle logic performs as described. This switch allows the user to select between the two voltage extremes and any other preloaded value.

The output of the duty-cycle flip-flop is fed to IC37-b, which converts its TTL-compatible voltage swing to a MOS-compatible voltage. Resistors R24 and R25 limit the maximum voltage input to the CMOS gate to slightly less than 10. The NOR gate IC41 is the CMOS driver. Its VDD supply lead is connected to the output of IC44, the precision voltage reference. Thus, the precision TTL-generated duty-cycle is voltage-level-shifted by parallel-connected NOR gates IC41-b, IC41-c, and IC41-d to produce the time and voltage requirement described earlier in this section.

A low-pass filter consisting of R26-C32, R27-C33 and R28-C34 produces a DC output whose value is equal to the desired voltage setting. The low-pass filter has a time constant of several seconds, so it takes about 10 seconds for the DC-output value to stabilize. Operational amplifier IC42 has a high-impedance JFET input that will not significantly load the low-pass filter's output. It is connected as a voltage-follower, guaranteeing a low-impedance output at PC board locations J and K. Trimmer resistor R34 nulls the op-amp's input-offset voltage and gives the operator a precise 0-volt setting.

Voltage-follower IC43-a has its input connected to the programmable voltage output. Its output, called Vhigh, feeds
the V_{PD} lead of CMOS gate IC40 in the time section shown in Fig. 1. Thus, whatever value is loaded in the volts section will be the voltage-high output of the time calibrator's 50% waveform.

A low-output-impedance, ±20-mV voltage generator is composed of resistors R29-R32, trimmer R35, capacitors C17 and C31, and voltage-follower IC43-b. The output is used as the ground return for the 10-volt reference IC. Since the precision output is measured with respect to its ground leg, offsetting ground by ±20 mV (with R35) also offsets the output by an equal amount. If you don't trim the volts-calibrator section, most of this section can be omitted.

Thumbwheel switches S1-S4 (Fig. 4) are coded as BCD-complement, meaning that 0 is a switch closure and 1 is a switch open. Pull-up resistors R1-R16 pull any open switch node to 5 volts, but any switch closure will force a ground potential on that node. These two voltage levels are TTL-compatible, therefore they directly drive the latch inputs of the time calibrator.

Three power-supply voltages are needed in the calibrator: +5, +15 and -5 volts. The first voltage powers all the TTL circuitry, and the second two voltages power the analog circuitry in the volts section. Transformer T1 (see Fig. 7) has two secondaries. Secondary 1 is full wave rectified by D1 and D2, filtered by C20 and C21 and regulated down to +5 volts by voltage regulator IC45. A bridge rectifier consisting of D3-D6 at secondary 2 provides both positive and negative voltages, which, in turn, are regulated down to +15 and -5 by IC46 and IC47. Separate secondaries in the power supply help minimize the possibility that the high-frequency voltage and current switching transients in the +5-volt power supply will appear in the analog section of the calibrator's time and volts outputs.

This concludes the theory of operation of the Time/Voltage Calibrator. Next month we will go into construction details and will present the PC board pattern and other pertinent information.

R-E

AUDIO TEST STATION

continued from page 63

IC701-a is simply an isolator. With S22 in its lower position the timebase frequency is the same as the power-line frequency, which produces one window per second. At the same time pin 8 of IC701 is grounded, which yields an output pulse train of the same frequency as the input signal.

Gate IC701-c, R701 and C702 form the delay circuit. IC701-c provides both isolation and a small amount of delay and R701 and C702 provide additional delay. When S702 is in the one-half-second update position, the input signal first arrives at pin 9 of gate A. Pin 8 is still low, the exclusive O function is satisfied and pin 10 goes high. A short time later, the signal arrives at pin 8 and pin 10 goes low. Sometime later the input pulse ends. At this time, pin 9 goes low and pin 8 is still high. The exclusive or is once again satisfied and pin 10 goes high again. A short time later the pulse at pin 8 also ends and pin 10 again goes low. The result is two narrow pulses for each single input pulse. The pulses occur at the beginning and end of the input pulse.

As the input frequency reaches about 300 kHz, the spacing between the two pulses reaches zero and the result is an output pulse the same frequency as the input. This is the only reason for having a one second update at all. That is, to extend the usefulness of the overall counter into this frequency range. If it was only to be used at lower frequencies, the one-second window need never be used.

