

ETI for Electronics & Computing Enthusiasts

Electronics Today

INTERNATIONAL

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MM70924

May 1983

Digital Voltmeter
Program for the PET

A Bunch of Fruit!

A look at three '6502' computers

BiFet and BiMos
Circuits Feature

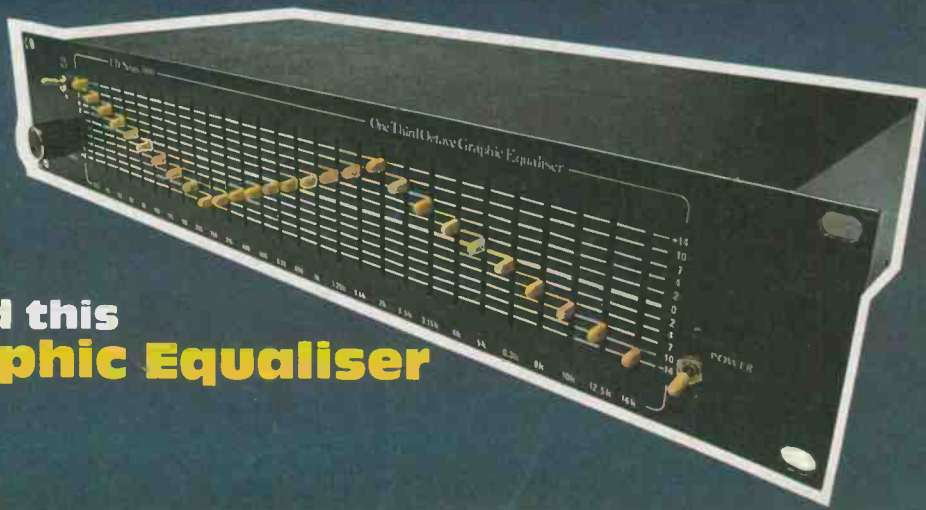
Electromusic
Techniques



History of Radar
An echo from the past

**Digital
Capacitance
Meter**

Counting up your
Farads



Build this
Graphic Equaliser





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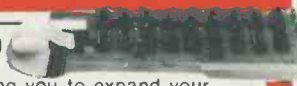
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(APPROX.)

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Circle No. 11 on Reader Service Card.



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INTERNATIONAL

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25 Using biFET and biMOS Op Amps
End those sleepless nights of worrying about excess bias current.

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It saved our bacon during the last Great Unpleasantness, and now it gives us speeding tickets.

54 Electromusic Techniques Part 1
She sells synthesisers by the sea shore; explanations and practical circuits for electronic music.

66 Computing in Britain
Exciting things are 'appening back 'ome.

71 Into Digital IC's Part 9
Ian Sinclair continues his explanation series.

Projects

13 Graphic Equaliser
Gyrate, v.i., to move in a circle. Oddly, you don't have to wind any coils for this third-octave 28-band equaliser.

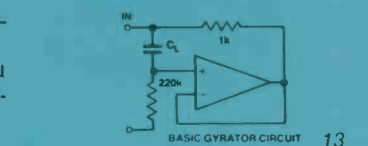
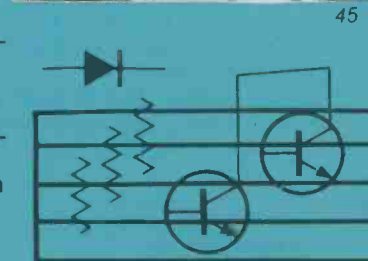
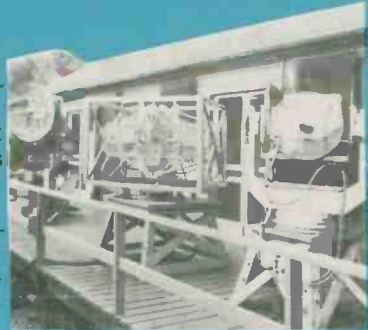
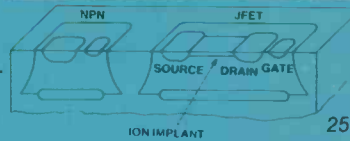
32 Digital Capacitance Meter
Checks capacitor values quickly and accurately and saves you having to learn those awkward colour codes.

60 Audio Analyser Part 2
Held up by technical problems, Part 2 appears in all its analytical glory.

Our Cover

Still Life With Fruit: The Franklin Ace 1200, the Surplustronics 6502, and the Orange Peel computers strut their stuff starting on page 39.

Graphic Equaliser Project: a professional quality unit for equalising problem acoustics; see page 13.



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We can supply photocopies of any article published in ETI 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. ETI 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 0.1uF 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 5.60hms 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 on 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.

B-C-D Electronics, P.O. Box 6326, Hamilton, Ont., L9C 6L9.

Wentworth Electronics, R.R.No.1, Waterdown, Ont., L0R 2H0.

Danocinths Inc., P.O. Box 261, Westland MI 48185, USA.

Arkon Electronics Ltd., 409 Queen Street W., Toronto Ont. M5V 2A5.

Beyer & Martin Electronic Ltd., 2 Jodi Ave., Unit C, Downsview, Ontario M3N 1H1.

Spectrum Electronics, 14 Knightswood Crescent, Brantford, Ontario M3R 7E6.

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ZX81

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ET5

for your information

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The Model 2988 oscilloscope from Brunelle features 20 MHz bandwidth, a video sync filter, TTL level Z-axis modulation, and very low power consumption (20 W). It also includes a component tester which works in or out of circuit. Contact Brunelle Instruments, 826 Belvedere St., Sherbrooke, Quebec J1H 4B8, (819) 569-1335.

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Editorial Queries

Written queries can only be answered when accompanied by a self-addressed, stamped envelope. These must relate to recent articles and not involve the staff in any research. Mark such letters ETI-Query. We cannot answer telephone queries.

IBM Canada Ltd. Extends Computer Line

IBM Canada Ltd., has introduced the IBM Personal Computer XT, extending the performance range and storage capacities of the company's personal computer line.

The base system, which is priced at \$7,545 at IBM Product Centres, features 131,072 characters of user memory, a dual-sided diskette drive with a 368,640 character capacity, and an integral Fixed Disk Drive with a capacity of more than 10 million characters. The IBM Personal Computer XT

also includes an Asynchronous Communications Adapter to enable the system to communicate with outside information sources, including other IBM Personal Computers, and larger IBM systems. The new product also includes eight expansion slots, three of which are used for the already installed communications adapter, diskette and fixed disk drives.

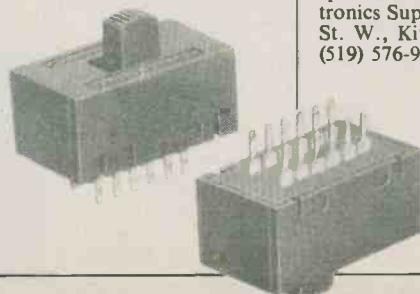
Also announced recently were a high resolution IBM Colour Display and Expansion Units which dramatically increase the storage capacity of both the XT and the IBM Personal Computer,



Miniature 4-Pole Slide Switches

A new series of miniature PC mounted slide switches designed for 4-pole, 2-position switching has been introduced by Switchcraft.

PC mounted on standard .100 x .220 inch centers, Series C6000 slide switches are especially suited to switching mA at up to 30 V DC. Applications include instrumentation, test and ground support equipment, computers, data-communications and medical electronic equipment.



ZX 81 Keyboard

The Memotech line of ZX81 peripherals now includes a convenient keyboard. It plugs directly into the back of the computer via cable and does not require soldering or opening up the ZX81. It also does not get in the way of stacking the other Memotech peripherals such as the Memocalc, a type of spreadsheet. From Orion Electronics Supplies Inc., 40 Lancaster St. W., Kitchener, Ont. N2H 4S9 (519) 576-9902.

a new, more powerful Disk Operating System (DOS) and application software.

The IBM 3290 Information Panel, also announced, is a state-of-the-art flat plasma panel using advanced technology to display up to 9,920 characters of data on a 10.7-by-13.4-inch screen.

The 3290 can simultaneously display combinations of character fonts, line drawings, charts, sketches, letters, or photographs, as well as still frames from television.

The 3290 attaches to IBM System/370, 30XX, or 4300 series computers, and the 8100 information system, via a 3274 control unit. Its thin-profile, flat display panel has a distortion-free screen that can display graphic images and up to 9,920 characters of alphanumeric data.

The 10.7-by-13.4-inch screen is made up of a sealed sandwich of two flat glass plates, less than 4 mils — 1/70th of an inch — apart. The space between the plates is filled with neon/argon gas which can be made to glow as electrical charges are selectively applied onto 737,280 intersections of a wire grid to create high-resolution orange-on-black images. An etched bronze glass filter reduces glare and resists fingerprint smudges.

Power Line Filters

If your computer or other sensitive equipment gets the hiccups whenever there's a flicker on the power line, you may be interested in the new Tycor Power Line Filter. Tycor Electronic Products claims that the unit nicely cleans up the power waveform, decreasing operating errors, minimizing parts failure, and decreasing service calls. The protection is said to be superior to parallel filters or isolation transformers. They can be contacted at Tycor Electronic Products, 208 Yorkland Blvd., Willowdale, Ontario, or at Simon Fraser Marketing Inc., 6011 East Hastings St., Vancouver, B.C.

Continued on page 10

Sinclair ZX81 Computer Etc . . .

Assembled \$99.95

ZX81

The ZX81's advanced capability. The ZX81 uses the same fast microprocessor (Z80A), but incorporates a new, more powerful 8K BASIC ROM — the "trained intelligence" of the computer. This chip works in decimals, handles logs and trig, allows you to plot graphs, and builds up animated displays. And the ZX81 incorporates other operation refinements — the facility to load and save named programs on cassette, or to select a program off a cassette through the keyboard.

New, improved specification. "Unique 'one-touch' key word entry: eliminates a great deal of tiresome typing. Key words (PRINT, LIST, RUN, etc.) have their own single-key entry. "Unique syntax-check and report codes identify programming errors immediately. "Full range of mathematical and scientific functions accurate

to eight decimal places. "Graph-drawing and animated-display facilities. "Multi-dimensional string and numeric arrays. "Up to 26 FOR/NEXT loops. "Randomize function. "Programmable in machine code. "Cassette LOAD and SAVE with named programs. "1K-byte RAM expandable to 16K. "Full editing facilities. "Able to drive the new Sinclair ZX Printer (to be available shortly).

If you own a ZX80. . . The new 8K BASIC ROM as used in the ZX81 is available as a drop-in replacement chip. (Complete with new keyboard template and operating manual). With the exception of animated graphics, all the advanced features of the ZX81 are now available on your ZX80 — including the ability to drive the Sinclair ZX Printer.

16K Memory Expansion Kit (No P.C. Board) \$49.00



\$149.00

Designed exclusively for use with the ZX81 (and ZX80 with 8K basic ROM), the printer offers full alphanumeric and highly sophisticated graphics. COPY command prints out exactly what is on screen. At last you can have a hard copy of your program listing and results. Printing speed is 50 characters per second, with 32 characters per line and 9 lines per vertical inch. Connects to rear of ZX81 — using a stackable connector so you can use a RAM pack as well. A 65 ft paper roll, instructions included. Requires 9 volts, 1.2 amp power supply (option extra).

Machine Language Software
ZXAS Machine Code Assembler. A full specification Z80 assembler. Standard mnemonics are written directly into your BASIC program **\$19.00**
ZXDB Disassembler/Debugger. Perfect complement to ZXAS, also provides single step, string search, block transfer, hex loader. **\$19.00**

Etc . . .

Software

GAMES (Arcade, Adventure, Strategy)

- KRAKIT - Win \$20,000 **\$24.95**
- 1K GAMES PACK - 11 games for 1K ZX81 **13.95**
- GOBBLEMAN - Famous arcade game. **19.95**
- ZX GALAXIA - SYNC said this ZX81 version was the best **19.95**
- ZOMBIES/SWORD OF PEACE - two exciting games **19.95**
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* Interface for any serial printer & 4 cassette recorders; includes plugs, cords and a detailed manual.

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MEMOPAK 32K \$179.00 and 16K \$89.00 MEMORY EXTENSIONS

These two packs extend and complete the Memotech RAM range (for the time being!) A notable feature of the 32K pack is that it will run in tandem with the Sinclair 16K memory extension to give 48K RAM total.

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Main Features — • Interfaces ZX81 and parallel printers of the Centronics type • Enables use of a range of dot matrix and daisy wheel printers with ZX81 • Compatible with ZX81 Basic, prints from LLIST, LPRINT and COPY • Contains firmware to convert ZX81 characters to ASCII code • Gives lower-case characters from ZX81 inverse character set **\$159.95**

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- Shipping Weight: 32lbs.

DISPLAY CHARACTERISTICS

- Black and white mode 24 x 80 character display.
- 128 character upper/lower case including control keys.
- Option: expandable to 256 characters.
- Black/white graphics resolution 160 horizontal x 72 vertical.
- Color graphics resolution 80 x 72.
- 64 colors, each with 4 intensities for a total of 256 colors.
- Simultaneous use of all colors
- 40 characters x 24 lines in color mode
- Video output standard NTSC television compatible.

INTERFACE

- RS-232 Serial Interface
- Centronic-style parallel Interface for I/O.

KEYBOARD

- 80 key layout.
- 62 key typewriter style
- 18-key numeric calculator-style keypad.
- Auto repeat
- User-selectable for 4 function keys.
- 4 cursor keys

GENERAL OPERATING FEATURES

- Z80 A (3.58 MHz) CPU
- 64K RAM memory.

- S-100 bus (IEEE-696)
- 4 slots for expansion
- Real-time clock programmable for 64 msec. to 4 mil. sec.
- Interrupt driven keyboard, real-time clock, serial port and cassette interfaces.
- 5 additional prioritized interrupts available
- Addressable up to 16 mBytes using bank switching.

SOFTWARE

- CP/M compatible
- 4K ROM Monitor with commands for loading and saving on cassette to and from memory and for program execution.
- Runs on any Z80-based CP/M compatible applications software.



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At last, a professional computer that doesn't cost more than a personal computer. It's called the Expander, and it's easy for beginners to understand, yet capable of the most complex tasks for your business needs. As a business computer, the Expander can also be used as a word processor, can display graphics in 256 colors, and handle numerous program languages. The Expander accommodates many existing peripherals, making it the most flexible professional computer on the market today . . . and all for the price of a personal computer. The Expander may well be exactly what you are looking for in a computer, but, until now, you haven't been able to find.

EXPANDER CAN BE USED FOR WORD PROCESSING
The Expander also works as a word processor, with a high quality typewriter-style keyboard. Any experienced typist will feel comfortable with the Expander. It's as simple as working with an ordinary typewriter! There are several different word processing programs available for use with the Expander.

EXPANDER DISPLAYS GRAPHICS IN 256 COLORS
The Expander can display your graphics in any or all of 256 colors, all selectable in either BASIC or the system monitor, making it easy for a programmer who wants graphics in many colors. S-100 boards are also available to plug into your Expander for very high-resolution graphic needs.

EXPANDER HELPS YOU TAKE CARE OF BUSINESS
The Expander can help you with all your business needs: Speed up customer service. Avoid hiring extra clerical help. Set up close inventory controls. Produce accurate, timely and complete management reports. Make billing easier. Monitor receivables and payables. Tap underdeveloped profit centers. Free staff from routine tasks for more important jobs. The Expander can help you make dramatic improvements in all these areas!

EXPANDER COMPATIBLE WITH MANY PERIPHERALS
The Expander is a S-100 (IEEE-696) compatible computer, and gives you the widest choice of boards and peripherals available. As a result, the Expander can be used for many applications not previously considered for small computers. For example, controlling very large inventories, communicating intensively with other computers, and monitoring a sophisticated burglar alarm or heating/air conditioning system in several different locations.

EXPANDER CAN USE MANY LANGUAGES
The Expander can use many different program languages: BASIC, PASCAL, FORTRAN, COBOL, APL, ALGOL, C, MACRO and many more that run under CP/M format. If you use a special program language, the Expander is likely to fit your needs.

EXPANDER IS EASY TO UNDERSTAND
The Expander has been designed for easy use, because a computer is only as useful as your ability to understand it. The Expander is very easy to understand, with an easy-to-read instruction book. You will start learning how to program in BASIC within 10 minutes. Try it for yourself. You'll be surprised!

EXPANDER DOESN'T NEED A TERMINAL
The Expander, unlike other more expensive professional computers, doesn't need a separate terminal. This gives you important advantages: faster operation, less cost, and less space.

EXPANDER AND ALL THIS
High quality typewriter-style keyboard. Built-in separate calculator keypad. 2 user-programmable function keys w/4 functions. 4 cursor control keys. Screen format: 80 Characters/line-24 lines. Characters in both upper and lower case. 4K ROM operating system. 64K RAM memory. Parallel printer interface (industry standard). S-100 Bus (IEEE-696) w/4 slots. CP/M compatibility. Z80 A processor (3.58 MHz). Real-time clock. RS-232 Serial Interface. Cassette tape interface. Video output & color graphics in 256 colors. Complex-tone generator w/internal speaker. Expandable to 512K of memory!

Includes 64K of RAM

WOWIE! LOOK AT THIS! 6502 BOARDS & ACCESSORIES



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AGC-1	\$219.00
Graphics Parallel Printer Card	
AKB-1	\$109.95
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AC-1	\$85.00
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APS-2	\$109.00
Switching Power Supply for APPLE II; +5V @ 3 amps, +12V @ 2 amps, -5V @ 1/2 amp, -12V @ 1/2 amp; c/w on-off switch & connecting wires	
AAA-2 (Siemens)	\$395.00
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ADC-1	\$99.00
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for your information

Electrical/Electronic Imports

According to the Electrical and Electronic Manufacturers Association of Canada, in conjunction with Statistics Canada, we imported \$583 million worth of electronic goods in December, 1982, the last month for which statistics are available. This compares with exports of \$328 million for the same period. The top six imported items in order of dollar value were semiconductors, tape players, electronic components, integrated circuits, commercial communication equipment, and radio-phonographs. No mention is made as to

how they decide the difference between integrated circuits, components, and semiconductors.

Digital IC Tester

A new digital IC tester provides semi-automatic, fast, reliable, functional testing of digital IC packages of up to 20 pins.

The IST Model 370A provides a single, four-digit absolute "go-no go" indication for a combination of tests which examine truth table functions, threshold levels, input and output currents, noise immunity, and total current drain.

A non-technical operator can test up to 35 ICs per minute. The IC to be tested is placed in-

to a ZIF (zero insertion force) socket. The test cycle starts automatically and displays when complete. The operator then checks the display and removes the IC to a "use" or a "discard" container.

No software or special training is required since all programming is done with plug-in program modules. Each program module is shared



by various types of ICs having the same pin-out pattern. Thus just a few program modules can handle many commonly used ICs.

Two program modules labelled A and B provide a complete self test of all internal functions of the instrument. These are included with the 370A.

Additional program modules available from the factory at \$5.00 each cover a program library of over 350 IC types, including 54/74 standard TTL, 54/74LS low-power Shottky TTL, 54/72S Shottky clamped series, 54/74L low-power TTL, 54/74H high-speed TTL, 54/74 ALS advanced low-power Shottky and CMOS logic families.

Contact Information Scan Technology, 487 Gianni St., Santa Clara, California 95054, (408) 988-1908.

Enduring Lo-Tech

A British firm is still making gramophone needles and exporting them by the million. Brian Shaw, marketing director of the Bradford Steel Pin Manufacturing Company in northern England, expressed mild surprise at the phenomenon in an age of stereo and digital recording and laser discs. The needles were originally manufactured as a diversification from textile pins, and the output has now grown to six million units per year, most of them exported to New Zealand, South Africa, Australia and the United States. The assumption is that they are going to collectors of antique gramophones. The



needles themselves are much the same as always; only the manufacturing process has been updated for better production. It would be possible to make a better, harder needle, but they would likely cause damage to old records.

Gramophone collectors with a needle problem may wish to contact the Bradford Steel Pin Mfg. Co., Dick Lane, Lalsterdyke, Bradford, West Yorkshire, England BD4 8J3.

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 Memory ROM: 32KB MASK ROM
 RAM: 64KB (standard equipment)
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 RAM pack: 4KB - 32KB (optional)
 Video RAM: 16KB

Keyboard:
 Number of keys: 90
 Screen configuration: 80 characters horizontal x 25 lines or 20 lines vertical
 Letter configuration: 8 x 8 dots

Color display: 8 colors (black, blue, red, purple, green, light blue, yellow, white)
 Graphic displays: 640 x 200 dots (Fine graphic mode)
 160 x 100 dots (Graphic mode)
 Dimensions (W x H x D): 16.5" x 3.9" x 10" (420 x 99.5 x 253mm)
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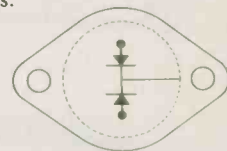
Okay, so the bottom's fallen out of oil. Start making personal computers. Try cloning UNIVAC's, anything, just make money, okay?

Fast Power Rectifiers

At one time, rectifiers with very fast switching times tended to be a special order item, or else you went with standard power diodes and very low efficiency. Now the high speed diode is much more readily available, perhaps due to the proliferation of switching supplies in personal computers.

Motorola's MUR800 series features ratings from 50 to 200 volts at 8 amps, and the MUR1500 series 50 to 200 volts at 15 amps. Both series have 35 nS recovery time.

