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Electronics Today

May 1986

Canada's Magazine for Electronics & Computing Enthusiasts

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BEST AVT-286: the IBM AT Compatible

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Circle No. 2 on Reader Service Card

Electronics Today

May 1986
Vol. 10 No. 5

Canada's Magazine for Electronics & Computing Enthusiasts

Our Cover

The Microlab 1 trainer serves to illustrate both our troubleshooting theme and its own review, which is on page 34; photo by Bill Markwick.

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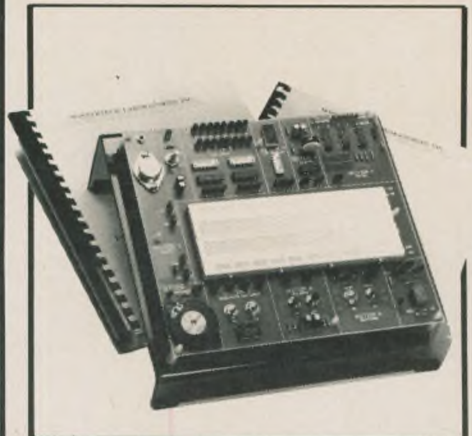

Product Review page 34

Troubleshooting page 30

Features

Projects

Product Review

Series

Columns and Information

For Your Information

Omni-Directional Heatsinks

The radial design of the 2296C heatsink utilizes airflow from any direction to cool LSI devices and gate arrays. Designed for forced convection applications with dissipation of power up to 10W, the seven-fin design provides more surface area for heat dissipation than extruded or stamped heat sinks of similar size and volume.

Standing only .695 inches tall and 1.25 inches in diameter, the 2296C comes in gold chromate, clear, or black anodized finishes for maximum performance in natural convection applications. To receive more information contact: Carol Cannon, Thermalloy Inc., P.O. Box 810839, 2021 West Valley View Lane, Dallas Texas 75381-0839, (214) 243-4321.

Circle No. 34 on Reader Service Card.

New Backup System for Hard Disks

Looking for an inexpensive, yet reliable form of backup, for your precious hard disk information? Well, stop looking. Alpha Micro of Santa Clara, California, has come up with a nifty system that utilizes a standard video cassette recorder (VCR). That's right!

The Videotrax (TM) videotape backup and restore subsystem consists of a special video controller board which links the VCR to any IBM PC/XT/AT or compatible hard disk, providing up to 80MB of highly reliable backup information.

The board is at home in any of the available expansion slots, and the MS-DOS menu driven software resides on a 5.25" floppy disk. One of the more attractive features is the use of regular, inexpensive consumer quality video tapes for making the actual backup; a two hour video cassette gives 80MB of storage. This gives the system an advantage in cost-efficiency, convenience, and reliability over both floppy disk and streaming tape backup and restore methods.

Two modes of operation are possible with the software: disk image and file-by-file. The disk image mode allows for high-speed backup and automatic detection of bad disk sectors for reassignment. The file-by-file mode permits backup of all files, specific files by name, file groups or selected files modified in prior sessions. Tape quality checks, full backup verification, a file directory, and audit trail are all available to the user through the software.

With the Videotrax's capability of transmitting pure video signal data, it's possible to send stored information over satellite, cable, and regular broadcast systems at a considerably reduced cost in comparison to present data communications methods.

Alpha is offering the Videotrax in two configurations: the videotape subsystem which includes the controller, software, and a computer controlled VCR (all tape functions such as play, fast-forward, etc. controlled by the software) for $2290; and the second configuration, for those with their own VCRs, carries a current list price of $995 (controller and software). The computer controlled VCR is available separately at a cost of $1295. The Videotrax is available across Canada through Olivetti office equipment dealers.

For more information contact: Paul Manina, Vice President Micro Computing Products, Olivetti Canada, 3190 Steeles Ave. E., Markham, Ontario, L3R 1G9.

Circle No. 35 on Reader Service Card.

Contest Update: We said we'd draw for the contest winner and publish it in the May issue. Gulp... we messed up the timing on this one, because the May issue has to be at the printers at the end of March. The deadline is still April 15, but the results will have to wait until the next issue. The winner will still be notified as mentioned in the rules. Our apologies for making everybody wait, and we've bought a bigger calendar.

Liability
While every effort has been made to ensure that all constructional projects referred to in this magazine will operate as indicated efficiently and properly and that all necessary components are available, no responsibility whatsoever is accepted in respect of the failure for any reason at all of the project to operate efficiently or at all whether due to any fault in the design or otherwise and no responsibility is accepted for the failure to obtain component parts in respect of any such project. Further no responsibility is accepted in respect of any injury or damage caused by any fault in design of any such project as aforesaid.

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We can supply photocopies of any article published in Electronics Today Canada; the charge is $2.00 per article, regardless of length. Please specify both issue and article.

Component Notation and Units
We normally specify components using an international standard. Many readers will be unfamiliar with this but it's simple, less likely to lead to error and will be widely used everywhere sooner or later. Electronics Today has opted for sooner!

Firstly decimal points are dropped and substituted with the multiplier: thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one nanofarad is 1000pF). Thus 0.1 uF is 100nF, 5600pF is 5n6. Other examples are 5.6pF = 5p6 and 0.5pF = 0p5.

Resistors are treated similarly: 1.8Mohms is 1M8, 56kohms is the same, 4.7kohms is 4k7, 100ohms is 100R and 5.6ohms is 5R6.

PCB Suppliers
ETI magazine does NOT supply PCBs or kits but we do issue manufacturing permits for companies to manufacture boards and kits to our designs. Contact the following companies when ordering boards.

Please note we do not keep track of what is available from who so please don't contact us for information PCBs and kits. Similarly do not ask PCB suppliers for help with projects.

K.S.K. Associates, P.O. Box 266, Milton, Ont. L9T 4N9.

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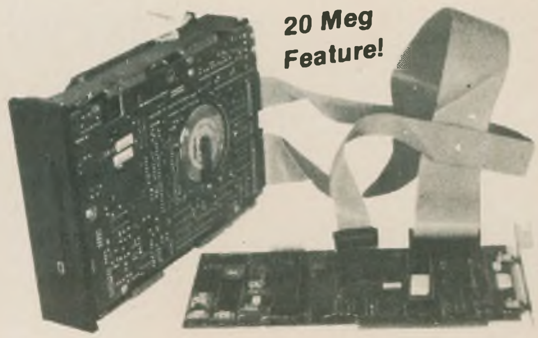

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XT	■	■	■		■	■	
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Circle No. 5 on Reader Service Card

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Now Tek has improved its 2213/2215 scopes with brighter displays. Greater accuracy. And more sensitive triggering. At no increase in price.

The 60 MHz 2213 and dual time base 2215 have been the most popular scopes in Tektronix history. Now, Tek introduces an "A" Series update with more than 25 specification and feature enhancements— things you have asked for such as single sweep—all included at no added cost.

A brighter display and new vertical amplifier design provides sharp, crisp traces. That makes the 2213A/2215A a prime candidate for tasks like TV troubleshooting and testing, where fast sweeps are typical.

New features include 10 MHz bandwidth limit switch, separate A/B dual intensity controls (2215A only), and power-on light: additions customers have suggested for giving these scopes the final measure of convenience.

Triggering, sweep accuracy, CMRR and many more major specifications are better than ever. Check the performance chart: not bad for scopes already considered the leaders in their class!

Specification enhancement	2213/2215 "A" Series	2213/2215
CRT brightness	14 kv accel. potential	10 kv accel. potential
Vertical accuracy	3%, 0° to 50°C	3%, + 20° to 30°C
Chop rate	500 kHz	250 kHz
Input capacitance	20 pF	30 pF
CMRR	10 to 1 at 25 MHz	10 to 1 at 10 MHz
Channel isolation	100:1 at 25 MHz	Not specified
A Trigger sensitivity (int)	0.3 div at 5 MHz	0.4 div at 2 MHz
TV triggering	1.0 div compos. sync	2.0 div compos. sync
Sweep accuracy (in 10X)	4%, 15° to 35°C	5%, 20° to 30°C
Delay jitter	20,000 to 1 (2215A) 10,000 to 1 (2213A)	10,000 to 1 (2215) 5,000 to 1 (2213)
Holdoff Range	10:1	4:1

The Price: Still $2206* for the 2213A and $2638* for the 2215A. Or, step up to the 100 MHz 2235 for just $3114*. Prices include two 10X probes, 15-day return policy, world-wide service back-up and comprehensive 3 year warranty. Ask about our extended warranty.

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Circle No. 3 on Reader Service Card

Parallel Speech Peripheral

An inexpensive vocal add-on for your micro.

By David R. Green

THE FOLLOWING is a description of how to construct your own speech processor peripheral for about $20 to $75 depending on how well stocked your junkbox is. The speech unit interfaces to a centronics print or user parallel port allowing almost any micro to obtain easy speech capability.

Since actual speech requires only 10 to 12 sounds per second, this unit can be driven from a BASIC program, by sending each successive address for each allophone sound. The only caution is: unless you have a fast processor/BASIC interpreter in your micro, don't use read and data statements as it will cause minute delays between some allophones as the processor runs through the program looping to and from the data statements. Also, to end a word, you must send a pause, varying in length from PA1 through PA5, to stop the speech processor from vocalizing the last allophone.

Circuit Description

This unit is so simple it defies description, but here we go anyway. Referring to the block diagram, the 74LS245 buffers the data and control lines between the computer I/O port and the speech processor. The LS245 is enabled only when pin 11, the EN pin, is grounded. This usually occurs when the cable is plugged into the connector on the speech peripheral.

Referring also to the timing diagrams, the computer sets up the data on the I/O data bus, allowing for bus settling time, then pulses the handshake STROBE line low. This loads the data into the address latch buffer area of the SPO256-AL2 speech processor, which in turn utilizes this data to generate an internal address for the appropriate speech sound data location in the internal 16k ROM. The speech processor then shifts the speech sound data out of the digital out pin. At the same time as this, as soon as data is removed from the input address latch buffer area, the speech processor asserts the LRQ line and lowers the SBY line, signalling to the computer to send the next allophone address.

The low pass filter comprised of the 33k resistors and the u022 disc capacitors, eliminates clocking noise above 5kHz generated internally in the speech chip.

The LM386 and its associated components form an amplifier with a gain of 200 to supply sufficient level to drive the speaker and line output terminals.

Construction

As this is a reasonably simple unit, almost any technique may be used, perfboard or printed circuit.

The majority of the passive components are not critical in value, but try not to stray too far off. Referring to the schematic diagram, depending on what you have for power supplication, a complete +5 and +12 supply might have to be built. As little as +5 volts may be used to operate the LM386 audio IC supplied by the on-board 7805, but I chose to run it at +12 volts to obtain the maximum power output capability. Be sure you do not supply more than +12 volts to the audio IC as its absolute maximum specification is +15 volts.

Also, if you use a wall adaptor or build your own supply, be sure it is well filtered and regulated so as not to introduce hum in the audio.

The SPO256-AL2 speech chip is

available from Radio Shack (cat # 276-1784) for about $20. It comes complete with a full set of instructions including the alllophone address chart.

your interpreter uses, send the decimal or hex value for the specific allophone required to the peripheral.

The 3.12 MHz crystal for the unit was not as easily available, so instead I used a 3.2768 MHz crystal which is only about 5 faster and simpler to get.

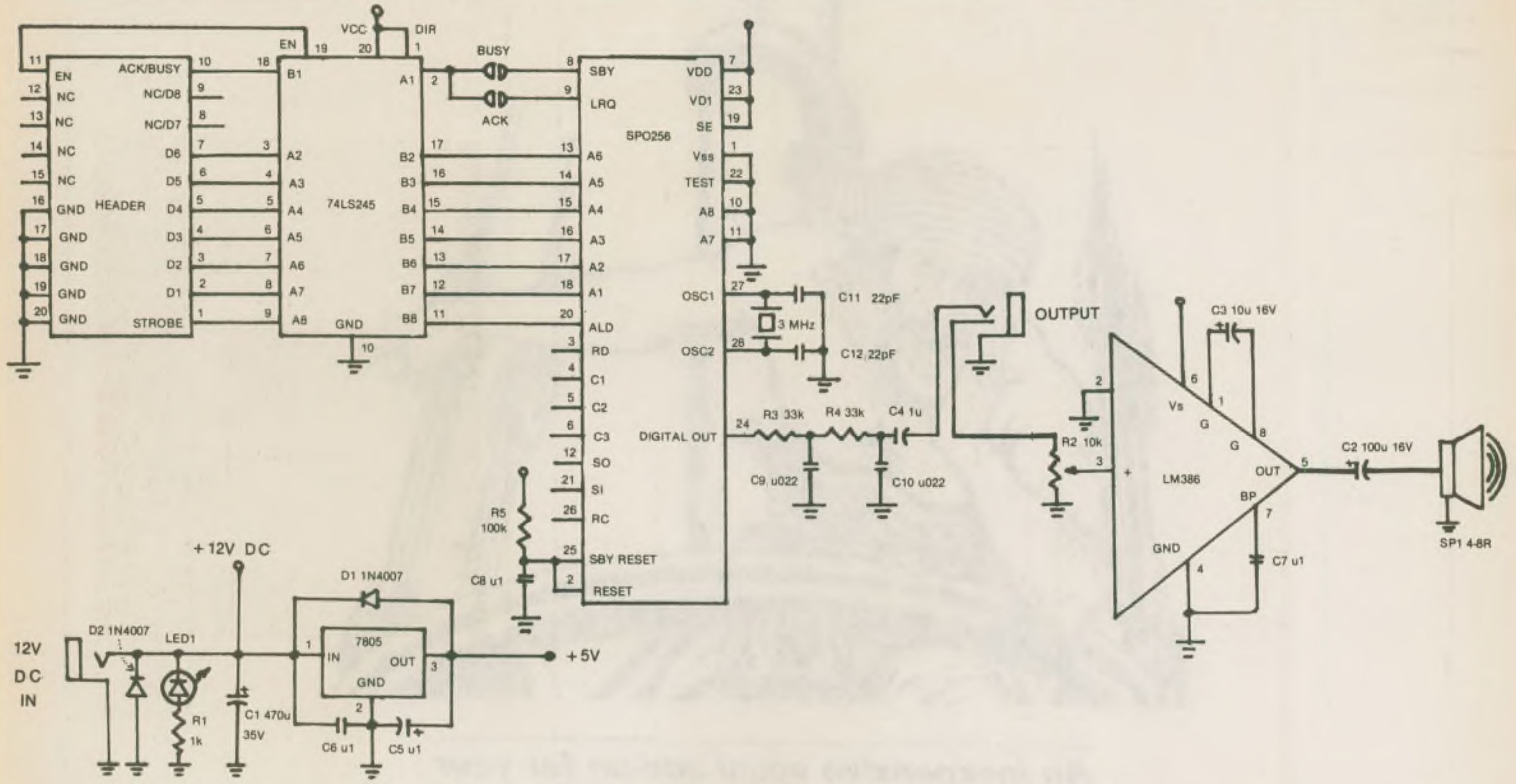


Fig. 1. Circuit for the speech peripheral.

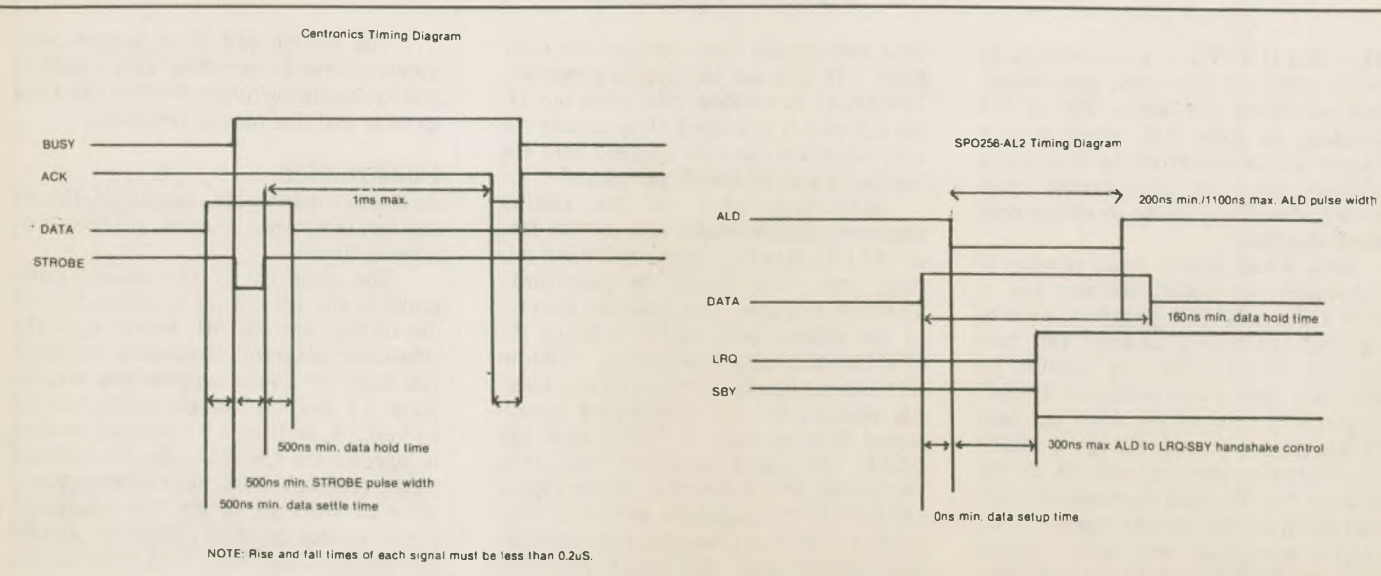
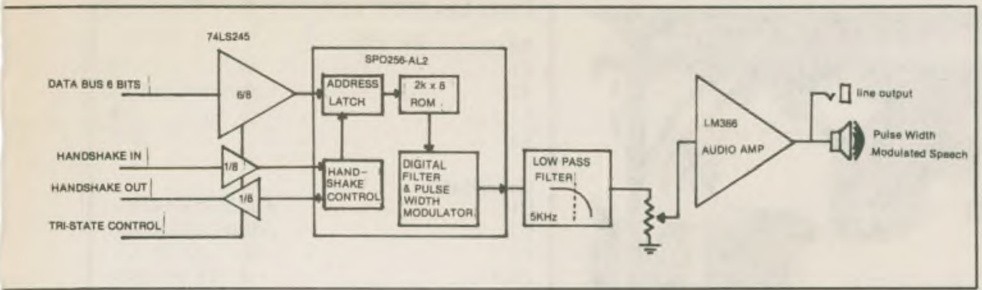


Fig. 2. Timing diagrams for the two types of connectors



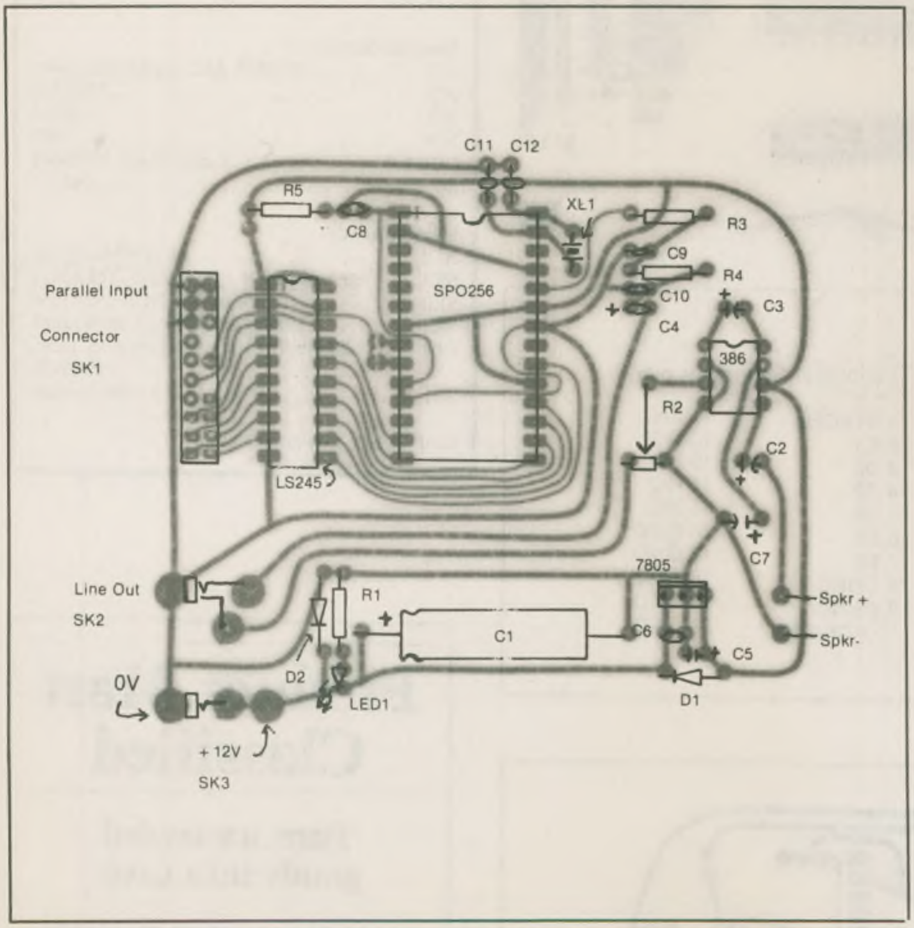


Fig. 4. Parts overlay.

Although many people complain about the use of the LM386 audio IC, I find it sufficiently loud when used in a high gain circuit and driving a reasonably decent speaker. If it is still not loud enough for you, the circuit includes a line out jack that can be hooked to your monitor, if it has audio in, or to an external high power audio system.

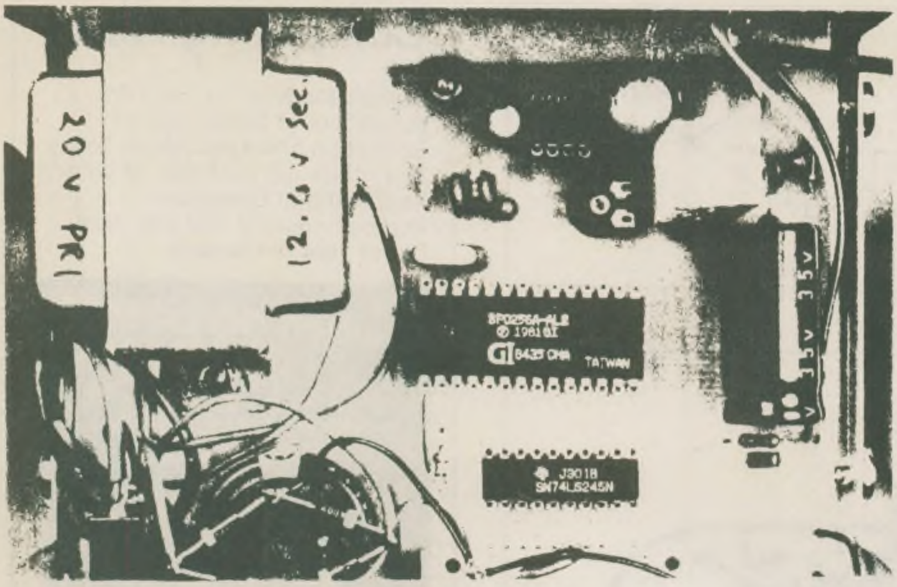
Programming

From BASIC, OPEN the parallel port or enable your print card. Using POKES, PRINT CHR$(xx), or whatever method

eg. TI-99/4A BASIC

```
10 OPEN#1:'PIO.LF.CR'
20 PRINT#1:CHR$(27);CHR$(7);
CHR$(45);
    CHR$(15);CHR$(53);CHR$(0)
30 CLOSE#1
40 END
```

If you are using a printer port, be sure to suppress any automatic line-feed or carriage-return codes, or the unit will talk forever.