IC704 is the actual counting element. When the clear input pin is low, IC704 counts the input at pin 36. When the store input pin is low, the number in the counter is transferred continuously to the display. When the clear input is high, the counter is reset. It starts over again at zero when the clear goes low. When the store input goes high, whatever number was last displayed remains displayed until the store goes low again. Since the store input only goes low for a brief period of time at the end of each counting window, the display shows the number the counter contained at the end of the previous window. Immediately after transferring the number present in the counter at the end of the period, the clear input goes high briefly, which initiates a new period.

The display is multiplexed. That is, only one digit is actually displayed at a time. IC705 provides power to the anode and IC706 provides ground for the cathode. Capacitor C705 establishes the scan frequency. IC704 through IC706 power each digit sequentially in seven segment format. If the LED's were continually powered, each number in the counter would flash sequentially on all six digits simultaneously. IC704 provides the digit scan through IC705. This simply powers each LED display sequentially. Therefore, a particular digit is only powered when the corresponding number from IC706 is to be displayed.

IC705 provides the voltage gain as well as a current gain. This allows IC704 to power the display from the unregulated supply. R705 and R701 provide current limiting for the displays.

Figure 14 shows the location of the Frequency Counter section and Fig. 15 shows the location of the components.

This wraps up the construction phase of the Audio Test Station. Next month we will go into calibration, tests and applications of this valuable addition to your bench.

R-E

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BOWLING GAME
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by one as they are attached to their respective resistors, R20 - R29. Use a 6-volt supply with a 220-ohm resistor in series (or a 1.5-volt battery with a 100-ohm resistor) to individually light the LED’s for identification. Attach the 22-gauge anode lead to the positive power supply. The reset pushbutton, S2, connects to point “R” on IC’s 1 - 4 and to the V+ line.

It is prudent to test the gating circuits before hooking up the photo-Darlington transistors. Apply power to the circuit and use test leads to connect each of the inputs to either ground or V+. Use a voltmeter or logic probe to follow each signal through the gates and into the diode matrix. If an error has been made, it can be traced and corrected in a matter of a few minutes. Try all the combinations shown in Table 1, checking each for the proper output.

Now, connect the photo-transistor leads to their appropriate points on IC’s 1 - 4, apply a light source and selectively block each of the slots to make sure the voltage swing from light to dark is sufficient to trigger the CMOS latches. In general, the dark voltage at the junction of the collector, the resistor and the gate must be greater than 0.7 times the V+ voltage, and the lighted voltage should be less than 0.3 times the V+ voltage. If these voltages are too low, try decreasing the value of the pullup resistor. If they are too high, increase the value. If this doesn’t work, replace the transistor. In tests of over 40 junk-box photo-Darlington transistors, 32 were usable with a pullup resistor value near 15K and with a 40-watt incandescent lamp 48 inches away. Normal room lighting is usually well above this level.

NOTE: IC’s are shown as mounted with pins facing up. (See Text)

FIG. 8—WIRING GUIDE for the point-to-point connections between the IC’s and the diode gates.

FIG. 9—HOW PHOTOTRANSISTORS are mounted. Be careful when bending pins.
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Originally used by HYGA In to indicate time and channel on an expensive C.B. mini size, self-contained module. Not a kit. Four digits plus flashing indicator for seconds. Includes MM5369 and 3.58 MHZ crystal for super accurate time base. With hookup data.

MFGR's CLOSEOUT LIMITED QTY.

MINI PROJECT CASE
Black Molded Plastic 2" x 1.75" x 2.2". Has open front, with mounting ears so unit can be easily attached to auto dash. Case has molded card guides for mounting PC Board inside. Perfect for digital clocks, car burglar alarms, or almost any electronic project. Can also be used for encapsulating circuits or modules. 75¢ each Super Special Purchase

SOLD OUT
SONY 30 WATT AUDIO AMP MODULE
#STK-056. 30 WATTS SUPER CLEAN AUDIO. 20 Hz to 100 KHZ ± 2 DB. HYBRID, SILICON, SELF-CONTAINED MODULE. ONLY 1½ x 2½ IN. WITH DATA. COMPARE AT UP TO TWICE OUR PRICE! $9.00 EACH

TERMS: Add 30¢ postage, we pay balance. Orders under $15 add 75¢ handling. No C.O.D. We accept Visa, Mastercharge, and American Express cards. Tex. Res. add 5% Tax. Foreign orders (except Canada) add 20% P & H. 90 Day Money Back Guarantee on all items.