If you'd prefer a dual diode with common cathode, the MUR1600 series handles 16 amps from 50 to 200 V, and is also available from RCA as the RUR-D1600 series. The Motorola diodes are in TO-220 plastic packages, and the RCA in TO-204 steel cases. From Motorola and RCA dealers.



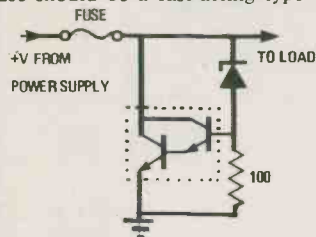
Do-It-Yourself Censorship

Lurid scare stories of the damaging effect of TV on children accompany the information on the Censorview unit, a programmable timer which allows you to automatically cut off any TV show by entering the time and the day of the week on which you'd like the program or programs suspended. The small box, a cross between a calculator and a channel converter, is installed with only a screwdriver and gives control over video recorders and games as well. No mention is made of an optional ball and chain in case your kids take off to watch TV at their friend's place. O.E.M. Marketing Group Ltd., Unit 12, 351 Steelcase Rd. W, Markham, Ont. L3R 3W1.

Simple Overvoltage Protection

Bill Markwick

The circuit shown will protect computers, audio equipment, etc., from excessive voltage if the power supply should fail. The transistor is any large Darlington, such as the TIP141 plastic or 2N6282 metal case. The resistor is 100 ohms, quarter watt, and the zener diode is a 400 mW type with a voltage rating equal to (or near) the power supply output voltage; a 5 V supply would use a 4.7 V zener, for instance. The fuse should be a fast-acting type with a



current rating slightly greater than the rated load current. Normally, the circuit will have no effect on operation, but should the power supply malfunction, the rising voltage will cause the zener to conduct and turn on the transistor. The output voltage will now be held down, and the excess current drawn should blow the fuse. The transistor should be on some sort of reasonable heatsink (the supply chassis, for instance) because it will be dissipating a fair amount of heat until the fuse blows. If the power supply is negative, invert the zener diode and replace the NPN Darlington with a PNP.

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*8.	—	Evolution	Sydney Corp.	49.95
9.	8.	Wizardry	Sir-Tech	68.95
10.	—	Sea Dragon	Adventure Int.	47.95



BOOKS

1.	Apple Graphics & Arcade Game Design	Book Company	25.95
*2.	Book Of Apple Software '83	Book Company	25.95
*3.	Apple II User's Guide	Osborne	22.95
4.	Beneath Apple Dos	Quality	26.95
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SOFTWARE

1.	1.	Miner 2049'er	Roklan	Rom-69.95
*2.	7.	Wizard of Wor	Roklan	Disk-50.95
3.	5.	Frogger	On-Line	Disk-47.95
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*5.	—	Zaxxon	Datasoft	Disk-54.95
6.	—	Snooper Troops #1	Synapse	Disk-59.95
7.	—	Astrochase	First Soft	Disk-41.95
8.	9.	Protector II	Synapse	Rom-59.95
9.	—	Gorf	Roklan	Disk-50.95
10.	2.	Canyon Climber	Datasoft	Disk-41.95

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3.	Atari Assembler	Prentice Hall	16.95
4.	Atari Basic Ref. Manual	Atari Inc.	15.95
5.	Your Atari Computer 400/800	Osborne	22.95
*6.	The Book Of Atari Software '83	Book Company	25.95
7.	Technical Notes	Atari Inc.	44.95
8.	Understanding Atari Graphics	Alfred	3.95
9.	Kids & The Atari	Datamost	25.95
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*1.	7.	Frogger	Cornsoft	Tape-20.95	Disk-25.95
2.	2.	Weerd	Big Five	Tape-27.95	Disk-27.95
3.	1.	Outhouse	Softsector	Tape-20.95	Disk-25.95
4.	3.	Sea Dragon	Adventure Int.	Tape-34.95	Disk-34.95
5.	4.	Penetrator	Melbourne	Tape-32.95	Disk-32.95
6.	8.	Flight Simulator	Sublogic	Tape-32.95	Disk-42.95
7.	5.	Panik	Fantastic	Tape-23.95	Disk-29.95
8.	6.	Caterpillar	Softsector	Tape-20.95	Disk-25.95
9.	9.	Stellar Escort	Big Five	Tape-21.95	Disk-27.95
10.	10.	Laser Delence	Med Systems	Tape-25.95	Disk-32.95

TRS-80

BOOKS

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6.	TRS-80 Disk & Other Mysteries	I.J.G.	29.95
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8.	Basic Faster & Better	I.J.G.	38.95
9.	How To Write A TRS-80 Program	Datamost	19.95
10.	Interface Project TRS-80	Prentice Hall	16.95

SOFTWARE

TM LM

*1.	1.	Grid Runner	Hes	59.95	Rom
*2.	9.	Skibbereen	U.M.I.	54.95	Rom
3.	4.	Martian Raiders	Broderbund	27.95	Tape
4.	2.	Choplifter	Creative	59.95	Rom
5.	—	Shark Attack	Broderbund	27.95	Tape
6.	8.	Deadly Duck	Sirius	52.95	Rom
7.	10.	Swarm	Tromx	38.95	Tape
8.	3.	Crossfire	On-Line	47.95	Tape
9.	7.	River Rescue	Thorn Emi	52.95	Rom
10.	—	Serpentine	Creative	59.95	Rom

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4.	Commodore Software Encyclopedia	Sam's	13.95
5.	Starting With Basic On The Vic-20	Prentice Hall	12.95
6.	The Elementary Commodore	Datamost	19.95
7.	Vic-20 Programmer's Ref. Guide	Sam's	23.50
8.	Programming The Pet/CBM Ref. Encyl.	Compute	39.95
9.	Vic-20 Program Writing Book	Arcsoft	6.95
10.	Vic-20 User's Guide	Osborne	10.95



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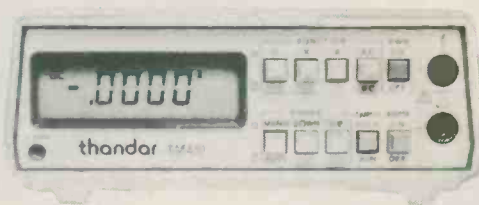
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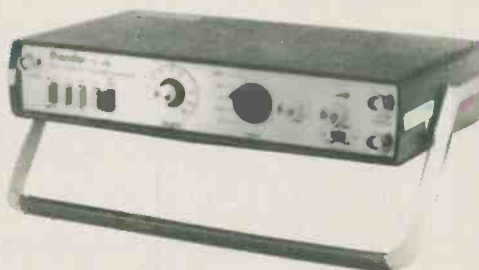


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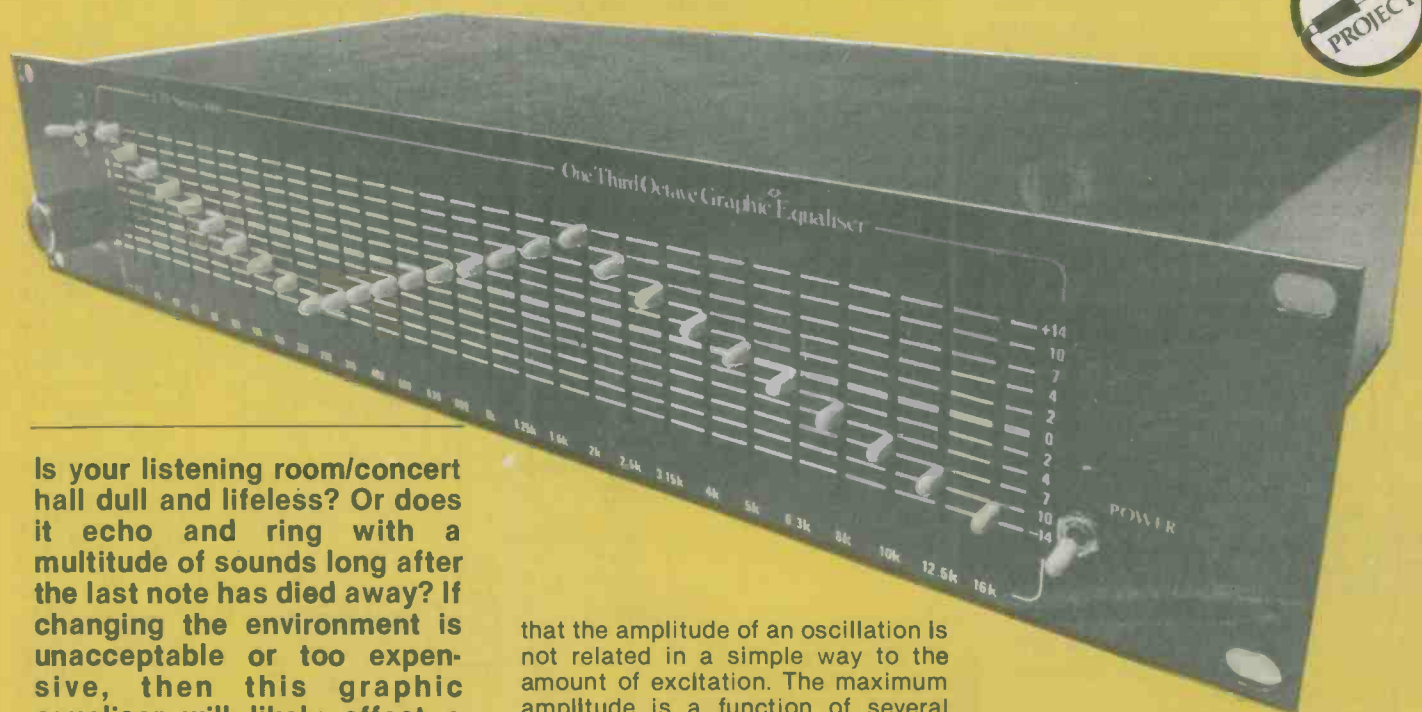
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Graphic Equaliser



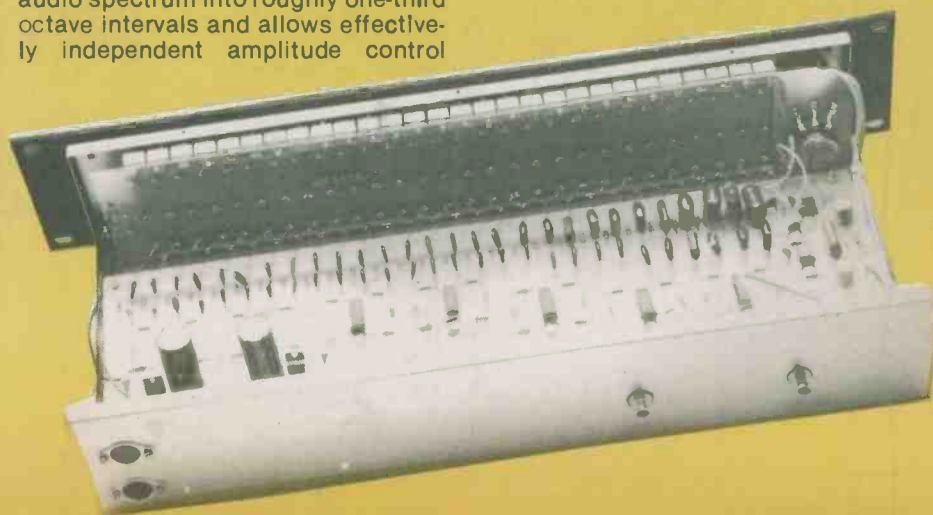
Is your listening room/concert hall dull and lifeless? Or does it echo and ring with a multitude of sounds long after the last note has died away? If changing the environment is unacceptable or too expensive, then this graphic equaliser will likely effect a distinct improvement. For obvious mechanical reasons, this is a mono unit; two are required for stereo.

SINCE THE Series 5000 preamplifier and power amplifier were published (during 1982) we have had many requests for this project. The inherent reliability and superlative performance of the MOSFET power stage makes the 5000 power amp ideally suited for use in professional applications. Unfortunately many of these applications are in difficult or 'problem' listening environments such as large halls or simply rooms with poor acoustic properties. Listening environments with too little damping lead to resonances and reverberation that can seriously degrade the intelligibility of music or speech. By contrast, rooms with too much damping lead to muffled and lifeless acoustic performance due to excessive attenuation of certain bands of the audio spectrum. To a certain extent these problems are unavoidable, at least with present technology. It is impossible to completely cure a listening environment of inherent problems such as resonances or excessive reverberation. The latter phenomena can cause feedback resulting in oscillation of the sound system. The problem is

that the amplitude of an oscillation is not related in a simple way to the amount of excitation. The maximum amplitude is a function of several variables, one of which is the damping of the listening environment. This converts sound energy into heat and prevents it from being reflected back into the room to further excite the resonance. The time taken for the resonance or oscillation to reach its maximum is also a function of the excitation level, i.e: the volume at which the sound is being reproduced. Problems associated with overdamped listening environments are slightly easier to correct, although a complete cure is again almost impossible, especially in bad cases.

The equipment used most often to correct faults in the listening environment is the one-third octave graphic equaliser. This divides the audio spectrum into roughly one-third octave intervals and allows effectively independent amplitude control

over each of the frequency bands. To meet the demand for a full one-third octave equaliser we have designed the Series 5000 unit offering noise and distortion performance that will not seriously degrade the performance of a high quality system. It should be noted however, that the use of any one-third octave equaliser will affect the performance of the system simply because it is in circuit. Each of the filters has a relatively high Q and will therefore cause significant modification to the overall phase linearity as well as the frequency response when cut or boost is applied. I have seen many otherwise



Graphic Equalizer

high quality systems degraded significantly by the excessive use of one-third octave equalisers and we do not recommend the incorporation of these units into a high quality system unless a specific need is apparent. Nevertheless, when modification of the frequency response is required, no matter how drastic or how modest, a one-third octave graphic equaliser is an almost ideal way of doing this.

Each channel of the equaliser is controlled by a separate slide potentiometer so the array of pots gives an approximate indication of the response inserted by the device. Further, the relative ease of operation ensures that setting up can be accomplished in a reasonable time.

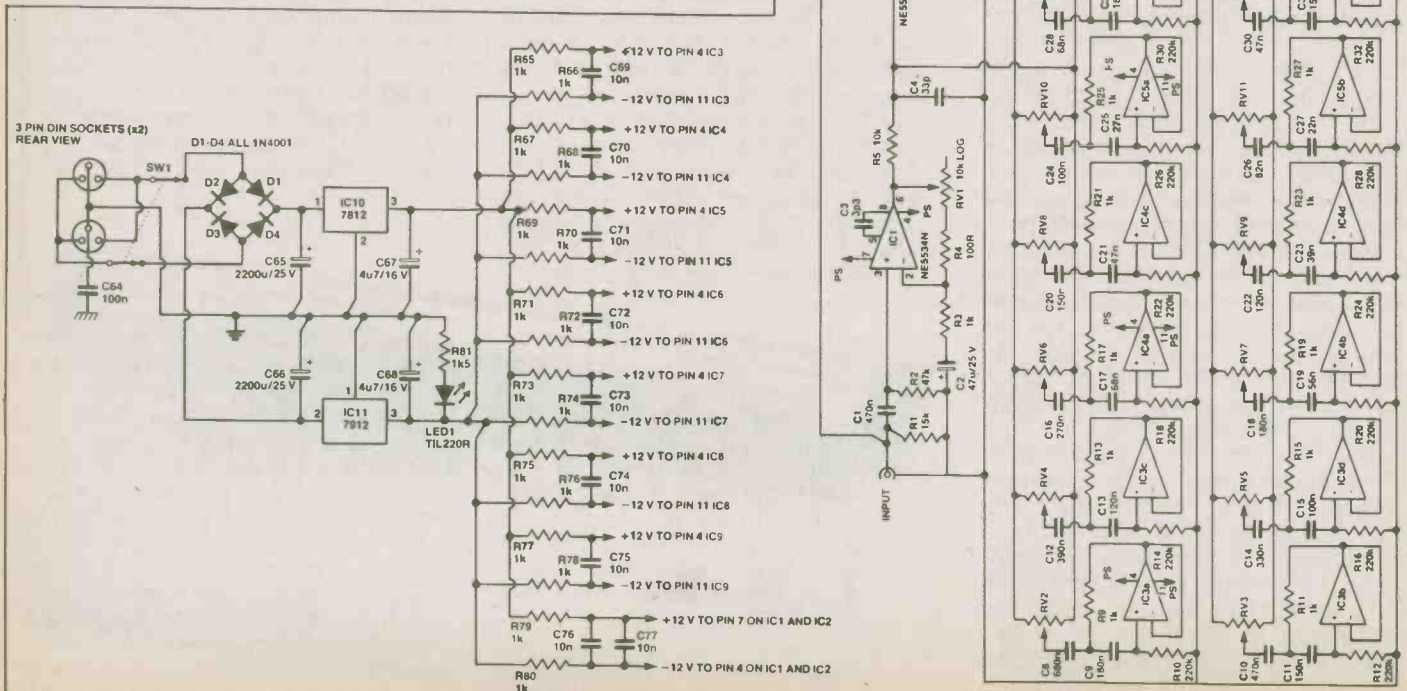
Design

Each filter is formed by a series resonant network incorporated into the feedback loop of a high quality operational amplifier. In this case we have used the NE5534N, the same op-amp used in the Series 5000 preamplifier. The advantages of this device are covered in the series of articles describing that project.

'Gyrators' are used to simulate the inductors necessary for the series of bandpass filters so there are no coils to wind. The gyrator is covered in more detail in the How it Works section, but the main problem associated with this approach is caused by phase shifts occurring in the op-amps used in the gyrators. The basic principle of a gyrator is to invert the phase response of a capacitor so

simulate the characteristics of an inductor. The problem is that all amplifiers introduce a phase shift which increases towards the extremes of the frequency response. For this reason, care must be taken when choosing op-amps for use in gyrators at the top end of the frequency spectrum. This problem is accentuated when the Q of the filters concerned is increased. Since the Q of the filters must be higher in a one-third octave equaliser than in a one-octave equaliser, an op-amp with greater phase linearity at high frequencies must be used. Fortunately, op-amps with the desired characteristics are not difficult to obtain and we are using the TL074 or uA774. These are both quad FET op-amps with almost identical performance and are capable of excellent results in the circuit, even at the top-most filter.

A kit of the case, pcb's and faders for this project will be available from Dacor Ltd., P.O. Box 683, Station Q, Toronto, Ontario M4T 2N5.



HOW IT WORKS

In order to illustrate the principle of operation of the graphic equaliser we first need to consider the operation of a simplified version of a single stage, as illustrated in Figure 1. Here, the input signal is fed to the non-inverting input of an op-amp through a 10k resistor. A potentiometer is connected between the non-inverting and inverting inputs with its wiper going to signal common (ground) via a network represented by Z. Here, a series-resonant circuit is employed. Feedback is provided between the op-amp output and the inverting input.

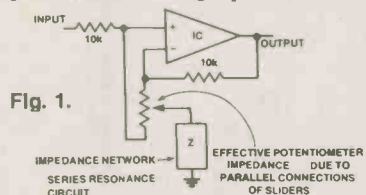


Fig. 1.

The input resistor forms a potential divider with part of the potentiometer (from the op-amp + input to the wiper) and the impedance Z to common. The feedback resistor also forms a potential divider with the end of the pot from the inverting input and the impedance Z to ground.

If the wiper of the pot is set to mid-travel, the attenuation of the input signal due to the potential divider is compensated by the gain of the op-amp and the overall gain from input to output is unity. If the pot-wiper is now moved toward that end of the pot connected to the op-amp's inverting input, the gain of the stage is increased as the feedback ratio is reduced owing to a reduction of the impedance from the op-amp's inverting input to common. At the same time less attenuation of the input signal occurs as the impedance from the non-inverting input to common is decreased. The stage will have gain, maximum gain being determined by the impedance of the series resonant network. If this is low, gain will be high. Series resonant networks exhibit very low impedance, rising either side of the frequency.

When the wiper of the pot is moved toward the non-inverting input of the op-amp, the attenuation due to the input potential divider is increased. The gain of the op-amp is decreased at the same time as the feedback ratio is increased because the impedance from the inverting input to common is increased. Once again, the overall gain of the circuit is a function of the im-

pedance of the series resonant circuit, but this time the gain is at a minimum — in fact, attenuation occurs.

By choosing a suitable Q for the series resonant network, the bandwidth can be set to cover a desired frequency range. The potentiometer then sets gain or attenuation of the stage at the centre of the chosen frequency band.

The technique just described above can be used whenever it is desired to incorporate a relatively large number of filters into the signal path as in graphic equalisers or tone controls. The filter networks need not be bandpass or notch filters; simpler bass and treble controls can also be used.

Once this basic configuration is set up, all that remains is to design the filter networks. As mentioned before, series resonant networks were used since these give the required characteristic of low impedance at the resonant frequency. In their simplest form these networks consist of an inductor, capacitor and resistor in series. At the resonant frequency, the impedance of the circuit is equal to that of the resistor, assuming a perfect inductor and capacitor were used. To eliminate the inductor an op-amp circuit has been used to simulate the characteristics of an inductor. Such a circuit is called a 'gyrator'.

The gyrator circuit can provide both the inductance and the series resistance required in the network so this can simply be placed in series with the capacitor to form the required resonant circuit. This is shown in block diagram form in Figure 2.