Parts List

Resistors 1/4W 5%

R1	1k
R2	min. p.c. pot10k
R3,4	33k
R5	100k

Capacitors

C1	470uF 35V electro.
C2	100uF 16V electro.
C3	10uF 16V electro.
C4,5	1uF 35V tantalum
C6,7,8	u1 disc
C9, 10	u022
C11, 12	22pF

Semiconductors

IC1	SPO256-AL2 speech processor
IC2	74LS245
IC3	LM386
IC4	7805
LED1	Radio Shack #276-041
D1,2	1N4007

Miscellaneous

XL1	3.12MHz crystal
SK1	20 pin, 0.1 in. header, 3M #3428
SK2	pc mount RCA-type jack
SK3	2 conductor closed circuit jack
PL1	20 pin, 0.1 in. insulation disp. plug, 3M #3421
SP1	2-4 in. 4 or 8 ohm speaker

case; +12V power source

Table 1

Centronics pinout (pins 1-20)		Peripheral Connector pinout	
1 STROBE	11 BUSY	1 STROBE	11 EN
2 D1	12 Po	2 D1	12 NC
3 D2	13 STAT	3 D2	13 NC
4 D3	14 AFXT	4 D3	14 NC
5 D4	15 NC	5 D4	15 NC
6 D5	16 GND	6 D5	16 GND
7 D6	17 GND	7 D6	17 GND
8 D7	18 NC	8 D7/NC	18 GND
9 D8	19 GND	9 D8/NC	19 GND
10 ACK	20 GND	10 ACK/BUSY	20 GND

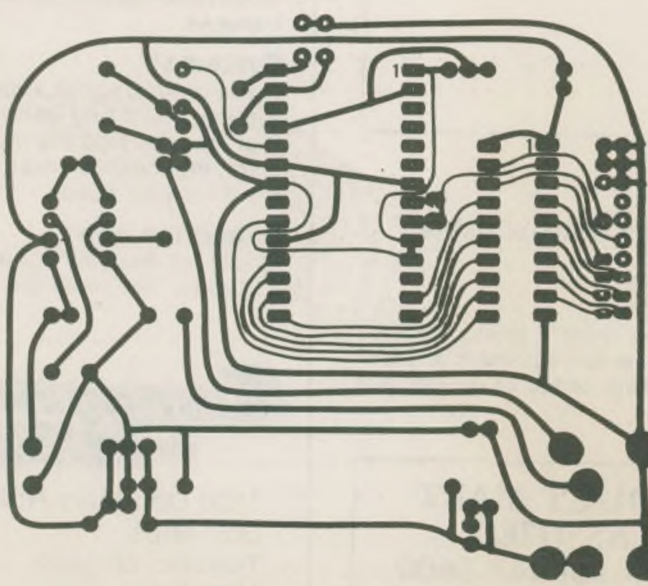


Fig. 5. Printed circuit artwork.

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• 360K DS/DD Disk Drive	$125.00
• XT Compatible Mother Board OK	$225.95

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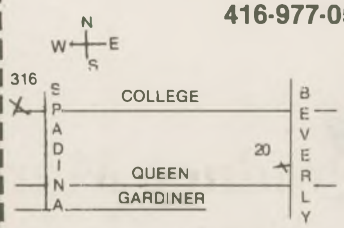

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Display Technology

Some recent developments in solid state display technology.

By Keith Brindley

IT'S only right that we should give priority to age, and the CRT is certainly getting on a bit. It has been around for a hundred years or so in one form or other, although only as a display device in televisions since about 1930.

The resolution of a CRT display is dependent primarily on the distance between the phosphor spots produced by the electron beam as it forms the picture. In a colour CRT, the resolution depends on the distance between triads of primary colour spots, which in turn is dependent on the accuracy of the shadow mask used to direct the three beams to their respective colour phosphors. CRTs with spot distances (known as pitch sizes) as small as 0.2mm have been made, but typical television CRT displays have pitch sizes of about 0.6mm. In terms of resolution, the CRT has a way yet to develop, but we can expect television pictures of tremendous clarity from high resolution CRTs.

The problems associated with CRTs are not to do with picture clarity. They are large, ungainly and heavy; their depth is often as bit as or greater than the screen size. They consume a lot of power, up to 200 watts or so. They are fairly easily damaged. none of this is any great disadvantage for AC-powered, fixed-site equipment, as long as you don't mind your television taking up all of the corner of the living room, or your computer taking up most of the room on your desk. If lightness, durability, and power consumption are important, then the conventional CRT will not do.

Sinclair's flat-screen CRT is one development of a traditional technology. As it stands, however, the device, though ingenious, is monochrome, difficult to view and constrained by its very ingenuity to remain small. Philips is one company developing a flat-screen colour CRT. While similar to the Sinclair device in that the electron beam is side-projected, it is totally different in other respects (Fig. 1). The Sinclair tube uses a familiar electron gun bent through 90 degrees. To engineer such a tube for the accuracy required of colour television would be very difficult. Philips use a single electron beam, like Sinclair, but it scans at three times the normal rate, so it can cover all three spots in a colour triad. It also has an unusual approach to deflection. After reversal of the beam, frame plates bend it to the required spot on the screen. Before hitting the screen the beam passes through an electron multiplier, increasing the number of electrons and so making a brighter spot. ITT and Siemens are the other two companies working on the developments of flat-screen colour CRTs.

The Liquid Crystal Ball

Apart from dabbling at new developments in CRTs (Sony's Trinitron CRT, a single electron beam device, and Toshiba's flatter, squarer tube) the Japanese appear to be leaving major CRT developments such as flat-screen devices well alone. Instead they are concentrating efforts towards flat-panel displays which do not use electron beams at all.

The main force of their work so far has been in the development of LCD devices, but other technologies will probably form the display devices of the future.

There are a number types of LCDs, but the principle is the same in all of them (Fig. 2). A layer of liquid crystals is sandwiched between two transparent electrodes. The molecules of

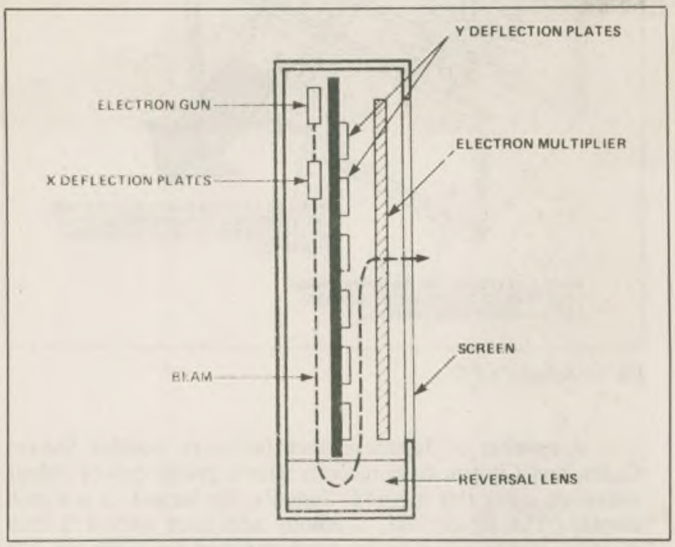

Fig. 1. Philips flat-screen CRT (simplified).

the liquid crystals are generally aligned in one direction and so light from behind the device can pass through. When a potential is applied across the electrodes, however, the molecules of the crystals all became polarized into another alignment, which prevents light from passing through the layer, making the layer appear dark.

Three main varieties of liquid crystal are used to make LCDs: nematic, cholestric and smectic (Fig. 3). The major difference is in how the molecules are aligned, and this produces greatly different LCDs.

Nematic liquid crystals are more commonly called 'twisted nematic' crystals, because the crystals sandwiched between the

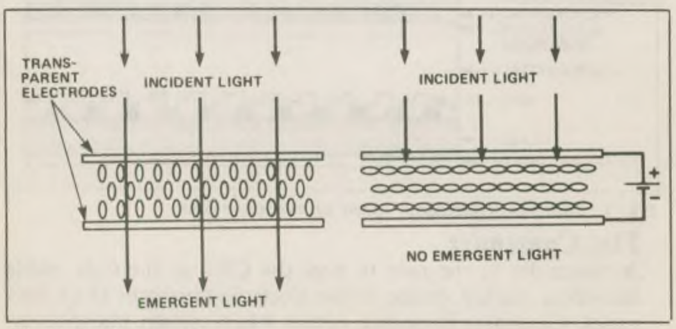

Fig. 2. LCD Operation.

transparent electrodes are twisted through 90 degrees between one electrode and the other when no potential is applied. Polarizing sheets (at 90 degrees to each other) are applied at the front and back of the device, so that light entering the LCD is polarized in one plane by the first polarizing sheet, passes through the liquid crystal where it is twisted through 90 degrees by the twisted nematic structure, then leaves the device through the second polarizing sheet (Fig. 4). Typically the LCD wouldn't normally be used like this, but a reflecting surface would direct the emergent light back through the setup, so that an observer on the same side as the incident light would see a transparent area.

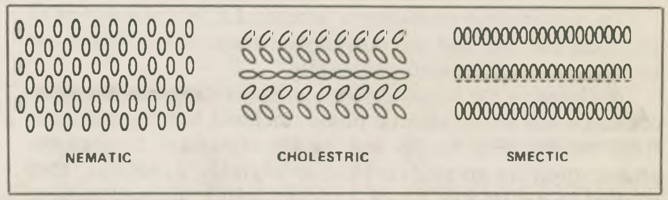

Fig. 3. Temperature dependent structures in liquid crystals.

When a potential is applied across the electrodes, the crystal becomes active, and the molecules are all aligned in one direction. The incident light, which is polarized by the first sheet, now passes through the liquid crystal without being twisted. It cannot pass through the rear polarizing sheet, cannot be reflected, and therefore cannot be seen by the observer. An opaque area is produced.

Cholestric crystals do not need polarizing sheets since a dye is added to the liquid crystal to absorb the incident light. LCDs using this principle are sometimes known as "guest-host"

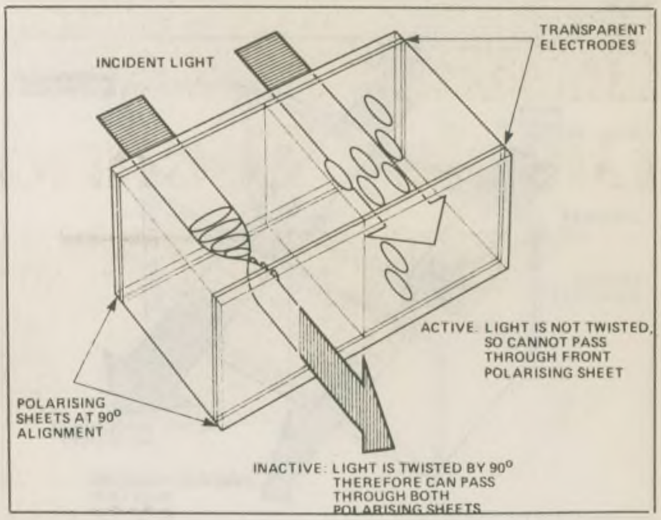

Fig. 4. Twisted nematic LCD.

devices. Dichroic dyes, which produce a different colour depending on which way their cells are aligned, are the "guests" in the liquid crystal "host".

In an inactive state, incident light passing through the liquid crystal is polarized by the natural twist in the structure, and because of the dye the emergent light appears coloured (Fig. 5). As with twisted nematic LCDs, when the activating potential is removed the structure reverts back to its inactive, though this time coloured, state.

Heat Waves

All liquid crystals have several temperature dependent phases, in which the ordering properties of the molecules change. Three phases: isotropic, nematic and smectic are used in smectic liquid crystal devices to create a different type of LCD. Smectic LCDs rely on three phenomena to do their job:

1. In the smectic phase, the molecular arrangement of the liquid crystals cannot be changed by an applied electric field.

2. When liquid crystals are heated to the isotropic phase then cooled to the smectic phase with no applied electric field, they become strongly disordered.

3. When heated to nematic phase, then cooled with an applied electric field to the smectic phase, the orientation of the molecules will be as in the nematic phase.

To exploit these phenomena, smectic LCDs use a matrix of electrical lines so that each display element in the display can be addressed and heated electrically.

By heating the liquid crystals to the isotropic phase, then cooling them to the smectic phase, incident light is prevented from passing (Fig. 6). By heating the crystals to the nematic phase, applying an electric field to align the molecules, then cooling to the smectic phase, incident light is allowed to pass.

The really clever bit is that by maintaining the temperature so that the liquid crystal is held in the smectic phase after it has cooled from an isotropic or nematic phase the crystal molecule arrangement remains fixed at what it was, prior to cooling. Smectic LCDs have a memory facility so that removing the "addressing" potential has no effect. to change the molecular arrangement requires a further addressing, heating and cooling procedure.

Most of the work currently being undertaken into computer-type LCDs is along the smectic lines. One of the latest LCD developments is STL's smectic-A 760 x 420 pixel prototype display which, it is hoped, will be on the market soon.

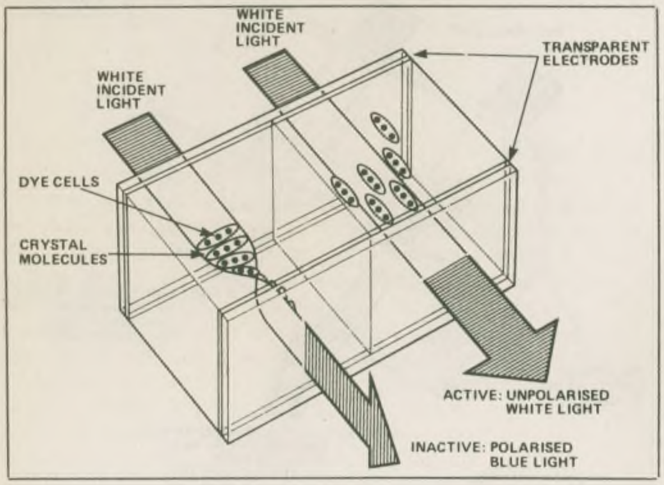

Fig. 5. Cholestric LCD.

Colour LCDs

The LCD techniques we've looked at so far have been for dot-matrix displays, ideal for computers but not so good for televisions. There are three reasons for this. First, the displays are monochromatic, and who wants a black-and-white television? Second, the display type is dot-matrix - each dot can only be on or off, unlike CRT screen spots which are graduated in brightness. Most important is the response time of these devices (the time it takes for the device to switch between active and inactive states). Common response times are around 300ms -great for computer or alphanumeric displays, but certainly not fast enough for television where each spot on the CRT screen is addressed by the electron beam every 40ms.

Two of these problems, colour and response time, are being tackled by a number of Japanese manufacturers with LCD devices which use thin-film transistors (TFTs) mounted directly on the glass which forms the casing to contain the liquid crystal. The transistors are thus in direct contact with the crystal itself (Fig. 7).

The use of TFTs dramatically reduces the LCD response time, down to a level approaching that required to display television pictures. By making an LCD element so small that it can be considered as a spot, and by grouping three spots into triads, coloured filters can be placed over the individual spots so that the triads can be addressed much like the triads of a conventional CRT. And, hey presto, we have an LCD colour television display device.

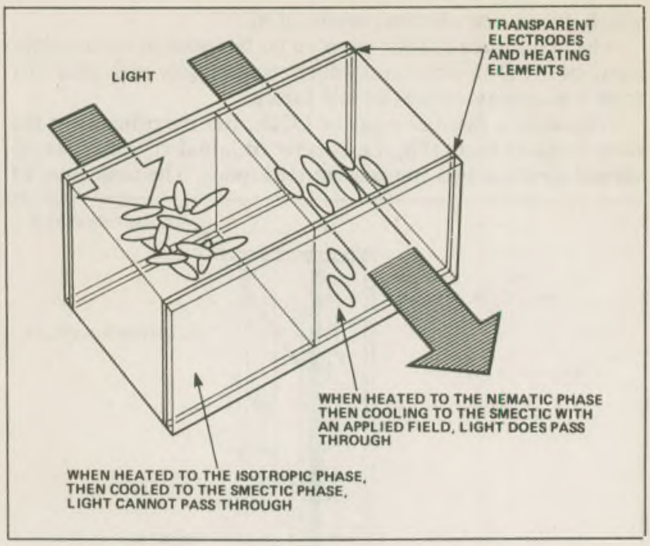

Fig. 6. Smectic LCD.

A number of Japanese manufacturers, notably Sanyo, Casio, and Citizen, have recently shown prototypes of colour television using this method. Sanyo's, the largest, is a 4 inch display. The Epson Elf, a colour television with a 2 inch display, was the first to be produced and has been on sale abroad for a year or so already.

The resolution of these displays is limited by the number of liquid crystal triads which can be produced in the device. At present the resolution doesn't even approach that of typical low-grade television crts, but it is only a matter of time - and research money.

Size is probably the colour LCD's greatest enemy. The quality of the colour display is limited by the constancy of the thickness of the layers in the device. The larger the device, the more difficult it becomes to maintain constant thickness. So, no wall-sized flat-panel television screens using LCDs yet, I'm afraid.

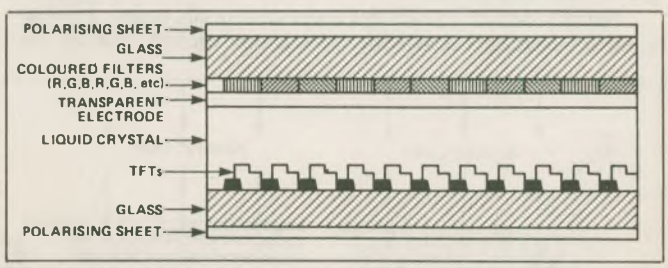

Fig. 7. Thin film transistors speed up response time.

Flat Contender

A contender in the race to beat the CRT as the only viable television display device is the electroluminescent (EL) flat-panel. Electroluminescence occurs when certain phosphorescent materials are influenced by an electric field.

Figure 8 shows a cross-section of an EL display, with criss-crossed electrodes allowing each point where two electrodes overlap to be addressed. The material sandwiched between the layers of electrodes is typically zinc sulphide, which emits a bright yellow-orange colour when an electric field is generated through it, but red, green and blue emitting materials have recently been isolated.

EL displays are of four main types: DC thick-film, AC thick-film, DC thin-film, AC thin-film. Thin-film varieties have proved to be the most successful so far, in terms of reliability and power requirements. In these, a layer of powder phosphor, typically around 30 um thick is deposited onto a sheet of transparent oxide which forms the front electrode. This layer is then covered by a vacuum evaporated aluminium rear electrode. After etching horizontal and vertical rows and columns into the front and rear electrodes, the device is more or less usable. Such displays are of monochromatic dot-matrix form suitable for alphanumeric computer displays and graphics. By overlaying thin films of red, blue and green emitting phosphide layers, there is hope that EL displays suitable for reproduction of colour television pictures can be made. Their availability on a commercial basis is many years off yet.

EL displays generally need quite a high operating voltage (over 100V) and considerable current, so they are probably not the display to be used in portable equipment, but for flat-panel home or office use their potential is great.

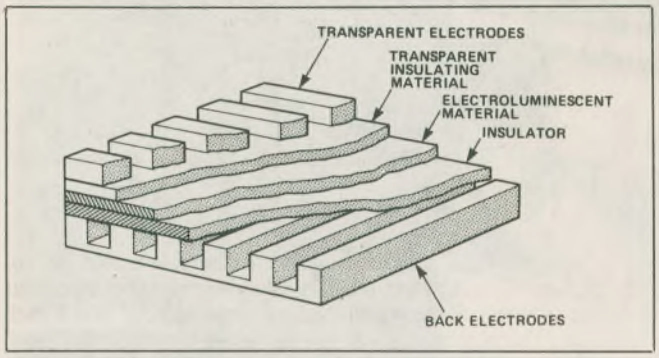

Fig. 8. Structure of electroluminescent display.

Plasma Gas Discharge

Plasma gas discharge of inert gases under a strong electric field is the basis of another type of flat-panel display - the plasma display panel (PDP). The gas breaks down into a plasma and gives off light. Neon indicators work in the same way.

The two main varieties of PDP differ in the applied voltages. In the DC plasma display the criss-crossed electrodes

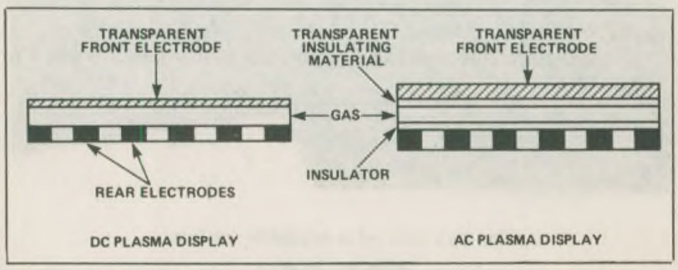

Fig. 9. DC and AC plasma displays.

are in direct contact with the gas. In the AC plasma display, the electrodes are close to the gas but electrically isolated from it (Fig.9).

Large sized PDPs have been developed, initially for military use, and now available on a commercial basis and used in many computers. Thomson-CSF, for example, has recently produced a 1024 x 1024 dot-matrix PDP display, whose resolution is not far short of a CRT.

PDP displays still have many disadvantages. Operating voltages are quite high (typically around 80V), they're not solid-state devices and can't be as rugged as LCD or EL displays. Colour displays suitable for television use are going to be difficult, if not impossible, to make.

ECDs

One new form of display device, just now reaching the market, looks as though it might topple the CRT in years to come. The electrochromic display (ECD) uses the fact that an electrochromic material changes its colour reversibly by redox reaction.

For example, amorphous tungsten trioxide (a-WO3) turns reversibly from transparent to blue by reacting with lithium ions in an electrolyte, following the formula;

$$WO_3 + Li^+ + e^- \upsilon LiWO_3$$

A simple display is illustrated in Fig. 10.

This display is much simpler in operation than an LCD, and

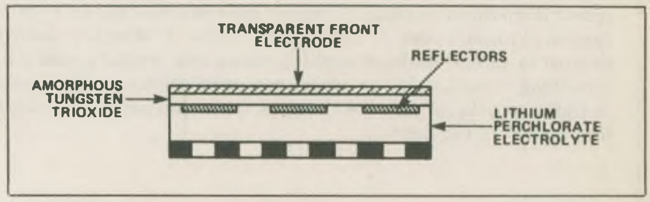

Fig. 10 A simplified electrochromic display.

would be much cheaper to make. It does, however, have significant disadvantages, not the least of which is its response times (over half a second to change from white to blue, and over two seconds to change from blue to white!). Significant development work is underway, and it['s probably true to say that ECDs are only at the stage which LCDs were at 15 years ago (nowhere). Given a few years and some hard research and development...

Old and New

The problem for manufacturers is not just one of research and development because other factors, mainly financial, are also involved. CRTs are an old technology. They've been made for many, many years by experienced manufacturers. They are used mainly as a television display device, but they're also used in test equipment: oscilloscopes, spectrum analysers, logic analysers and frequency response analyzers, as well as in computers. Because of the numbers involved and because of tried and tested manufacturing techniques, they are very cheap.

Flat-panel displays, on the other hand, are new. They're relatively difficult to make and therefore expensive. So, manufacturers are going to be very careful to analyze the situation before they decide on any one other display technology which they think can fit the bill. No one display technology is yet capable of being better than the CRT in all applications. LCDs use much less power, but they have a very restricted viewing angle, low contrast, and can't be viewed in the dark (they are a non-emissive technology); EL displays are much thinner and are an emissive technology, but their power requirements are not much less than those of the CRT. ECDs are thin, have a wide viewing angle and high contrast, but they still have an unacceptably long response time.

At present, CRTs are unbeatable because technology rides on the back of its own success. New developments such as flat-screen, low-powered, high resolution colour CRTs will be along soon. But time is the CRT's own worst enemy. Given a few years, easier manufacturing techniques and lower manufacturing costs, flat-panel displays must surely beat the CRT. The questions are: which flat-panel device will do it, and when? ■

Almost Free PC Software

Volume IX

The premise that good software ought to be cheap isn't one that the microcomputer industry as a whole seems to embrace, what with most programs costing several hundreds of dollars... and usually being copy protected, infested with bugs or poorly documented when you finally do get them. We think that cheap software is almost as fundamental as clean water and classic Coke.