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OF TEXAS
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WOW! DIGITAL TIMER-COUNTER

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FAIRCHILD SUPER JUMBO LED READOUT
A full .80 inch character. The biggest readout we have ever sold! Super efficient. Compare at up to $2.95 each from others!

YOUR CHOICE $1.49 EA
FND 847 Common Anode
FND 850 Common Cathode
(6 for $6.95)

16K DYNAMIC RAM CHIP WORKS IN TRS-80 OR APPLE II
16K x 1 Bits. 16 Pin Package. Same as Mostek 4116-1. 250 NS access. 410 NS cycle time. This state of the art RAM 32K and 64K RAM boards, using this chip are ready available. These are new, fully guaranteed devices by a major mfg.

VERY LIMITED STOCK!

"MAGAZINE SPECIAL" — 8 For $79.50

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2N4042. TO-92 Plastic. Silicon PNP Driver. High Current VCEO-40 VDC. Collector to emitter 0.250. Collector to base 200. Collector to case 150. Collector to 150 MA. ET-100W. A Super "Magazine Special" at only $1.95 each

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2N4304. Brand New
N Channel, Junction Fet
BVCEO-30V DSS-15 MA Typ.
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Case MfG by Teledyne
6 FOR $1

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WIELEK ETHER GATEWAY KIT
WARNING: KIT INCOMPLETE UNTIL PLUGGED INTO YOUR VCR AND TV OUTLET. CIRCLE 116 FOR FREE INFORMATION.

SMART BURGLAR ALARM
This deal on the cute electric bell from Diamondback Electronics is a hot one. The kit even includes a vibrating buzzer that can be connected to a strobe light. The kit comes with everything you need to set up a simple burglar alarm. The bell can be used alone or with a strobe light for added security. The kit includes instructions for easy assembly and installation. Don't miss out on this great deal!
LPRINT
SERIAL
$19.95
1200, 2400. parity
parate circuits
 cable
No. 232A
parts
Part
t to

TRS-80 E S
SERIAL I/O
• Can input into basic
• Can use USIT and LPRINT to output. or
output to
• RS-232 compatible
• Can be used with or
without the expansion
bus • On board switch
selectable baud rates of
110, 135, 300, 600, 1200, 2400, parity or
no parity odd or even.
5 to 8 data bits, and 1
or 2 stop bits. D.T.R
line • Requires +5
-12 VDC • Board only
$19.95 Part No. 8010
with parts $59.95 Part
No. 8010A or
$79.95 Part No. 8010
C. No connectors pro-
vided. see below.

MODEM*
• Type 103 • Full or
half duplex • Works up
to 300 baud • Origina-
lize or Answer • No
cools, only low cost
components • TTL in-
put, output, and output-
signal • Connect B &
earth and Crystal
directly to board.
• Uses XR FSK demod-
ulator. • Requires +5
volts • Board only
$760 Part No. 109,
with parts $27.50 Part
No. 109A

APPLE II+
SERIAL I/O
INTERFACE
Baud rate is continuously adjustable from 0
to 30,000. • Plugs into
peripheral
connector. • Low current drain. RS-232 input
and output • On board switch selectable 5 to
8 data bits, 1 or 2 parity or no
parity either odd or even • Jumper selectable
address • SOFTWARE • Input and Output
routine from monitor or BASIC to teletype or
other serial printer. • Program for using an
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Also can output in correspondence code to
interface with some seletrics. • Also watches
DTR only Board only $15.00 Part No.
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$62.00 Part no. 2C

8K EPROM
PICICON
Saves programs on PROM permanently fuelled
erased up to 8K bytes. Programs may be
directly run from the program saver
such as fixed routines or assemblers. • 5-
100 bus compatible • Room for 8K bytes of
EPROM non-volatile memory (2078)'s. • On-
board PROM programming • Address
relolocation of each 4K of memory to any 4K
boundary within 256 • Power on jump and
jump option for 'current' systems and
computers without a front panel • Program
saver software available • Solid state and
both sides • Full silkscreen for easy assembly.
Program saver software in 1278 EPROM
$25, Bare board $35, Bare board with parts but no
EPROM $139, with 4 EPROMS $179, with 8 EPROMS $219.