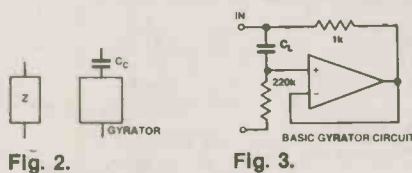


Fig. 2.

Fig. 3.

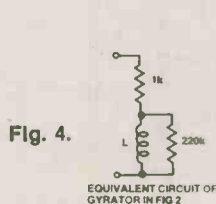


Fig. 4.

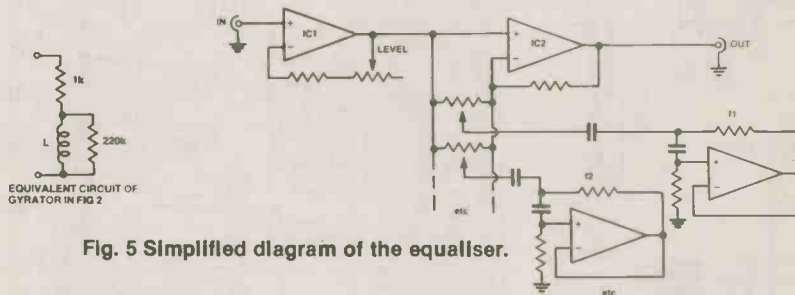


Fig. 5 Simplified diagram of the equaliser.

Figure 3 shows the general circuit of the gyrator used in this project. The amount of inductance 'generated' by this circuit is given by the simple equation: $L = 1k \times 220k \times C_L$ in Henries where the value of C_L is in Farads.

The equivalent circuit of the gyrator is shown in Figure 4. The series resistance is equal to the 1k resistor while the 220k resistor becomes the parallel resistance of the coil. This value is high enough not to affect circuit operation drastically. The resonant frequency of this filter is given by the standard formula:

$$F = \frac{1}{2\sqrt{LC}} \text{ in Hertz}$$

The general circuit, simplified, of the Series 5000 third-graphic equaliser is shown in Figure 5. IC1 is simply a variable gain stage which also provides some input buffering. IC2 is the filter stage with a group of 28 gyrator circuits, all connected in parallel, in the feedback circuit. Commencing at a centre frequency of 31.5 Hz, each gyrator filter has a Q chosen such that its bandwidth covers one-third of an octave. Thus the upper and lower 3 dB points of adjacent filters 'touch'. A total of 28 filters are required to cover the audio frequency band. Filters are not placed on the band limits of 20 Hz and 20 kHz as they are not really required. To reduce the IC count a set of seven quad op-amps (TL074s or uA774s) are used for the gyrators.

Slide pots are used to set the gain or attenuation inserted for each third-octave band as it is easy to see, at a glance, how much gain or attenuation has been set and, as all the pots are lined up in parallel across the front panel, one can instantly see the total modification made to the audio system's frequency response.

Construction

The one-third octave equaliser divides the audio frequency band into 28 segments, so a total of 28 slide pots are used. Cutting the required slots in a front panel is an extremely difficult task so this is one project that is probably best built from one of the kits, supplied by various outlets, which incorporate a pre-punched chassis and front panel. For those with the necessary equipment to construct their own chassis we have supplied detailed drawings for the metal

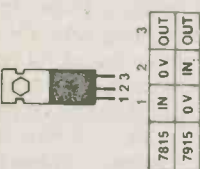
work required. Assuming that the project is constructed from a kit, most of the work is restricted to assembling two pc boards. One of these holds the bulk of the components while the other holds the slide pots and the 'power on' LED and its associated current limiting resistor.

Construction of the main pc board is not difficult. The usual precautions should be taken with the orientation of all polarised components such as electrolytic capacitors, transistors, diodes and ICs. Note that the two voltage

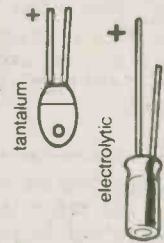
regulator ICs are not mounted in the same direction. Check the component overlay for the correct orientation. It is probably wise to leave the insertion of the quad op-amps until last since these are FET devices and are therefore more sensitive to static electricity than the other components in the unit. Be careful when handling these devices before insertion on the board. Use a grounded soldering iron and discharge yourself by touching a grounded metal appliance before handling the ICs. The inputs are protected and should therefore be

Graphic Equalizer

VOLTAGE REGULATOR
PIN OUT



Capacitors

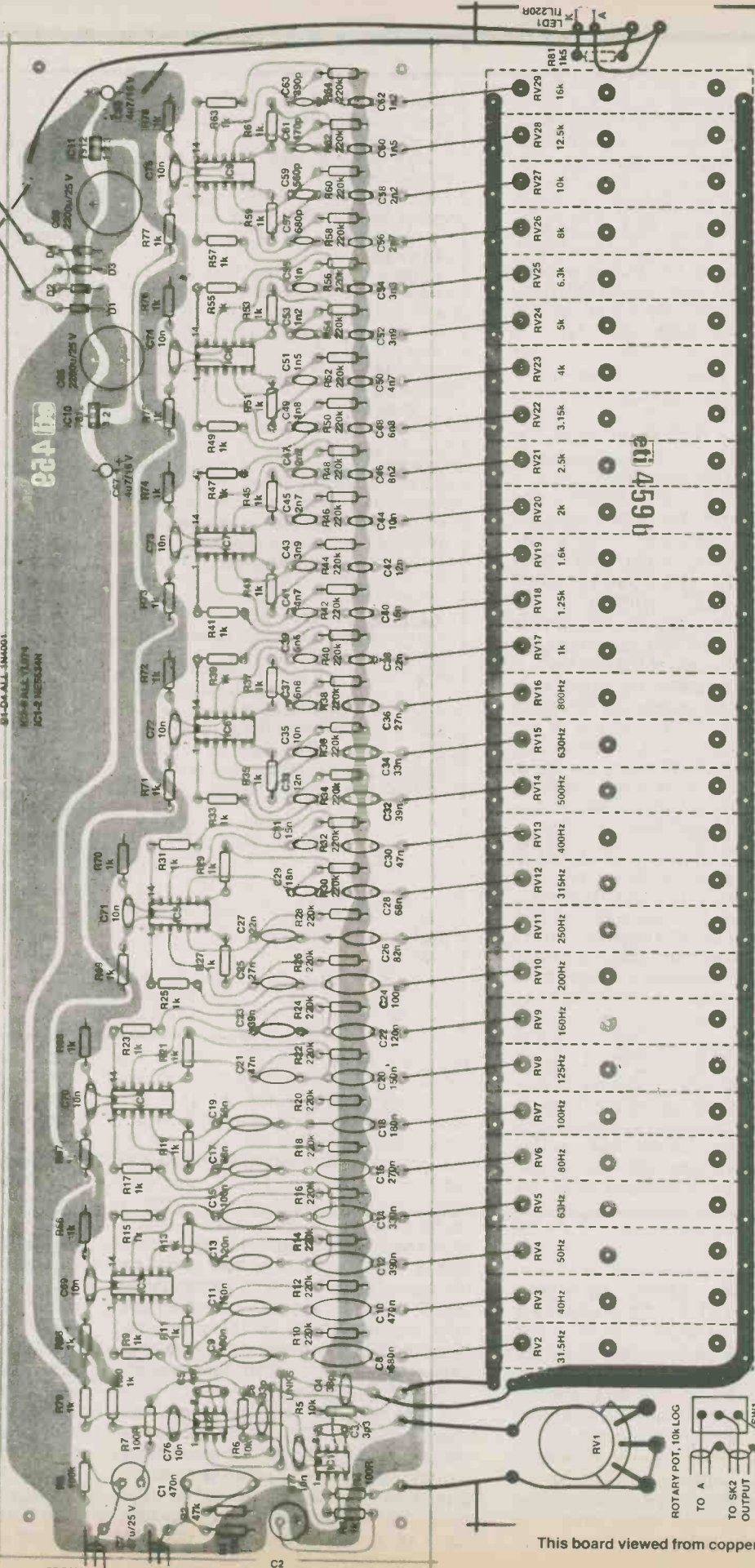


COMPONENT PINOUTS



ALL RESISTORS 1/4W, 5%
RV2-29 45 MM SLIDE POTS, 100k LINEAR

This board viewed from component side.



This board viewed from copper side.

FROM A TO SK1 INPUT C2 47n/25V

PARTS LIST

reasonably safe from damage by static electricity.

Construction of the second pc board is not difficult either, although some care should be taken to ensure that the slide pots are mounted so that their shafts are as close as possible to forming a right angle with the pc board. Probably the easiest way to do this is to first solder one pin of the slide pot and adjust the position of the slider while heating the joint with a soldering iron. When the pot position is satisfactory, solder the remaining pins and proceed to the next slider. The single resistor can be soldered on at this stage but I found it easier to leave the mounting of the LED until after the pc board is attached to the front chassis.

Mount the RCA sockets on the rear panel. Note that these sockets are insulated from the chassis. The same technique is used for this as was used in the Series 5000 preamplifier. First insert a rubber washer of the appropriate inside diameter into the holes drilled in the rear panel, then mount the sockets. A photograph has been included with the construction details to illustrate this.

The chassis of the unit is not connected directly to the power supply earth. A 100nF capacitor is soldered between the 0V point on the power supply DIN sockets and the chassis to provide RF shielding to the rest of the circuitry but no dc connection should be used. This is consistent with the grounding principle of the entire Series 5000 range of components and is a good general principle to adopt to ensure freedom from ground loops. If you are constructing the unit for operation in systems not including a Series 5000 power amplifier you will need a small transformer to supply the necessary 30 V centre-tapped ac supply. There is sufficient room to allow mounting of the transformer on the back panel above the centre section of the pc board. When using a transformer inside the chassis the mains must of course be connected securely to the chassis using a solder tag bolted directly to the chassis. Do not however connect the chassis directly to the signal; use the 100nF capacitor as mentioned before.

When the rear panel has been completed, the main pc board can be roughly positioned in place and all flying leads soldered to it, allowing sufficient length to run to front and back panels. The connection between the slide pot wipers and the main pc board is best done with tinned copper wire. The rest of the wiring should be done with insulated wire.

Resistors (all ½ W, 5%)

R1,5,6	15k
R2	47k
R3,9,11,13, 15,17,19,21, 23,25,27,29, 31,33,35,37, 39,41,43,45, 47,49,51,53, 55,57,59,61, 63,65-80	1k
R4	100R
R7	100R
R8	100k
R10,12,14, 16,18,20,22, 24,26,28,30, 32,34,36,38, 40,42,44,46, 48,50,52,54, 56,58,60,62, 64	220k
R81	1k5
RV1	rotary pot, 10k log
RV2-29	45 mm slide pots, 100k or 50k linear.

Capacitors

C1,10	470n
C2,7	47u/25 V electro
C3	3p3 ceramic
C4,6	33p ceramic
C5	4p7 ceramic
C8	680n
C9,18	180n
C11,20	150n
C12	390n
C13,22	120n
C14	330n
15,24,64	100n
C16	270n
C17,28	68n
C19	56n
C21,30	47n
C23,32	39n
C25,36	27n
C26	82n
C27,38	22n

C29	18n
C31,40	15n
C33	12n
C34	33n
C35,44,69-77	10n
C37,48	6n8
C39	5n6
C41,50	4n7
C42	12n
C43,52	3n9
C45,56	2n7
C46	8n2
C47,58	2n2
C49	1n8
C51,60	1n5
C53,62	1n2
C54	3n3
C55	1n
C57	680p ceramic
C59	560p ceramic
C61	470p ceramic
C63	390p ceramic
C65,66	2200u/25 V electro.
C67,68	4u7/16 V tantalum

Semiconductors

IC1,2	NE5534N
IC3,4,5-9	TL074
IC10	7812
IC11	7912
D1-4	1N4001
LED1	any T-13/4 LED

Transformer

If used without Series 5000 preamplifier, requires 30V center-tapped transformer, about 150 mA, such as Hammond 166 E30.

Miscellaneous

a & b pc boards; SW1 DPST toggle switch; chassis and panel as per drawings; two 3-pin DIN sockets; knobs for slide pots; SW2 — SPDT toggle switch; nuts, bolts, wire, etc.

The most difficult part of the construction is the mounting of the front panel components. The two switches are mounted directly to the front panel, behind the slide pot pc board. All wiring to these switches should be done before mounting since it is not possible to solder to these once the switches are in place. Shielded cable should be used for the three cables going to the equaliser in/out switch. Two of these must be sufficiently long to go to the input and output sockets on the rear panel, and the other must go to the input on the main pc board. The shields of the three cables going to this switch can be connected together using the unused half of the switch. Put a shorting link between the three unused contacts on the back of the switch and use this as a tag point. Now solder four wires to the power switch. Two of these must go to the rear

panel and the other two to the power input points on the main pc board. Check the construction diagrams if in doubt about these connections.

The slide pot pc board is secured to the front panel by eight bolts that are screwed directly into eight of the slide pots. Countersunk bolts are used and the heads of these bolts are used and the heads of these bolts are concealed by the front panel. The two switches should first be placed in their respective holes and secured by nuts to the front of the chassis. These nuts must be removed later when fitting the front panel but are used at this stage to hold the switches in place while the front pc board is mounted.

The easiest way to mount this pc board is to pass all of the bolts through the chassis front securing them in place with a small piece of adhesive tape placed across the front

on the head. Slide brass spacers over the bolts, tilting the chassis up if necessary to keep these from sliding off the bolts. Now position the pc board in place, passing the slide pot shafts through their respective slots. One at a time the pieces of tape can be removed and the bolt screwed in the slide pots.

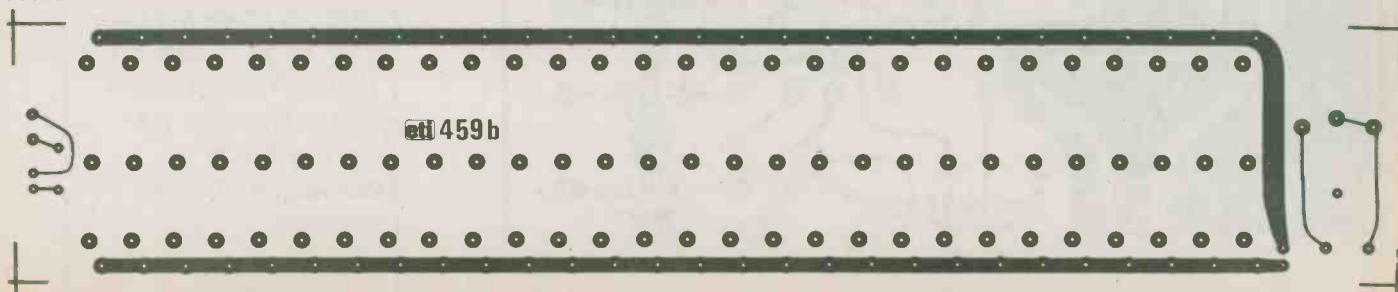
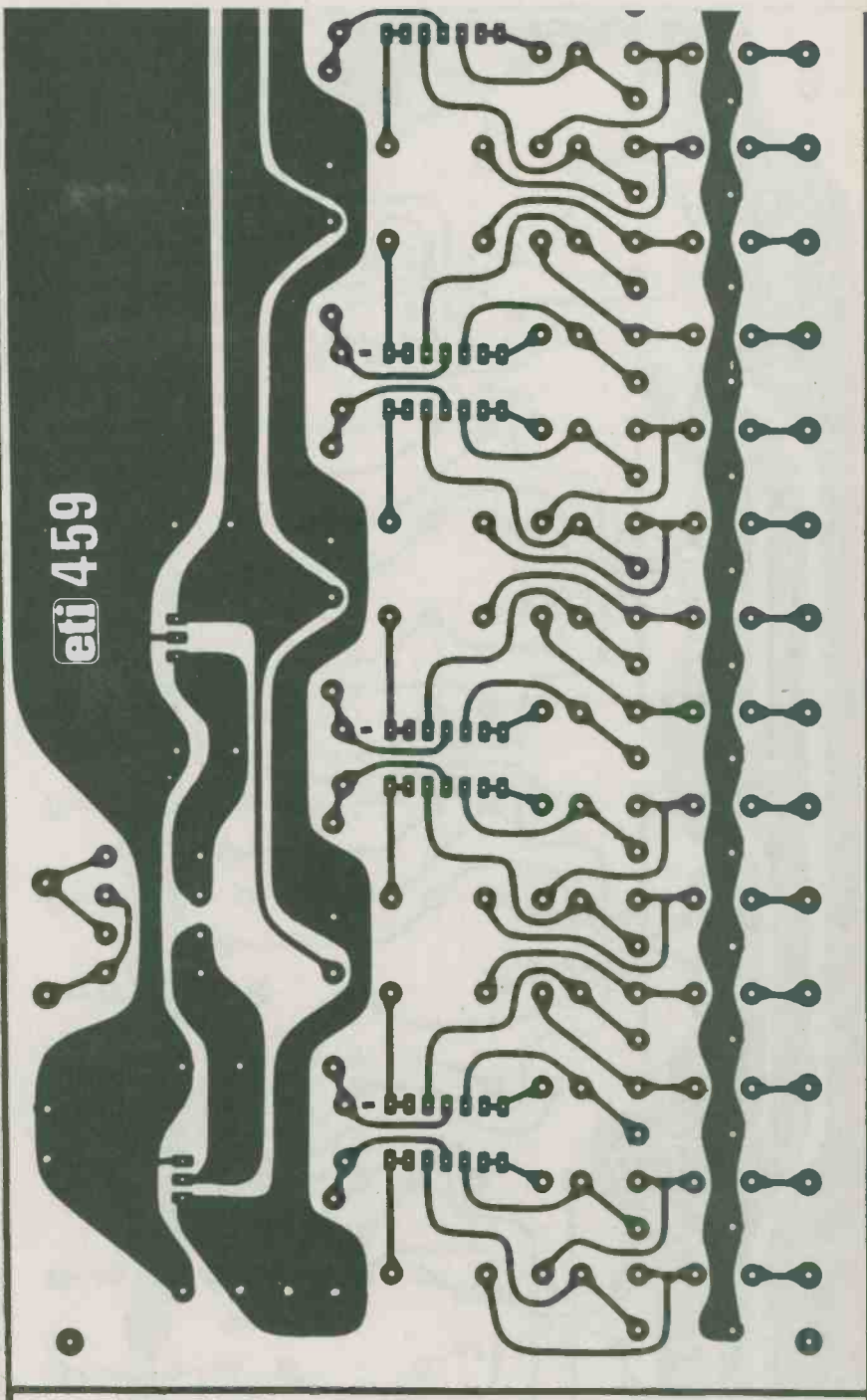
Mount the main pc board on spacers and carry out the necessary interconnections using the flying leads already secured to the board.

Finally, mount the front panel to the chassis. First remove the switch nuts. Secure the front panel with four 2 BA nuts and bolts. Use a washer between the front panel and the switch nuts when securing the switches to the front panel. This helps prevent the possibility of scratching the front panel when tightening the nuts. Push a LED mounting washer through the front panel. The LED can now be mounted. Be careful to insert the LED the correct way around.

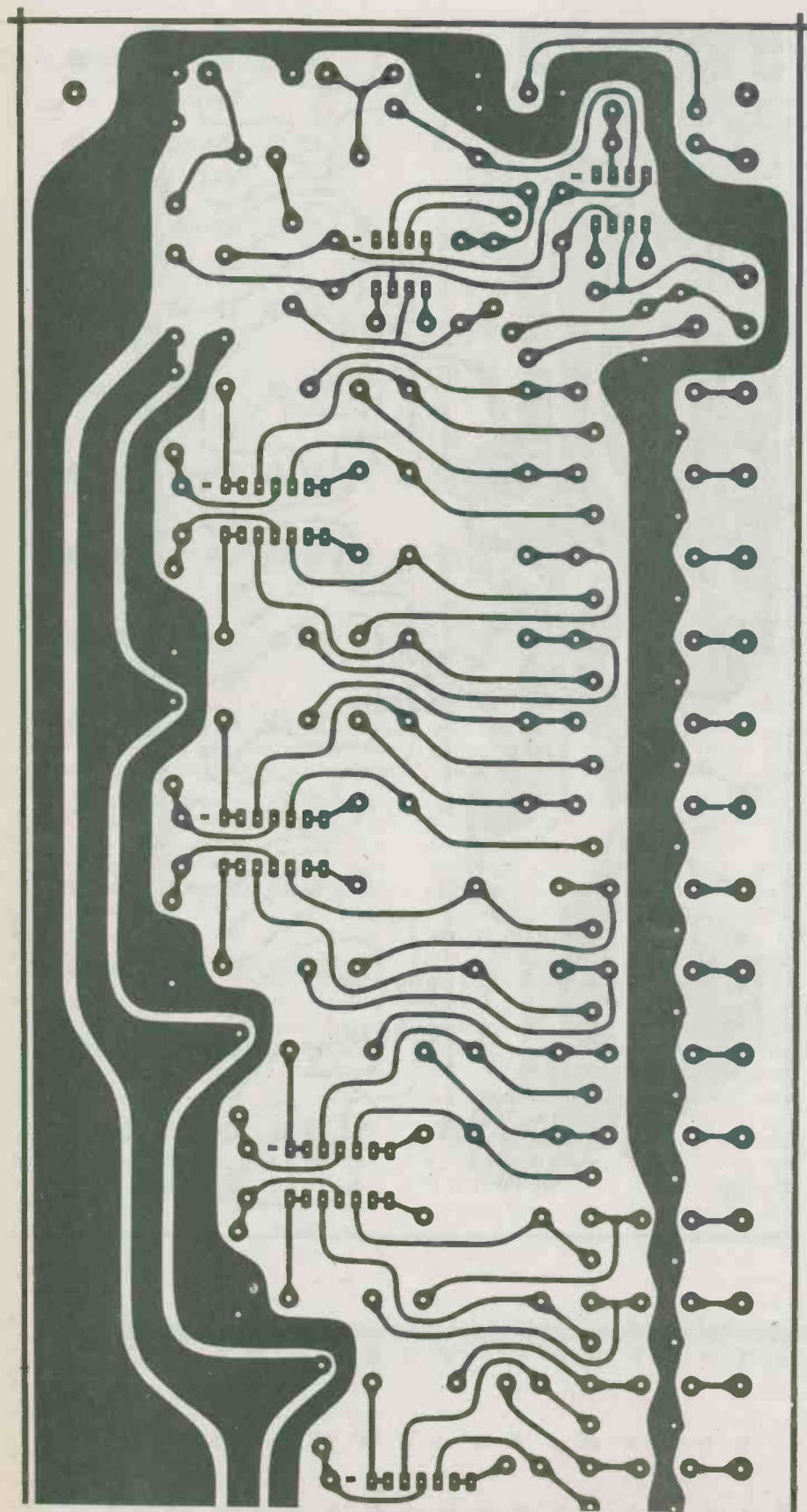


Place the leads through the pc board and then push the LED into the washer from behind. You may have to bend the leads a little to get them into the holes in the pc board. Finally, solder leads. All that remains is to secure the cover. Use self tappers passed through the cover into the main chassis. Since the pots are mounted on half inch (12.5 mm) spacings there is not enough room for the usual slide pot knobs. We used small rubber covers supplied originally for use with small toggle switches. These are very common and are available in a variety of colours.