This ninth volume of our popular almost free PC software represents another superb collection of programs for the IBM PC and compatible systems. Whether you're into games, business, hacking or just being in the same room as a microcomputer, this disk will enhance the usefulness of your PC at a cost that won't even dent your wallet, let alone blow it out of the sky as most applications packages can.

Small C If you've ever wanted to try writing programs in the C language, this compiler will fascinate you. It's a restricted implementation of C, producing code which is compatible with Microsoft's MASM and LINK programs... you'll need these to get it going.

Map is an interesting little utility which will check how DOS is situated in the memory of your computer and tell you a number of things about it. It's a useful programming tool, especially helpful if you're debugging software which interacts directly with DOS.

Note is the source file for the memory resident note pad that we ran in the March 1986 edition of Computing Now!. It requires MASM and LINK to use. It will create a resident memo page that you can call up from within any application.

Pango is one of the wildest games we've come across for the PC. While its premise is a bit improbable, it's fast and weird and more fun than a stoned house cat.

PC-Spell is a pretty decent spelling checker written in BASIC. Despite its pedestrian sounding origins, it's fast, accurate and easy to use. It can be listed if you want to see how it works, and comes with a large dictionary file and a utility to assist you in customizing it.

Peacock is a memory resident program which allows you to change the colours of your screen with alternate function keys. It's useful, for example, if you run software which insists on changing the screen to something loathsome.

Recover is a utility to assist you in getting data back from damaged files. It lets you look at your files one sector at a time and put the pieces back together.

SDB is a small relational database. It isn't dBASE III, but it also doesn't cost quite as much. It's still pretty powerful and is eminently suitable for many business applications. It features on line help.

Tally is a program which accurately counts the number of characters, words and lines in a file... all within your lifetime.

Xeno edits the tracks and sectors of your disks in a user friendly format... or, at least, one that doesn't lunge for your throat every time you boot it. You can use it to explore DOS, fix trashed disks, unerase files and do all the other low level magic that sector editors are renowned for.

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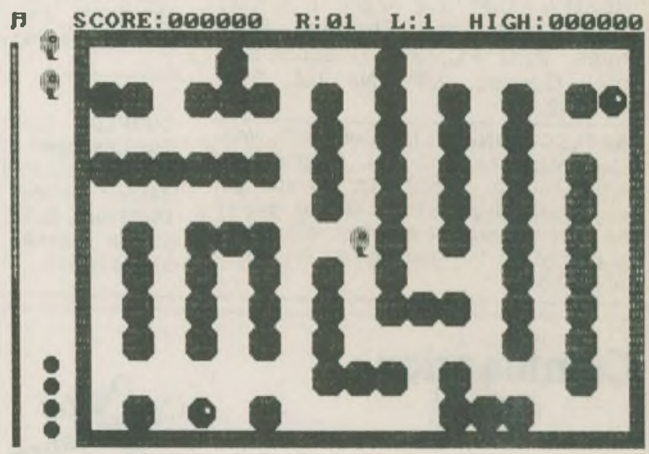

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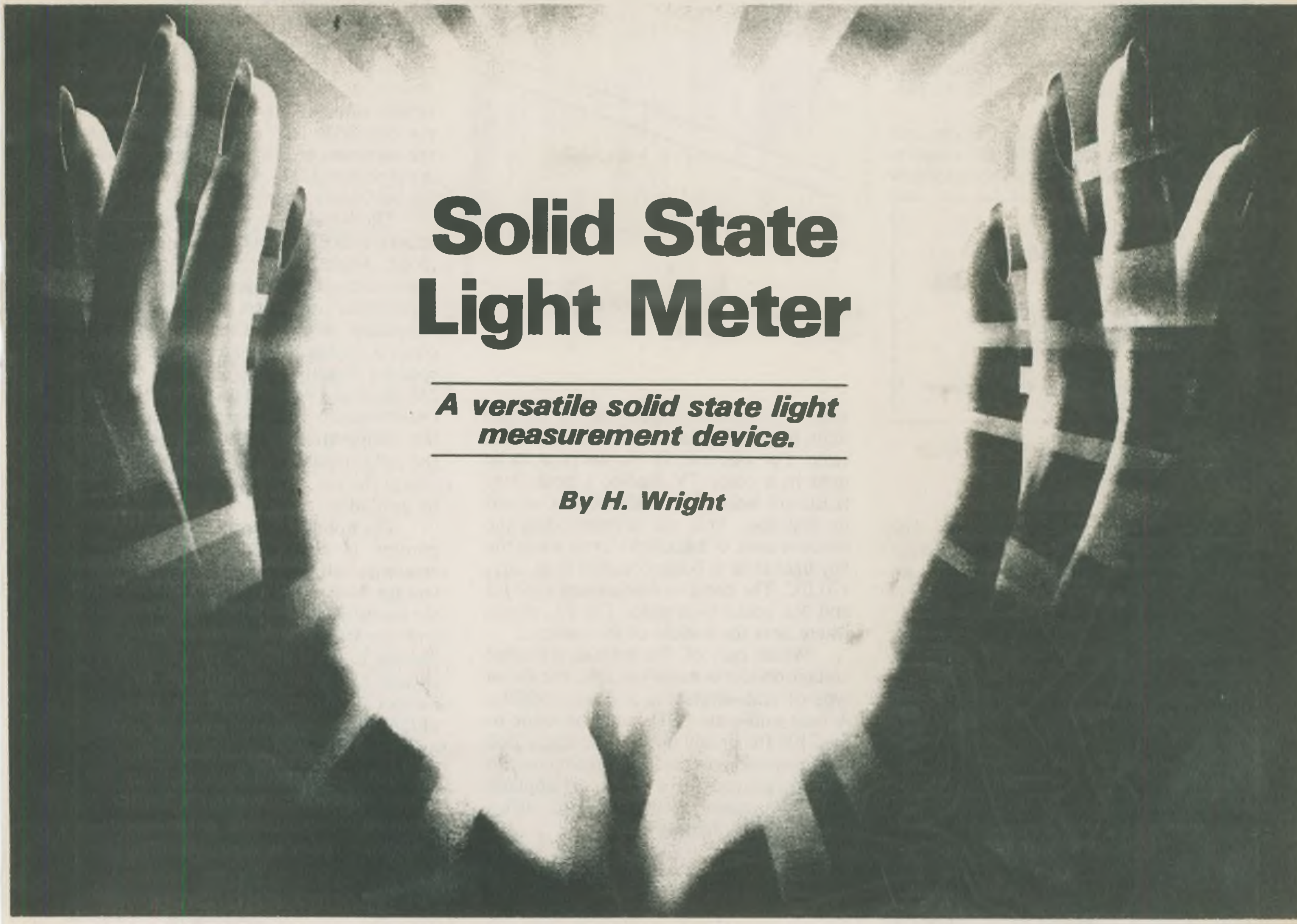

Solid State Light Meter

A versatile solid state light measurement device.

By H. Wright

IN THE PAST, light meters used a delicate D'Arsonval analog meter movement for the readout display. These meters were easily damaged beyond repair if they were dropped on the floor or banged against a hard object. They also had no provision for calibration and groups of meters fresh from the factory frequently showed wide variations from meter to meter, and readout scales were coarse and nonlinear, requiring time consuming extrapolations between marked numbers. The result was often guesswork. **Fig. 1** is a reproduction of the scale from a once popular foot-candle meter. Note the extreme cramping on the upper end of the scale.

Solid-state technology allows the elimination of the D'Arsonval readout. This gives us a meter without delicate mechanical parts; the only moving part is the on-off switch. Calibration adjustments can be provided so that groups of meters may be made to read the same, and, if drift occurs with time, a re-calibration is possible. Scales can be programmed to suit specific applications; an advantage not usually possible in a light meter that depends on the D'Arsonval readout.

The meter described here is versatile. It can be used to establish light levels in ftC., for example, in a TV studio or on a motion picture set. It will measure industrial light levels in critical factory areas or will establish correct office lighting levels, and the scale can be adjusted to measure luminence values on a cathode ray tube face. Simple modifications combined with mechanical exposure calculators make it applicable to photographic exposure measurements.

The Sensor

The sensor chosen for the meter is a Vactec blue enhanced photodiode. This photodiode was considered to be the best choice because of its fast response and its availability with a spectral response close to that of the human eye. **Fig. 2** shows the spectral response of the Vactec 9413B photodiode, and the linearity, which is also excellent over a wide range, is shown in **Fig. 3**.

The Circuit

Fig. 4 is the schematic diagram of the meter. It's built around the LM3914 which contains a string of ten comparators combined with an internal string of ten, 1,000 ohm resistors. The resistors provide the ascending set of references for the comparators, turning them on progressively with an increase in the input voltage. The light sensor provides these input voltages directly; the complications of an amplifier are avoided because the IC can be arranged to operate as a millivoltmeter.

The usual method of operating this IC is by tying the internal resistor string to the IC's internal reference voltage of 1.20 volts. When using millivolt input ranges, this method cannot be used because the reference output load resistor also determines and regulates the LED current in the range between 2.0 and 30 milliamps. Both ends of the internal resistor string are brought out to external pins on the IC. This permits use of a ground referenced external reference IC. This separates the functions of LED current control from those determining input range. Pin 9 of IC1 is connected to pin 11 to program the IC into dot mode of operation. The bargraph mode is not suited to this meter because it places a heavy load on the battery.

If Fig. 4 is examined, the external reference system for a millivolt range is easy to follow. IC2 is a 2.5 volt reference

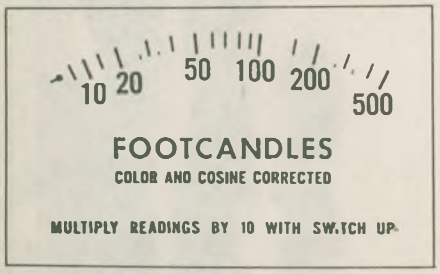

Fig. 1. A reproduction of the scale of an early type foot-candle meter.

IC driven by the 9 volt battery supply. The reference output is connected to a voltage divider consisting of a fixed resistor R3 and a trimpot R2. The ratio of resistors is such that R2, the scale range adjustment, provides a good range in millivolts for application to the internal resistor string. The value of R1 now determines only the LED current and therefore the maximum

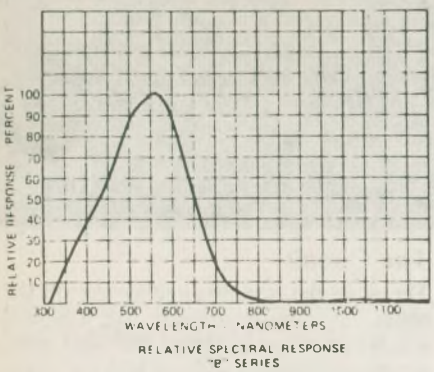

Fig. 2. Spectral response of the Vactec VTB 9413B photodiode.

value of total instrument current drain. In the prototype R1 was given the value of 470 ohms. Run-of-the-mill red LEDs were used. Some economy of battery drain could be gained if R1 was made larger and combined with narrower angle, more costly, high efficiency LEDs. Addition of a red filter or the even more effective 3M louvered neutral density filter, would also improve readability in the presence of strong ambient light.

The setting of R2 determines the instrument sensitivity. The actual input voltage in millivolts from the sensor, for a given light level, will be determined by the setting of R5, the calibrating load resistor. With R2 determining the full scale volt-

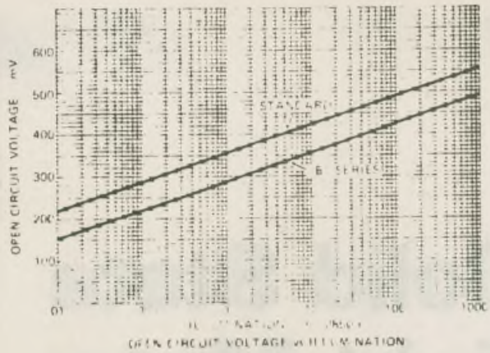

Fig. 3 Voltage vs. illumination for the photodiode (open circuit condition).

age, R5 then determines where a specific light level will indicate on the ten dot scale. For example, if the meter is to be used in a color TV studio, a peak level (LED-10) indication of 350-400 ftC would be desirable. This will accommodate the measurement of back light levels when the key light level is being roughed in at, say, 170 ftC. The combined adjustments of R2 and R5 could then place 170 ftC somewhere near the middle of the scale.

When part of the voltage reference voltage divider is made variable, the above type of scale-stretching is made possible. A near mid-scale LED could be made to read 100 ftC or any other value best suited to the service required. Thus the meter can be programmed for a variety of applications, TV studios, film operations, office and industrial lighting etc.

Flasher-Sounder Option

The basic meter of Fig. 4 is complete. Where the application requires frequent setting of light levels to the same value, a flasher or sounder can be added. The flasher is driven from a chosen LED output circuit on IC1, the one that indicates the particular level where flashing or beeping is required. **Fig. 5** is the circuit for the flasher/sounder option.

The flasher or sounder is driven by a standard 555 IC which runs in the astable mode. With the R-C values shown the flash rate will be approximately 2-3 Hz. Electrolytic tolerances could affect the frequency slightly. The 555 will drive either a flasher LED or a small solid state sounder directly. Q1 is in series with the 555 pin 8 and V+ and forms an electronic On-off switch. The switch is controlled by the comparator IC3. Only one section of the 339 comparator is used. All other pins except the pin 3 positive supply pin, must be grounded.

The non-inverting input of the comparator is connected to the 2.5 volt reference through R8. The tripping voltage from the LED circuit is applied to the inverting input through trimpot R7, and the tripping voltage is obtained by placing a 100 ohm resistor between the chosen LED anode and V+. The comparator input is taken from the junction of the LED anode and R6. When the LED is off, the junction voltage approaches the supply voltage of 9 volts. When the LED is on, the LED current produces a small voltage drop and the junction voltage drops sharply without appreciably reduc-

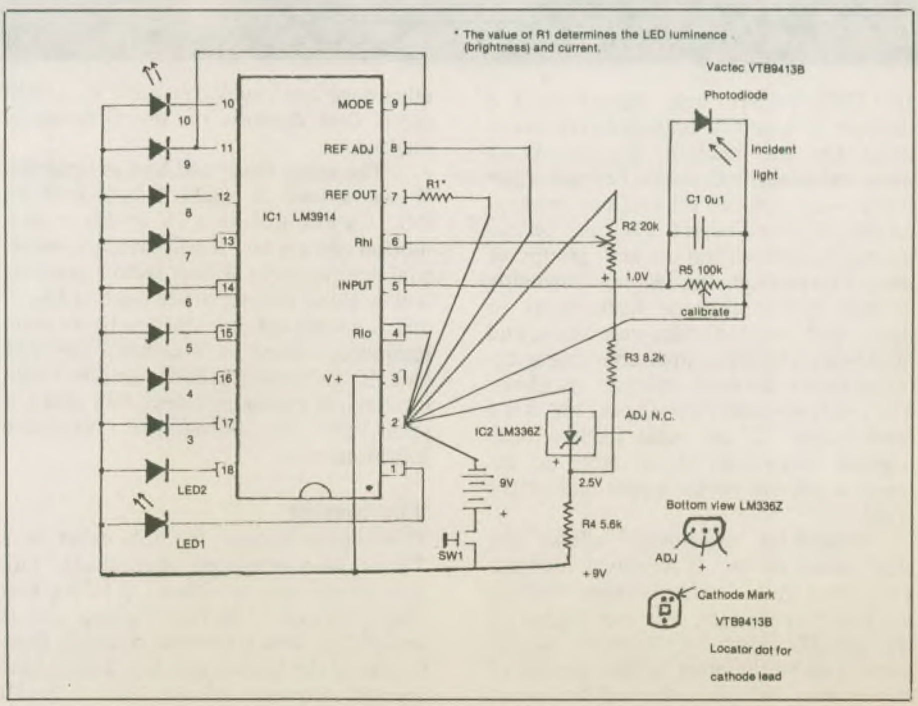

Fig. 4 Schematic of the lightmeter circuit.

ing the brightness of the LED. R7 is adjusted, with the LED off, to apply a voltage slightly greater than 2.5 volts. When that LED lights, the inverting input of IC3 drops below the reference input and the comparator trips, turning on Q1. This option increases the battery drain, but because the on-off switch is a spring loaded return push button, the extra current is only drawn when taking a reading.

The flasher circuit also doubles as a low battery indicator. If the battery voltage drops to somewhere between 7.5 and 8.0 volts, the voltage at the R6/LED junction drops low enough to trip the comparator, even though the LED may be off. It should be remembered that the flasher-low battery indicator circuits do not in any way affect the operation of the light meter. It will function normally without them. This is simply a useful option to be used or left out as the builder wishes.

cuit side of the board. If copper tape is used, it is desirable to run a second copper tape on the component side of the board under the ten LED anode leads, to anchor them firmly in place. Sockets for the ICs, with the exception of IC2, will simplify the soldering procedure and allow for easy replacement in case of failure or damage. **Fig. 7** shows the position of components.

The aluminum bottom of the case becomes the front panel for the meter. A row of holes is drilled that will just allow the LEDs to be a very light push fit. These holes are spaced at 0.40' intervals to match the LED mounting positions. Retain the panel position that existed when the box was purchased.

In the prototype the photodiode was mounted in the end of the barrel of a miniature phone plug. A matching jack was positioned in the end of the case. Make sure the photodiode polarity is correct when mounting it. The anode should

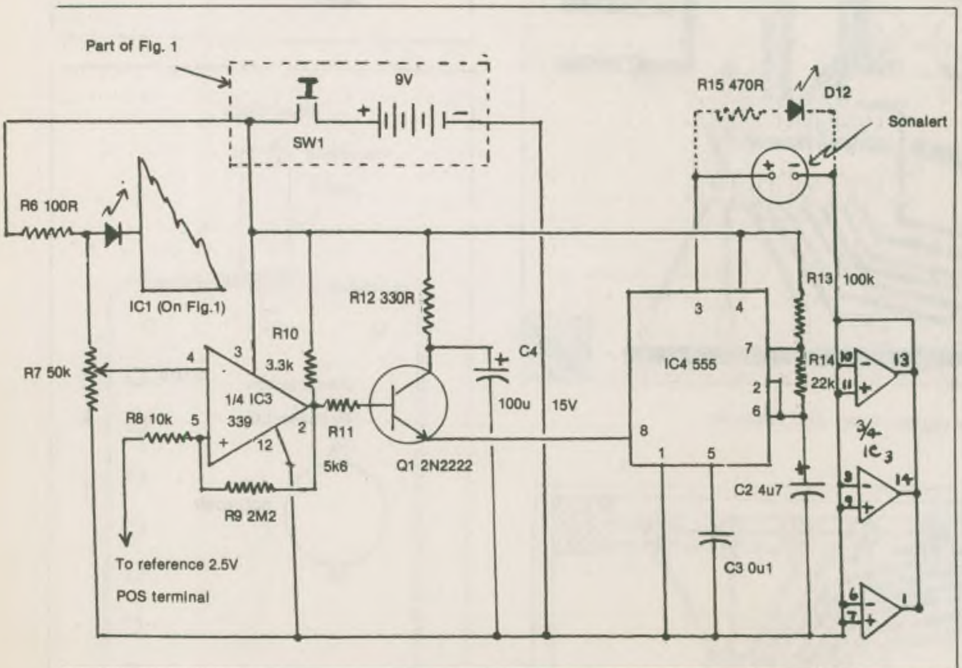

Fig. 5 Schematic for the flasher/sounder indicator.

Construction

The small number of components makes this light meter an easy construction project. It will fit into a small box such as Radio Shack # 270-233 (21/2' x 5' x 11/2'). The components can be mounted on a small 41/2' x 21/4' rectangle of perf board with 0.10 hole spacing. **Fig. 6** is a pattern for either a printed circuit or one fabricated from stick-on copper patterns and tapes (Bishop Graphics E-Z system). The latter method was used for the prototype. It is simple, fast, does not require photography or chemicals and is easier to trace and check than point-to-point wiring. The LEDs are mounted on their leads, standing up in a row from the cir-

go to the tip and the cathode to the sleeve. A dab of silicone rubber will hold the photodiode firmly in place and provide some shock-proofing. If you prefer, the sensor can be mounted in a small hole in the end of the case, using a rubber grommet or silicone rubber. **Fig. 8** shows the relationship of the panel, LEDs and sensor.

Before the panel is assembled with the perf board, clean it and spray it lightly with zinc chromate. This prevents the finish coat from peeling from the aluminum. A sprayed-on coat of gold will look good with the black case. Once the instrument has been calibrated, ftC. numbers opposite each LED can be added. Rub-on numbers will give a professional look. The wear life will be improved if the panel is given a coat of clear lacquer. The prototype was calibrated for TV studio use and **Fig. 9** shows the scale.

No guide is given for the location of the on-off push button switch. It should be placed so that it lies comfortably under the thumb when the meter is held to aim it at a light source. This will put it somewhere in the lower part of the panel to the left of the LED row.

Measure the locations of the three trimpots along the edge of the circuit board and the depth of the adjusting screws from the inner face of the front panel. use these dimensions to locate and drill three holes in the appropriate side of the case. Make them large enough to admit a small jeweller's screwdriver.

volts. Do not be surprised if the measured reference IC output is not right on 2.5 volts. Exactly 2.5 volts is not a requirement for this application; the important point is that the reference remain constant as the battery voltage drops. To get IC2 exactly at 2.5 volts would require more components. The adjust terminal of IC2 is left unconnected.

The only way the light meter can be calibrated with good accuracy is by reference to a high quality incident light meter that reads in ftC or an exposure meter that has a foot-candle scale. If the reference light meter has interchangeable covers for the light cell, use only the flat faced cover during calibration. Many of these meters have a domed or humped translucent cover over the cell that integrates the light from an included angle

The most accurate calibration could be obtained if the meter is referred to a photometric laboratory foot-candle standard, but few have access to such a standard. Assuming a good meter of the D'Arsonval type is available, set up a table-top calibration procedure. The surface of the table should be covered by a dark, low reflectance material and there

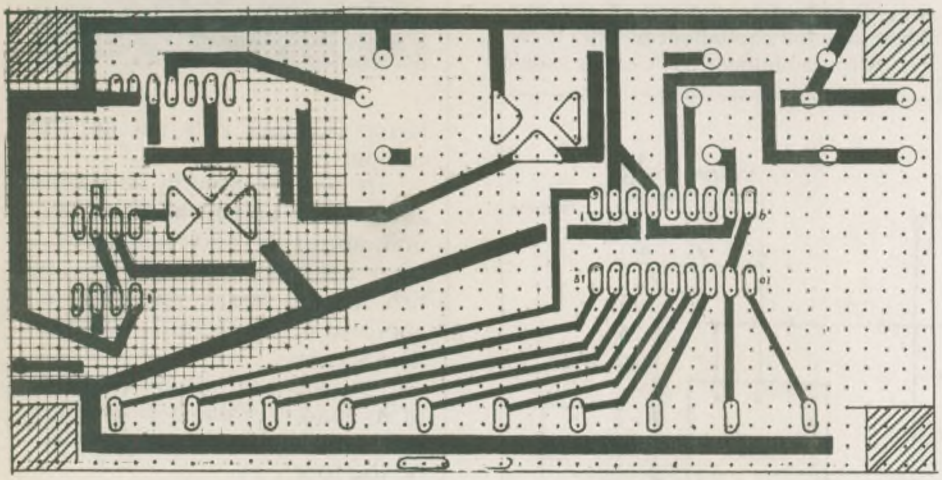

Fig. 6. Pattern for the printed circuit or E-Z system copper tapes and patterns.