VERBATIM
MINIDISK
Box of 10
$29.95

RS-232 / TTL:
INTERFACE
• Converts TTL to
and RS-232, and converts RS-
232 to TTL • Two separate
circuits. • Requires +12 and +12
volts • All connections
go to a 10 pin gold
plated edge connector
• Board only $4.50
Part No. 232, with
parts $7.00 Part No.
232A 10 Pin edge
connector $3.00 Part
No. 10P

RS-232 / TTL:
INTERFACE
• Converts RS-232 to
20mA current loop,
and 20mA current loop
to RS-232 • Two separ-
ate circuits. • Requires +12 and +12
volts • Board only
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with parts $7.00 Part
No. 600A

WAMECO INC.
FDC-1 FLOPPY CONTROLLER BOARD
will drive shgbert, perke, revem 5 & 8" drives
up to 6 drives • Board only $12.00
• With power
board, will operate with
CPM not included, PCBC
$42.95
FPB-1 Front panel (Finally) AMSAI size
double displays. • By order only
board $24.95, Kit
$24.95, Kit

MEM-1A 8K x8 full buffered, 5-100, uses
$100 type RAMS
$24.95, $168 Kit

GMB-12 MOTHER BOARD, 13 slot termi-
nated 5-100A 
$32.95
CPU-1 8080A Processor board S-100 with
8 level vector interrupt PCBC
$25.95

RTC-1 Real time clock board. Two independ-
ent and interrupt. Software program
$25.95, $60.95 Kit

DC POWER SUPPLY:
• Board supplies a regulated +5
voltage at 3amps, -12, -12, and -5
volest at 1 amp. • Power required is
8 volts AC at 3amps. and 24 volts
at 1.5 amps. • 12.50 Part No. 6085
with parts $15.00 Part No.
101A, 4 pin edge con-
nector $4.00 Part No.
44P

S-100 BUS
ACTIVE TERMINATOR
Board only $14.95 Part No. 900, with parts
$24.95 Part No. 900A

URT &
BAUD RATE GENERATOR:
• Converts serial to
parallel and parallel to
serial • Low cost on
board baud rate gener-
ator. • Baud rates
110, 150, 300, 600, 1200,
and 2400 • Low power
drain +5 volts and +12
volts required • TTL com-
patible • All characters
contain a start bit, 5 to
8 data bits, 1 or 2
stop bits, and either
odd or even parity. • All
connections go to a 44
pin gold plated edge
connector • Board only
$24.00 Part No. 44P

To Order:
Mention part number, description, and price. In USA, shipping paid for orders accompanied by check, money order, or Master Charge, BankAmericanExpress or Visa
number, expiration date and signature. Shipping charges added to C.O.D. orders. California residents add 6.5% for tax. Outside USA add 10% for air mail
postage and handling, no C.O.D.'s. Checks and money orders must be payable in US dollars. Parts kits include sockets for all IC's, connectors, and circuit
board. Documentation is included with all products. Prices are in US dollars, No open accounts. To eliminate tariff in Canada, all boxes are marked "Computer
Parts." Dealer inquiries invited. 24 Hour Order Line: I4082-226-0664

For free catalog including parts lists and schematics, send a self-addressed stamped envelope.

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The McKAY DYMKE DA 100.

The DA 100 is a compact, wide dynamic range, broadband, untuned, Omni-directional receiving antenna covering the frequency range of 50 kHz to 30 MHz.

The exterior module, a small weather-proof box with a 56 inch (142 cm) whip delivers the signal to the power supply unit through a supplied 50' coaxial cable.

The power supply locates near your general coverage receiver and attaches with a supplied patch cord.