To avoid having to mail the PC art work to readers, we are publishing the main PC in two sections. They can be fitted together for reproduction. Since there are many variations on slide pots, we include a 45 percent reduction of a typical mounting board.



Graphic Equalizer



Power up

Once construction is complete, check all power supply wiring before powering up. This is especially important if a transformer has been included inside the chassis. In the latter case, make certain all 120 V connections are secure and check the chassis ground. If all is correct, power the unit up. The LED should light to indicate that the unit is on.

An equaliser in/out switch has been provided to ensure that a flat response can be obtained easily and without the necessity of changing the equalisation that may have taken some time to set up. The equaliser is intended for use immediately before the power amplifier. If used in this position the level control will probably not be used. In this case turn the control fully counterclockwise. The overall gain of the equaliser with the controls set at centre will be approximately unity. If the equaliser is intended for use from a typical line level output, the gain control can be used to supply the output levels needed by the power amplifier input.

ETI

Arthritis Facts:

- More than three million Canadians have arthritis.
- More than 30,000 arthritis victims are under 15.
- Nearly one million arthritis victims are between 30 and 45.
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Arthritis is everybody's problem and it's time we took it seriously. Contact The Arthritis Society office nearest you for the facts about this terrible disease.



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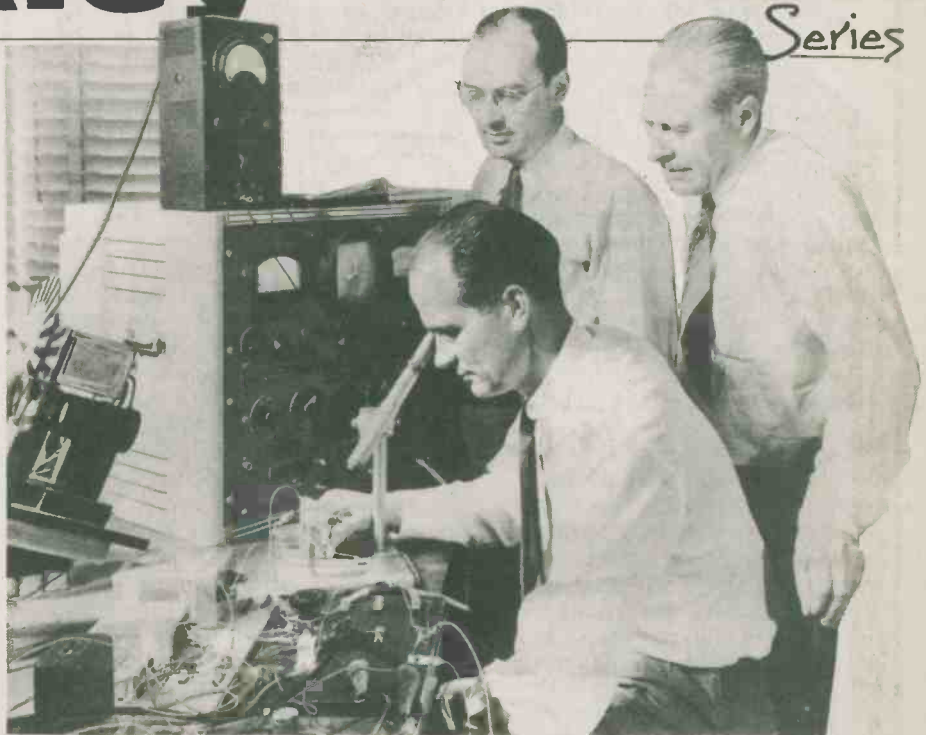
Co-inventor of the transfer-resistor.

SHOCKLEY, Bardeen and Brattain are three names that ring across the post-war years like a summons to a new age. And a new age is just what they started, with their invention of the bipolar transistor in 1948, but there were years of painstaking research before that triumphant announcement in the journal, "Physics Review". Shockley was one of the men who changed the 20th Century more abruptly than anyone else, and this is how it happened...

William Bradford Shockley was born in London in 1910 but was educated in the US where his family had moved. He started work, after university, at the Bell Telephone Laboratories in 1936. This, in itself, must have been a remarkable experience because of all the research laboratories around the world, the Bell labs were foremost in telecommunication research, nourished by the profits of the Bell Telephone Corporation. Yes, it's possible to have a telephone system which offers low prices to the user and still make profits for the provider — but don't tell Ma Bell!

Solid States

Throughout the 30s, the Bell labs had pursued a lot of very fundamental physics research which in this country is normally carried out only by universities. Solids, you see, are rather remarkable and when you look at their electrical properties, they seem even more remarkable. Why should one solid element be a metal, bright and lustrous, conducting electricity well, and another solid element be a non-metal, dull and shapeless and an insulator? The nature of gases was dimly understood in the 17th Century, and our understanding greatly increased during the great years of discovery in the 18th and 19th Centuries. The liquid state was being unravelled by theorists in the 19th and 20th Centuries, but the solid state remained very much of a mystery. The main problem was that the atoms of a solid are packed together so tightly that they affect each other much more than happens in gases and liquids. Any theory that



Seated is Dr. William Shockley, who initiated and directed the Transistor Research program at Bell Laboratories. Standing are Dr. John Bardeen, left, and Dr. Walter H. Brattain. The photo was taken in 1948, when Bell labs announced transistor gains "as high as 20 dB".

took account of the effect that atoms have on each other was likely to become too complicated to solve. The big breakthrough came early in the 20th Century, as a result of work by the great theoretical physicists Planck and (later) Dirac — and the steady follow-up to their work continued in laboratories all around the world. Bell Telephone Laboratories were concentrating on the electrical aspects of solid materials, in the hope that something of importance would emerge. Research is like that; providing that it's genuine scientific research, then there's always some useful outcome, even if it's years later or in some quite unexpected way.

In particular, Bell labs were following up the work on hole conduction in crystals, which had been discovered at the turn of the century, and on the properties of semiconducting materials; it was in these materials that the effects of impurities on conduction (an important clue to what was going on) were most marked.

Foundation Stories

The foundations for the invention of the transistor were being laid, then, all through the 30s. There was no

great pressure for spectacular results, but there was a steady stream of publications which map out for us how much progress was made. When war broke out, Shockley, along with most of his research team, was seconded to the US Navy to become Director of Research in the Anti-submarine Warfare Operations Group. He worked on all aspects of submarine detection and the effect of depth charges, returning to the Bell Laboratories early in 1945 to resume his research on semiconductors.

By this time, the work was beginning to bear recognisable fruit. The importance of purity was recognised, and the method of re-crystallising germanium by zone refining was developed, leaving the way clear to investigate the doping of the material without the complicating effect of other, stray impurities. It was with such a doped sample that the team, following work which had been done in the 20s with copper sulphide crystals, was able to produce the point-contact transistor.

We should remember that the principles which were being followed were quite old. All the way through the 20s, the crystal-and-catswhisker had been used as a sensitive detector (demodulator) for radio waves. The

Shockley

principle was that certain types of crystals, of which metal sulphides were the most useful, conducted; when a fine wire contact, the catswhisker, was allowed to touch the surface of the crystal, a rectifying contact or diode was created. These early detectors used natural crystals and their behaviour was unpredictable and unsatisfactory. You could be listening (using headphones) to a broadcast when it would suddenly vanish until a new sensitive spot was found on the crystal. The problem was that the material of the crystal was never pure and the rectifying action, caused by the material of the catswhisker doping the crystal, would eventually overdope the crystal and stop the action.

There had been reports, too many of them to ignore, of amplifying action obtained by using more than one catswhisker on such crystals, and Shockley's team were hoping that their thoroughly purified materials would allow more consistent results to be observed. They had produced some N-doped germanium crystals and were making contact to them with fine metal wires spaced very close together, in the hope of fin-

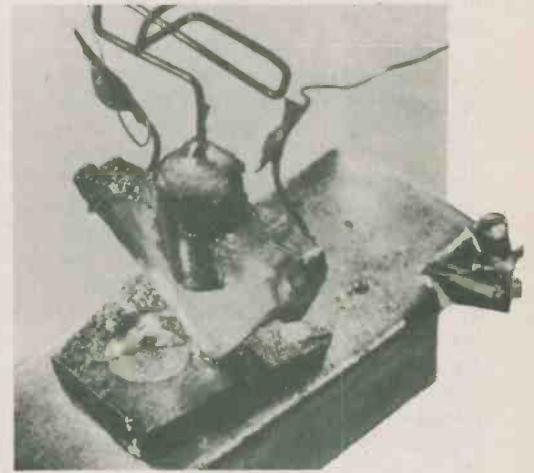
ding some amplifying effect. The results must have been most gratifying. Those first point-contact transistors were unreliable and had either too little gain for practical use, or so much that they were unstable — but they worked, and worked well enough to allow their characteristics to be studied.

Naming Names

The crystal of germanium was dubbed the "base", because it was on this slab of material that the fine wires were located. One wire was called the "emitter", because it appeared to be emitting holes into the base; the other wire was called the "collector", because it appeared to be collecting the holes emitted by the emitter, rather than allowing them to be carried into the base. The circuit was what we would now call a common-base amplifier, and it was this circuit that dominated early transistor technology. The action, by the way, seemed to be that of a resistor which could transfer current to a third connection, so it was called a transfer-resistor, and it was no time at all before someone shortened that to transistor.

The importance of the invention was recognised at once and Shockley, now head of the Transistor Physics Research Dept, initiated a new programme of research to improve the primitive point-contact transistor design. The faults were obvious — instability when used as an amplifier, manufacturing difficulties and unreliable operation. By this time, the reasons for transistor action, which had been worked out in

the long years of research, were increasingly better understood and the team was able to turn to better methods of creating the junction between P-type and N-type material, which was so crudely achieved by the point-contact method. It's a matter of history that they succeeded, using the well-documented method of making a sandwich of N-type crystal wafer with contacts of P-type impurity on each side and then heating the sandwich so that the P-type impurity diffused into the germanium, creating regions of P-type germanium on either side of the N-type. This "diffused junction" technique was to dominate transistor construction until the advent of silicon transistors, bringing new techniques that were



A 1947 point-contact transistor assembled by the inventors. The contact type has been replaced by today's junction transistors.

readily useable only with silicon.

Shockley was appointed visiting Professor at California Institute of Technology, Pasadena, in 1954, and was further honoured by the Nobel Prize for Physics in 1956. He had, by this time, left Bell Laboratories. From there on, his career turned in a more academic direction as he became, in 1958, a lecturer at Stanford University and, in 1963, the first Poniatoff Professor of Engineering Science. In these latter days, he has been more noted for outspoken comment on the topic of genetics and inheritance than on the subjects which made him one of the most illustrious of our Pioneers of Electronics.



Dr. Shockley in 1956, receiving the Nobel prize in physics from King Gustav VI Adolph of Sweden. The award was shared with Brattain and Bardeen for their work on the invention of the transistor.

ETI

next month

At the time of going to press, the articles mentioned are in an advanced stage of preparation. However, circumstances may result in changes to the final contents of the magazine.

Polyphonic Organ Project

A compact, inexpensive organ that's polyphonic (it can play all the notes at once). It also eliminates having to buy and wire a keyboard; it's right on the printed circuit.



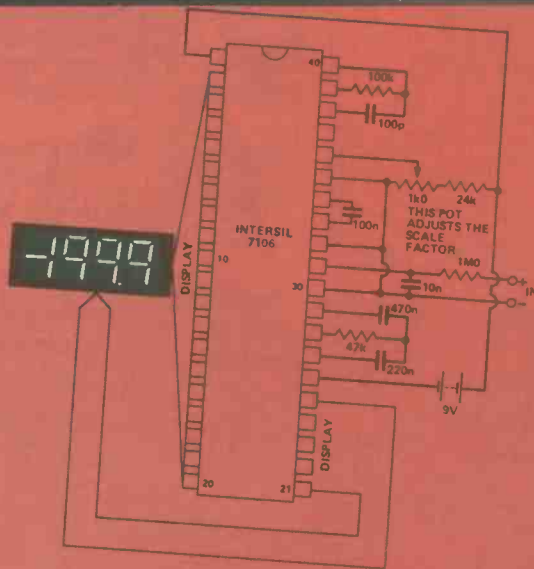
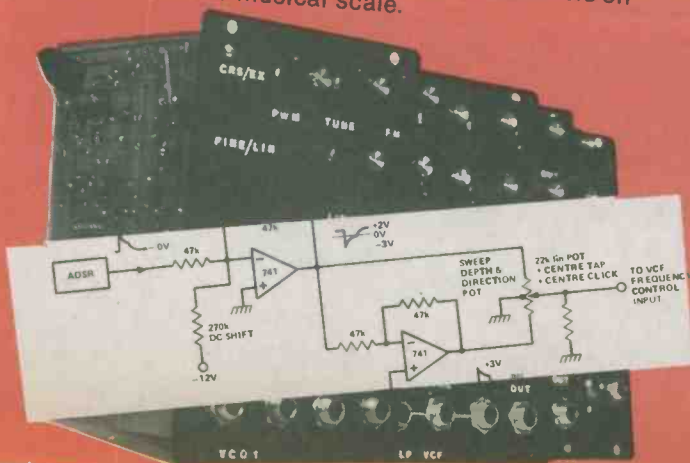
Saturn Up Close

Space probes Voyager 1 and Voyager 2 passed within about 100,000 km of the planet Saturn, causing the Saturnians to phone their radio stations with reports of UFO's from the weird planet near the Sun. We look at the Voyager telemetry next month.

PLUS!
Tanover (sunburn) timer!
Infrared Proximity Detector!
Audio Overload Indicator!

Electromusic Techniques, Part 2

Continuing on with practical circuits and explanations of how synthesizers convert your average oscillator into a musical instrument. Also included is a short article on the derivation of the musical scale.



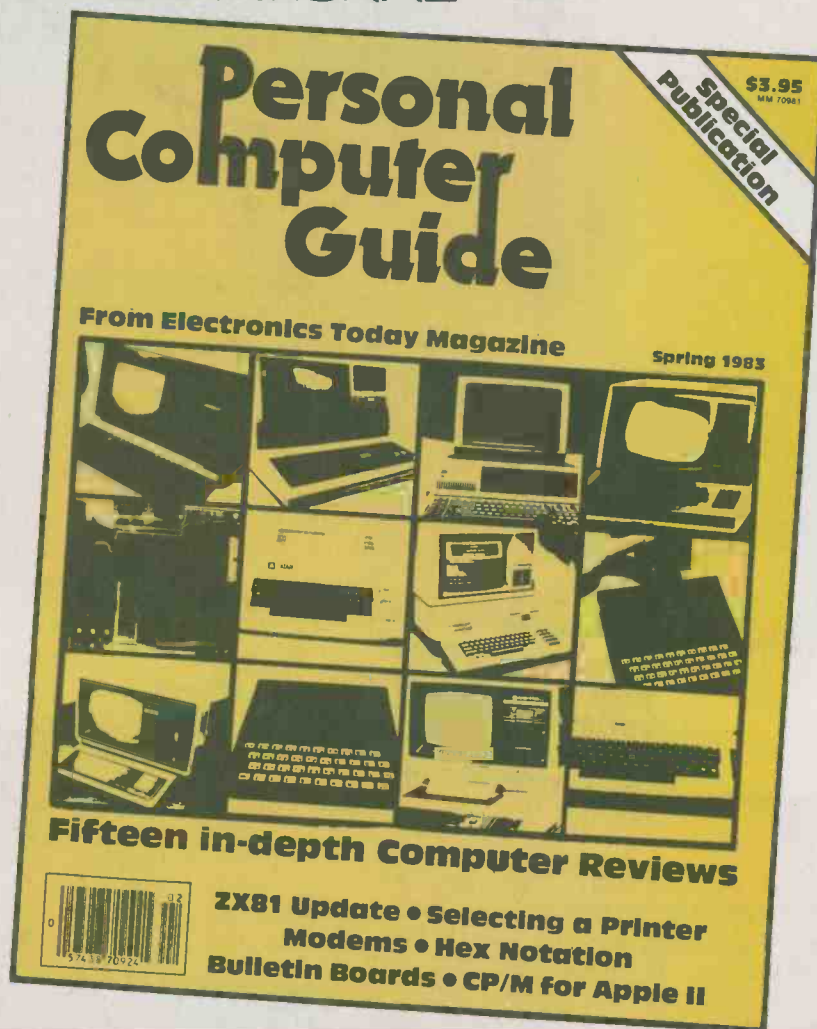
Instrumentation Techniques, Part 1

The 7106/7 digital voltmeter is a nifty enough IC on its own; Designer's Notebook shows how to give it all the functions of a multimeter.

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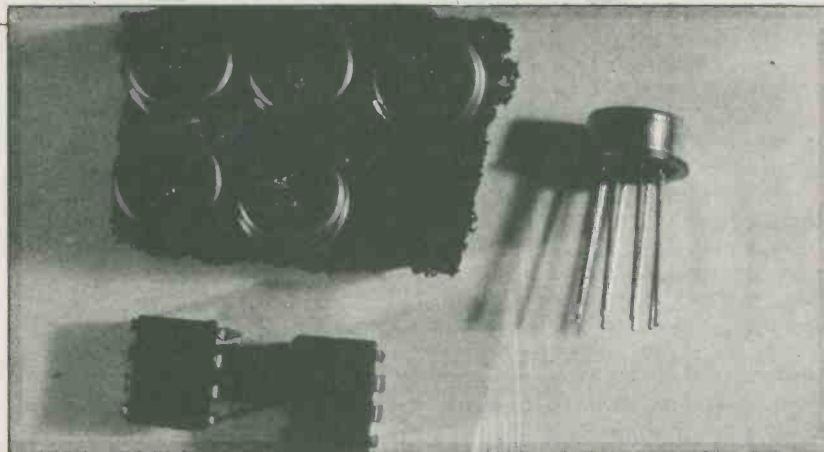
Using BiFET & BiMOS Op Amps

The availability of BiFET and BiMOS op-amps has revolutionised circuit design since they appeared on the scene five or so years ago. While we've used devices like the CA3140 op-amp in projects we've not got around to describing practical applications circuitry. This 'Lab Notes' fills that gap.

THE AVAILABILITY of BiFET and BiMOS devices in various packages with one to four operational amplifiers per package has revolutionised the operational amplifier market. Apart from the relatively expensive hybrid FET input devices, other FET input operational amplifiers had been available for some considerable time, so why should BiFET and BiMOS devices be so important?

The first point to note is that amplifiers with FET input stages can offer far higher input impedances than devices with ordinary bipolar transistors in their input stages. For example, the well-known 741 has an input impedance of the order of 1M and a maximum input bias current of 500 nA. The use of bipolar transistors to obtain a high input impedance has been pushed to the limit in devices such as the LM108, using supergain input devices to provide a typical input impedance of 70M and an input bias current of just under 1 nA. These values may be compared with those of some of the economical BiFET and BiMOS devices, where typical input impedances are of the order of 1 Tera-ohm (one million Megohms!) and input currents are some tens of picoamps (pA) at room temperature.

Thus if one connects the input of one of these BiFET or BiMOS amplifiers to almost any circuit, it will impose a very small load on that circuit. This can be a vital consideration when one is designing such high-impedance circuits as those used in pH meters or in ionisation chamber smoke detector circuits, whose output current is inadequate to drive devices such as the 741.



Modern BiMOS and BiFET op-amps come in both can and DIL packages.