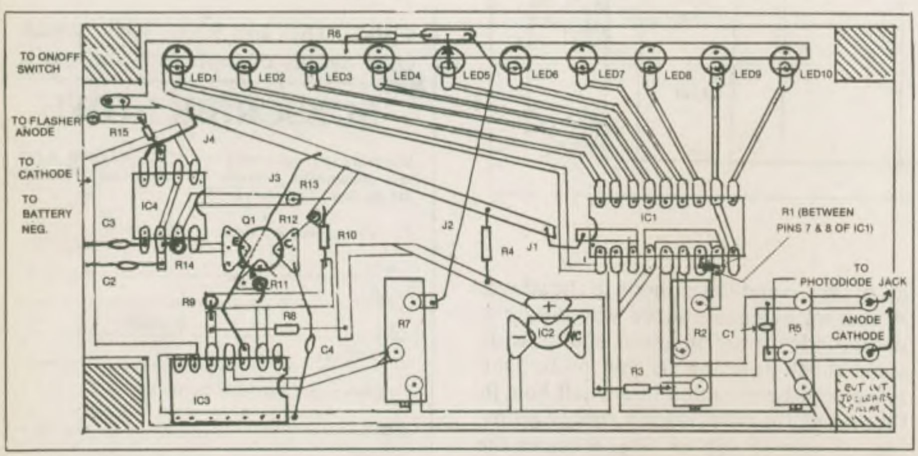

Fig. 7. Component positions for the meter and flasher/sounder option.

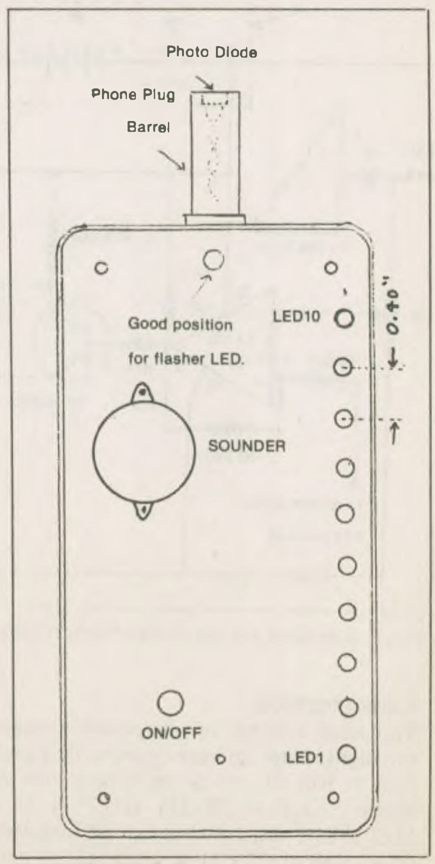

Fig. 8 Panel layout.

Continued on page 42

Calibration

If you have included the flasher or beeper in the meter, the first adjustment is to set the trip level of the comparator. With the electronics outside the case, connect a good voltmeter between R7 arm and ground. Adjust R7 for a reading of 2.6

greater than 180 degrees. Such a meter does not give anywhere near a true incident light reading. The meter described here has a very narrow angle of acceptance and will give an accurate indication of incident light when aimed carefully at the light source.

should be no other lights besides the test lamp and no uncovered windows. Use a desk or worktable lamp with a conical reflector and fit it with a diffuse 60 watt bulb. Lay this light source flat on the table as shown in **Fig. 10.** Further diffuse the light by taping a piece of good quality

Continued from page 6

Portable 10 MHz Mini-Scope

The Model 1010, full-featured, oscilloscope is a compact device offering DC to 10 MHz bandwith, 12 sensitivity ranges and 21 time-base ranges in a 10' x 2.5' x 7' package weighing just two pounds.

The mini-scope includes internal and external triggering with sensitivity of 1 div internal and 1V external. Coupling modes include: AC, DC, TV frame and TV line, and the slope is plus/minus selectable.

The unit contains a 1' x 1.5' blue-white (5 horizontal and 4 vertical divisions) display and includes a built-in calibration circuit as well as a full complement of adjustments.

For further information contact: Len Finkler & Co., 80 Alexdon Rd., Downsview, Ont., M3J 2B4. (416) 630-9103.

Circle No. 36 on Reader Service Card.

Automotive Electric Technogripes: Yer Humble Editor's car is into its fifth year, and by Detroit standards, ready to be pressed into a cube of scrap iron. Some grousing about its electrics: why do they even bother with the red idiot lights for the alternator? The "idiot" must refer to the designers; they'll only detect a complete failure of the alternator output, not a lowering of the voltage. On three cars now, the alternator output has slipped below 12V, letting the battery die with nary a glimmer from the red light. Also, auto electric designers should buy pocket calculators so they can discover that a car's total electrical load often exceeds the alternator's output, particularly if you're stuck in traffic with the engine idling a lot. And why not have headlights that shut off with the ignition? No one does this, but there doesn't seem to be much reason to want headlights on with the keys out. Four-way flashers fill the bill for emergency parking. And let's use relays that are strong enough to carry the rear-window defroster current without needing replacement the second the warranty runs out. And move the fuse cluster to where you don't have to lie upside down to get at it. We probably should forget microprocessors and fibre optic control channels until the engineers learn some basics. There.

Zentronics is offering a free Tranzorb Selector Guide, designed to assist in designing transient overvoltage protection in electrical circuits. Choose the reverse standoff voltage or maximum clamping voltage and the guide will select the protection device that suits. Contact Zentronics, 8 Tilbury Court, Brampton, Ontario L6T 3T4, (416) 451-9600.

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For Your Information

3M Canada Ltd. will transfer marketing, sales and service responsibilities for 3M photocopiers and facsimile equipment to the Canadian subsidiary of a new international company, Harris/3M Document Products Inc., starting May 1.

Telecommunications fans can now purchase a subscription to the iNet 2000 information service at 11 Eaton Business Centres across Canada. The iNet 2000 gives you access to information databases, electronic messaging, data conferencing, etc., and is available from Eaton's for a $50 startup fee. PC owners get the communications software on a floppy disk.

Synercom of Houston, Texas, developers of computerized mapping services, has donated a $144,000 software system to Ryerson Polytechnical of Toronto and a similar grant was made to the University of Quebec in late 1985. The software will be used by the 17 members of Ryerson's Geography department. Synercom plans to donate $7 million of its software to Canadian universities over the next three years, and $15 million to US universities. May their tribe increase, too.

The VCR was a hot item in 1985, according to the Consumer Electronics Marketers of Canada, with sales of 1.28 million units, up 11 percent from 1984. CEMC estimates that one Canadian household in three owns a VCR, and three out of four will own one by 1988.

Automated Production Equipment of Medford, NY, makers of PCB repair equipment, have sent us a press release for a Combat Circuit Repair Kit. Tools, fixtures and materials to repair any kind of PCB damage. In combat? Perhaps it's aimed at the service tech who makes house calls, fixing a TV while fending off three kids and a dog.

NCR Canada has produced a through-the-wall automated teller which they claim is faster than other bank machines and holds more currency. The Model 5084 is said to reduce lineups and minimize downtime due to cash depletion, particularly on weekends and holidays. May their tribe increase.

Keithley Instruments of Ohio has sold its handheld multimeter product line to TEGAM Inc. of Madison, Ohio. TEGAM also manufactures a wide range of thermometry products, voltage and battery testers, signal conditioners, etc. The Keithley company said that the sale completed their program to exit from the handheld test and measurement business.

Continued on page 33

Troubleshooting

Building a project is often the easy part; getting it going is where the fun begins.

By Peter Phillips

BEFORE describing fault finding techniques, a short but true story is appropriate to illustrate an aspect of servicing that often goes unmentioned. The author, who claims a good grasp of electronics, recently agonized over a fault in a popular model TV set. After a week of fruitless searching using sophisticated test equipment, circuit manuals, textbooks and copious headscratching, a painful decision was made. On the pretext of inquiring about his health, a phone call was made to a friend in TV servicing.

Following his advice and a bit of soldering in an area remote from where the trouble *should have been,* the set was soon working perfectly. Embarassed and humbled, the next question was how the fault had been found in the first place. "By going around the set tapping things with the back end of a screwdriver." He then continued to rub it in, suggesting that technical knowledge could be something of a hindrance, and that many faults could be found with a non-textbook approach.

Before the many technically-minded readers wince in horror, this is not intended to promote the hit-it-with-a-hammer technique, but rather to impart some of the more commonly used ploys in tracing the problem.

Fault Categories

A fault in a peice of equipment can be categorized in three ways. The first is the problem occurring in a unit that worked normally prior to the fault. Classified as a breakdown, this fault is most typical and generally the result of a component failure. Another fault category is the construction error in a circuit, likely to be experienced by hobbyists both experienced and otherwise. The final type, the design error, is the nastiest and is often assumed by frustrated project builders. It should be considered only when all else fails.

Another fault variety is the intermittent type. Intermittents are very difficult to find; Murphy's Law will ensure that the problem occurs only when your back is turned. Even so, the beginner can often solve these faults, given the right approach. Yet another possibility is two or more faults occurring simultaneously.

If a project fails to work after its construction, try to determine which of the three categories the fault fits. If this is done prior to troubleshooting, a lot of time can be saved. For example, rule out design error by asking around to see if anyone else has had problems with the same thing. Where a category cannot be determined, assume a constructional fault.

The Breakdown

A fault in previously proven equipment will be in a component, a faulty connection, a printed circuit board, or will be the result of an accident. The servicing approach should begin by examining the events surrounding the fault. If the appliance belongs to someone else, don't always take their story for gospel. Few people are objective in describing a fault, particularly if they're embarassed about the circumstances. Dropping the thing down two flights of stairs may be described as a minor bump. Details to establish include any previous history of the fault and other related problems. Like solving a crime, any information that can give a lead should be sought.

Before removing any covers, identify for yourself what symptoms the device is exhibiting. Identify unusual smells, sounds, visuals, vibrations, or any behaviour of any kind. Try all controls, seeing what is working and what is not, and how the controls affect each other.

Also, before prying into equipment operated from the AC power line, be sure that the equipment is isolated by a power transformer or isolation transformer. Some inexpensive tube-type radios aren't. If you don't understand the difference yet, *don't mess with the AC line.*

Now remove the covers and repeat the process, looking for anything that might give an indication. Ensure that all plug-in cards are tight and in the right places, and wobble any plug and socket combinations. Also apply pressure to any socketed components to see if loose connections are at fault.

Spraying contact cleaner on all switches, plugs and sockets with the power off is a good idea; even if it doesn't cure the problem, it's good maintainence.

The PCB

Having ensured that the problem is more than a loose connection, try a tap-test, using the plastic end of a small screwdriver. This maybring bad solder joints to light. As solder has little mechanical strength, likely problem areas are those where some physical strain is involved. Soldering in areas with heavy components or where subject to heating, or with PC mounted pins should be examined carefully. Gently wobbling large components or terminal posts while observing solder joints can often identify a dry-soldered or broken connection. Badly solderd joints may not manifest themselves for years, and are the cause of a lot of trouble. Figure 1 shows some of the problem areas where solder joints are likely to fail.

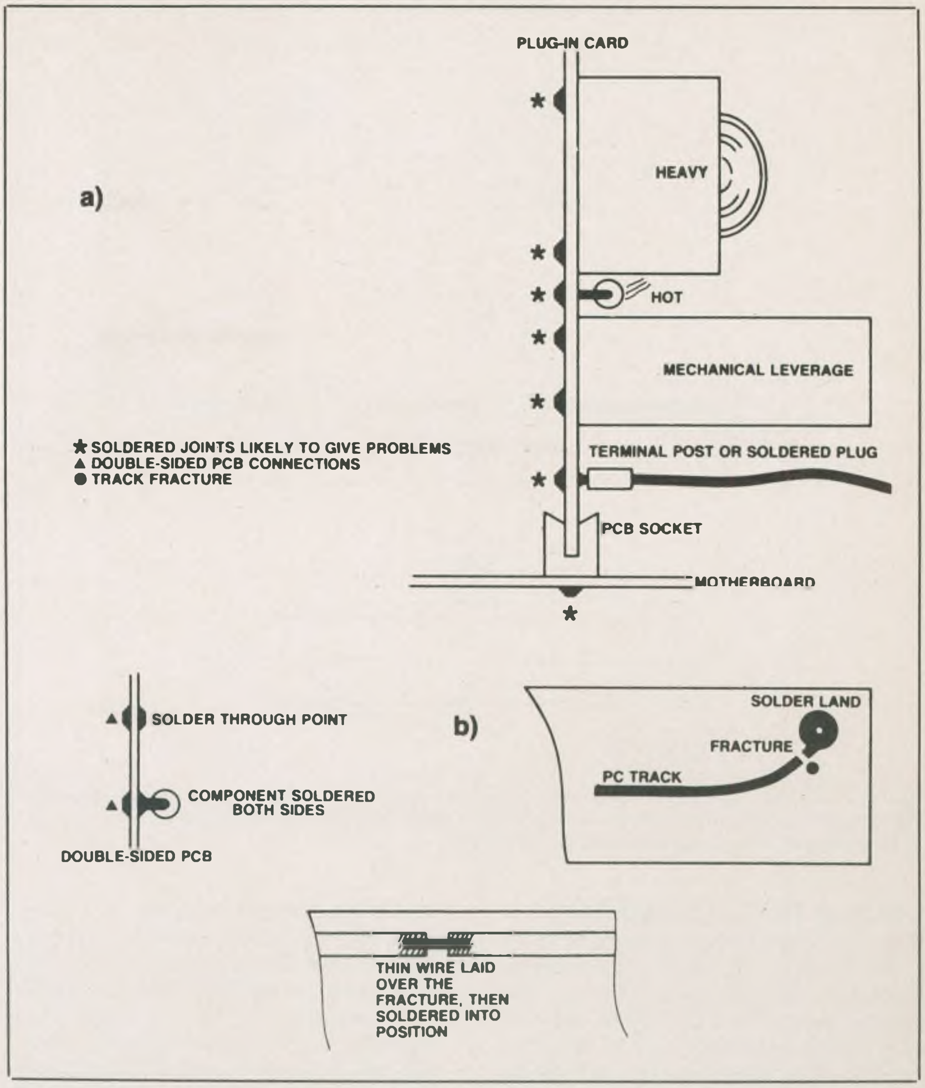

Figure 1. Some pc board problems.

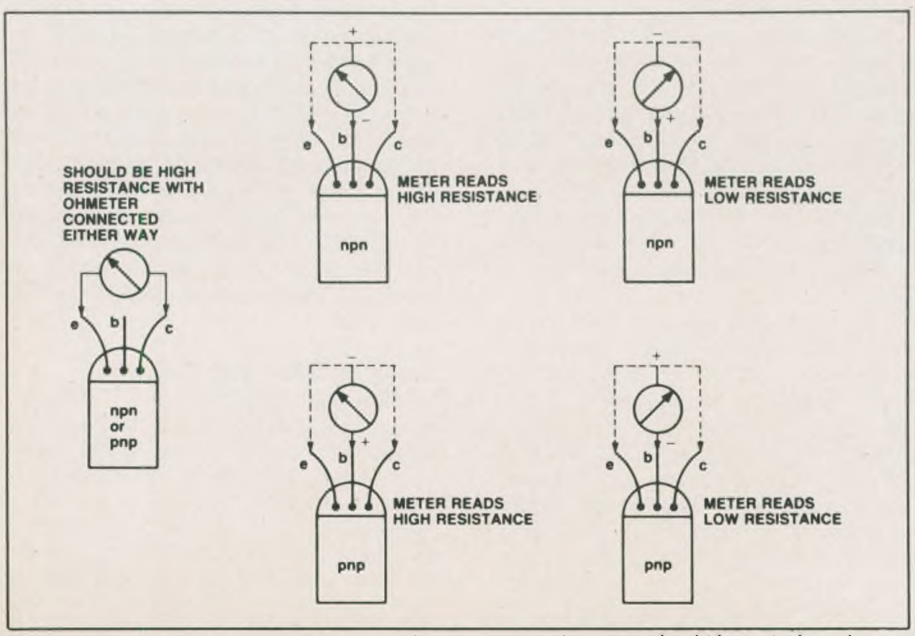

Figure 2. How to test a transistor using a multimeter. An analog meter should be on its low ohms range. Note that the polarity of the meter will reverse; the black lead (—) becomes the positive potential. Digital meters should be on 'diode' test without reversed lead polarity.

Flexing the board gently can identify possible problems with PC tracks or connection points. If the fault is affected by bending the PCB, go to work with a soldering iron and magnifying glass. Double-sided PCBs are more prone to soldering failures where no strain is involved compared to single-sided boards. Careful rosoldering of all connections in the affected area can do wonders.

Breaks in PC tracks are not uncommon, particularly at the point where the track joins the solder land. Some servicemen, after having tried everything else, run solder over every PC track in hopes of repairing invisible fractures. Repairing a track should be done by cleaning the track where the soldering is to occur and then overlaying a piece of wire across the break and soldering it into position.

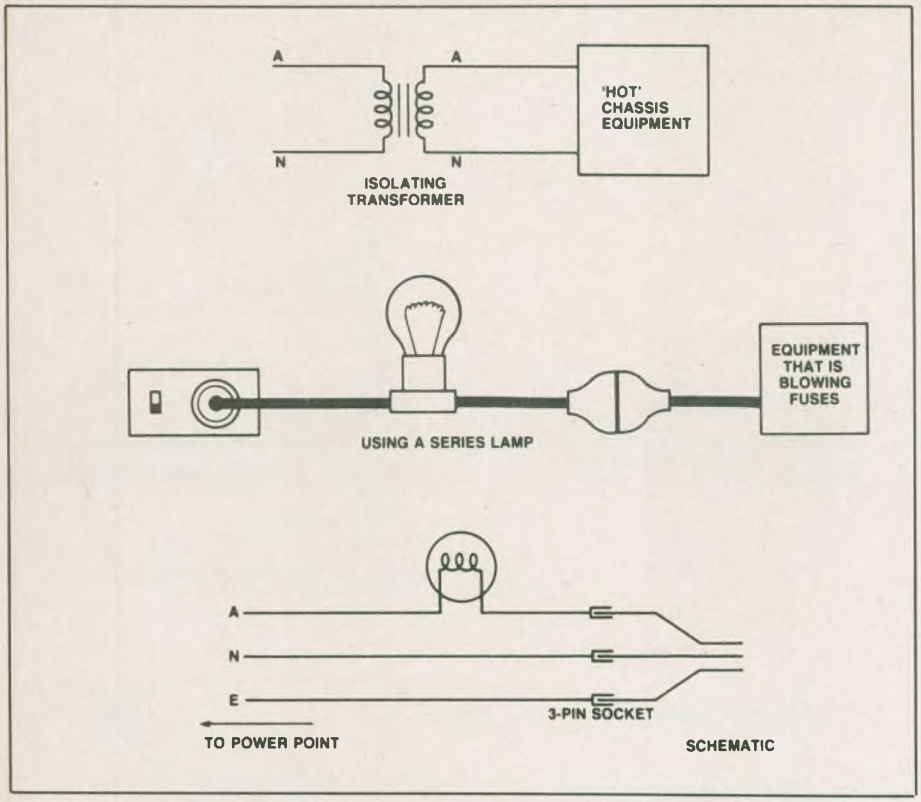

Figure 3. Power line consideration. Lamp wattage should be equal to or greater than, up to two or three times, that of the equipment being serviced.

Locating Faulty Components

If the appliance has not responded to the probe-and-prod test, then a component is probably the problem source. The simplest way to find out which one is to replace each component, one by one, until the fault is encountered. This is practical only on devices with very small component counts.

As a basic rule, try all the active components first. If a replacement is not available, test each component as well as possible using the techniques decribed further on in this article. Overheating of a component will at least pinpoint the area of a fault.

Sometimes the faulty section can be isolated using basic tests. If the equipment contains an audio amplifier, applying a signal to the volume control will determine if the amplifier section is working. This is done by touching the centre pin of the volume control with the blade of a screwdriver held in contact with the fingers. If an output buzz results, the problem is ahead of the volume control. No output suggests a fault in the power supply, amplifier or speaker. Power supplies can be tested with a voltmeter, or even a trouble lamp; if you have a voltmeter, test the power supply circuitry to see that it's producing the required voltages.

Active Component Faults

Active components generally break down more often than passive ones. As ICs are often in sockets, searching for a faulty chip is usually the best place to start. The quickest way to establish if an IC is faulty is to replace it, but it should be remembered that there might be more than one fault. So leave the new IC in its socket even if the trouble is not found and go on to the next.

Some faults, particularly power supply faults, may have destroyed every onboard IC, and the fault is destroying ICs as fast as you replace them. To avoid burning out a storeful, try to test each IC as it's removed. This is often difficult, but preferable to burning out all your ICs. Placing the old one in another piece equipment can tell you if it's working or not, but this method obviously has its limits.

Transistor replacement should follow the IC check, unless all the ICs happen to be soldered in. The idea is to test the easiest things first, and transistors are more easily replaced than ICs. Often replacements are unavailable, requiring the testing of each transistor. Generally, transistors should be removed for testing, as parallel components can give misleading readings. Figure 2 shows how to test a transistor using a multimeter. When using an analog meter, set it to the low ohms range, and remember that the polarity of the leads is reversed for ohms measuring; that is, the black lead becomes the positive. A digital multimeter should be on the diode setting, and its polarity not reversed.

If all the ICs and transistors appear to be working, and checks have shown no bad connections, PC track break or PSU problem, then the remainly components should be examined. Be wary of introducing more faults as you go, by bridging PC tracks or inserting wrong components.

Faults in Capacitors

A valuable hint in servicing is to test the capacitors associated with the power supply. If hum is present in the speaker, the PSU capacitors are suspect. Many a peculiar fault has been found by merely going around the circuit placing a known good capacitor across all those in the circuit, one at a time.

Ensure the polarities match when substituting, and always discharge the test capacitor before paralleling it with the next section. This is necessary in case the stored voltage from one section does damage to the next.

Capacitors rated over 100V can become leaky; this problem is prevalent in tube equipment. Always replace capacitors with one having a working voltage equal to or greater than the original, and use the same type as far as possible, though paper capacitors can be replaced with film types.

Faults in Resistors

Resistors, diodes, transformers, wiring and so on can all become faulty. But the possibility of this is less than for those items already discussed, meaning that the above should be checked last. Resistors, particularly old style types, can change their value; higher-valued types have a greater chance of doing this than the low-valued types. Normally a resistor will increase its resistance with time and use, the effect of which is easily tested with an ohmmeter. If an in-circuit resistor shows a higher value than it should, replace it; if it shows lower, lift one end and retest. In general, resistors are reliable unless their power dissipation rating has been exceeded. Wirewound resistors are prone to becoming open circuit, even under normal operation.