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Claremont CA 91711
RCA Cosmic Super Elf Computer $106.95

Compare features before you decide to buy any other computer. The Cosmic Super Elf computer is a unique system today that has all the desirable features of the Super Elf for a little more money. The Super Elf is a small single board computer that does many big things. It is an excellent computer for training and for Hacking programs, with its machine language and yet it is easily expanded with additional memory, Tiny Basic, ASCII KeyBoard, remote control

The Super Elf includes a ROM monitor for program loading, retting and execution with SINGLE STEP. All programs on which the chip is included are in order to the same price. With SINGLE STEP you can view the microprocessor chip operating with the unique 16k memory. Data bus displays before, during and after executing instructions. Also, CPU mode and instruction cycle are decoded and displayed on red LED indicator lamps. An RCA 16K video graphics chip allows you to connect to your own TV or an inexpensive video monitor to display graphics. This is a powerful system for writing your own music or using many music programs already written. This unit may also be used in digital control for store checkout.

$9.95

A 24 key hex keyboard includes 16 hex keys

Super Expansion Board with

This is truly an astounding value! This board has been designed to allow you to add to the board you want to expand the board. The Super Expansion Board comes with 50 low power RAM fully addressable anywhere in 64K with built-in memory protection and a cassette interface. Provisions have been made for all other options on the same board and 4 files neatly into the hardwired cabinet alongside the Super Elf. The board includes store ($275.62). A timer and Tiny Basic or other powers.

A K Super ROM Monitor $19.95 is available as an on board option in $270 EPROM which will come pre-programmed with the program a user and editor and error checking mini file cassette readable/writable format (erasable cassette file) another exclusive from this board. It includes register save and readout, trick move capability and video display driver with sound circuit. Break points can be used with the register save feature to isolate program bugs quickly, then follow with single step. The Super Monitor is written with subroutines allowing users to take advantage of monitor functions simply by calling them up plus load, reset, run, wait, input, memory pro-
test, monitor select and single step. Large on

board displays provide output and optional high and low address. There is a 4 pin standard connector for PC cards and a 50 pin connector for the Quest Super Expansion Board. Power supply and sockets for an IC's are included in the price plus a detailed page instruction manual.

Many schools and universities are using the Super Elf as a course of study. OEM's use it for training and research and development.

Remember, other computers only offer Super Elf features at additional cost or not at all. Compare before you buy. Super Elf Kit $106.95. Add high address option $4.95. Low address option $9.95. Customer Cabinet with divided and labeled presgreat front panel $24.95. NiCad Battery Memory Saver Kit $4.95. All kits and options also come completely assembled and tested.

Questdata, a 72 page monthly software publication for 1K computer users is available by subscription $12.00 per year.

Tiny Basic for ANY 1802 System


Cassette Interface $89.95

Improvements and revisions are easily done with the monitor. If you have the Super Board and Super Monitor the monitor is up and running at the push of a button. Other board options include Parallel Input and Output Ports with full handshake. They allow easy connection of an ASCII keyboard to the input port. RS 232 and 20 ma Current Loop for teletype or other device are on board and if you need more memory there are two $100 stop for static RAM or video boards. A Godspeed 8K RAM board is available for $135. Also a T Super Monitor version 2 with video driver for full capability display plus Tiny Basic and a video interface board. TTY 20 ma (IF $1.95, TTY $10.00-$4.95. A 5 pin connector with ribbon cable is available at $12.50 for easy connection between the Super Elf and the Super Expansion Board.

The Power Supply Kit for the Super Expansion Board is a 5 amp supply with multiple positive and negative voltages $29.95. Add $4.00 for shipping. Freguency frame $5.00. Case $10.00. Add $5.00 for shipping.

Digital Temperature Meter Kit

$15.95


$7.25

A great little idea that can't hold a charge and then charges itself up, all in one kit with test tools and instructions.

$24.50

Rockwell AIM 65 Computer

$90.00 based single board with full ASCII keyboard and 20 column thermal printer. 20 char.

For manucrher's display. ROM monitor fully expand-

able, $375.00. 4K Assembler $85.00. 68 Basic $100.00. Power supply assembled in case $40.00.

Multi-voltage Computer Power Supply

$26.95

Full six digital battery operated. 2-5 volts, 3.2765 MHz crystal accuracy. Times to 5 min. $10.95. 8K RAM. Times to 10 min. Hand held $10. (LCX) displays, auto zero, polarity, overrange $74.95.

Hickok 3½ Digit LCD Multimeter

$23.95

For 0.1 volt, 1 range 0.5% accuracy. Resistor, 6 leads, power ranges 0.1 ohm to-20M ohm. DC cur. to 10mA. Hand held $10. (LCX) displays, auto zero, polarity, overrange $74.95.