INTRODUCTION TO THE BiMOS AND BiFET OP-AMP

The first BiFET products were announced by National Semiconductor in 1975 (the LF155, LF156 and LF157 series, where LF signifies Linear FET device). The main advantages of these products is that the junction FET devices used in their input stages are fabricated on the same silicon chip as the remainder of the operational amplifier. Although hybrid operational amplifiers with FET input stages had been available for some considerable time previously, all of these hybrid devices contained the junction FET devices fabricated on a separate silicon chip from the remainder of the operational amplifier. Such hybrid devices can be made to have a very good performance if adequate trouble is taken in their design, but the extra labour costs involved in the testing of the separate chips for appropriate matching characteristics and in connecting the two chips in a single hybrid package inevitably resulted in a price tag far above that of modern BiFET devices. The general type of construction of a BiFET device is shown in Figure 1, the channel between the source and the drain electrodes of the FET input devices being fabricated by ion implantation.

Although National Semiconductor produced the first BiFET products, it was not long before other manufacturers entered the BiFET market, and

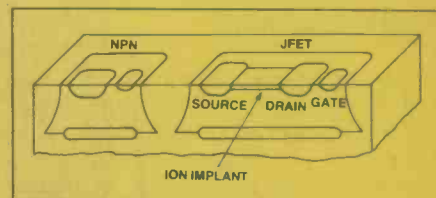


Fig. 1 Construction of a BiFET device.

such products are now available from Advanced Micro Devices, Analog Devices, Fairchild, Harris Semiconductor, Motorola, Intersil, Precision Monolithics, Raytheon and Texas Instruments, although National Semiconductor still offer the widest range of BiFET products, details of which can be found in their Linear Databook.

Very soon after National Semiconductor had announced the first BiFET products, RCA introduced their first BiMOS product, the economical CA3130 operational amplifier. This has some similarities to the BiFET amplifiers, but employs MOSFET transistors in the input stage rather than junction FET devices. RCA soon introduced further BiMOS devices, one of the best known type being the CA3140, which can be used as a pin-for-pin replacement for the 741 when a higher performance is required. More recently the CA080 series has been introduced as pin-for-pin replacements for the Texas Instruments series of TL080 BiFET types.

BIFET & BIMOS Op Amps

If one considers the very early types of monolithic FET input operational amplifiers (such as the Fairchild uA740), they do have the desired high input impedance, but their disadvantage is that their input offset voltage and its temperature coefficient are so high that they do not approach the high standard of performance required by the modern professional engineer. Modern BIFET and BiMOS devices provide a very high input impedance with relatively good stability and temperature performance — although the input impedance of any of these devices at 25°C is much greater than over the full temperature range.

In general BiFET and BiMOS economical devices offer a comparable performance. If anything, BiMOS devices tend to offer the lower input bias currents and BiFET products the lower noise levels. However, premium devices of both types are available with performances far above the average for the type of device concerned.

Half-Hertz oscillator

Figure 2 shows the use of the economical TL081 device in a simple 0.5 Hz square wave oscillator. The TL081 is a single operational amplifier in a dual-in-line package with the connections shown in Figure 2; the pin connections are the same as those of the well-known 741 devices, internal frequency compensation being employed so that no external compensating capacitor is required. External offset adjustment can be made when required by means of an external variable resistor. The TL071 is a similar low-noise device with the same connections, and is quite suitable for use in this circuit, but its low-noise characteristics are not needed. The TL061 is a low-power device with the same connections.

The frequency of oscillation of the Figure 2 circuit is given by

$$f = 1/(2\pi R_F C_F)$$

or about 0.5 Hz with the values shown. The high input impedance of the circuit enables a relatively high value of feedback resistor, R_F , to be employed, so the value of C_F can be reasonably small for a given frequency of operation. About nine-tenths of the output voltage is fed back to the non-inverting input to provide positive feedback to maintain oscillation. The capacitor C_F charges and discharges through R_F according to whether the

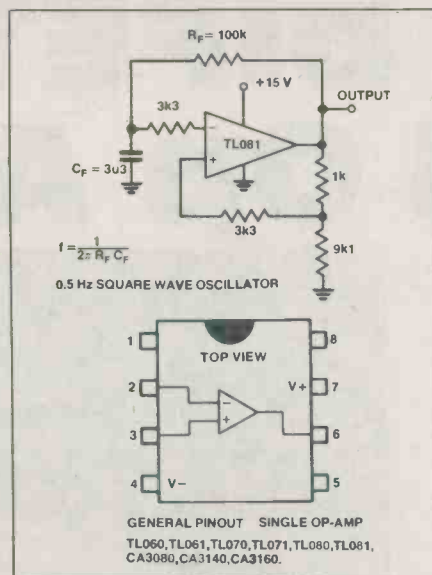


Fig. 2 Half-Hertz oscillator using a TL081 — pinout below.

state of the output voltage is 'high' or 'low' at the time concerned.

The circuit of Figure 2 generates square waves which are approximately symmetrical. However, if a circuit which generates waves with an unequal mark-to-space ratio is required, it is only necessary to connect a resistor of perhaps 10k to 50k in series with a diode across R_F . The direction in which the diode is connected determines whether the output spends the greater part of its time in the 'high' or in the 'low' state.

100 kHz oscillator

Figure 3 shows the circuit of a 100 kHz oscillator providing two outputs which are 90° out of phase with each other. Although the TL081 is perfectly satisfactory for use in this circuit, it is more convenient to use the dual TL072 low noise version device so that this one device is all that is need-

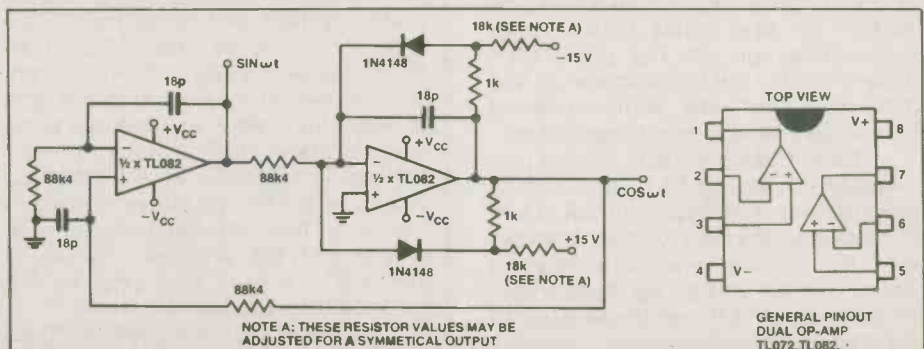


Fig. 3 Quadrature oscillator producing two outputs 90° out of phase, using a TL082 dual op-amp — pinout as right.

ed. The connections of the 8-pin dual-in-line TL082 device are shown in Figure 3; it employs internal frequency compensation, but has no external offset adjustment facilities.

BiMOS generator

A function generator which produces square and triangular waveforms is shown in Figure 4. It employs a CA3140 BiMOS device together with a CA3080A and CA3080. A particular feature of this circuit is that a frequency range of one million to one can be obtained by the use of a single variable resistor, or alternatively by the use of an auxiliary sweeping signal.

A CA3130 device may be employed instead of the DA3140 shown, but in this case a frequency compensating capacitor (about 56p) must be connected between pins 1 and 8, since the CA3130 is not internally compensated. The CA3160, which does not require any external frequency compensation, is also suitable for use in this circuit.

The high frequency linearity of the ramp is adjusted by the 7-60p variable capacitor connected between the output of the CA3140 and the output CA3080 device. The triangular wave output level is determined by the four 1N914 level-limiting diodes in the output circuit and the network connected to pin 2 of the CA3080.

It is important to minimise lead length and parasitic coupling capacitance in this circuit by careful layout.

Notch filter

The circuit of Figure 5 shows the use of a TL071 low-noise amplifier in a notch filter circuit. This is the normal 'twin-T' filter in the input circuit, in

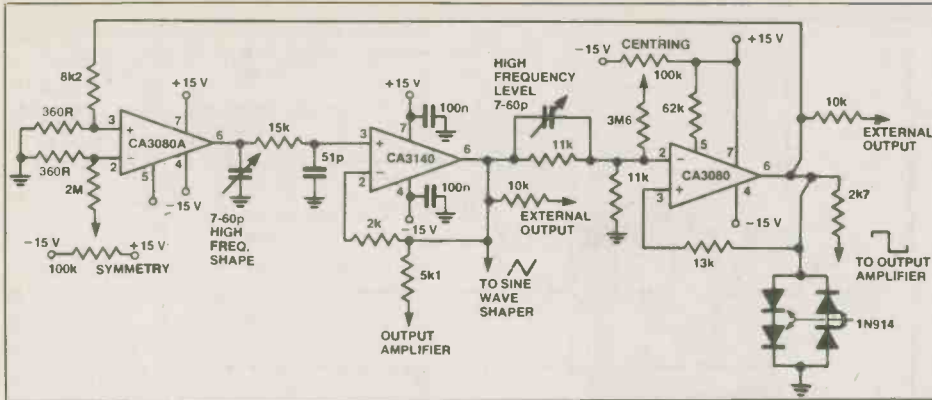


Fig. 4 Function generator circuit. Sourcing or sinking current from pin 5 of the left hand CA3080 will vary the frequency.

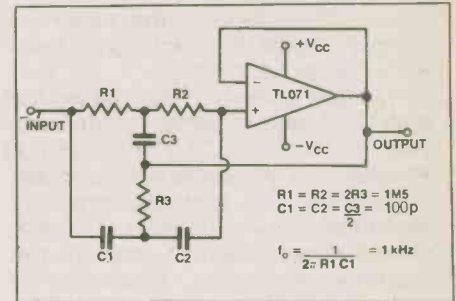


Fig. 5 Notch filter using a 'Twin-T' filter section on the input of a TL071 op-amp.

which one of the 'T' sections consists of R1, R2 and C3 and the other part of C1, C2 and R3. It is designed to reject signals of one particular frequency (the notch frequency), whilst passing signals of any other frequency virtually unattenuated.

For optimum performance, when a sharp notch in the frequency response is required, the components should have matched values (to within 1% or 2%). When the values shown are employed, the notch frequency occurs at approximately 1 kHz. An advantage of using a high input impedance device such as the TL071 is that relatively large values may be employed for R1, R2 and R3 and, therefore, for any given frequency, C1, C2 and C3 can have a relatively low value. Large value, close tolerance capacitors are expensive, so the ability to employ devices of low value is important.

Tone controls

Two tone control circuit using the CA3140 are shown in Figures 6 and 7. Figure 6 is of the Baxandall type, which provides a gain of unity at the mid-frequencies and uses standard linear potentiometers. The high input impedance of the CA3140 enables low-value (and therefore cheap) capacitors to be employed in a circuit which has an impedance great enough to avoid excessive loading of the stage feeding this circuit.

Bass/treble boost or cut are about +15 dB at 100 Hz and 10 kHz respectively. Full peak-to-peak audio output is available up to at least 20 kHz, since the CA3140 has a relatively high slew rate (about 7 V/us). The gain falls by about 3 dB at a frequency of around 70 kHz.

The circuit of Figure 7 provides similar boost and cut facilities, but the gain of this circuit is about

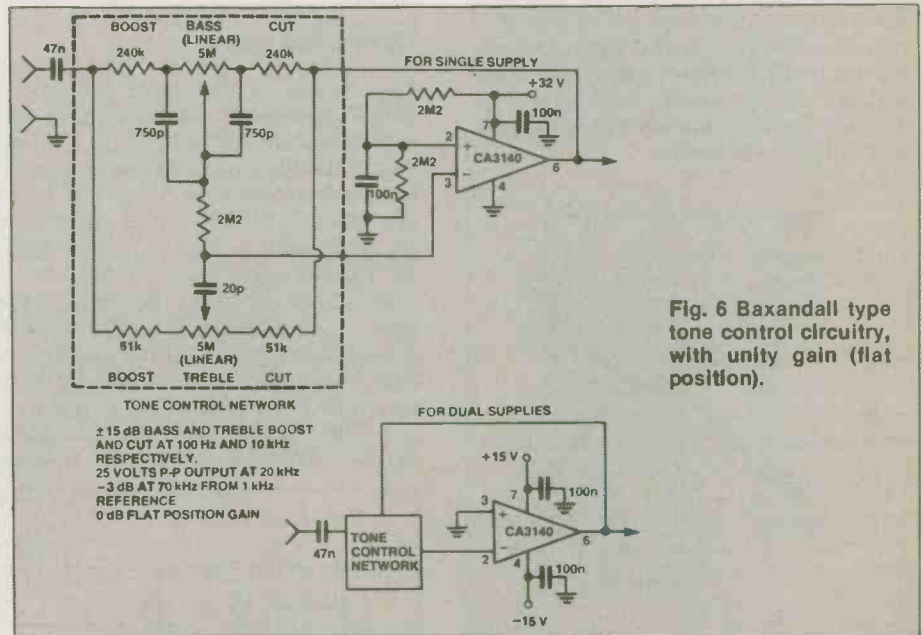


Fig. 6 Baxandall type tone control circuitry, with unity gain (flat position).

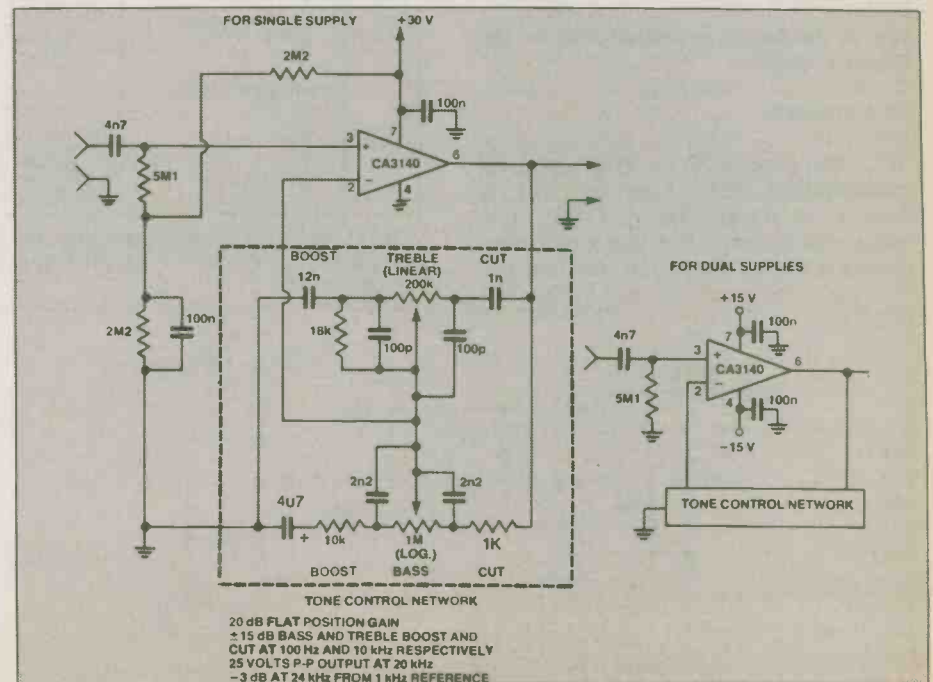


Fig. 7 Tone control circuit with 20 dB of gain, flat position.

BIFET & BIMOS Op Amps

eleven. The input impedance is basically equal to the resistor from pin 3 to ground.

A tone control circuit using the TL060 low-noise BIFET devices is shown in Figure 8. The TL060 is not internally compensated and therefore requires the 10p external frequency compensation capacitor shown connected in the circuit of each device. Similar circuits can, of course, be made using the TL080 devices at the expense of a higher power level. A further alternative is the use of TL066 programmable BiFET device without any compensating capacitors, but with a suitable value of the programming resistor between pin 8 and the negative line (about 1k, depending on the trade-off between bandwidth and power consumption which is required). Figure 9 shows the response of the Figure 8 circuit.

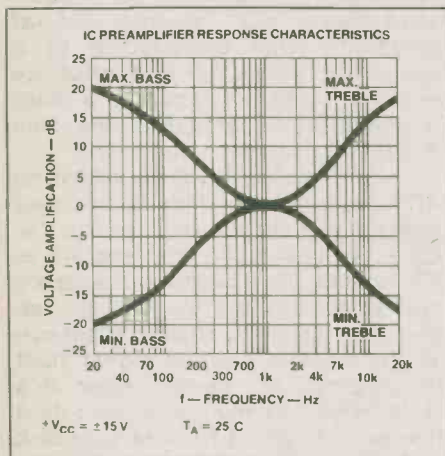


Fig. 9 Response characteristics of the Figure 8 circuit.

Mic preamp

A moving-coil microphone preamplifier with tone control is shown in Figure 10. A TL061 low-power device which is internally compensated is employed in this circuit.

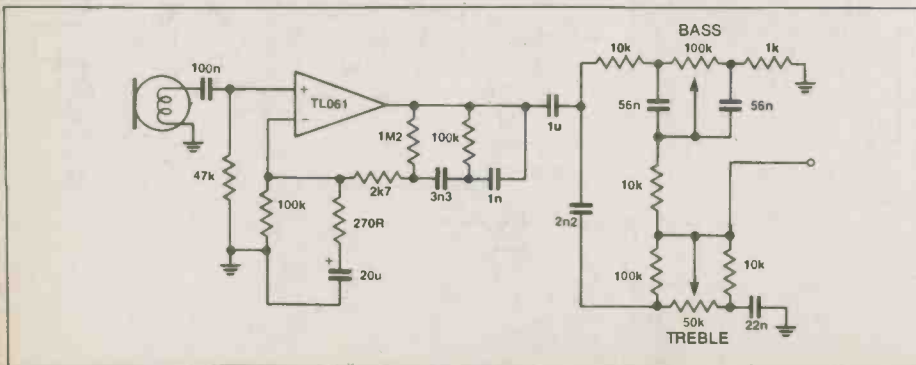


Fig. 10 Moving-coil mic preamp with tone controls, using an internally compensated TL061 device (same pinout as TL071).

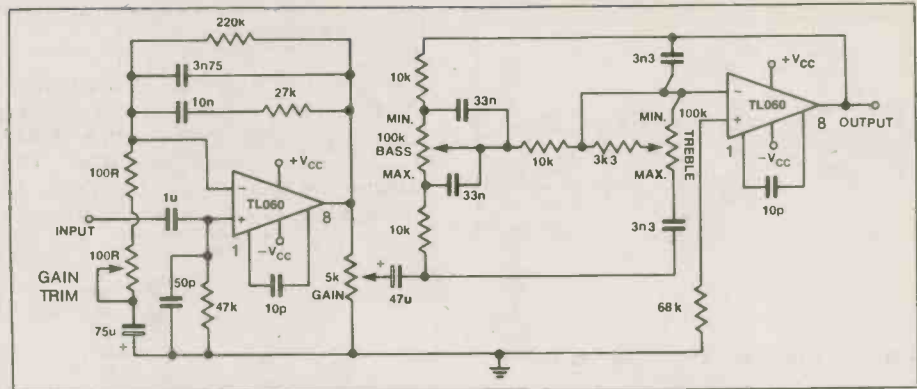


Fig. 8 An RIAA preamp and tone control circuit using TL060 devices. (Same pinout as TL070).

Distribution amp

The Texas Instruments series of BiFET devices is also available with four separate amplifiers in a single 14-pin dual-in-line package. Figure 11 shows the connections of the TL064 low-power BiFET quad amplifier, together with a circuit for an audio distribution amplifier using one of these quad devices. The input stage acts as an input buffer and the other three stages act as output buffers, so that no signal from output A finds its way into any of the other outputs.

The TL084 and the low-noise TL074 have the same pin con-

nections, whereas the TL085 and the low-noise TL075 devices are quad types with connections similar to the RC4136. There is no TL065 at present.

Offset Nulling

Tolerances within the amplifier cause a small DC error voltage to appear on the output. This can usually be neglected for most applications, but may cause problems in sensitive DC circuits such as meter drives. The circuit shown in Fig. 12 includes a potentiometer for trimming the output to zero volts.

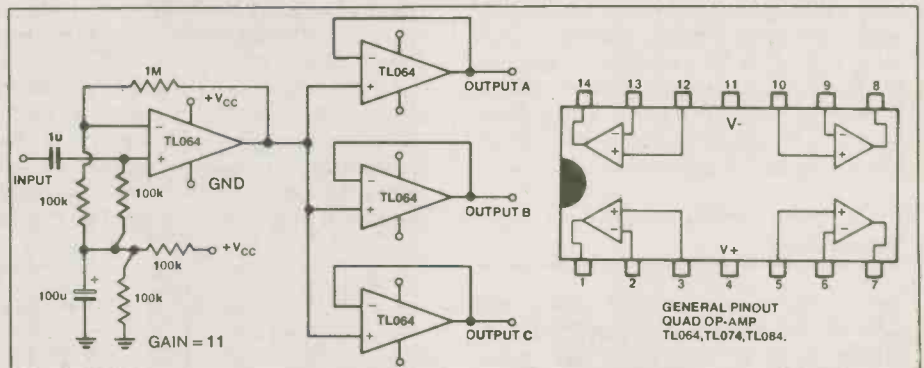


Fig. 11 An audio 'distribution' amplifier for 'slaving' several pieces of equipment from a single source. Pinout for the quad op-amp is shown at right. Circuit is for single — supply operation.

Ice warning

The circuit of Figure 13 employs three of the four amplifiers of the TL084 device in an ice warning detector. It is especially suitable for use in vehicles to warn the driver when the temperature of the thermistor (placed outside the vehicle) falls below 0°C.