Transformers and PSUs

Transformers and inductors usually go open circuit. Alternatively, transformers can burn out, made obvious by the smell. In this case, find out why the transformer burned out before replacing it. Power supply transformers are usually protected by a fuse, and any inclination to increase the fuse rating should be avoided. A blown fuse is usually indicative of problems associated with circuitry that handles power, and not necessarily the power supply. A good servicing technique

Continued on page 43

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For further data contact: Mr. Henry Taub, RCC Electronics, Phone (416) 252-5094; Telex 06-984874

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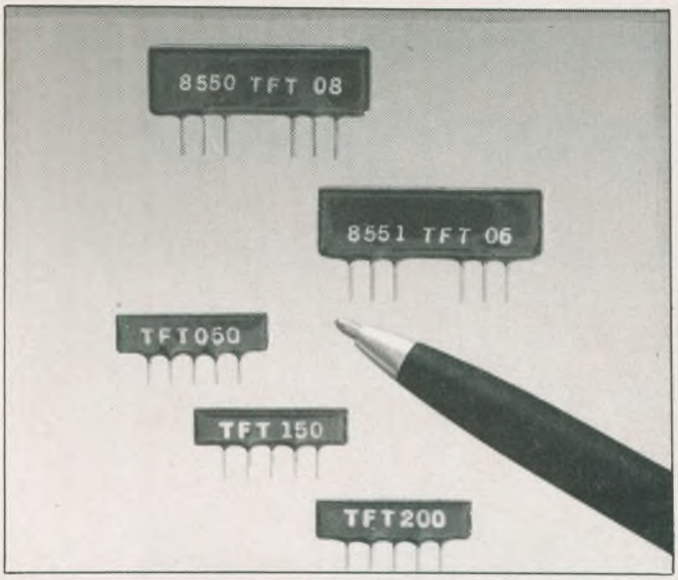


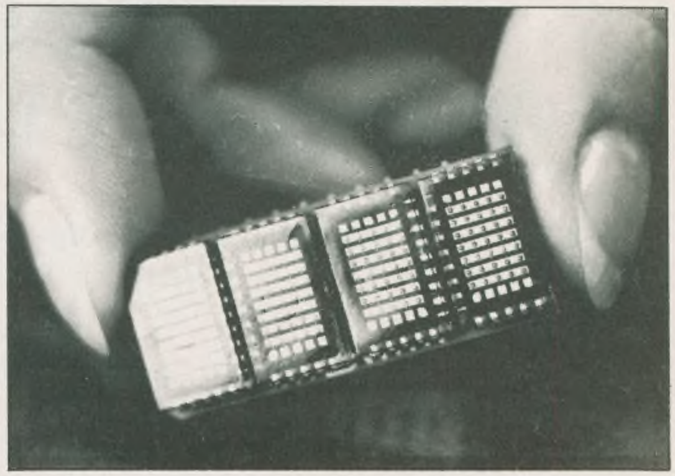
Designed for high-speed applications, these devices feature SIP construction for space savings and distributed capacitance for a remarkably consistent waveform throughout the signal path.

Other features include: time delay range of 100 pS -2.5 nS in 100 pS increments; broad frequency range up to the GHz band; high quality reproduction of original waveform; and low impedance to match high-speed gate arrays.

For more information contact: Ken Snyder, Thin Film Technology Corp., 6955 Washington Ave. So., Suite B, Edina MN 55435. (612) 829-0930.

Circle No. 38 on Reader Service Card.

Intelligent Dot Matrix Display



Seimens Electric Ltd. has added a new intelligent dot matrix display to its current line. The PD3435 features programmable brightness, blinking, display testing and darkening in a 5 x 7 matrix organization with 7mm symbols.

The PD3435 also contains 96 figures and characters in ASCII code, saving the user from having to supply character memory and generator, multiplex oscillator and driver circuit himself.

The device is of the 4-digit variety, of which up to seven can be connected in a strip without extra assembly costs. Colours available include: orange and green.

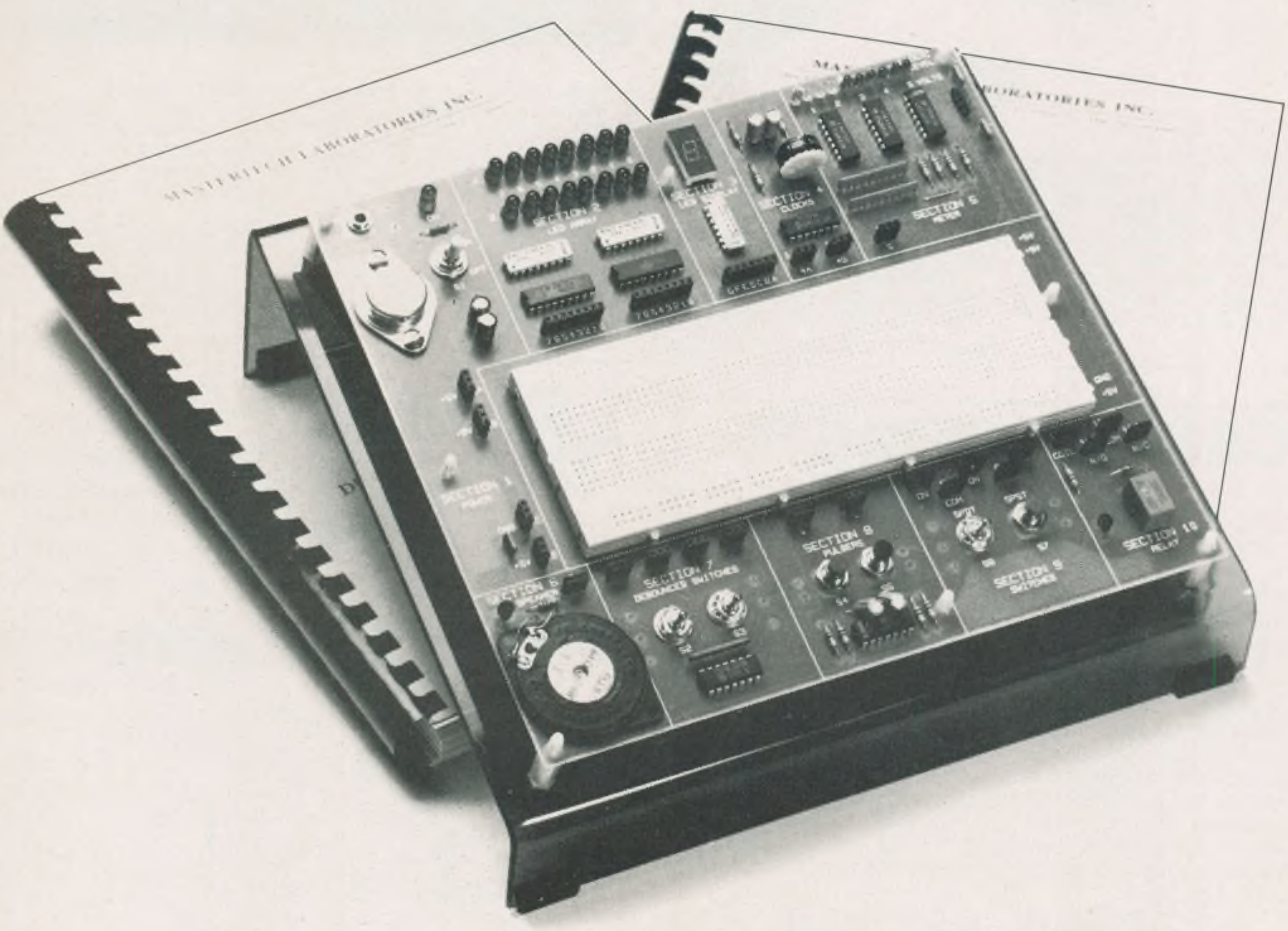
For further information contact: Mr. G. Springer, Seimens Electric Ltd., 1180 Courtney Park Drive, Mississauga, Ontario, L5T 1P2. (416) 673-1995.

Circle No. 39 on Reader Service Card.

Product Review
Microlab 1 Digital Trainer

A thoroughly-designed protoboard plus a complete course in basic logic circuits.

By Bill Markwick



TO begin with a summary: there are lots of ways to learn logic circuits and basic digital techniques, but few as well designed and as complete as the Microlab 1 training course.

The package consists of a printed circuit eight inches square and mounted on an acrylic stand, two thick manuals, and all the wires and components needed for the course. On the printed circuit is a solderless breadboard and all the basic switches, clocks, and displays to perform the various experiments. It's powered by an included 9V plugpack and onboard 5V regulators.

The course is designed for someone with no knowledge of electronic components, although the user should at least be aware of Ohm's Law and know how to read simple schematics. The engineering department of the University of Victoria evaluated the Microlab 1 and decided it would be suitable for a digital electronics course in Grades 11 or 12, and the trainer is now being used in a computer technology course at Victoria High School, British Columbia. Of course, this doesn't mean that the unit won't be ideal for any of our readers who'd like a way to get a grasp on digital techniques conveniently (you don't even need tools or solder).

The Board

At the upper left of the board is a TO-3 version of the 7805 5V regulator, which supplies operating power to the power strips on the protoboard as well as driving the onboard circuits via printed circuit traces. The voltages and currents available mean that the unit is self-protecting from shorts and overloads, as well as being completely safe for the operator.

There are three types of displays to indicate circuit status: 16 LEDs with driver ICs (each LED with its own input), a seven-segment LED numeral, and a ten-segment 0-5V voltmeter. Audible indication is provided by a piezo sounder at the bottom left. A relay at the bottom right can be used either as an audible sounder or as an output driver.

Circuits are provided with input signals in a number of ways. There's a clock with both 1kHz and a very slow variable output, two debounced toggle switches, two pulse generators with pushbutton triggers, and two unbuffered general purpose switches.

The Course

In general, each section of the course consists of a detailed (and clear) explanation of the particular technique involved, then a demonstrative circuit easily made up from the included components and jumper wires, and finally a series of self-test questions.

Not surprisingly, the course begins with an explanation of logic gates and inverters, basic switching and logic input-output levels. It's very easy to slip the jumpers into the clearly-labelled pins and get the circuit going; the layout of the board concisely demonstrates the input-output signal flow.

Once the user is familiar with gating, the course demonstrates how flipflops work; the various switches and pushbuttons show clearly how the input and clock pin work together to produce the desired output.

Counters are next, with a 4-bit ripple counter put together from 74LS74s driving the LED arrays for a binary output. Counting and resetting are covered before up-down counting and data loading are shown with the 74LS193.

Shift registers are thoroughly covered; the user can construct his own from flipflops before going on to the IC version to learn loading, cascading, etc.

Lastly comes the data-handling section, demonstrating data-handling with the BCD to 7-segment decoder, various types of multiplexing, and the magnitude comparator.

One of the most tedious tasks in working with logic ICs is looking through stacks of manufacturer's specification sheets for basic facts. The Microlab includes a large appendix to the manual, and it's stuffed full with data sheets, further explanations, a glossary, and the test question answers.

And finally...

How long it takes to complete the course depends on the user (or the school). There are 40 labs in the manual, each one an in-depth coverage of a particular circuit; how fast you can build circuits is less important than how well you retain the derived information, so completion time will vary from person to person. In any case, you can learn at the rate best for you.

Once you do get it finished, the manual says that you can purchase add-on options such as analog-digital converters, arithmetic circuits, and microprocessor circuits.

It's obvious from only a few moments of experimenting that a great deal of careful thought has gone into the trainer design. It condenses an enormous amount of explaining into an eight-inch PCB and a clearly-written manual (besides that wonderful Appendix).

The trainer was originally introduced into the American market at $249 (US), and by the time you read this, it will be introduced for sale in Canada. For more information on the Microlab 1, contact Mastertech Laboratories, 302 Royal Trust Building, 612 View Street, Victoria, BC V8W 1T5, (604) 388-6631. ■

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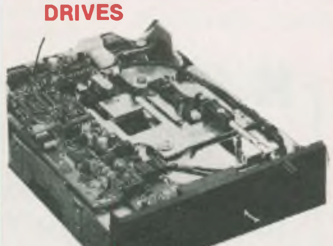

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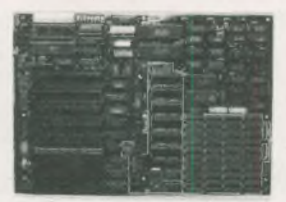

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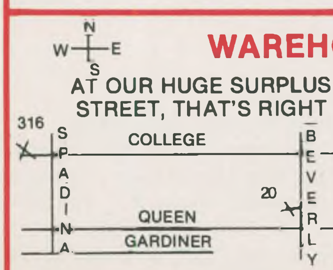

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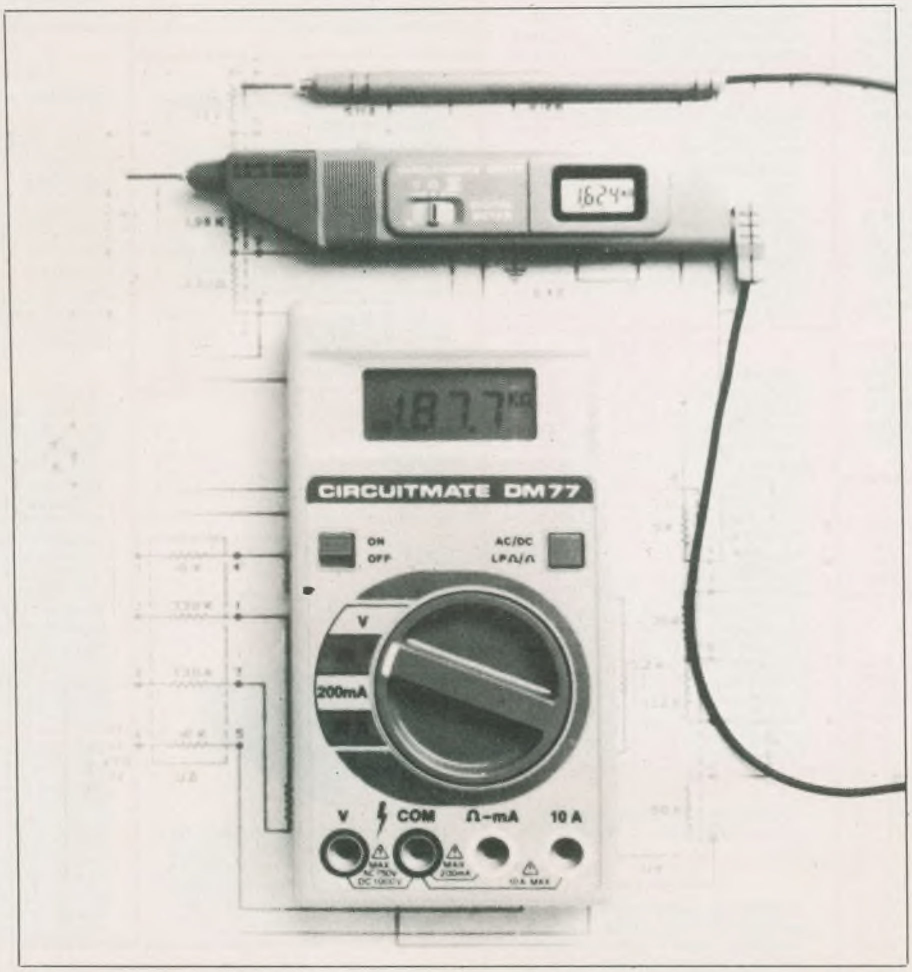
The Beginner's Bench, Part 1: Troubleshooting

By Bill Markwick



HELLO again. Welcome to a new series which will feature articles by various authors on building, troubleshooting and modifying your projects. We assume that you've had some grounding in basic electronics, such as our past series *Electronics From The Start,* that you have at least a grasp of Ohm's Law, and that you can solder. By soldering we mean clean, small, reliable joints that hang together forever, and also the ability to rapidly go over a project, find poor solder work and correct it. If you're still struggling with that, the *Troubleshooting* article in this issue is a good grounding.

I'll start off this first part by taking up where the above article left off; that is, the assumption is that you've poked and prodded and thumped a defective device and have finally decided that it isn't going to work unless you start measuring.

Someone once said "Once we can describe something in numbers, we begin to know something about it." I'm not sure who said that, but high school teachers used to put things like that up on the wall all the time. It's a true saying, as opposed to the harmless untruths they usually tell you.

To start getting those numbers, the best and most common device is the multimeter. If you don't already have one, they range from $15 pocket analog types to digital bench types costing $300 and up. I'd stay away from the bottom-of-the-line multimeters; for economy purposes, they have poor sensitivity and draw too much current from the circuit. They also have a limited number of ranges, and sometimes have jack sockets instead of a switch. I'd go for one with a sensitivity of 10,000 ohms per volt or higher. Incidentally, this sensitivity business was poorly explained in the *Electronics From The Start* series. All it means is the number of ohms that will be placed across the circuit under test; the value is multiplied by the selected number of full-scale volts. For instance, a 10k per volt meter set to the 5 volt range has a resistance of 50,000 ohms.

This has important consequences, as we've pointed out before in *ET*. We all have a tendency to believe religiously in what our meters are telling us, but if you place that 50,000 ohm meter across a voltage source which is fed through a 47k resistor, the error is nearly 50 percent. Yow.

As far as range features go, you'll need DC volts down to about 1V full scale, DC current up to 500mA or more, and AC volts from about 5 to about 500. AC current is rarely included on the lower-cost models and rarely comes in handy anyway.

Don't fret if you've taken possession of a meter that doesn't match my specs. It's more a matter of convenience than anything. I used one of those little tiny guys with 1000 ohms per volt for years, until recently when I left it on the current range and put it across my car battery, turning it into a ball of smoking plastic. I thought it had a protection circuit. Guess not.

Dead Circuits

Let's assume that you have an amplifier or simple logic circuit that isn't working. It not only lacks an output, it's totally dead, and there's no sign of obvious overheating. After checking out physical layout problems, set your meter to a DC volts range higher than the supply voltage.

Take a hard look at the range switch on your meter. It features volts, amps and ohms. In other words, you have an Automatic Ohm's Law Detector. No other single rule in electronics is as important. When you can relate the volts, amps and ohms of a circuit while you're asleep and dreaming about something else, you're starting to get the hang of it.

Next, you should have a schematic of the circuit under test. Once you get familiar with basic layouts and the techniques of troubleshooting, you can get by without one, but for now there'll be enough unknowns without a missing schematic.

Testing PSUs

Connect the negative lead to a ground point, using short lengths of flexible wire with insulated alligator clips on the ends. These leads are indispensable, by the way, and you can save time by buying a package of them at Radio Shack or other stores. The first thing to find out is whether the main power supply (PSU, Power Supply Unit) is working. If the unit has its own internal supply, make the first test by touching the positive lead to the positive terminal on the main filter capacitor. If the unit is battery powered, test the point where the battery holder or battery lead is soldered into the circuit. You should get a reading approximately equal to the required operating voltage, depending on the power line voltage at the moment or battery condition. We'll get back to what happens if you don't.

Another possibility is that the circuit is powered by a bipolar supply, i.e., plus-and-minus voltages. This is a bit of an inconvenience with analog meters that don't have a polarity switch; it means lead-switching to test the negative voltages. Digital meters have automatic polarity indication. By the way, the plus-and-minus approach doesn't mean that we have two different kinds of electricity. With a plus-and-minus 15V power supply, for instance, it simply means that we've taken a 30V supply and called it's midpoint ground, or zero volts. This is best seen when the bipolar supply is implemented with two 9V batteries in series with the ground (or zero volts, or common) connected to the midpoint. We have 18 volts split in the middle. Nothing to it, except for that annoying lead-switching.

Yet another possibility is that there's a series regulator after the main filter. These have been used more and more in recent years as they get cheaper and smaller. We'll come to regulators in a moment.

About the reading: if you didn't get one, or you got one far too low, don't assume that the supply is at fault. There could be a short or excessively low resistance in the following circuitry. Check for a blown fuse; if there is one, don't replace it with a higher-valued one or you may increase any damage already done. To prove out the PSU for sure, you'll have to open up the supply lead to the following circuit so that the PSU can run on its own. It may mean desoldering, or you may have to cut a PC track. It's worth the trouble. Did the PSU voltage come back up to normal? If so, you'll be looking for an overcurrent condition. If not, there are usually three possibilities: the filter cap, the diodes and the transformer. If you keep getting blown fuses, skip to the last paragraph of the *Narrowing Down* section.

The filter cap is usually an easy one: substitute another. If the PSU has been disconnected from the circuit, you can use almost any electrolytic with a suitable voltage rating just to see if it will come back to life. Individual diodes in the rectifier can be checked with an ohmmeter *with the power off.* They should read open in one direction and some low value in the other. Exactly what value is hard to say, because the voltage across a diode depends on the current through it and there's no telling what current your meter applies in the ohms position. This is why ohmmeters appear to give very inconsistent results when testing semiconductors, especially when you change ranges. The power transformer is easily checked; set the meter to AC volts (always start with the highest range if you're not sure which one) and put the leads across the secondary. The output should be about 70 per cent of the DC operating voltage, though it will rise if there's no load connected. If there's no output, check all the power wiring. If you have 115VAC going into the primary and nothing coming out of the secondary, you can assume a dead power transformer. This is a rare occurrence.

If the filtered DC is okay and there are voltage regulators, reconnect any open wires and test the output of the regulator(s). The main point here is that almost all regulators have some sort of current-limiting circuitry inside them to protect against shorts and overloads. This limiting action reduces the output voltage if the current goes too high, giving the appearance that the regulator has gone wrong. The only way to check it is to open up the output wiring from the reg and see if it runs okay open-circuit. Hint: is there a fuse in the DC line, either before or after the regulator? If so, it's an easy place to test PSU voltages and currents.

Let's assume that things are in this state: you've opened up the PSU output and connected the voltmeter. The voltage is OK. With the meter still connected, you reconnect the PSU and the voltage drops abnormally. Obviously, we're looking for an overcurrent condition, or as Mr. Ohm would have put it, an R that's too low for the E and causes too much I.

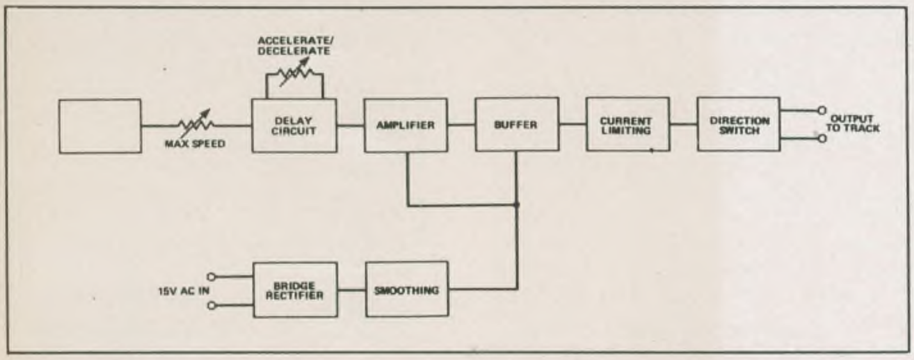


Fig. 1. All circuits no matter how complex break down into series-parallel function blocks like the above. The power and ground lines are in parallel and the signal path can be series or parallel or both.

The Hunt

The moral of the story so far: since the PSU runs everything, make sure it's okay first. Then you can continue with the hunt for the overcurrent condition (or whatever else is wrong).

Most electronics can be reduced to a power supply line feeding various functions, like a string of parallel resistors. The trick is to find out which one has gone wrong, with everything complicated by the fact that various functions can control each other via signal lines.

Suppose your project is a digital one, full of TTL or CMOS chips, and the PSU will only put out about a volt due to an overload somewhere. With only one volt, none of the ICs will work, and there's no hope of testing the project section by section. The only alternative is to start opening the power supply line section by section until the trouble is located. Sometimes this can be done just by pulling ICs out of sockets; sometimes it means desoldering or cutting PC tracks. In any case, leave the voltmeter connected to the positive supply rail and start disconnecting. The method to follow is to disconnect large function blocks at one time; for instance, in an audio amp, disconnect the preamp, then the tone control (or other function) and then the power amp. If it's all on one board, this may not be possible. Anyway, the whole idea is to narrow down the fault's location by testing in large blocks at first. This isolates much faster than testing a zillion small things.

Narrowing Down

Once you isolate things down to large subsections, you can save a lot of time by looking through the suspect section for obvious troublemakers while eliminating the innocent. In other words, our low supply voltage is going to be caused by something drawing lots of current, and this usually eliminates tiny transistors in series with 10k resistors and so on. I use the word "usually" to hedge my bets, because in reality absolutely anything can go wrong. However, go for the obvious first and then track down the unlikely.

At some point you'll pull an IC or disconnect a wire and *voila!* The voltmeter returns to the proper power supply reading. The probable cause of the trouble on the homebuilt project will be one or more of: solder bridges on the PC, components in the wrong place, component orientation, or wrong connections.

All the above assumes that the PSU will keep working into a short. If it just keeps blowing fuses whenever you go to test, you'll have to reverse the above procedure: disconnect everything, prove that the PSU is okay, and then start reconnecting things one small section at a time. The one that blows the fuse is the culprit. If it's a bipolar supply, connect and disconnect both plus and minus leads with the power off, then power up for a test.