Stopwatch Kit

$29.95

S-100 Computer Boards

$35.00

$135.00

$255.00

$43.00

$30.00

$470.00

$519.00

$23.95

FREE. Send for your copy of our NEW 1979 QUEST CATALOG. Include 26c stamp.
**THE MOST ADVANCED TIMEPIECE OF ITS KIND IN THE WORLD!**

LCD Quartz Alarm Chronograph with calendar and dual time zone!! Watch is the same as Sliko but you pay a lot more for the name!! Features:

- 24 hour alarm
- Chronograph counts up to 12 hrs, 59 mins, 59.9 sec.
- Precision of chronograph up to 1/10 sec indicated by 10 second moving arrow.
- Led time function (chrono running uninterrupted).
- Time displays by LCD for hour, min, sec, day, date of the week and AM/PM.
- Calendar gives out date/day.
- Dual time zone for any two cities of the world at your own choice.
- With light switch to allow you to see the time in the dark!

**SPECIAL** $95.50

**ONE YEAR FULL WARRANTY!**

**JUMBO 1" LED ALARM CLOCK MODELE**

Assembled - not a kit!

Features: 1. 1" 4-digit led display 2. 12 hours real time format 3. 24 hours alarm output (last used date/day) 4. Power failure indicator 5. Count down timer 5 minutes 6. 12.16V AC/60 Hz input 7. 10 min snooze control...

**SPECIAL** $8.50 EACH

**NEW MARK III 9 Stage 4 Colors LED VU**

Stereo level indicator kit with arc-shape display panel!! This Mark III LED level indicator is a new design, PC board with an arc-shape 4 colors LED display (change color from red, yellow, green and the peak output indicated by rose red). The power range is very large, from 350VA to +50V. The Mark III indicator is applicable to 1 watt-200 watts amplifier operating voltage is 2V-9V DC at max 400 MA. The circuit uses 10 LEDs per color. It's very easy to connect to the amplifer. Just hook up with the speaker output!!

**IN KIT FORM** $18.50

**ELECTRONIC DUAL SPEAKER PROTECTOR**

Cut off when circuit is shorted or overloaded to protect your amplifier as well as your speakers.

A must for OCL circuits...

**KIT FORM** $8.75 EACH.

**FM WIRELESS MIC KIT**

It is not a pack of cigarettes. It is a new FM wireless mic kit! New design PC board fits into a plastic cigarette box (case included). Uses a condenser microphone to allow you to have a better response in sound pick-up. Transmits up to 350 ft. With an LED indicator to signal the unit is on...

**KIT FORM** $7.95

**GENERAL PURPOSE INSTRUMENT BOXES**

All boxes are made of aluminum. Too is anodized black. Bottom is silver and comes with 4 rubber pedestals.

**P/N** | **SIZE** | **PRICE**
----------|----------|----------
FT4251 | 4 1/8" (W) x 1 1/2" (H) x 2 7/8" (D) | $2.10 ea.
FT452 | 4 3/8" (W) x 2 1/8" (H) x 5" (D) | $3.50 ea.
FT572 | 5 3/8" (W) x 2 3/4" (H) x 7 1/2" (D) | 4.55 ea.

**DIGITAL AUTO SECURITY SYSTEM**

4 DIGITS

- **PERSONAL CODE!!**
- proximity triggered
- voltage triggered
- mechanically triggered

**3-WAY PROTECTION!**

This alarm protects you and itself! Entering protected area will set it off, sounding your car horn or siren you add. Any change in voltage will also trigger the alarm into action. If cables within passenger compartment are cut, the unit protects itself by sounding the alarm.

**SPECIAL** $19.95

**TIMATRON RACK MOUNT TYPE CABINET**

All are of aluminum and machine made to very high-precision quality with sleek, black anodized finish. Front panels come blank and unidelled to allow you to make panels of your own design. For large quantity orders Formula International will silk screen print and drill panel holes at a minimal extra charge.