When the temperature of the thermistor falls, its resistance rises and the current flowing through the thermistor decreases. Thus the inverting input of the TL084 connected to this thermistor receives less current from the positive supply line and its

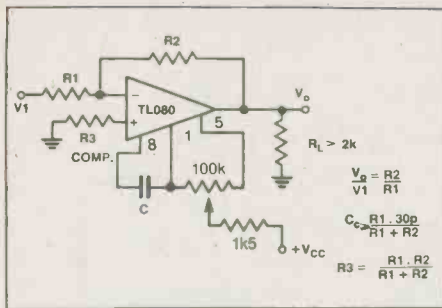


Fig. 12 Offset adjusting using the TL080.

output voltage tends to rise. This output voltage is fed to the TL084 output amplifier and produces a voltage across the LED, which lights, providing the required warning.

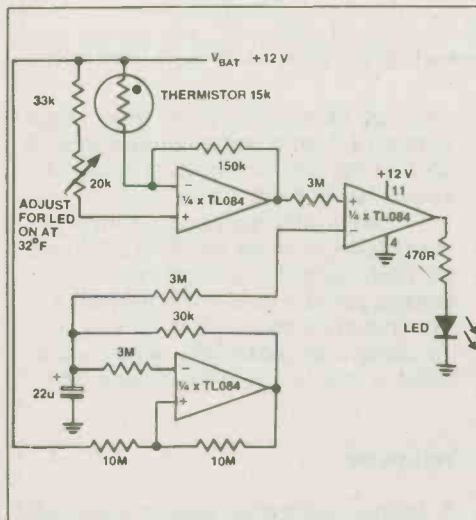


Fig. 13 An ice warning indicator.

Light detector

The circuit of Figure 14 is a low-level light detector preamplifier using the low-power TL061 device with a TIL601 or similar phototransistor. The variable resistor can be used to balance the output at any particular value of light level.

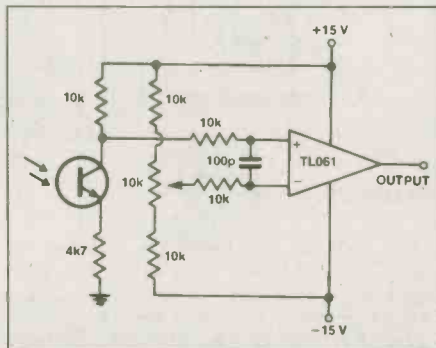


Fig. 14 Low-level light detector using FPT100 or similar phototransistor.

Sine shaper

The circuit shown in Figure 15 uses a CA3140 as a voltage follower device. In combination with diodes from the CA3019 array to convert the triangular signal from a function generator into a sinewave output, which has typically less than 2% harmonic distortion.

The circuit is best adjusted using a distortion analyser, but a fairly good adjustment can be made by comparing its output signal on an oscilloscope with that from a good sinewave signal generator. The initial

slope is adjusted by R1, followed by an adjustment of R2. The final slope is established by adjusting R3, thereby adding additional segments that are contributed by these diodes. Repetition of the adjustments may be necessary, since there is some interaction between the adjusting potentiometers.

Wien bridge

A CA3140 BiMOS amplifier is used in the circuit of Figure 16, together with a CA3019 diode array, to form a Wien bridge oscillator. One of the package diodes is used as a zener diode to shunt the 7k5 feedback resistor and, as the output signal amplitude increases, the zener diode impedance rapidly decreases so as to produce more feedback, with a consequent reduction in gain. This action stabilises the output signal amplitude. This combination of a monolithic zener diode and the bridge rectifier tends to provide a zero temperature coefficient for this regulating system.

As the output circuit contains no RC time constant, there is no lower frequency limit for operation. If C1 = C2 = 1u (polycarbonate) and R1 = R2 = 22M, the operating frequency can be about 0.007 Hz. At high frequencies, as the frequency is increased the amplitude of the signal must be reduced to prevent slew rate limiting from taking place. An output frequency of about 180 kHz will reach a slew rate of about 9 V/us when the output voltage amplitude is about 16 V peak-to-peak.

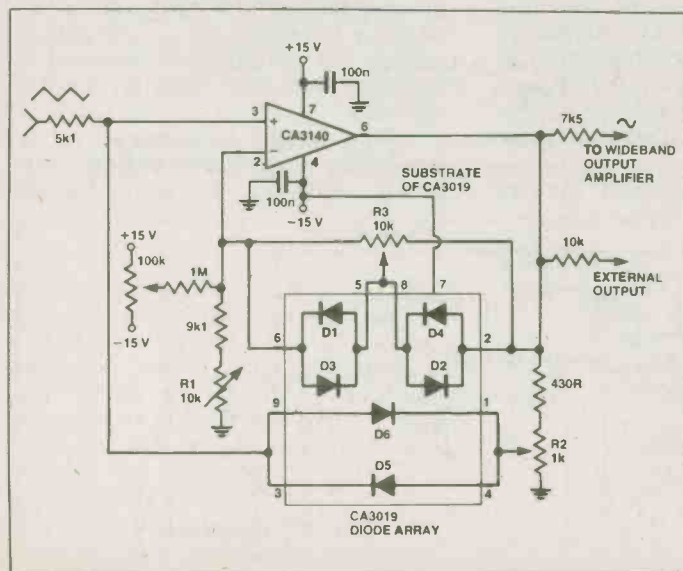


Fig. 15 A triangle-to-sine waveshaping circuit employing a CA3140 op-amp and a CA3019 diode array.

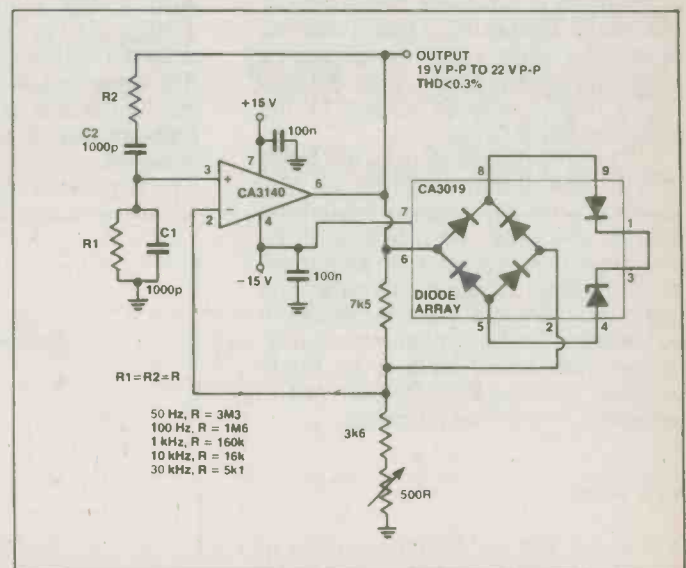


Fig. 16 A Wien bridge oscillator featuring amplitude stabilisation via the zener action from the CA3019 diode array.

BIFET & BIMOS Op Amps

Meter

The high input impedance of BiFET and BiMOS devices has led to their use in many voltmeters of high input resistance and also in meters to measure very small currents.

The circuit of Figure 17 was designed by Texas Instruments for the measurement of voltages in the range $\pm 0.6\text{V}$ to $\pm 600\text{V}$, where the source resistance may be quite high, and to measure currents from 6 nA to $6\text{ }\mu\text{A}$. The instrument was required to accept inputs of either polarity and be inexpensive, robust and reliable. It also had to have a long battery life, so a TL061 low-power operational amplifier device was selected. An inexpensive centre zero meter is considerably cheaper than a liquid crystal display and would provide adequate accuracy for the purpose.

When the switch is in one of the positions A to D inclusive, the instrument is set for the measurement of voltages. The amplifier has a non-inverting gain of 10 and range selection is achieved by a simple potential divider network with a fixed input impedance of 1000 megohm. A panel-mounted 'centre zero' control is included in the circuit to facilitate corrections for the mechanical movement of the meter zero and for the change in the operational amplifier input voltage offset (for example, with temperature).

In the current measuring mode of switch positions E to H inclusive, the amplifier operates as a current-to-voltage converter. For the most sensitive range of 6 nA , a transimpedance of 1 Gigaohm is required to produce a full-scale deflection of the meter. Rather than use a resistor of such a high value, a resistance multiplier arrangement was devised with a 100M feedback resistor for the most sensitive range.

The two diodes across the input of the operational amplifier in conjunction with R6 provide protection against any gross overloading of the instrument. A suitable arrangement incorporating a fullwave rectifier into this circuit would allow alternating input signals to be measured, but arrangements would have to be made to allow for frequency roll-off of the response at high frequencies.

3 pA meter

A CA3160 and a CA3140 are used in the circuit of Figure 18 to construct a picoammeter with $\pm 3\text{ pA}$ full scale deflection (one picoamp = 10^{-12}

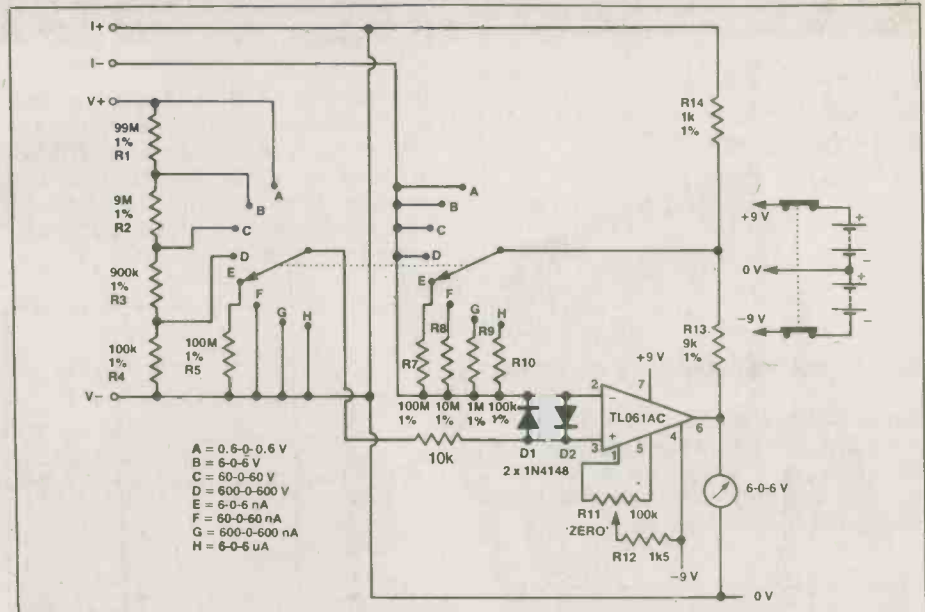


Fig. 17 A multi-range voltmeter with high impedance input plus multi-range low-current meter.

amps). Pins 2 and 4 of the CA3160 are connected to ground, so the input pin 3 between them is effectively 'guarded'. If slight leakage resistance is present between terminals 3 and 2 or 3 and 4, there would be zero voltage across this leakage resistance and this would reduce the leakage current by a large factor.

It is preferable to operate the CA3160 with its output pin 6 near the ground potential, so as to reduce the dissipation by reducing the device supply current. The CA3140 serves as a $\times 100$ gain stage to provide the required plus and minus output voltage swing for the meter and feedback network. A 100:1 voltage divider network consisting of a $9\text{k}9$ resistor in series with a $100\text{ }\Omega$ resistor sets the voltage at the $10\text{ k}\Omega$ resistor to $\pm 30\text{ mV}$ full-scale deflection. This 30 mV signal results from $\pm 3\text{ V}$ appearing at the top of the voltage divider network, which also drives the meter circuitry.

It is possible to switch the $9\text{k}9$

and $100\text{ }\Omega$ network in the output circuit so that current ranges from 3 pA to 1 nA can be handled using the single $10\text{ k}\Omega$ resistor.

The writer has seen circuits using BiMOS devices published for use in measuring currents down to 100 femtoamps (0.1 pA), but obviously extreme care is required to ensure the insulation is adequate when such small currents are being measured.

Voltmeter

A further voltmeter circuit covering the range 10 mV to 300 V is shown in Figure 19, which also uses a CA3160 device. The range switch SW1 is ganged between the input and output circuitry to enable the proper output voltage for feedback to terminal 2 through the $10\text{ k}\Omega$ resistor to be selected.

This circuit is powered by a single 8.4 V mercury battery, the power supply current being

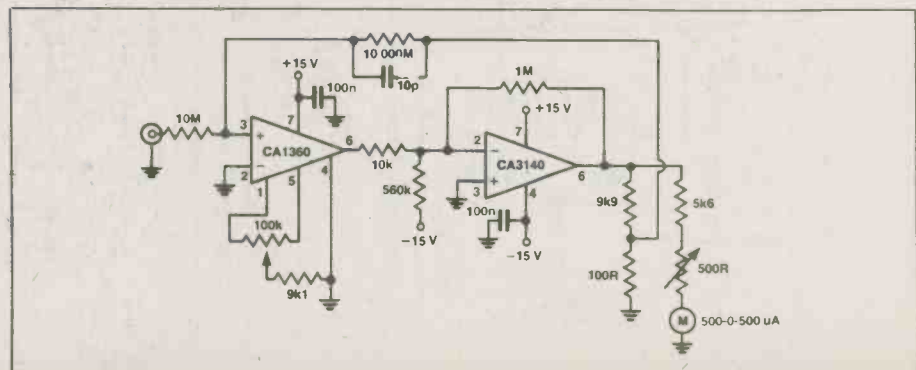


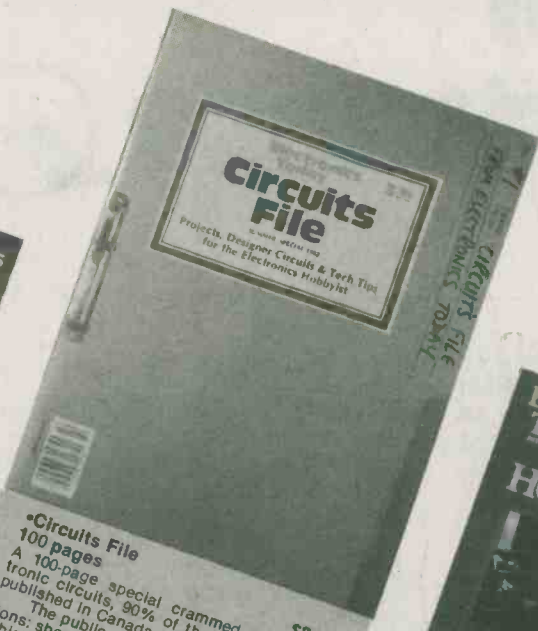
Fig. 18 This circuit will measure very low currents — full-scale deflection is \pm three picoamps!

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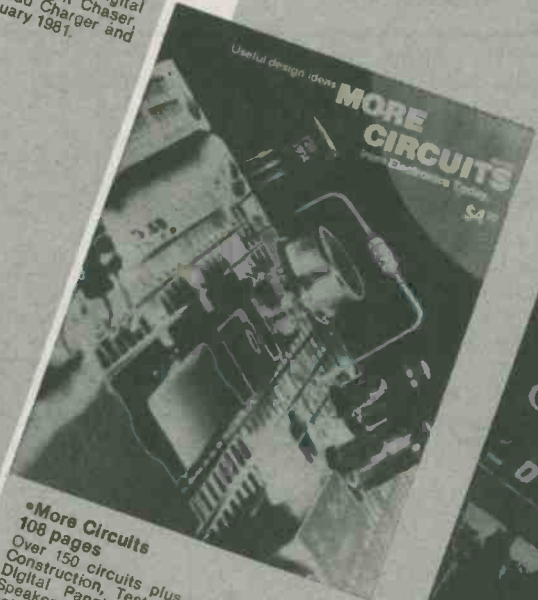
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Digital Capacitance Meter



It's fast, accurate and not too fancy. This Month's Digital Capacitance Meter is easy to build and will become one of the most used items in your workshop.

A GLANCE through an electronics catalogue soon shows that most of the cheaper multimeters do not measure capacitance. A few may measure values in the microfarad range, but not many measure in the nanofarad or picofarad ranges. This low-cost meter will, therefore, be very useful; it covers values from 100pF to 9900uF with two digit accuracy and it's cheap and easy to build. It also provides a good indication for values in the 10-100pF range but, in general, the main ranges will satisfy the requirements of most hobbyists.

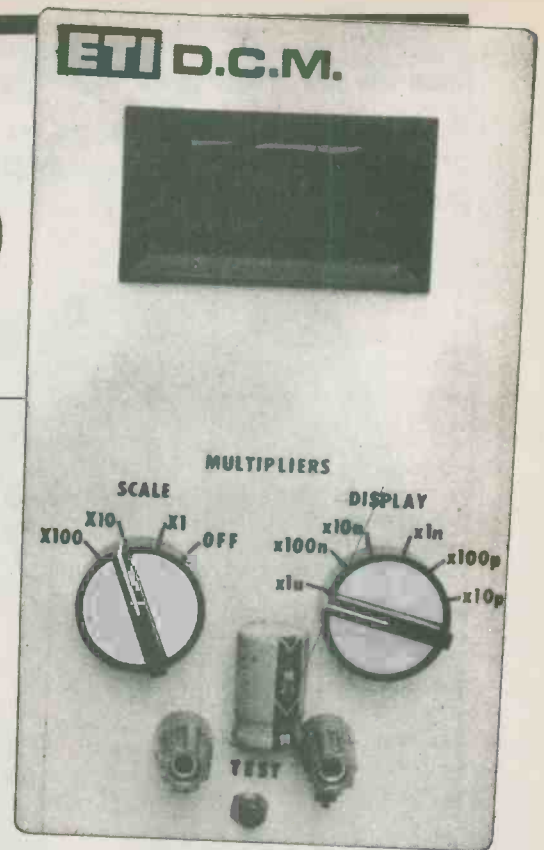
Many types of capacitors are manufactured to about 10% tolerance, yet for building filters, tuned circuits, timers and the like, it is often important to be able to know the precise value of a capacitor. Electrolytic capacitors, for example, are notorious for having very wide tolerance and for changing capacitance with age and use. Then there are all those look-alike polystyrene capacitors, which are marked in ink that seems specially prone to rub off at the first handling (their physical size is no real guide to their value, by the way). Finally, there are the bargain packs, containing an assortment of imported capacitors whose markings bear no recognisable relationship to any known classification system. When using these, the perplexing question is: "What have we here?". So, a capacitance meter is a distinct asset for these and many other circumstances.

The Circuit

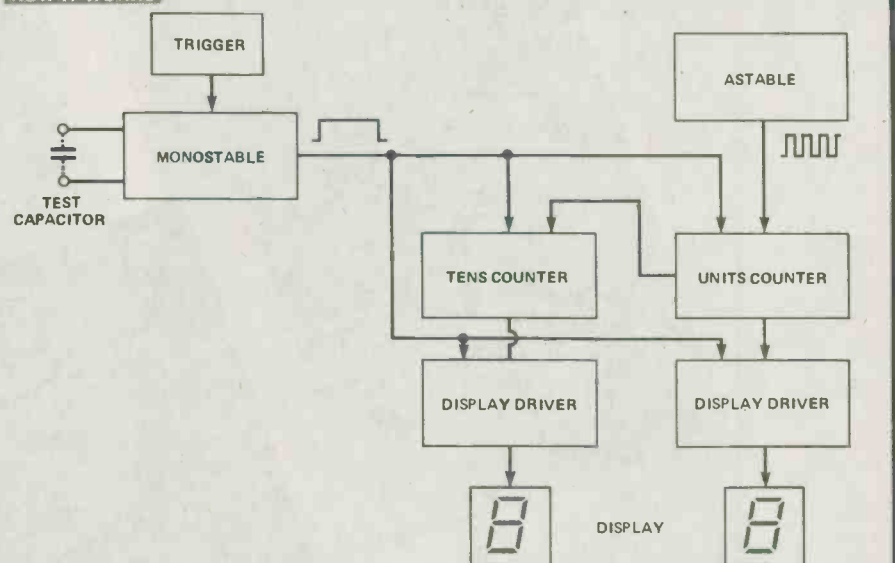
The circuit uses the 556 dual timer IC in two common configurations. One

half, IC1b is an astable multivibrator used to produce a square wave at either of two fixed frequencies. The pulses from the astable are counted by IC3, which contains two complete decimal counters. The first counts units and its output carries over to the second, which counts tens. The display drivers, IC4 and IC5, convert the BCD (Binary Coded Decimal) outputs from the counters to provide the outputs required for driving the 7-segment displays.

The counting action is controlled by the other half of the timer, IC1a, connected as a monostable multivibrator; when triggered, this



HOW IT WORKS



The DCM measures an unknown capacitor by counting the number of clock pulses which occur during the period of a gating pulse, produced by the monostable. The pulse is triggered by operating a push button switch (the trigger circuit ensures a clean start to the pulse) and its width is proportional of the value of the test capacitor, which is connected into the RC timing network of the monostable.

The gate pulse 'enables' the display drivers and the counters, which then begin to register pulses from the astable

multivibrator. At the end of the monostable gate pulse, the display drivers are locked and a two digit number is displayed. The counters are reset to zero, ready to begin a new count.

The DCM has eight ranges, produced by changing the frequency of the astable multivibrator and by controlling the width of the monostable pulse by using different resistors in combination with the test capacitor. This is described more fully in the text.

gives a single positive pulse. As the pulse begins (rises), the counters and display drivers are 'enabled' and pulses from the astable are counted. As the pulse ends (falls), the display drivers are latched to 'hold' and the count is displayed. The counters are reset to zero at this time, ready to restart the count at the next high pulse, but the display 'holds' the count. The display is returned to zero by the enable pulse at the beginning of each run and counting begins immediately.