No Signal

This is just as likely as the supply line short, if not more so. The rescue method is a little more difficult to describe, because so many different things can account for troubles, including the supply line short described above. To really check it out, you should have a signal generator and an oscilloscope, but there are some quick tests you can make. For audio amplifiers, you can use a screwdriver shaft to inject a hum signal here and there; this is well-covered in our feature article.

Yet another test for audio amplifiers is to measure some voltages. Unlike digital circuits which will usually have an output of all-or-nothing, audio amplifier outputs are usually biased so that the output reads about half the supply voltage. This allows maximum signal swing in either the negative or positive direction.

If the amplifier stage you're testing is an emitter follower, look for about half the supply voltage on the emitter. By supply voltage I don't necessarily mean the output of the PSU, but the voltage supplied to that particular stage; it may have been decreased considerably by decoupling filters, which I'll come to in another issue. If the stage is an emitter follower, measure the voltage on its collector and take this as meaning the supply voltage.

If the stage is a common emitter, the collector should be at about half the voltage that you measure at the top of the collector resistor (transformer circuits are a whole other story). This voltage can stray from halfway by a whole lot, say 25 percent, but if it's within a volt of the supply voltage or ground, the transistor is either defective or it's being biased improperly by a circuit fault ahead of it.

If the stage is an op amp, it will probably be driven by plus-and-minus supplies, and halfway between any plus-and-minus supply is zero volts. This gets tricky. How do you tell zero volts from an open circuit, or an output that's shorted to ground?

At this point I'm going to have to cop out and ask you to wait for a future article on troubleshooting amplifiers like this, but for now your main concern is presence or absence of signal. A crystal earphone from a portable radio is a quick way of finding out. Their impedance is high enough that they won't draw excessive current from the stage under test. I hesitate to suggest using magnetic headphones, like a stereo headset; they conduct DC, which will kill the action of the circuit under test, and even if you add a blocking capacitor, their impedance is too low for test purposes.

Between hum-injection, voltage-measuring, and a crystal headset, you should at least be able to localize amplifier faults.

Digital

Digital circuits are a paradox; they're both easier and more difficult to troubleshoot. On the one hand, all the fussy biasing components and so on are within the chip, leaving only pure functions to be tested. On the other, lots of things can go wrong that are very difficult for the beginner to trace without special equipment. What if one bit out of eight is missing? What if one bit out of eight is delayed?

If you've built a simple circuit that only has a few digital ICs in it, quick troubleshooting is limited to going over the PC traces for accuracy and lack of solder bridges, checking component locations, and finally substituting components.

But if you have some proper test equipment, even a simple logic probe, then you can start looking. Logic probes will at least tell you the hi-lo state of a logic line. Of course you can determine logic states of a static circuit with a voltmeter, but you can't detect a fast pulse or a burst of fast pulses. Sometimes one single pulse from a pushbutton conditioning circuit is necessary to start things off, or a strobe signal may be required for an IC to clock some data through. The logic probe will detect these for you.

But as you might expect, I can't give you an analog/digital testing course in two pages, so I'll have to wrap up with a summary until next month.

Summary

1. Learn Ohm's Law until it's as natural as breathing. You *do* breathe, don't you?
2. If you don't have any test equipment, the first investment should be a multimeter.
3. If you make any wiring or component changes for testing, make them with the power off, then power up when they're completed. This is especially true for computer ICs.
4. When testing, do not, repeat do not, jump around measuring here and there and everywhere. What's the point? You'll only muddle yourself further. Be methodical. Test from the output back to the power supply, or the other way around, but remember that each measurement is a clue. And a bunch of clues jumbled around and mixed together is no clues at all.
5. And, of course, I don't want to nag, y'hear, but we want to keep you around for a while yet, so don't test things that aren't isolated from the power line with a transformer, and if you have to work on the power line side, keep one hand in your pocket. Seriously.

Next month we'll be back with more information that's not so general in nature. Till then, may your circuits behave.

bond typing paper or letter paper over the front of the reflector. This is to get rid of bulb filament 'hot' spots. Provide a small box to support the meter at a level in line with the center of the light reflector and a weight to hold it in position. Set R5 to

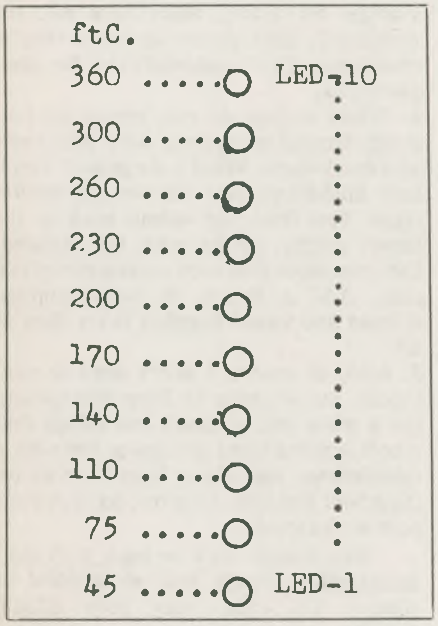


Fig. 9 The scale graduations used on the prototype.

mid-range and establish a light level reading on the reference meter that is to bed your peak reading. This is done by moving the box closer to or further away from the source. Adjust R2 until LED 10 lights. Now check some mid-range LED that you wish to have indicate some special level. This can be done by sliding the box again. Adjust R5 and recheck the peak reading. The two adjustments interact, so it will be necessary to go back and forth between them a few times. For example, in the prototype, LED 5 was set at 170 ftC. and LED 10 at 360 ftC. Spacing of the other indicators was surprisingly linear at approximately 30 ftC intervals with some slight cramping at the top end. It should be remembered that the 3914 IC responds in a series of discrete steps. A halfway point between LEDs is usable. This is where one LED is starting to extinguish and the next one is starting to light. This characteristic must be taken into account when going through the calibration procedure. It is particularly important when going through the calibration procedure to have the sensor faces on both instruments in exactly the same horizontal and vertical planes and at exactly the same distance from the light.

If a calibrating reference meter is not available a crude calibration can be performed with the same desk light. It should be diffused as before. With the meter on its support a level of approximately 100 ftC. will be present when the sensor face is about 11 inches away from the paper diffuser surface. 200 foot candles will be at 71/2 inches and 400 ftC. at 41/2 inches. This is a very rough calibration. If you do it this way, try to have it checked against a known meter before any critical measurements are made with it.

Operation

It is a good precaution to equip the meter with a neck cord. The ranges encountered in TV studios will center around 100 to 200 ftC. with the highest reading seldom above 400 ftC. If the meter is to be used outdoors, it is easy to double or quadruple the range by mounting a piece of Kodak neutral density filter (N.D. filter) over the photodiode sensor. A filter of 0.30 N.D. will double the range because it has a transmission factor of 50. if the meter had been calibrated to a peak reading of 400 ftC., the 0.30 N.D. filter will raise it to 800 ftC. and all other LED indications will be doubled. A 0.60 filter will quadruple the range to 1600 ftC and both filters will raise it to 3200 ftC. If the phone plug mounting has been used for the sensor, the filter could be mounted in a small cap over the end of the plug.

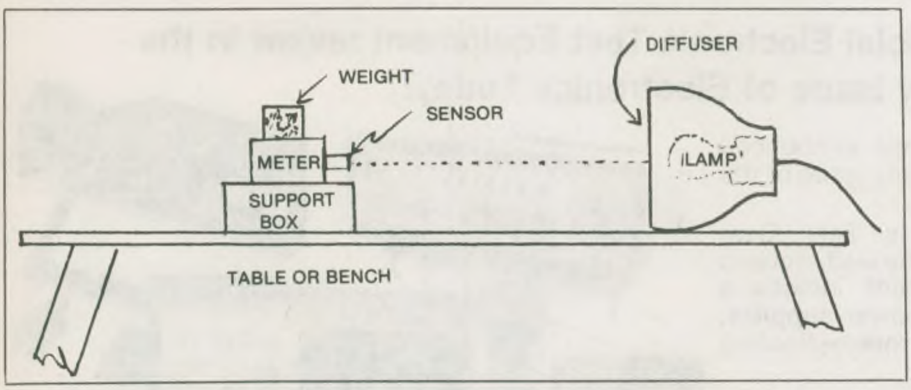


Fig. 10 Table top set-up for meter calibration.

Photographic Use

The meter could be adapted to photographic use. It can be used as it is if only ftC readings were required. A mechanical converter of the sort found on most exposure meters would be required to translate the readings into shutter speeds, lens apertures and film speeds. it might be necessary to have an integrating dome over the sensor. This field has not yet been explored with the prototype and it could be an interesting experiment for the builder to pursue.

Parts List

Resistors (all 1/4W)

R1,R15	470R
R2	20k trimpot
R3	8.2k
R4,R11	5.6k
R5	100k trimpot
R6	100R
R7	50k trimpot
R8	10k
R9	2.2M
R10	3.3k
R12	330R
R13	100k
R14	22k

Capacitors

C1,C3	0.1uF 16V ceramic
C2	4.7uF 16V
C4	100uF 16V

Semiconductors

IC1	LM3914 dot/bargraph driver
IC2	LM336Z 2.5V reference
IC3	LM339 Quad comparator
IC4	555 timer
D1-D10,D12	Red LEDs (Preferably high efficiency)
D11	Vactec VTB 9413B blue enhanced photodiode
Q1	2N2222

Miscellaneous

Sounder	Electrosonic #A1-250
B1	9V battery
S1	SPST push-button, N.O. spring return, shallow profile.

case (Radio Shack #270-233); copper tape materials, or perfboard, or PCB; bolts; sleeves etc.

Continued from page 32

for this type of trouble is to apply power through a 120V lamp in series with the power line and the device. Choose a wattage up to twice that required by the unit under test, and don't reapply power until the unit is fixed.

Diodes can become open or shorted. Power diodes in a bridge arrangement usually go faulty in pairs, but it's good practice to change them all anyway. Be careful to use components that match or exceed the original, especially with regards to the peak inverse voltage (PIV), sometimes called peak reverse voltage (PRV).

The Intermittent Fault

The intermittent fault is the bane of the serviceman. They're difficult to find, and you can never be sure that you've really fixed the fault. Bad solder joints are typical intermittent faults, and are best found by the prod-and-probe method. It often pays to resolder all the joints, taking care that each connection is in fact a good one rather than a mere dressing-up of a dry joint.

An intermittent fault in a component can often be found by using a can of freeze spray. If the component can't be isolated, spray methodically over the whole board. If the component is temperature sensitive, this technique will often find the problem. Often the fault will only appear after normal operating temperatures have been reached, in which case normal operation will be restored after a freezing spray. Heating a component with a soldering iron and then freezing it is another method of localizing troubles.

Flow Chart

Figure 4 shows a summarizes all the troubleshooting technique described so far. No flow chart can cover all situations, but the suggested plan of attack is a good way to start. Critics may suggest that the chart is too simple or that the order is wrong. Experience will soon show you how to adapt the chart to specific circumstances.

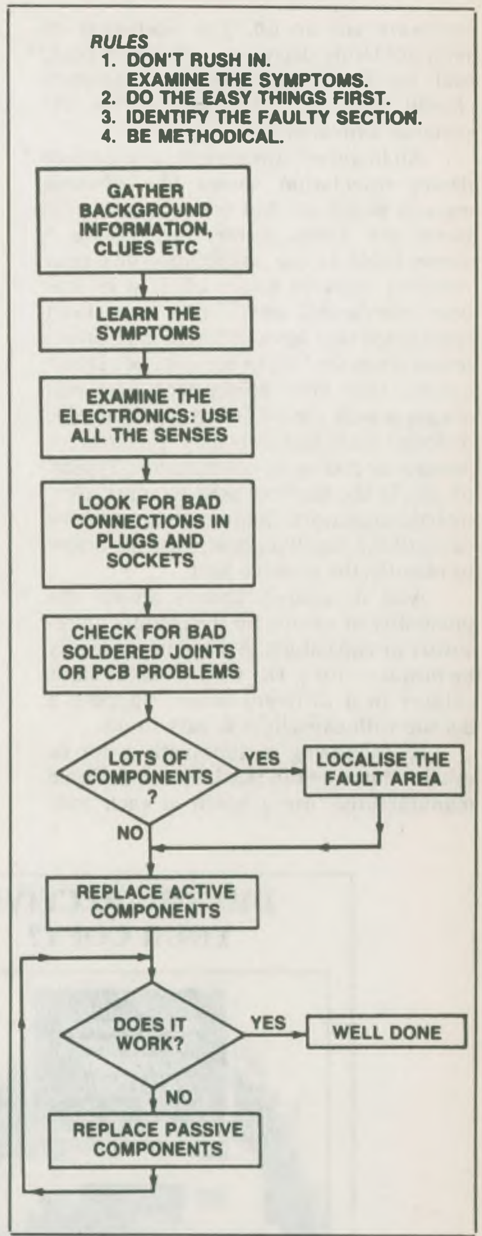


Figure 4. Fault finding flow chart.

With the chart are four basic rules. The rules are not in any particular order, but the intended message is to be scientific and methodical about the task. Luck has always played a part in servicing, but you can never rely on it. Remember that if the device used to work, it can be made to work again.

It is oft-quoted that "He who never made a mistake never made anything." The construction error is not necessarily the exclusive province of the amateur. Typical errors in circuit building are faulty soldering, bridged tracks, incorrect component orientation, incorrect components, mixed-up wiring in external

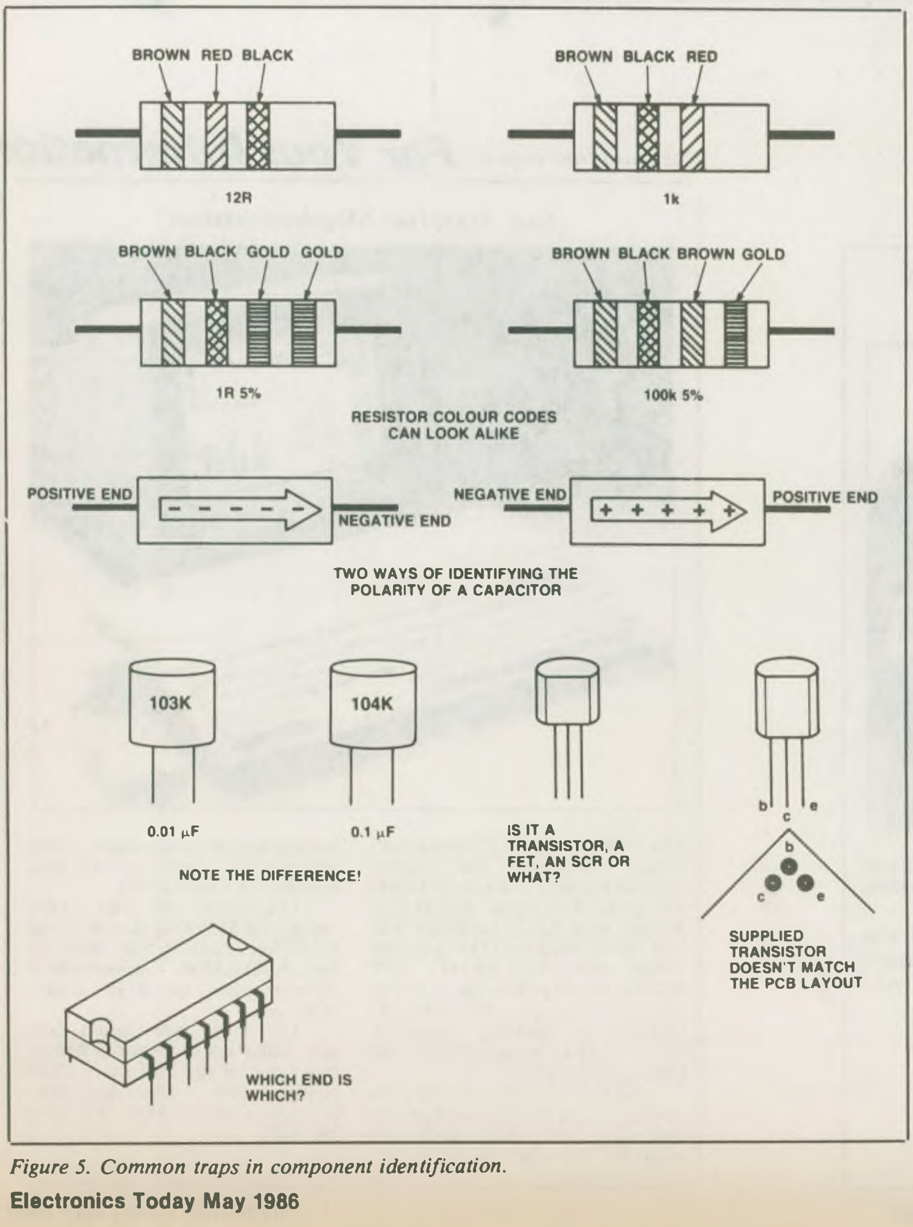


Figure 5. Common traps in component identification.

hardware and so on. The likelihood of poor soldering decreases with experience, and for this reason, complex projects should only be undertaken after experience with simpler ones.

An incorrect component, or incorrect device orientation sound like obvious enough problems, but some bizarre problems are worth mentioning. Figure 5 shows some of the possibilities that constructors show be aware of. If a kit has been purchased, parts may have been substituted that have different lead orientation from the one in the manual. Don't assume that any replacement part will always match the PCB layout. Similarly, different manufacturers may use different pinouts or coding or orientations. Typical of this is the method used to mark electrolytic capacitors. Some employ an arrow to mark the negative, others use the arrow to identify the positive lead.

And of course, there's always the possibility of mixing up the colours on resistors or capacitors. A 12 ohm can easily be mistaken for a 1K, which has the same colours in a different order. Slipping a decade with capacitors is easy to do.

IC polarizing is done with a dot or notch on one end to mark Pin One. Some manufacturers use a notch at each end, one deeper than the other. The potential for reversing these is obvious.

Some toggle switches make contact when the toggle moves toward the contact in question, and some are the other way around. It pays to test switches with an ohmmeter or continuity tester before installing them.

Summary

This article has purposely stayed away from describing any technical fault finding methods. A knowledge of Ohm's Law and its implications is very useful, and in many cases indispensable. Given this background and a multimeter, servicing becomes easier, as faults can often be found very quickly. By noting the hints presented here, those starting out in electronics can give it a try.

Although they may not care to admit it, many service technicians repair equipment that they know nothing about by using the methods that have been outlined. ■

Continued from page 33

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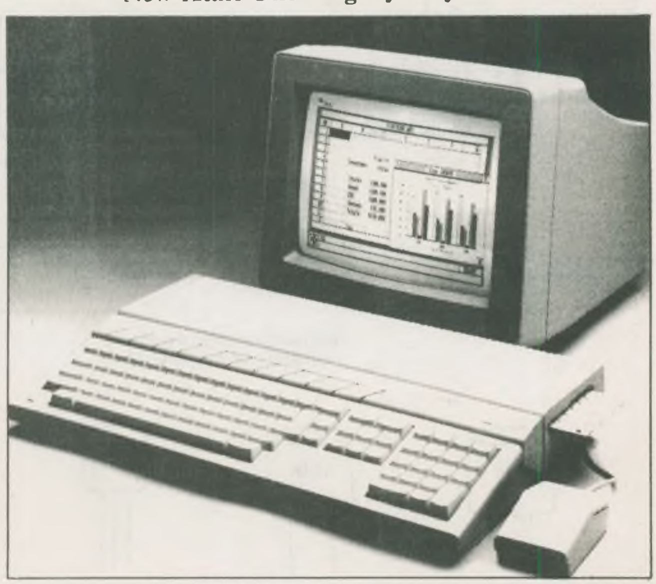

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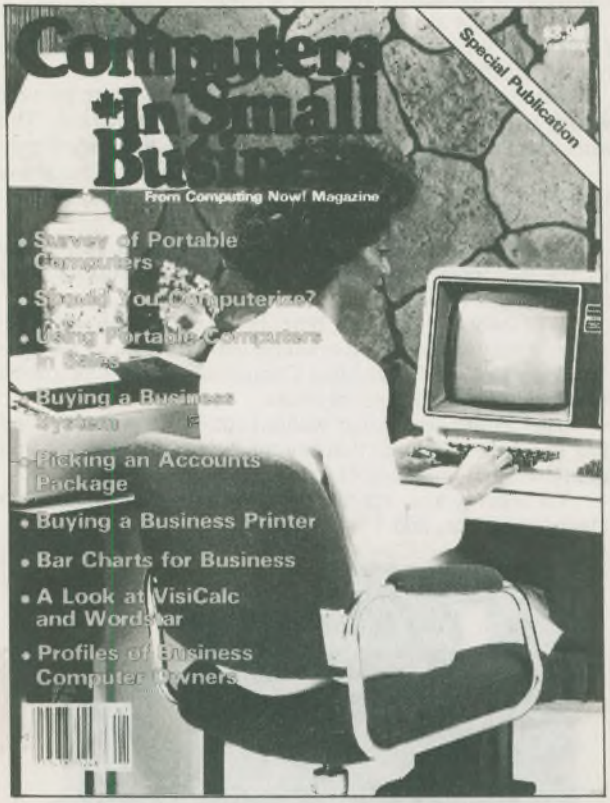

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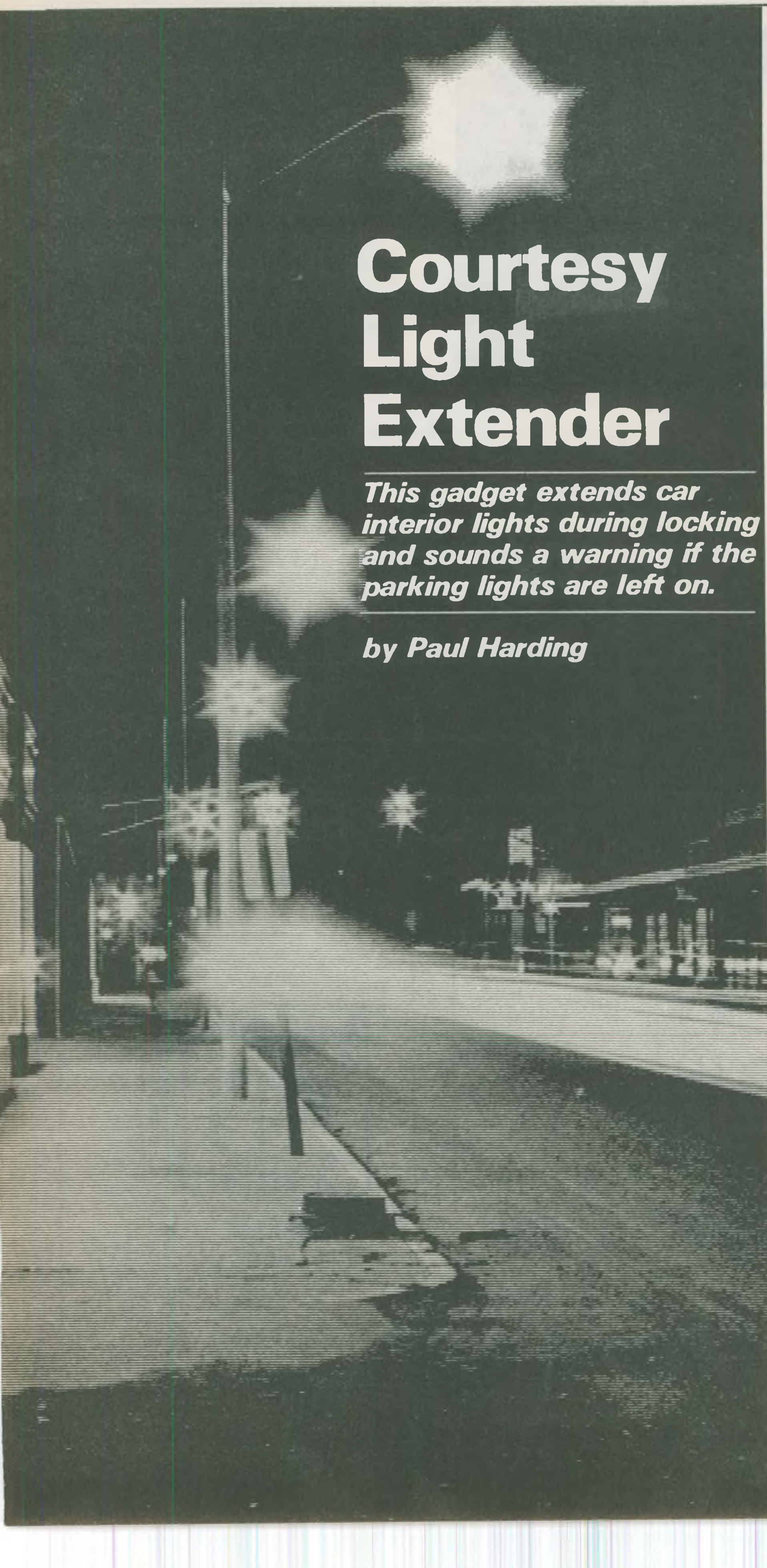


Courtesy Light Extender

This gadget extends car interior lights during locking and sounds a warning if the parking lights are left on.

by Paul Harding

IF you have ever left your car lights on, only to return to find the battery resolutely flat, or had to grope around in the dark to find the ignition switch after you have closed the car door, or even both, then this is the circuit for you. On the one hand, it holds the courtesy light on the twenty seconds after the car door has first been opened, and on the other hand it bleeps if the car door is opened while a light (any light you designate) is still on. Up to five lights can be monitored, and to cause minimum inconvenience, both functions are cancelled when the ignition (phase 1) is turned on.