<table>
<thead>
<tr>
<th>SIZE</th>
<th><strong>PRICE</strong></th>
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<tbody>
<tr>
<td>15&quot; (W) x 2 1/4&quot; (H) x 12&quot; (D)</td>
<td>$36.85</td>
</tr>
<tr>
<td>18&quot; (W) x 4&quot; (H) x 12&quot; (D)</td>
<td>45.75</td>
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<td>18&quot; (W) x 4&quot; (H) x 8&quot; (D)</td>
<td>33.45</td>
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<tr>
<td>18&quot; (W) x 2&quot; (H) x 12&quot; (D)</td>
<td>35.45</td>
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<tr>
<td>9&quot; (W) x 4&quot; (H) x 17&quot; (D)</td>
<td>24.50</td>
</tr>
<tr>
<td>6&quot; (W) x 4&quot; (H) x 8&quot; (D)</td>
<td>20.75</td>
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**HICKOK LX303 DIGITAL LCD MULTIMETER**

- 3 1/2 digits display
- 200 hours 9V battery life
- A.C. Zero, polarity, overrange indication
- 100MV DC F.S. sensitivity
- 19 ranges and functions
- D.C. voltm: 0.1 V to 1000 V
- A.C. voltm: 0.1 V to 600 V
- Resistance: 0.1Ω to 20 MΩ
- D.C. current: 0.01 A to 100 MA

OUR PRICE $71.45

**60W + 60W STEREO AMPLIFIER**

**COMPleted UNIT - NOT A KIT!**

OCL pre amp. & power stereo amp. with bass, middle, treble 3-way tone control. Fully assembled and tested, ready to work. Total output distortion less than 0.5% at full power. Output maximum is 60 watts per channel at 8Ω. Power supply is 24-36V AC or DC. Complete...

Assembled $49.50 ea.

**POWER TRANSFORMER** $5.50 ea.

**GREEN COLOR 0.6" LED ALARM CLOCK**

- 24 hr. alarm
- 10 min. snooze time
- Alarm/PM Indicator
- Power interrupt Indication
- Green color 0.6" display
- 110V AC 60Hz input
- Factory assembled

NOT A KIT $17.50 EACH

**LCD CLOCK MODEL!**

- 0.5" LCD 4 digits display
- X'tal controlled circuits
- D.C. powered (1.5V battery)
- 12 hr. or 24 hr. display
- 24 hr alarm set
- 60 min. countdown timer
- On board dual back up lights
- Dual time zone display
- Stop watch function

NiC1200 (12 hr) $24.50 EA.

NiC2400 (24 hr) $26.50 EA.

**UNIVERSAL PROTOBOARDS **

*CIRCUIT FIT*

All Boards are made of High Quality G10 Fiber-glass and Phenolic Paper. Please consult the price and specifications for any kind of standard components to fit board.

**P/N** | **SIZE** | **HOLE** | **PRICE**
----------|----------|----------|----------
SP 624 | 2 1/16" x 5 1/2" x 1/2" | 30 | $0.70 ea.
SP 122 | 2 5/8" x 2 1/2" X 1/2" | 22 | $0.65 ea.
SP 550 | 2 1/4" x 2 3/8" x 1/2" | 14 | $0.60 ea.
SP 123 | 2 1/4" x 2 3/8" x 1/2" | 14 | $0.60 ea.
SP 201 | 2 1/4" x 2 3/8" x 1/2" | 14 | $0.60 ea.

**ELECTRONIC WHEEL OF FORTUNE KIT**

With 10 numbers split into black and white on dial. The LED turns when you hit the play switch, then it stops down and stops on one number. It sounds like a motor inside, but there is none. Lots of fun and easy to build. Kit comes with nice looking case, all electronic parts, P.C. Board and LEDS. Battery not included.

**$12.50**

**22W + 22W STEREO HYBRID AMPLIFIER KIT**

It Works in 12V D.C. As Well! Kit includes 1 PC SANYO STK-024 stereo power amp IC LM 1458 as one amp. All other electronic parts, PC Board, all control pots and special heat sinks for hybrid. Power transformer not included. It produces ultra hi-fi output up to 44 watts (22 watts per channel) yet gives out less than 0.1% total harmonic distortion between 100Hz and 10KHz.

**$32.50 PER KIT**
MINI ELECTRONIC ORGAN KIT
PET-102 (25 KEYS)

The kit contains all electronic and mechanical parts, key boards, speaker, switches and PC Board as well as the wooden cabinet. Ideas for school projects or all to children interested in electronics. Uses 6V C size x 4 battery (not included).