The length of the pulse from the monostable, IC1a, is proportional to the capacitance of the test capacitor; the greater the capacitance, the longer the pulse and, therefore, more pulses from the astable are counted. The two-figure display is read according to the format indicated by the range-setting knob.

The period of the monostable is set by the test capacitor and whichever resistor, R3, R4 or R5, is selected by SW2a. The frequency of the astable, IC1b, is set by the timing capacitors C2, C3 or C4 and resistors R6, PR1, R7 and PR2. By selecting the appropriate combination of timing components, the meter provides eight decade ranges from 100pF upwards.

Construction

Most of the circuit is accommodated on the printed circuit board. It is best to begin construction with the display circuit. The two 7-segment LED displays are soldered to the board first; make sure the iron is hot and work quickly, so as not to overheat the LEDs. It is better to solder a few

pins, then wait a few minutes for the heat to escape before continuing; the decimal point pins (dp) do not need to be soldered. Next, mount R9-22 (or you could use two 14-pin DIL resistor arrays, if you wish).

When you have mounted the displays and resistors, make the battery connections and test the display. Temporarily join the positive line to each of the resistors in turn and check that the correct segments light up on the display. WARNING — the current *must* go through a resistor before it goes to a segment.

The two segment-drivers, IC4 and IC5, are wired in next. The counter, IC3, completes the display section of the meter. To check its operation, connect a pulse generator to pin 1 of IC3; the displays should show a regular count up to 99, returning to 00 and repeating. If you do not

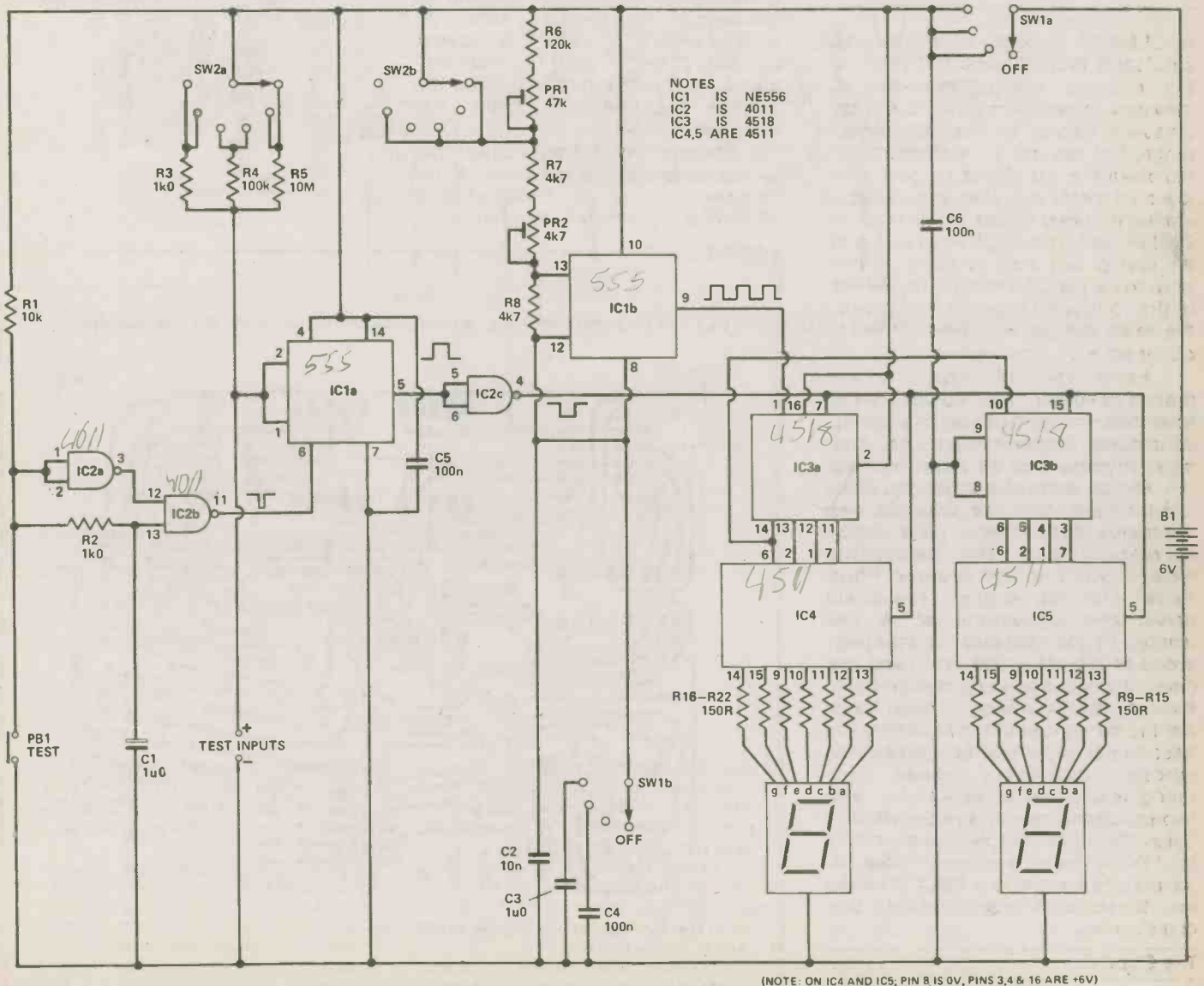


Fig. 1 The circuit of the Digital Capacitance Meter.

Digital Capacitance Meter

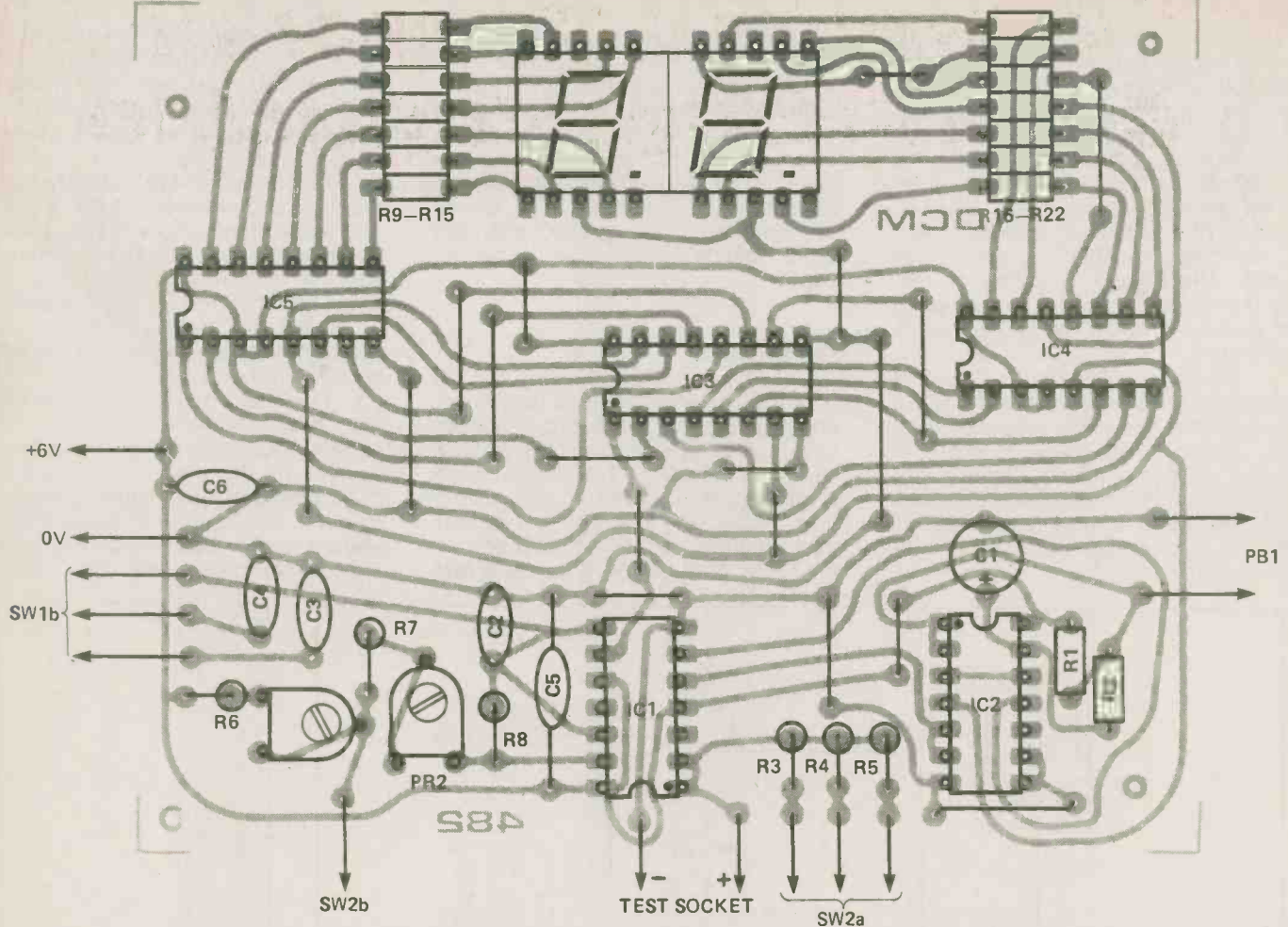
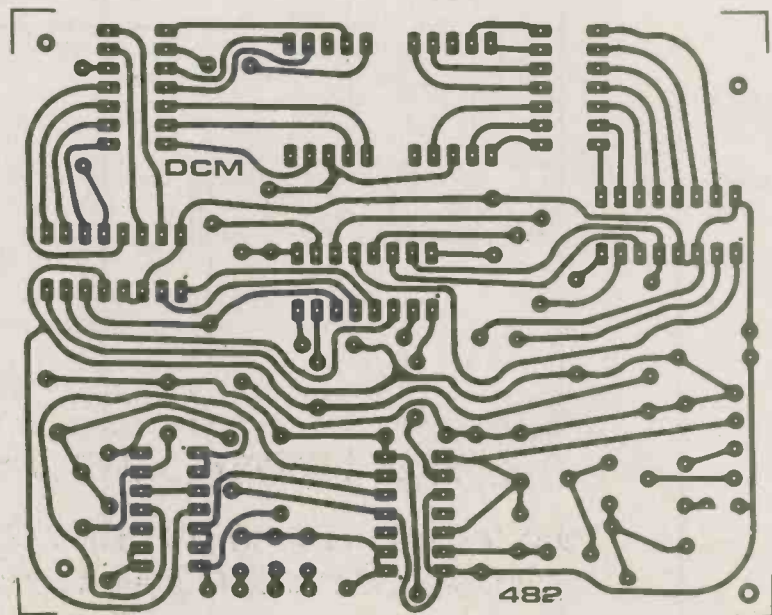


Fig. 2 The component layout; note that R9-15 and R16-22 can be either individual resistors (as shown) or 14-pin DIL resistor arrays.

have a generator, you can use the output from IC1b which, with its associated components, is the next section of the circuit to be completed.

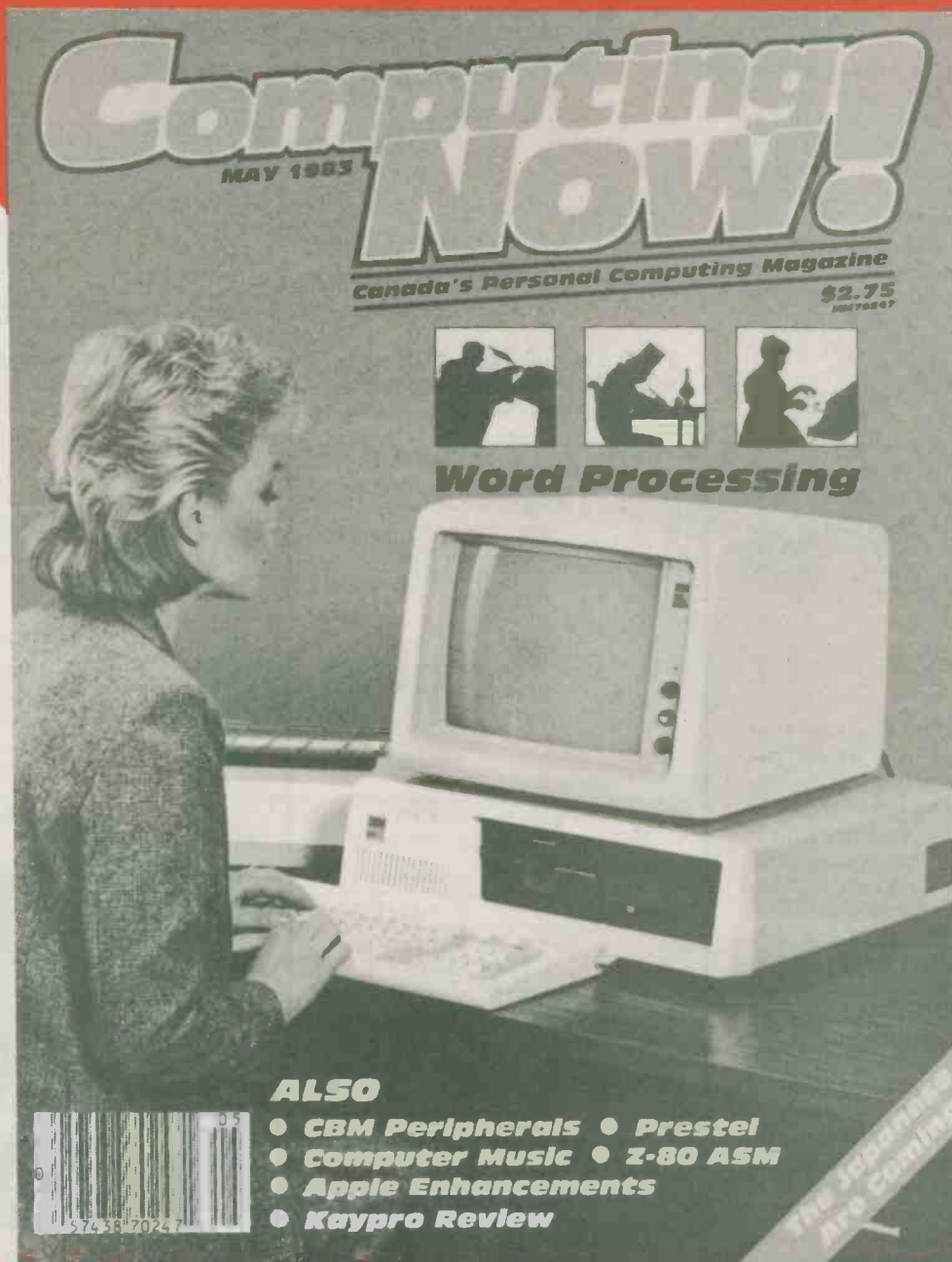
When the pulse generator (or astable) circuit is complete, connect the power supply. When pin 4 of IC2c is taken low (to 0V), the display should count rapidly at about 1 kHz. When it is taken high, the count freezes at its current value. The rate of counting is too fast to see properly (the display will appear to show a steady '8'), but you can slow it down by temporarily wiring a large value capacitor (say, 10uF) in parallel with C2. This will let you check that the counters are working properly.

Finally, complete the monostable and trigger circuits, IC1 and IC2, and the remaining components. You will need to make off-board connections to SW2, PB1 and the capacitor test sockets before this part can be tested. It is probably best to mount the panel components and complete all the off-board wiring now. Determine the orientation of SW1 and SW2 and drill the registration holes



The foil side of the printed circuit board.

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Digital Capacitance Meter

accordingly. If PB1 and the negative capacitor test socket are correctly positioned, the tag of the socket can be soldered directly to one of the lugs of PB1. The power comes from four pen-lite cells in a battery holder, which can be held in place by double-sided tape. To test the complete circuit, mount a capacitor in the test sockets; it is useful to have a pair of test leads, with 4 mm plugs at one end and crocodile clips at the other, for short-lead and otherwise 'difficult' capacitors. Remember to observe polarity, when testing electrolytic or tantalum capacitors.

You are now ready to switch on and . . . the display should immediately show a value. If nothing happens when you switch on, check that the trigger circuit, which normally has a high output (IC2b, pin 11), goes low for an instant (about 1 mS) when PB1 is pressed. The output of IC1a (pin 5) should normally be low, going high for an instant when PB1 is pressed. If you use a 100 uF test capacitor with SW2 at X1n, the output should stay high for about 10 seconds and, during this time, the display will run from 00 to 99 several times.

Calibration

IC1a is a monostable oscillator that controls the period for which the display counts pulses from IC1b. The period, t , is equal to $1.1RC$, where C is the value of the test capacitor and R is the value of whichever resistor (R3 to R5) is switched into circuit. For example, if the test capacitor is 10 nF and we use R4 (100k), $t = 1.1 \times 100 \times 10^{-9} \times 10 \times 10^{-6} = 1.1$ mS. During this brief period the counter has to count 10 pulses from IC1b so that the display shows '10' at the end of the counting period. Now 10 pulses in 1.1 mS is equivalent to a frequency of 9.09 kHz, and this is the frequency to which IC1b is set when PR1 and R6 are short-circuited out of the timing chain by SW2b. If the test capacitor is 100 nF, the period becomes 11 mS; the display must again count 10 pulses, to show '10', so the frequency of IC2 must be reduced to 0.909 kHz by switching PR1 and R6 into circuit.

To calibrate the instrument we simply have to adjust PR1 and PR2 to give frequencies of 9.09 kHz and 0.909 kHz. The easiest method is to use an oscilloscope. Switch SW2 to position 1, bypassing PR1 and R6; monitor the output from pin 9 of IC1b and adjust PR2 until the period of the signal is 1.1 mS (9.09 kHz). Now switch SW2 to position 2 and adjust PR1 until the period is 11 mS (0.909

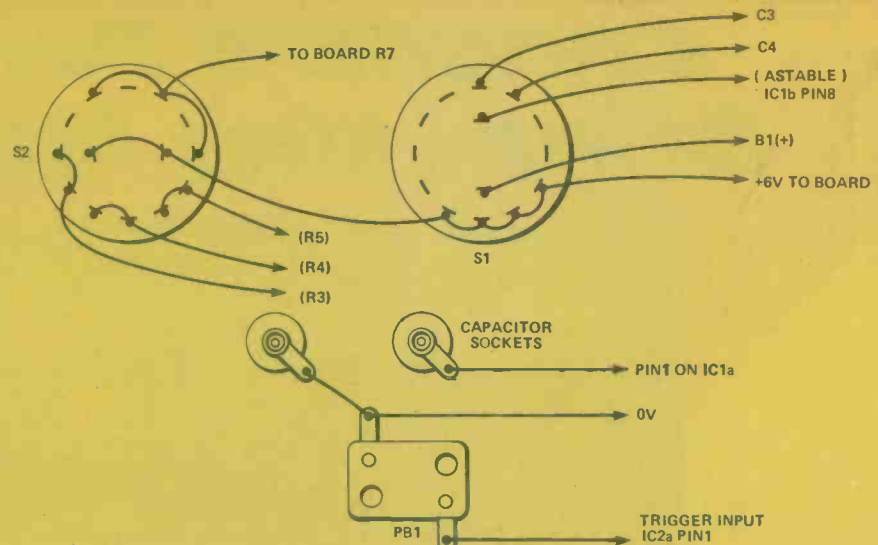


Fig. 3 Wiring diagram for the panel-mounted components. Check against the circuit to ensure all the wires go to the right place!

PARTS LIST

Resistors (all 1/4 W, 5% except where specified)

R1	10k
R2	1k0
R3	1k0, 1% or 2%
R4	100k, 1% or 2%
R5	10M, 10%
R6	120k
R7,8	4k7
R9-22	150R (or two 14-pin DIL thick film resistor networks)

Potentiometers

PR1,2	47k sub-miniature horizontal trim pots.
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Capacitors

C1	1u0 35V tantalum
C2	10n polyester
C3	1u0 polycarbonate
C4-6	100n polyester

Semiconductors

IC1	556 dual timer
IC2	4011B quadruple 2-Input NAND
IC3	4518B dual decade counter
IC4,5	4511 7-segment decoder/ drivers

Miscellaneous

PB1	push button switch
SW1,2	2-pole 6-position rotary switches.
PCB	two 7-segment LED displays (common cathode 0.5"); ABS case 190 mm x 110 mm x 60 mm; knobs for SW1,2; 2x 14-pin, 3 x 16-pin DIL sockets; 4 mm terminal sockets (1 red, 1 blue); battery holder for 4 x AA cells; 1.0 mm terminal pins; self-adhesive feet; connecting wire; solder, etc.