The completed project is small enough to fit in almost any nook or cranny, and since it only used CMOS chips, it requires no power switch. A light reminder that has been switched off is no use to anybody.

The Circuit

Looking at the block diagram first, it can be seen that the circuit falls in to three main parts: a monostable, a gated oscillator and some mixed logic.

The monostable drives a relay, which in turn simulates the closing of a door switch, keeping the courtesy light switched on. It is triggered by opening any of the car doors.

The logic decides when the gated oscillator should be on; i.e, when any light is on, a door is open and the ignition is off.

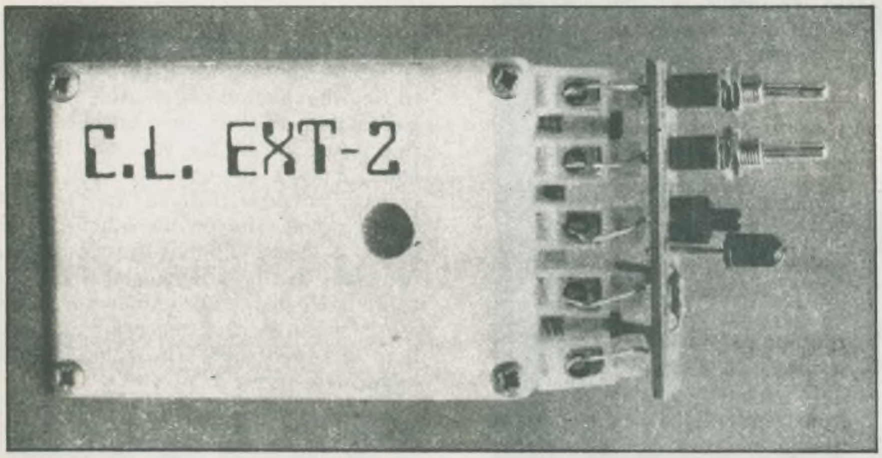
The gated oscillator is merely a tone generator feeding a piezo element, switched on and off by a slow (2Hz) astable.

When the ignition is on, both the monostable and the oscillator are held off.

Now look at the circuit diagram (Figure 2). Since a negative going input is generated at CL when a door is opened, and a positive triggered monostable is used, an inverter (IC1a) is placed at he latter's input. The monostable consists of IC1b and c, and C1 and R3. A negatively triggered monostable is not used here because another NOR gate is required elsewhere in the circuit. R1 holds IC1a's input high; although the courtesy light will do this itself, a bulb failure would otherwise cause this input to float, leading to unpredictable circuit behaviour, and possible static discharge damage. Q1 buffers the monostable's output so that RLA1 can be driven.

The IGN line is tied to one of IC1's inputs, and this forces the monostable into a reset state when the former is high.

The lights reminder has five wired-or inputs, which will go high when a light is turned on. Opening a door will bring IC1a's output high, and these simultaneous high states will be inverted by IC1d, and the slow oscillator around IC2b is gated on. This, in turn, will gate



to use a grounded soldering iron, solder pins 7 and 14 first (to allow the internal, protection devices to work) orientate them correctly, and install them last.

Short lengths of wire can be soldered into the holes for off-board connections, and flexible leads attached to these. Insulate the connections with rubber sleeving, and terminate the leads at a terminal block screwed to the outside of the case.

The connections to the various existing wires can be made using connectors, or by stripping the insulation off at a convenient point and soldering. Such connections must be insulated to avoid possible pyrotechnics.

The wiring diagram clarifies the connection details.

The circuit will work on any negative-

on the fast oscillator around IC2d, via IC2c, activating X1.

R1, 2,5,6,9, 10 and 11, and D7 protect the CMOS ICs from static damage. C4 is a supply decoupling capacitor, and D6 removes inductive spikes from the relay coil.

Construction and Installation

Construction is simplicity itself, since all the components, except for X1, fit onto one PCB. There are two wire links, one of which goes under the board (shown as a dotted line on the overlay diagram, Figure 3), and these should be fitted first. Next, insert and solder the resistors, diodes, transistor, relay and capacitors, in that order. Remember to observe the polarity of the diodes, and the electrolytic and tantalum capacitors. Some of the components are mounted too close to the ICs to allow sockets to be used for the latter, even though they are CMOS. Remember

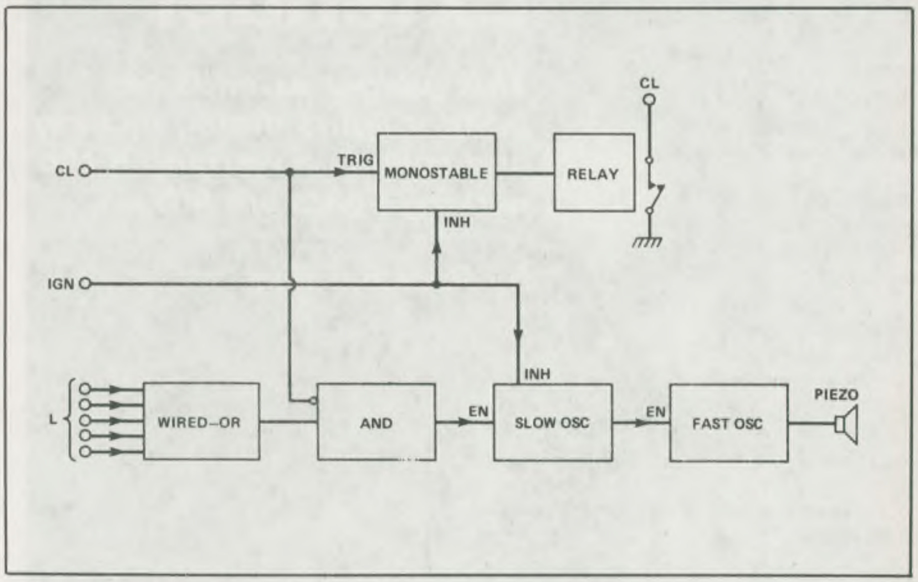


Fig. 1 The block diagram

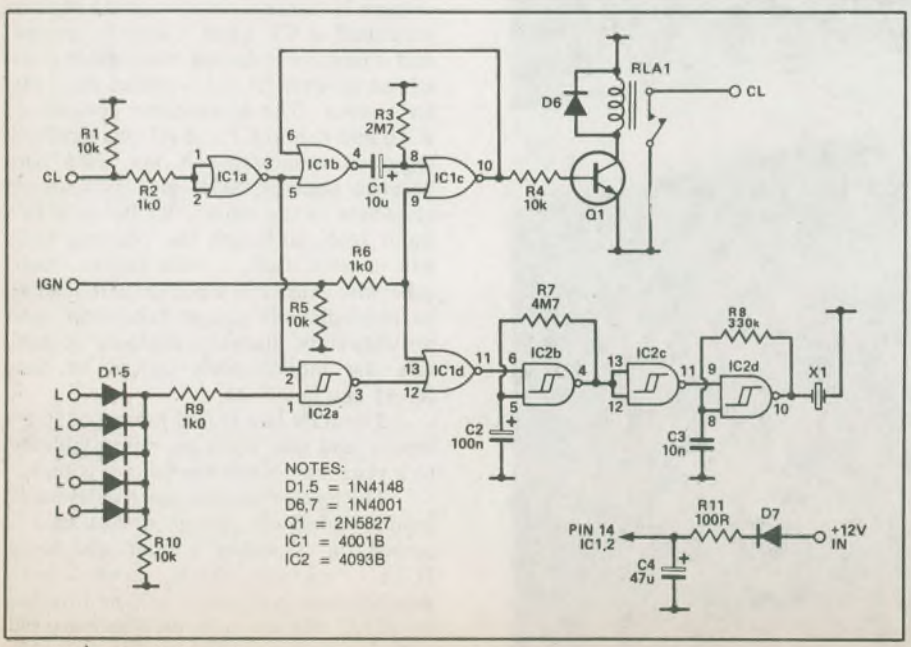
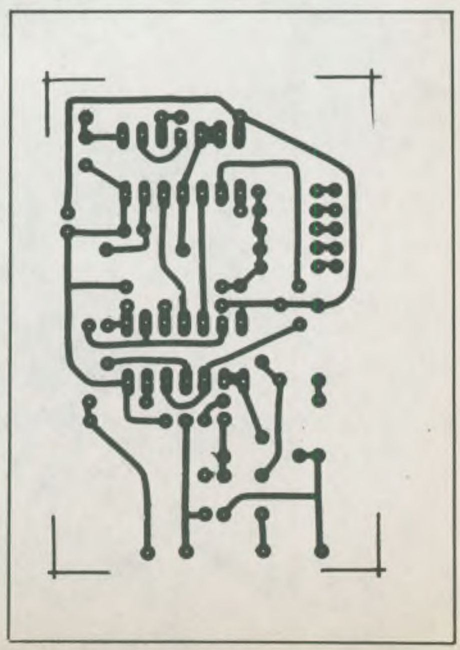


Fig. 2 The circuit diagram.



The PCB artwork.

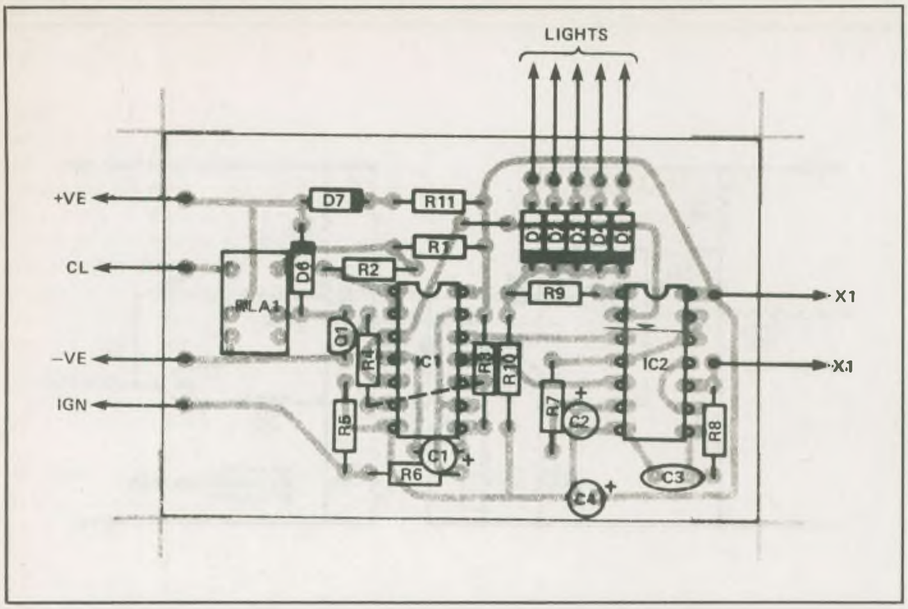


Fig. 3 The component layout. Note the wire links (one under and one above the board). Sockets cannot be used for the CMOS ICs, so note the handling precautions in the text.

Parts List

Resistors (All 1/4W, 5 percent)

R1,4,5,10	10k
R2,6,9	1k
R3	2M7
R7	4M7
R8	330k
R11	100R

Capacitors

C1	10u, 16V tantalum bead
C2	100n film type
C3	10n film type
C4	47u 16V electrolytic

Semiconductors

D1-5	1N4148, 1N914
D6,7	1N4001 or equiv
Q1	2N5827
IC1	4001B
IC2	4093B

Miscellaneous

RLA1	12V, 2A contacts
X1	piezoelectric sounder

Utility case, terminal block, wire, etc.

ground car whose lights are switched positive, and whose courtesy light is grounded when a door opens, i.e, most cars.

If the specified case is used, it will be necessary to trim off the corners of the PCB to ensure adequate clearance.

X1 can either be a cased or uncased piezo element. The former is screwed to the outside of the case, while the latter is stuck inside the lid of the case, over an 8mm hole to let out the sound. Remember to insulate the bare element to prevent short circuits.

Testing

Switch on any one of the lights being monitored, and open the car door. The piezo device should sound. Close the door, and the courtesy light should then remain lit for twenty seconds or so. Both functions should cease when the ignition key is turned to phase 1.

It will be found that the buzzer continues to sound even when the door has been closed. This is because the relay is holding the CL input low, and is unavoidable. ■

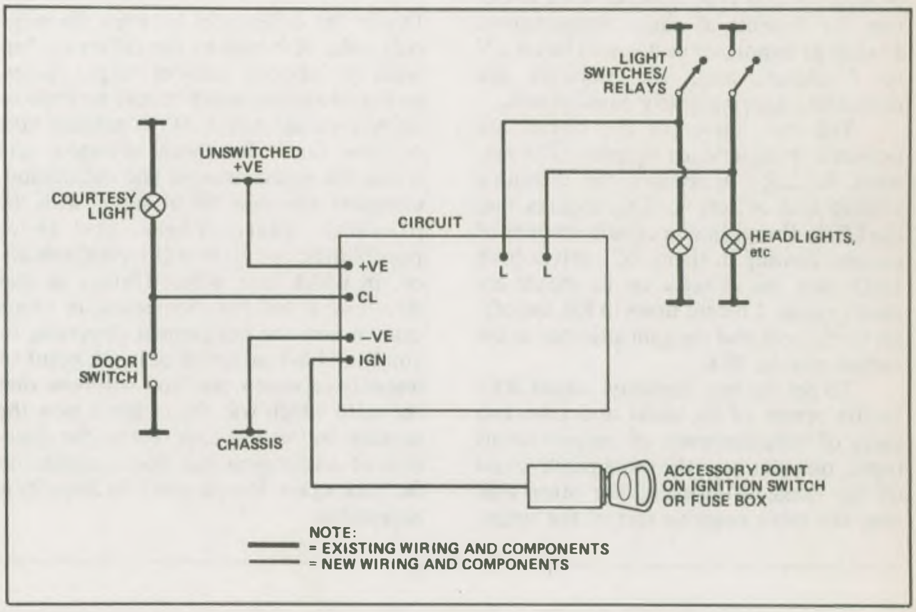
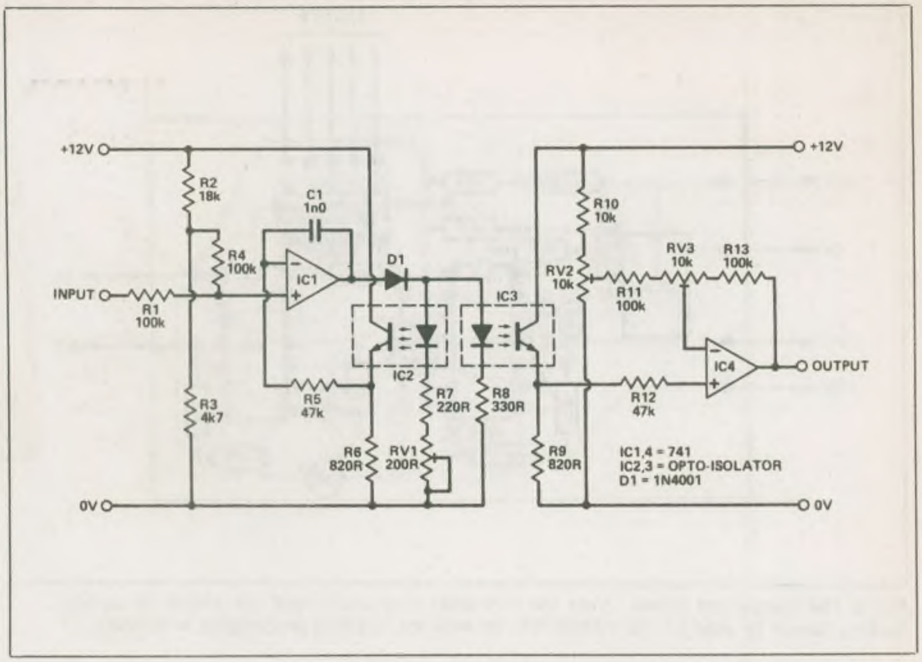


Fig. 4 The wiring diagram. The circuit will work for cars with negative ground, whose lights switch positive when a door opens. This includes most cars.

Analogue Opto-Isolator

By P. Cuthbertson



THIS CIRCUIT accepts an analogue input and transfers it to the output faithfully without any electrical connection, the link being optical. It is more usual to see V to f converters being used for this, but they demand more cumbersome circuitry and unless a train of pulses is required, the linear approach should be considered. Additionally, V to f converters integrate or smooth out the incoming waveforms, which may or may not be desirable. With slight modifications (changing a few resistor values) this circuit will feed A/D converters.

Linearity is maintained by using two opto-isolators; these are both non-linear, but equally so, and the effect can be made to cancel out. Although not done on the original, a dual type could be used to obtain the benefits of equal temperatures. It's not as important as it would be on a V to f circuit, and, the isolators are dissipating approximately equal power.

The two halves of the circuit are powered from separate supplies. The network R1,2,3,4 attenuates the incoming voltage and offsets it. This ensures that the LEDs always have a certain amount of current flowing in them. IC1 drives both LEDs and the voltages on its inputs are nearly equal. Current flows in R9, the offset is removed and the gain adjusted in the output circuit, IC4.

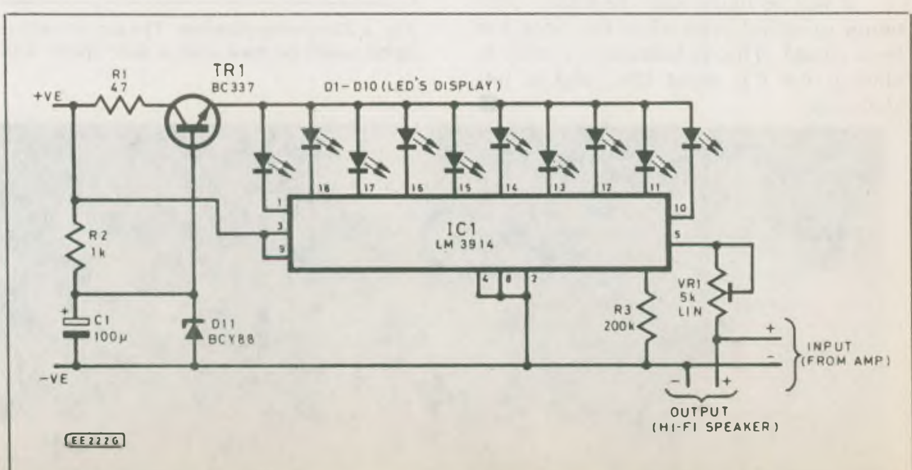
To get the best linearity, adjust RV1 to the centre of its travel and take two pairs of measurements of output versus input, one pair near the more positive end of the range of interest, the other pair near the more negative end of the range. Divide the differences between the adjacent pairs of inputs by the difference between the adjacent pairs of output values, giving two ratios which should be approximately equal. Adjust RV1, making note of how far it has been adjusted, and repeat the measurements and calculation. Compare this new set of ratios with the previous ones. There are three possibilities: the error will have diminished, in which case adjust further in that direction; it will have increased, in which case reverse the adjustment direction; or you may have adjusted past the point of linearity in which case you will note that the ratio which was the larger is now the smaller. In this last case reverse the direction of adjustment but don't adjust too far back again. Repeat until the linearity is acceptable.

In fact, the linearity is only a few per cent out with a 330 ohm resistor in place of R7 and RV1. If you can stand a certain amount of non-linearity substitute the resistor. If you possess a ramp generator and scope capable of XY display then you will be able to adjust the linearity by eye.

Adjust the gain and offset once the linearity is satisfactory. Do not be afraid to alter resistor values to suit other input values. C1 is not usually necessary but I have included it as it stops any tendency to oscillation. The power supplies are simple 3 terminal regulators. The original circuit runs IC1 ±15V but one may get away with just plus 15V, connecting pin 4 to ground. D1 would no longer be needed then since it only serves to protect the opto-isolator LEDs from polarity reversal.

Audio Amplifier Output Power Meter

By N. Walker



THE CIRCUIT uses the LM3914 Bargraph Display IC which is capable of driving ten LEDs and is therefore ideally suited to the readily available bargraph modules.

The circuit shows a single channel meter but an identical circuit can easily be made up to provide a stereo power meter. The unit operates in a range of 3V to 18V.

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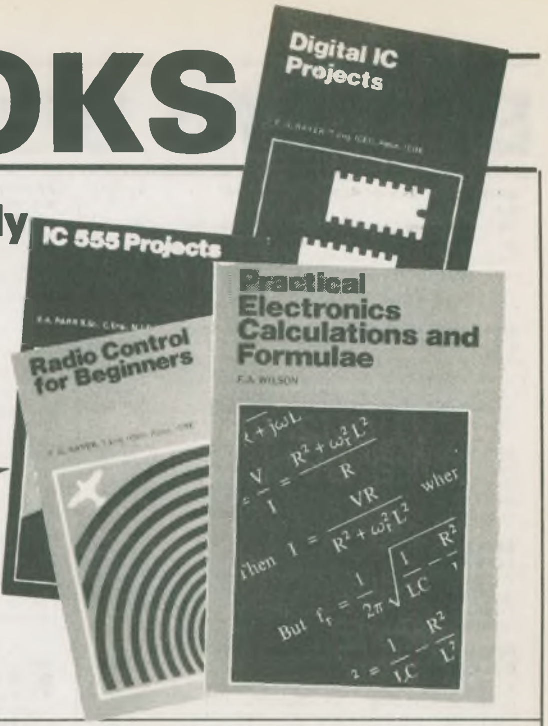

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R.A. Penfold $8.85
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BP104: Electronic Science Projects
Owen Bishop $8.85
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R.A. PENFOLD
We have all built circuits from magazines and books only to find that they did not work correctly, or at all, when first switched on. The aim of this book is to help the reader overcome just these problems by indicating how and where to start looking for many of the common faults that can occur when building up projects.

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BP67: COUNTER DRIVER AND NUMERAL DISPLAY PROJECTS $7.05
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BP107: 30 SOLDERLESS BREADBOARD PROJECTS — BOOK 1 $8.85
R.A. PENFOLD
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BP106: MODERN OP-AMP PROJECTS $7.60
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CIRCUITS

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BP80: POPULAR ELECTRONIC CIRCUITS — BOOK 1 $7.75
R.A. PENFOLD
Another book by the very popular author, Mr. R.A. Penfold, who has designed and developed a large number of various circuits. These are grouped under the following general headings; Audio Circuits, Radio Circuits, Test Gear Circuits, Music Project Circuits, Household Project Circuits and Miscellaneous Circuits.