$38.50

MANY SOUND DECISIONS!
Solid state sound Indicator Operating voltage 6V DC
Model EB1216 (Continuous) $3.60 each
Model EB1216 (Shift Key) $4.95 each
Model EB136 (Fast Bumper) $6.00 each

1 Watt Audio Amp Kit
All parts are pre-assembled on a mini PC Board.
Supply voltage 6V ~ 9.5V DC
Special Price $1.95 ea.

"FISHER" 30 Watt Stereo Amp
Each Kit:
Model FA-30L includes 2 speakers (6 x 80) and stereo interconnecting parts.
Board Power supply: 12V DC (3 x Ind.) operating range: 10V DC.
Supply voltage: 12V DC

$15.00 ea.

5W Audio Amp Kit
2 x 2050 with Volume Control
Supply Power 60 - 18V DC
Only $6.00 Each

TIMER KIT
Time Controlled from 1-100 sec.
Ideal for use as timing relay unit for burglar alarm, photo service, and other purposes.
Uses: Datasheet 110V, 2 x 2A
Supply voltage: 110V DC
$11.50 Each

ELECTRONIC ALARM SIREN
COMPLETE UNIT
Ideal for use as an Alarm Unit or Backup to your car back up system.
For use with 110V AC or 12V DC

$49.95

SOUND ACTIVATED SWITCH
COMPLETE UNIT
Ideal for use in a security system for burglar alarm, etc.
Supply voltage: 12V DC

$75.00

LINEAR SLIDE POT 500K (SINGLE)
Metal Case 3" Long
2 FOR $1.20

Battery Powered Fluorescent Lantern
Great for use as a flash light.

$5.25 PER PACK

Professional Case for our 030V Power Supply: 11" x 12" x 5" with giant 4" volt/amp meter; output blinding post and fuse holder, on/off switch and line cord! Only $21.50 ea.

Professional Case for our 030V Power Supply: 11" x 12" x 5"
Transformer for Power Supply: 2 Amp x 2 $8.50

Domain

ONLY $23.50 each

Super 15 Watt Audio Amp Kit
Uses STK-015 Hybrid IC, power supply with power transformer, front Amp with tone control, all electronic parts as well as PC Board. Less then 0.5% harmonic distortion at full power 50 Watt B response from 20- 100,000 Hz. This amplifier has QUASI-Complimentary class B output. Output max is watt (10 watt RMS) at 44!

SPECIAL ORDER $15.00 ea.

FM Wireless Mic Kit
This new model FM Microphone Kit uses 2 high frequency transistors, works in the FM range 160-108 MHz. Miniature all electronic parts, PCB board and microamping circuit. Transmitter has variable band frequency crystal (over 2000 MHz) kit comes with all electronic parts, PC Board and microamping circuit. Transmitter, Receiver, Antenna with a 4" mic, leads on top, can be used for 50 MHz. All parts included. Super Kit gets $29.95

Very Special Price 2 to $19.99

Sub-Mini Size Condenser Microphones $2.50 each
PET-Transmitter Built-in

Fluorescent Light Driver Kit
12V DC Powered
L-Grips w/ 7-15 Watt Fluorescent Light Tubes Ideal for Lamp, Outdoor, Indoor Auto or Boat
Kit includes high voltage coil, power transistor, heat sink, all other electronic parts and PC Board, Light tube not included! With CASE ONLY $5.60 PER KIT

Heavy Duty Clip Leads
10 pairs - 5 colors Alligator clips on a 22" long lead. Ideal $2.20/each for any testing.

Mini-Sized I.C. AM Radio
Size smaller than a box of matches
Receive all AM stations
Batteries and ear phone included

$10.50

Numeric and Hexadecimal
LED Display With Logic
HP 5062 7300

4 x 7 Dot Matrix 0.4" Digit
With On Board Decoder/Driver and Memory.

$50.00

Giant Size Vu Meter
1MA movement 3 1/2" scale length.
Scale in "Vu" to "+90o". Meter face 5 1/2" x 5 3/8" with a "smoke" plastic cover.

$85.00

Solid State Electronic buzzers
Vox type buzzers where you don't hear the buzz type buzzing tone...ideal for Alarm System

$1.50 each

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