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This book contains something of particular interest for every class of enthusiast — short wave listener, radio amateur, experimenter or audio devotee.

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Since it first appeared in 1977, Mr. R.N. Soar's book has proved very popular. The author has developed a further range of circuits and these are included in Book 2. Projects include a Transistor Tester, Various Voltage Regulators, Testers and so on.

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E.A. PARR
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BP65: SINGLE IC PROJECTS $6.05
R.A.PENFOLD
There is now a vast range of ICs available to the amateur market, the majority of which are not necessarily designed for use in a single application and can offer unlimited possibilities. All the projects contained in this book are simple to construct and are based on a single IC. A few projects employ one or two transistors in addition to an IC but in most cases the IC is the only active device used.

223: 50 PROJECTS USING IC CA3130 $5.00
R.A PENFOLD
In this book, the author has designed and developed a number of interesting and useful projects which are divided into five general categories: I — Audio Projects II — R.F. Projects III — Test Equipment IV — Household Projects V — Miscellaneous Projects.

BP117: PRACTICAL ELECTRONIC BUILDING BLOCKS BOOK 1 $7.60
Virtually any electronic circuit will be found to consist of a number of distinct stages when analysed. Some circuits inevitably have unusual stages using specialised circuitry, but in most cases circuits are built up from building blocks of standard types.
This book is designed to aid electronics enthusiasts who like to experiment with circuits and produce their own projects rather than simply follow published project designs.
The circuits for a number of useful building blocks are included in this book. Where relevant, details of how to change the parameters of each circuit are given so that they can easily be modified to suit individual requirements.

BP102: THE 6809 COMPANION $7.60
Written for machine language programmers who want to expand their knowledge of microprocessors. Outlines history, architecture, addressing modes, and the instruction set of the 6809 microprocessor. The book also covers such topics as converting programs from the 6800, program style, and specifics of 6809 hardware and software availability.

BP118: PRACTICAL ELECTRONIC BUILDING BLOCKS - Book 2
R.A. PENFOLD $7.60
This sequel to BP117 is written to help the reader create and experiment with his own circuits by combining standard type circuit building blocks. Circuits concerned with generating signals were covered in Book 1, this one deals with processing signals. Amplifiers and filters account for most of the book but comparators, Schmitt triggers and other circuits are covered.

BP24: 50 PROJECTS USING IC741 $6.75
RUDI & UWE REDMER
This book, originally published in Germany by TOPP, has achieved phenomenal sales on the Continent and Babani decided, in view of the fact that the integrated circuit used in this book is inexpensive to buy, to make this unique book available to the English speaking reader. Translated from the original German with copious notes, data and circuitry, a "must" for everyone whatever their interest in electronics.

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Although modern bipolar power transistors give excellent results in a wide range of applications, they are not without their drawbacks or limitations. This book will primarily be concerned with VMOS power FETs although power MOSFETs will be dealt with in the chapter on audio circuits. A number of varied and interesting projects are covered under the main headings of: Audio Circuits, Sound Generator Circuits, DC Control Circuits and Signal Control Circuits.

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DOERR
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Designer's Notebook: Better By Design

Even professionals make mistakes, and here are some of the common ones. If you're thinking of designing a circuit, the best place to start is here.

By Andy Armstrong

AFTER inspecting many designs at the draft stage, it is clear that there are some misunderstandings and design errors which crop up again and again. Some aspects of circuit design, for reasons unknown, seem to be ignored or glossed over by even the most seasoned practitioners.

Most of the problems fall into the category of "things which will work most of the time or work with certain samples of the components used".

A typical example was faced by a friend of mine in a vacation job after his second year at college, and involved unijunction transistors. Someone had designed (by dint of sheer building) a control unit, incorporating a unijunction, for an electric arc welder. The first production batch of welders worked very well, but none in the second batch worked at all.

It turned out that the circuit had been optimized by trial and error to work with a batch of unijunctions which were at the edge of the specification. The next batch purchased had more typical characteristics, and the circuit could not cope. The configuration of the circuit was not designed to take account of the tolerances of unijunctions, but a change of component values centred the circuit on the typical operating parameters. Subsequently only one component value had to be changed if a batch of unijunctions was too far from typical.

Design Posts

Nobody expects magazine projects to be designed to industrial standards. This would be uneconomic because of the very large amount of time required to design even a simple circuit to production standard, and because of the need to make more than one prototype to double check a design. These limitations notwithstanding, a project design needs to be as close in standard to an industrial design as possible, and should, in particular, avoid problems connected with variations in the electrical and mechanical characteristics of components.

Of course, there are differences in emphasis. For example, a circuit may rely on a particular component characteristic, perhaps requiring that two diodes have a similar voltage drop at a certain current. The home constructor could happily select the components, but in an industrial design, the cost of paying someone to grade components would mean that the real price of a 5 cent diode would be a lot more than 5 cents.

On the other hand, if too much decision-making on the part of the constructor is necessary to make a project work, then some of the people who build it will simply never succeed.

Family Characteristics

Many of the marginal designs encountered have used CMOS, so this is the place to start.

The 4000 series of CMOS is designed to work over a wide range of power supply voltages. Different manufacturers specify slightly different operating characteristics at different voltages, but here I shall refer to the Mullard/Signetics HEF4000B range. Some of the family specifications are reproduced here for reference.

A number of circuits use a CMOS gate output to switch a transistor, which is used to control a relay, lamp, etc. Normally, a small signal transistor is used to drive the load and in order to work well, the transistor must be switched on hard. This requires adequate base current; a rule of thumb is to use a base current of 0.1 times

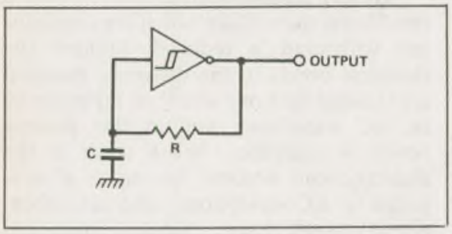

Fig. 1. Simple schmitt oscillator.

the required collector load current. This can exceed the current which the gate is guaranteed to supply, though in fact most gates manage well over the minimum specified current.

It is not a good idea to rely on your good fortune in selecting a gate. Back on the industrial front, I recently had to investigate a rash of mysterious board failures, and discovered that one of the CMOS gates was being asked to deliver

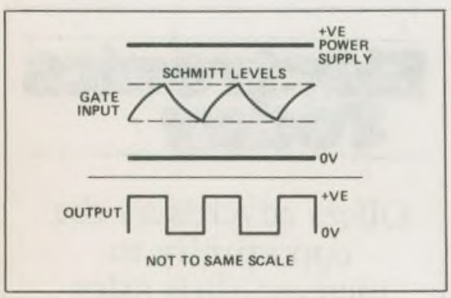

Fig. 2. Waveform diagram.

about twice its guaranteed output current. After a while, most gates from one batch failed, though the design had been produced without problems for several years beforehand. Presumably this batch of gates was unable to exceed its specification without damage.

To avoid this sort of problem in home projects, a CMOS gate sourcing current should have a load resistance of at least 1kohm per volt of power supply. If this means that the transistor it is feeding receives insufficient base drive to switch properly, then the answer is to use a Darlington transistor, or two transistors connected as a Darlington pair.

Alternatively, you could use a power FET suitable for the desired load current. A power FET capable of switching several amps may be driven directly by a CMOS gate. The switching speed may be low, because of the limited rate at which the

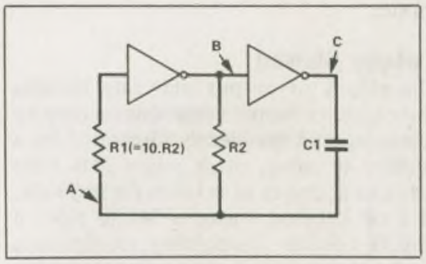

Fig. 3. Clock oscillator.

CMOS output can charge or discharge the FET gate capacitance. The heavy load presented to the CMOS gate output by this capacitance is of short enough duration not to risk damaging the CMOS chip unless a high frequency switching signal is used.

There is one exception to these stern warnings about overloading CMOS outputs. When powered from a 5V supply, most CMOS chips are designed to be short circuit proof. The practice of driving an LED from the output of a CMOS gate should not be harmful at this supply voltage, though the output will not provide a proper logic level when used in this manner. My recommendation is that this practice be confined to novelty circuits.

Clock Oscillators

Many projects incorporate some sort of oscillator, which may be needed to clock a counter, or to generate an audible tone. Figure 1 illustrates a simple oscillator circuit, using a Schmitt trigger IC. As shown in the waveform diagram, Fig. 2, the capacitor charges through the feedback resistor until the voltage on it reaches the positive threshold of the Schmitt trigger gate. The output of the gate then switches to logic 0 and the capacitor starts to discharge until it reaches the lower Schmitt threshold.

There are two drawbacks to this circuit. The Schmitt levels may vary widely from batch to batch of the chip, and the output frequency of the circuit is directly dependent on these levels. Also, the threshold levels are not symmetrical with respect to the power supply (the characteristic of Schmitts known as hysteresis), so the mark-to-space ratio of the output wave is not unity. If the mark-to-space ratio is not important, the circuit may be made more acceptable by the addition of a potentiometer to fine tune the frequency.

A more consistent circuit is shown in Fig. 3, and its waveform diagram in Fig. 4. The junction point of R2 and C1 alternately takes up voltages outside the power supply rails, and then charges or discharges to approximately half the power supply voltage. Because the voltage range over which the capacitor works is large, small differences in switching level between different samples of chip do not have much effect on the frequency or the mark-to-space ratio. The frequency is approximately 1/(2.2 x R2 x C1).]

Many project designers omit the resistor R1. If this component is omitted, then the junction of R2 and C1 is prevented from taking up a voltage outside the supply rails by the input protection diodes of the CMOS gate. The frequency is approximately three times the frequency given if R1 is included (and if R1 is, as specified, ten times R2). Variations in switching levels or gain between samples of chip now have a more significant effect, so the net effect is to decrease the predictability of the circuit's performance.

If very high value resistors are used in the circuit, then high frequency noise pickup on the input connected to R1 may be a problem. In this case, rather than lower R1 and make the operation less predictable, a capacitor of a few hundred picofarads may be added in parallel with R1. Practice has shown that this always solves the problem without any detectable effect on the correct operation of the circuit.

In some project designs, NOR or NAND gates are used instead of inverters.

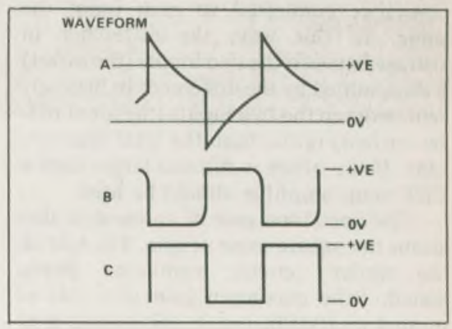

Fig. 4. Waveform for the clock oscillator.

The "spare" inputs may be used to gate the oscillator and turn it on or off in response to a logic signal. A logic 0 signal will stop a NAND gate oscillator, while logic 1 will stop a NOR gate oscillator. If it is necessary to start to clock a counter immediately the oscillator is started, then the rest of the oscillator should be considered. For example, if the signal is generated by pressing a switch, the response should be immediate or the user may begin to wonder if it is working.

The circuit shown in Fig. 5 will generate a positive edge on its output immediately a logic 0 is applied to its control input. By its nature, the circuit in its inhibited state will always charge its capacitor in such a way that it is ready to switch as soon as it is allowed to do so.

Op Amps

The correct use of op amps is another area which seems to be difficult for some project designers. There are several aspects which cause problems.

First of all, some designers simply fail to take account of the input bias and offset current. If a bipolar op amp is used, the bias resistors should be of a low enough value that the voltage drop in them is small. I recall seeing a reader's circuit in one electronics magazine, showing a 741 connected with all the bias current for the negative input flowing through a 4M7 resistor.

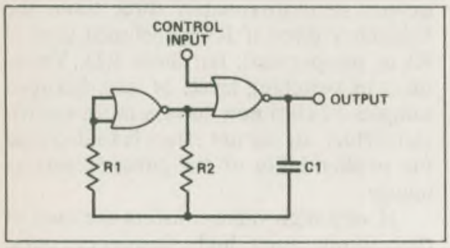

Fig. 5. An instant turn-on.

A good rule is to make the bias resistors as low as the rest of the circuit design allows, and to make the total DC resistance connected to each input the same. In this way, the difference in voltage between the two inputs (the offset) is determined by the difference in bias current between the two inputs (the input offset current) rather than the total bias current. If the offset is still too large, then a FET input amplifier should be used.

The open loop gain of an op amp also seems to confuse some people. The text of the reader's circuit mentioned above stated, "the maximum gain of a 741 is quoted as 20,000, but in this circuit it is wired to provide a gain of 47,000". This mistake arises from a misunderstanding about the way the op amp's gain is determined. The gain is determined by the ratio of the two feedback resistors in the circuit. You can use any ratio you please, but you cannot make the op amp give more than its maximum open loop gain.

A typical op amp frequency response is shown in Fig. 6. There are two relevant and related factors, the open loop gain and the gain-bandwidth product. The open loop gain defines the maximum low frequency gain the op amp can produce under any circumstances, and the gain-bandwidth product indicates the increase in gain with decreasing frequency.

An op amp having a gain-bandwidth product of 1MHz, for example, will have an open loop gain of unity at a frequency of 1 MHz. As the frequency is decreased, this gain will rise until the maximum open loop gain is reached, often at a frequency of about 10Hz, unless the internal stability capacitor is set to start rolling it off sooner.

Totally Slewed

The effects of output slew rate limiting and of power supply variations on op amp characteristics are clearly illustrated by a mistake of mine, made when 741s were the normal choice of op amp for any task. In a car project, I used a 741 to clock a CMOS counter. According to the data books, the slew rate of the output of a 741 is inadequate to clock the CMOS counter reliably, but still the circuit seemed to work, at least some of the time. After a little experimenting, I found that the car battery voltage affected the circuit. It all worked well when the engine was running and the lights were turned off, but couldn't be relied on when the battery was being drained and its voltage dipped.

It seems that the op amp's slew rate was slightly higher when the voltage was higher. This was just enough to make the counter clock on.

The moral of this is that the slew rate of the op amp can be crucial, and that you should not assume that a characteristic which is specified to be just good enough with, say, +/-15V power supplies will still be all right at lower voltages. This is true even though the op amp may be specified to work at much lower voltages. Data books never claim that a circuit will work precisely as well under all circumstances.

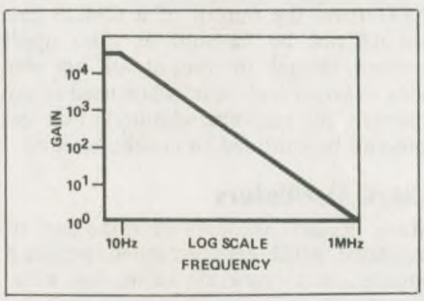

Fig. 6. Typical frequency response of an op-amp.

Passive Components

There are two common areas of misunderstanding which I have noticed in the use of passive components. The problem with resistors is very simple: ordinary quarter-watt resistors have a low voltage rating that you have to watch when connecting to voltages above 300V, say. Resistors rated 1/2 watt and greater have a higher voltage rating and are therefore generally okay to use in higher voltage circuits. Check the manufacturer's specs before assuming that resistance and dissipation are the only things to worry about.The voltage rating of a resistor can limit the maximum power that can be fed into it to less than its nominal wattage rating.

The other point of misunderstanding is in the use of non-polarized capacitors on AC, specifically when connected to the AC power line. Most people realize that a capacitor to be used on AC should have a DC rating equal to the peak of the AC waveform, but the problem does not stop there.

At any significant frequency, above a few Hertz, the voltage which the capacitor can withstand is reduced, because the chemical bonds in the dielectric material are stressed first one way then the other by an AC waveform, and in this process power is dissipated. Weak spots in the dielectric can become hot spots if subjected to AC waveforms, and can subsequently break down. Dielectric materials with higher levels of AC power dissipation suffer from this problem more severely. Generally, polypropylene capacitors are much better than polyester, while ceramics come in widely varying qualities.

One type of polyester capacitor, for example, is rated at 400VDC or 150VAC. A high quality polypropylene capacitor in the same catalogue is rated at 1000VDC, 350VAC at up to 5KHz. Some mica capacitors are rated to handle substantial RF signals. ■

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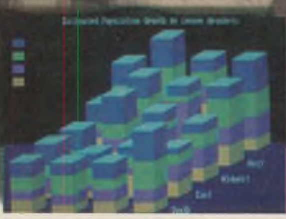

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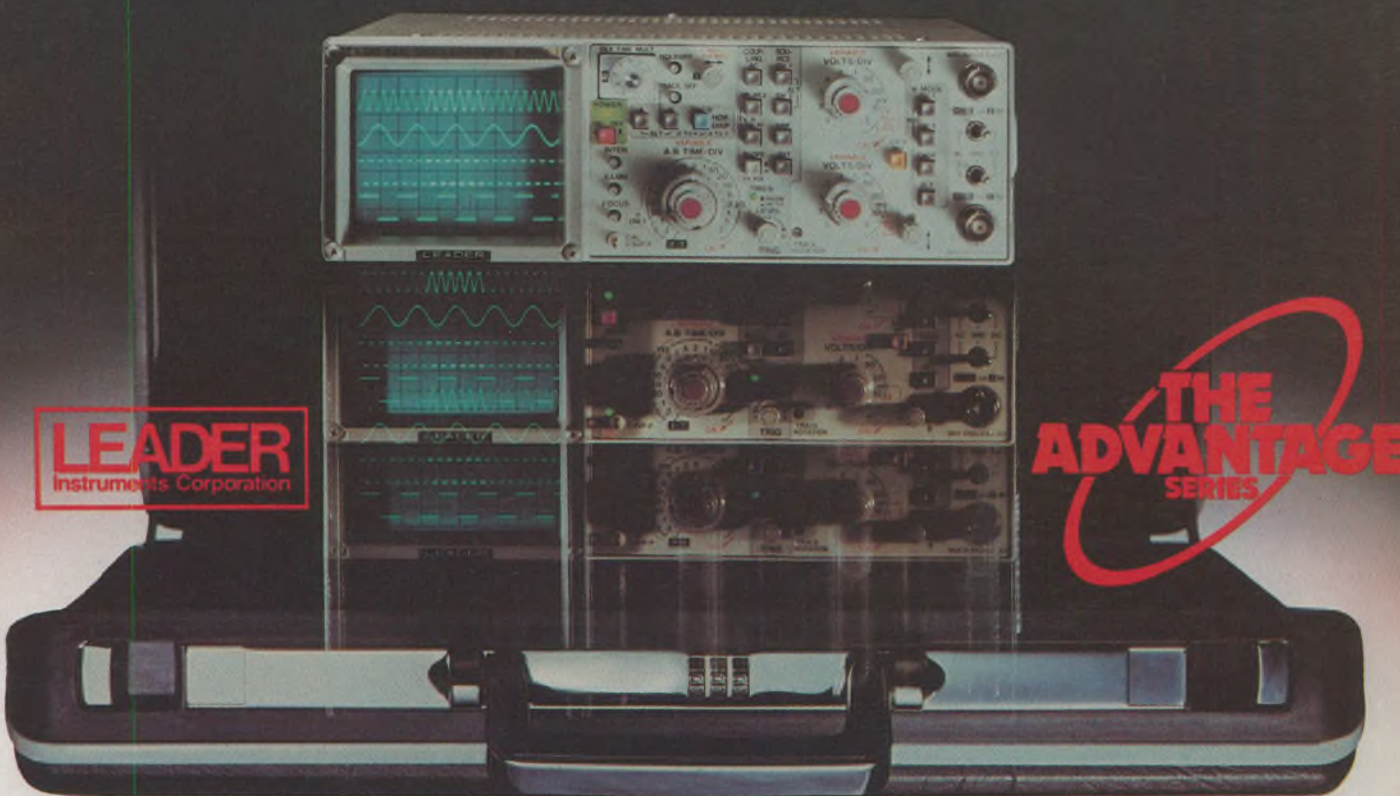

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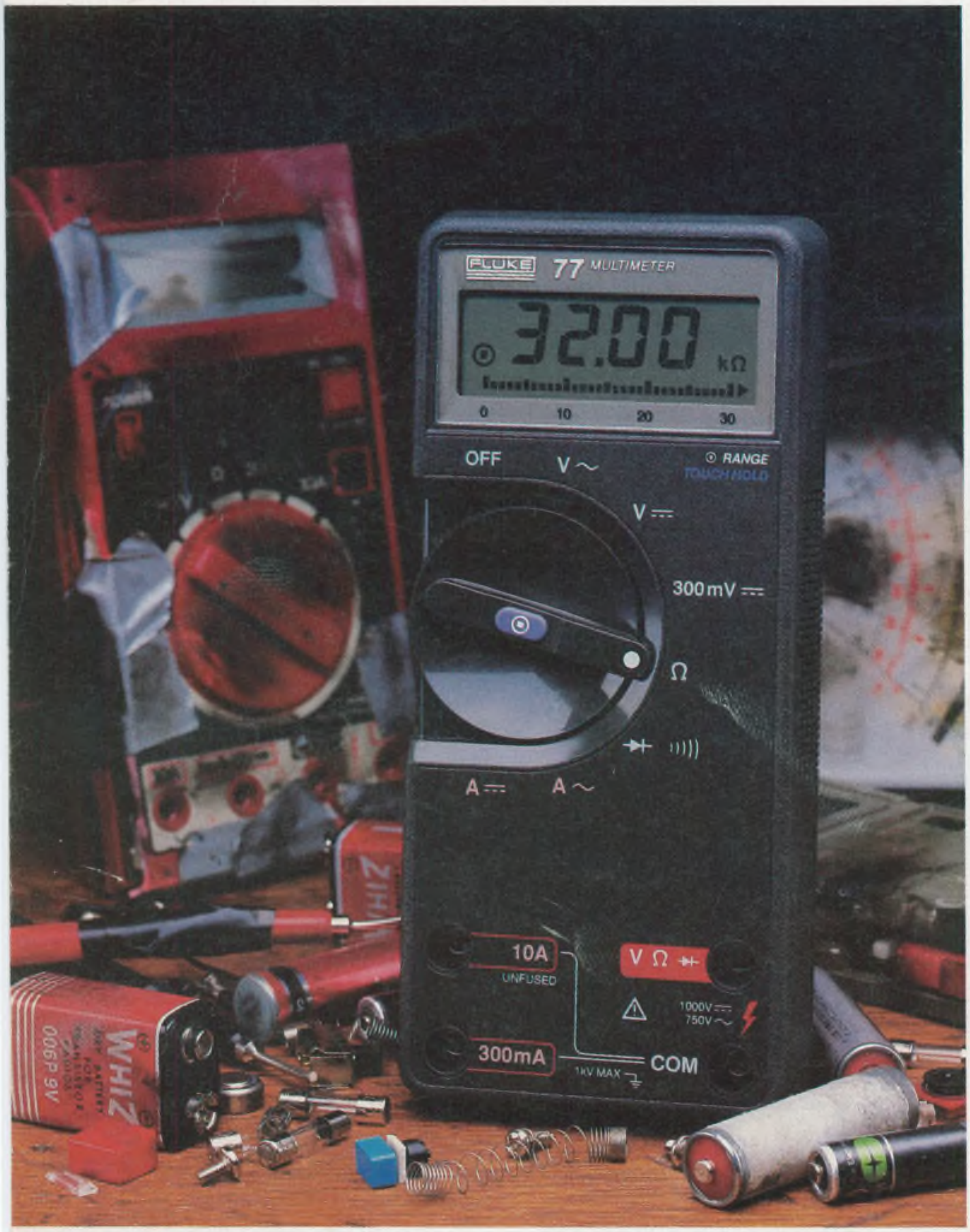

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