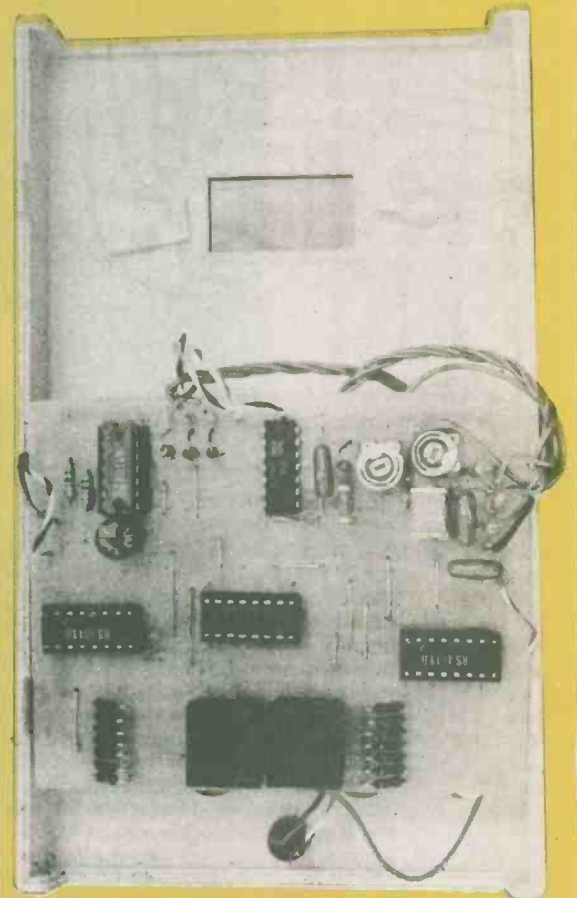


Fig. 4 Internal view of the completed DCM.

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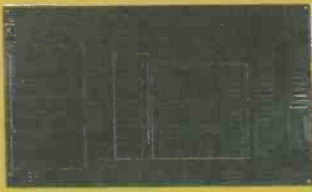
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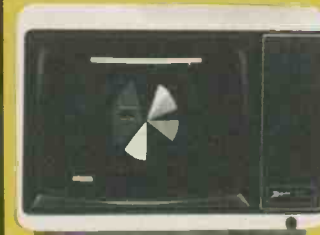
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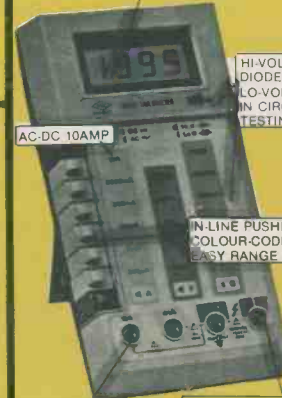
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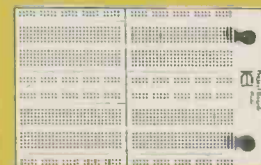
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A Bunch of Fruit!



Johnny Appleseed would be proud: the industry has spawned plenty of Apple™ compatible computers, and Steve Rimmer looks at three: the Surplustronics 6502, the Franklin ACE 1200, and the Orange Peel.

I FIGURE THAT In about twelve months or so it'll be impossible to register a fruit as the trademark of a micro-computer product without infringing on somebody's trademark. We now have Apples, Grapes, Peaches, Pineapples and Oranges. I myself have considered introducing my own

variety. It's a toss up between Passion Fruit and Green Banana ... possibly the Mango. This wouldn't be a complete copy of the popular 6502 system. For one thing, it would eliminate the need for expensive floppy disks by utilizing exorbitant magnetic tape vacuum drives.

Back in the real world, there are a lot of types of fruit, or fruit by any other name, rolling around in the bottom of the basket. The first of the so called Apple clones were just that ... more or less exact copies of the Apple computer. However, one of the facets of the Apple system which is rather less than splendid is the fact

that it's extremely old, and much of it is obsolete. For example, it has a forty column screen which lacks lower case characters. It can only support 48K of RAM on board, and its language in firmware is a dog. Its high resolution graphics facility is also a bit of a newt's doorknob, what with highly limited choices of colours available to the aspiring video artist, and things like sprites and complex drawing functions a thing of the mind.

Since modern technology now knows how to cure these things at birth, the designers of the clones were faced with the very real



The Surplustronics 6502

A Bunch of Fruit!

possibility of creating systems which could actually out — Apple the Apple itself. With a bit of work it was possible to create computers which could run all the Apple's software, handle all the hardware peripheral gizmos that have been flanged out on the unsuspecting universe for it and, at the same time, overcome many of the limitations of the original design.

The modern Apple clone is an amazing creation. It has 64K of RAM, the maximum the 6502 processor can address without bank switching. It supports lower case characters from its shift key, making it useful for word processors. Note, though, that this does not mean that you can program in Applesoft in lower case. As such, these systems generally feature caps-lock devices. One of the ones that we'll look at here has its disk controller right on board, as well as a switchable forty and eighty column screen. The addition of an extra processor card avails the system of CP/M, a second disk operating system, and the whole range of languages available for it. This includes a pair of custom Microsoft BASICs, one which emulates the graphics functions of Applesoft.

In fact, none of these systems do anything that can't be done with a regular old Apple II. However, in most cases, they do it more conveniently, much more economically and with vastly fewer bits and pieces to fool with.

If you've been following the exploits of the great fruit farm in Cupertino, the Apple Corporation, you may have noticed the arrival of the Apple IIe system, an enhanced Apple II that carries official sanction. One may, in fact, wonder how this compares with the clones, or if a wave of cloned II's are about to supplant the cloned IIs. In fact, the Apple IIe has basically the same features as the clones we'll be looking at here, although its keyboard is rather nice, and adds a few programmable keys. However, it has been designed with a number of custom LSI chips, making it all but un-cloneable. However, it adds virtually no additional features above what the clones now offer.

There are a number of clones which are built in the Orient and imported into Canada, and others that are either built here or in the States. The three in this article fall into the latter class. Two are, in fact, native sons, and represent some very clever bits of technology.

Just as we were going to press Patrick Heenan of Shamrock Computer Inc. wandered by with a cloud of his latest

clone drives, which turned out to be quite nice. They are Shugarts with a custom designed controller board and extremely quiet in all directions. The controller features a very low parts count for enhanced reliability, and intense greenness . . . what a shame you can't get these things with transparent covers. The controller card will work with most systems using Apple-like firmware although, as we discovered, it does make some calls to the ROM, so it's uncool on highly mutated systems. The drives are assembled in Canada, which is a good trip for service.

The Surplustronics 6502

One of the problems with this system is that it lacks a name. That's about all it lacks, though; it has its impressive bits. It is available through Surplustronics . . . across the street from Exceltronix, down the road from Parts Galore, a skip away from Supertronix, and so on. It is an extremely flexible system, and, above all, dirt cheap . . . if you own a soldering iron.

The system . . . how about 6502 BD . . . comes in kit form for \$649.00. This buys you the main mother board and all the parts you need to stuff it. At the moment you also get a blank Z-80 card to go along with it. This includes a case and keyboard, the latter with a numeric pad.

So, ho hum, another motherboard deal. Well, actually, this isn't just another motherboard. It has been completely redesigned, with a real high tech digital layout and everything. It has 64K of RAM on board, using eight 4164's, an eighty column feature built right in there, as well as an onboard disk controller. This has reduced the need for peripheral slots considerably . . . there are only five now. However, the best bit can be found in the lower left hand corner of the keyboard.

It has real actual genuine total lower case!

Yes, friends, for the first time on this or any other planet you can see a fully Apple compatible system in which the shift key actually runs the lower case function. No more CTRL-A . . . it's still there but you don't need it.

Well, I thought it was neat.

The lower case feature works in both eighty and forty column modes, and can be switched out with a caps lock button for those times when you're just programming in BASIC.

Now, there are a few catches to this thing which may sneak up on you if you aren't looking. The first thing is that there are basically the same minor interactive hassles involved between this board's eighty column circuitry and the basic 6502 drivers as one encounters with an Apple and an eighty column card. To wit, the HOME function from BASIC doesn't clear the screen . . . it just homes the cursor. You can go from forty to eighty



The Franklin ACE 1200 with an AVT monitor.

easily enough . . . just IN#3 . . . but reversing the procedure requires a CTRL RESET, something a bit more drastic. There are, of course, no high resolution graphics allowed when you're in the eighty column mode . . . you can't have everything.

There is one serious problem as well. Because the eighty column card switches the video from forty to eighty in software, everything goes through it. If it gets confused, you're sunk. Unfortunately, some copy protected game disks load chunks of their programs into unusual places in the computer to confuse would-be pirates. Some seem to be bent on using a block of RAM that the eighty column card is fond of. As such, you can't actually run these games. One example of this phenomenon is David's Midnight Magic, the pinball simulator.

There is an on board jumper which switches the eighty column circuitry out entirely for this sort of situation, which, yes, will cure the problem. This can be brought out to a switch if need be. As far as I could tell, this will affect about ten percent of the available game software at the moment.

The big catch, however, involves the EPROMs. When you get the board it comes with a full set of EPROMs . . . many of which are blank. These are the proprietary ones . . . the folks who are flogging this system are taking no chances with the heat, so you will have to get your own firmware. This isn't quite so heavy as it may seem . . . locating a ROM bandit these days usually involves walking onto a main street and whispering . . . very quietly

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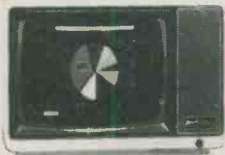
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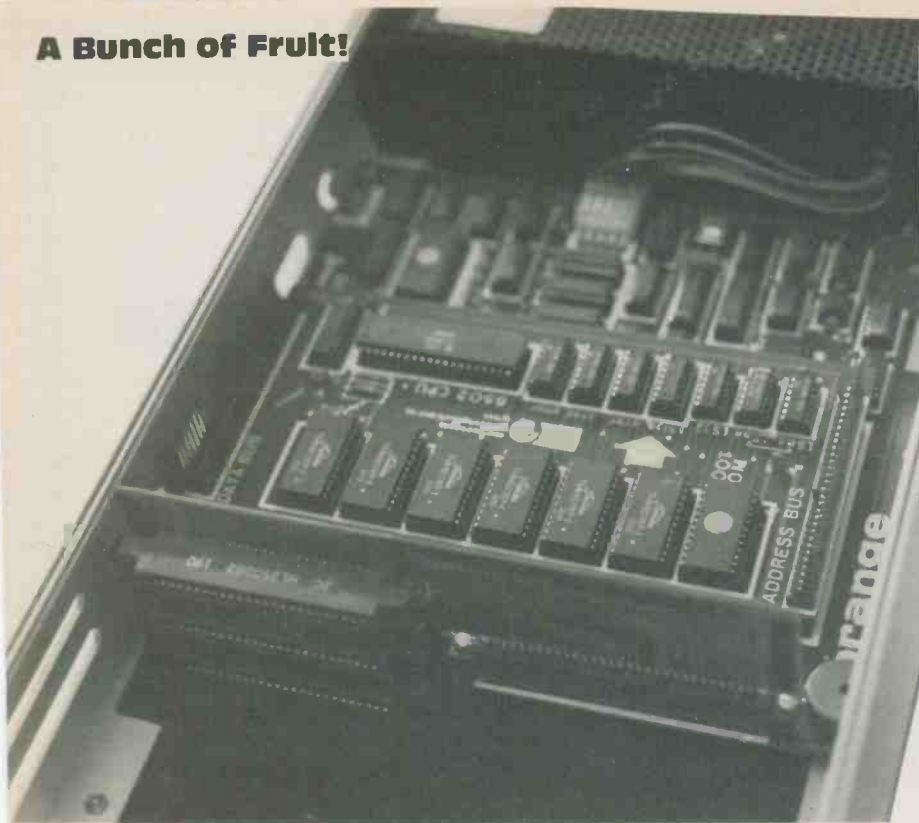
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A Bunch of Fruit!



The Orange Peel computer with detachable keyboard and a Zenith monitor. (Left) Its innards. Lowermost connectors are the I/O ports.

... "I need some chips". Just remember to bring a large club to fight off the latecomers.

In fact, this system was supplied to us with blank EPROMs. The firmware for the system proper lives in two chips for this board, instead of the traditional six, one 2732 and one 2764. After some figuring we managed to combine the contents of a standard set of EPROMs into these little fellows.

This system, despite some of the funkier aspects of its distribution, represents one of the better values of our day. It's fully Apple compatible, so far as I've been able to tell, as well as running Apple CP/M with a Z-80 card. It seems to overcome most of the limitations of the Apple II design. It even runs cooler, using rather more modern chips, and a lot fewer of them.

The board is also available without the case, and can be installed in place of an existing 6502 clone... or even a real Apple.

The ACE 1200 The ACE 1200 is the only non-Canadian fruit we've looked at... it's built in the land of Reagan. An interesting thing, this. More or less an Apple clone, it has a number of highly interesting innovations.

The Ace comes in a rather large ABS case which looks like it was designed to withstand shelling. It's made up of two bits, the bottom part where the motherboard, power supply and keyboard live and an upper "hood" that contains the disk drives.

As such, aside from the necessity of having a monitor, this thing is a one piece system.

The first thing one notices about the ACE is that it has a lot of keys. There is a QWERTY pad, of course, and a numeric pad. The numeric pad can do double duty, as it is programmable in its shifted mode to be a cursor movement controller. You can, I'm told, set it up for any system you like, although it comes with the codes for moving the cursor in Wordstar.

The keyboard produces a full lower case character set from the shift key in both forty and eighty column mode, with a caps lock key for programming in Applesoft.

The system we got to play with came with two disks up in the hood and a dual disk controller, a combination serial/parallel port driver, a Z-80 card and 64K of RAM. On booting up it said ACE 1000, but it ran pretty much like an Apple.

Some of the software was quite interesting. There was all the usual stuff, and it all ran very well indeed. However, as this system was a bit of a fore-runner... the first in Canada, I think... there was no 80 column card in it. It did, however, come with a CP/M based program called 70COLUMN which, when run, produced a 70 column display on the screen by plotting the characters in high resolution graphics. They looked a little chunky but they were readable, and they moved around with no visible snow or weirdness. Clever, this.

The system comes with a very

good manual that augments the available documentation from Apple quite well. Whether for reasons of corporate pride, or, more likely, protection of the corporate behind, many of the usual Apple disk utilities have been renamed and slightly altered... this is all explained in the book. CP/M is explained very briefly, with the more common commands outlined. There are a number of cute drawings that make the thing seem real friendly. There's even a section that explains exactly how and where the system differs from a standard Apple, in case you run into freaky compatibility problems.

My favourite bit in the manual detailed the addition of a second disk drive to a single drive ACE. The disk drives, it seems, came packed in a very sturdy metal sleeve. The neat thing about this sleeve is how much it resembles a standard Apple type disk case. You remove this packing sleeve and bolt the drive to a plate in the disk hood.

This computer is a fairly good trip for anyone who wants to run Apple and CP/M based software in a sort of turnkey environment. It's probably not so good for those of us who get into playing with the peripheral cards and prodding around inside the case. The disk hood is a moderate pain, in this respect; you can't get at the peripheral slots without lifting it up, a bit of a chore. This invariably rips the disk controller out of its slots. Plugging cards involves some calisthenics in bending over the open hood and

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A Bunch of Fruit!

aiming for a slot, but this is probably good for you. Short people may have to stand on a box or develop a "leap and plug" technique.

Despite the fact that the ACE is made in the States, it is distributed by a Canadian company, which is a good trip. It is well built, and, it appears, well supported. If you want a no-hassle enhanced Apple clone and like having all the squirming creatures in one unbreakable cage, it's probably a very good system to consider.

The Orangepeel

The Orangepeel is a rather unique Apple compatible system. Built entirely in Canada, it involves a number of radical departures from the traditional fruit. At the very least, it's an interesting looking thing.

The Orange, first off, comes in two pieces. There's the keyboard, a very fancy hall-effect serial deal in which all the non-alphanumeric keys are bright orange. Everything else is tan. There is full shift key lower case and a caps lock feature for programming in BASIC ... complete with status LEDs to tell you what's happening. The keyswitches have a very comfortable feel. Then there's the main computer proper, a very low profile thing that looks like a TV converter of some sort. A coiled telephone-like cord connects the two. There is a phono jack to drive a monitor; alternately, an RF modulator can be plugged in to fondle a TV set.

The system will support the usual assortment of Apple peripheral cards but, as it turns out, rather few of them at any one time.

Old South

As it turned out, I didn't get to see as much of the Orange as I might have liked to. However, what there was was quite innovative. The case is made of some very clever extruded plastic which is held together with bolts and, when you get these out, with velcro. As such, getting inside the thing is a bit of a pain, and the system is probably not ideal for someone who is up for doing a lot of card swapping.

The heart of the Orange ... Oranges can't really be said to have cores ... is a single main motherboard which in no way resembles that of the Apple II. It holds the 6502 and allows a number of other things to plug into it. However, one thing it does not have is any place to mount ROMs. The Orange does not use pirate firmware by the simple device of its not having any firmware to speak of at all.

The top chunk of the memory bus, which is usually occupied by firmware in an Apple system, is dealt with by a piggyback board in the Orange which can access the address and data busses through pins prodding out of the motherboard. It holds 12K of RAM plus a boot PROM. When you boot the system it wants to load Applesoft or some other language from the disk into this area. As such, if you don't have a disk drive you're quashed ... it just sits there scrolling "Orangepeel Computer" followed, in rapid succession, by the names of the four guys who own the company that makes the thing.

However, as we found out much to our dismay, even if you do have a disk you may well be quashed. The system, as I have just observed, does not have any ROMs, and, as it happens, some disk controller cards will not run in a system which is ROMless. P.J. Heenan's card, otherwise quite respectable, is lost in such an environment. Many clone cards from the mysterious East don't seem to work either. The only cards which are sure to work are the proper Apple II controllers or exact clones thereof. There is some indication that Orange will release a controller.

The astute observer will, mayhaps, look at the case of the Apple II and then look at the case of the Orange and commence to wondering exactly how all that Apple stuff can fit in such a little box. It's simple; it doesn't. The Orange has been designed using much more modern ... denser ... ICs, and fewer of them, which improve its reliability considerably. However, those of keen orb will also note that the case is rather shorter than that of the Apple, which is to say, shorter than the average Apple peripheral card. One wonders how one can get seven peripheral slots into such a thing.

Well, one can't. In fact, the system only has three. They are set on a daughterboard that plugs into momma and puts the slots horizontally along one side of the case. The cards can be accessed by unbolting and de-velcroing a side panel. There are slots out the back to allow cables to exit the box.

This strikes me as a supreme pain for real peripheral card honchos ... and, with the low cost of these cards it's easy to become one. The lowest slot is permanently filled by the drive controller, leaving two blank ones. Add a Z-80 card and perhaps a printer interface and that's all she wrote. Swapping cards around a lot is not particularly convenient; you must either leave the side panel off or keep

fighting with the velcro.

There is fairly little to say about the documentation; what we got was a handful of photocopied pages. If you are sufficiently clever to be able to make sense of these you can probably figure out the computer for yourself. However, they were amusing in places and, we understand, proper documentation is due out shortly. Why do people always write the books last?

The Squeeze

The Orange is probably not a real hacker type hobbyist system. It is quite well suited for applications wherein one wants to use the system for something specific ... word processing, order entry, etc. In this sort of trip there is relatively little requirement for a large array of cards, and, usually, you aren't up for getting really low cost accessories; you can buy a drive card that you can be sure will run in it.

It's probably a fairly good choice if you are interested in a computer solely to write programs on ... there are a few other assembled systems available for its price. It would be a great box for schools, being much less easily pried open than a traditional Apple.

The system has the distinct advantage of its being built in Canada; if it commits smokey suicide one fine afternoon you don't have to ring up the sunny South to try to get a spare fuse. It's actually beginning to get a pretty good dealer network happening, so getting support for it probably won't be a problem. Overall, its construction is very sturdy, and it should take fairly kindly to strenuous work. Its detachable keyboard lends it to all sorts of applications where one does not want to have the system exposed to the real world.

Another distinct advantage in the Orange is that it does not fall into any of the ROM legality hassles. Thus, one can expect its creators to be around even if a future legal dartgame spells doom for the firmware banditos.

If you are considering the purchase of a fruit you should at least try an Orange. It has a lot to be said for it ... and some failings, as is the case with most systems.

One thing you can't deny, though ... those orange keys are a freak out.

The Orange is available from Altair Electronics, 660 Progress Avenue, Kingston, Ontario K7M 4W9, 1-(613)-384-3876 for \$790.00 plus provincial graft for Ontario residents.

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The APPLE II+ was one of the world's most popular home microcomputers. The brand new APPLE IIe is a redesigned and upgraded version of this computer. Some of the features common to both computers are: a 40x24 text display, 290x192 high resolution graphics in 6 colours, 40x48 low resolution graphics in 16 colours, a 6502 microprocessor, built-in keyboard, composite video output, built-in cassette interface, a joystick/paddle interface, and a full set of I/O bus connectors. It is all of these features that made the APPLE II+ so popular, and it is this that make the APPLE IIe compatible in all ways to the old machine.

The new features of the APPLE IIe are 64K of RAM on-board (instead of 48K), a full 64-key upper/lower case ASCII keyboard with auto-repeat that puts out all 128 ASCII codes and has 6 new keys (DELETE, "open-apple", "closed-apple", TAB, "up-arrow", and "down-arrow"), all logic circuitry built



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puter while the power switch is on, and a redesigned power back panel that gives the user better control of the cables coming out of his computer.

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- See Multiflex Slim-Line Disk Drive for the Apple II series on page 4.
- See the Multiflex Apple-compatible disk drive on page 4.



Slimline Disk Drives

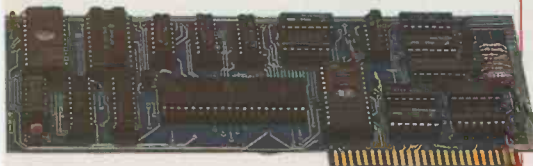
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- *Gives 80 columns and upper/lower case on your APPLE II/II + /Ile computer.
- *Works with PASCAL and CP/M.
- *Auto-switch between 40 columns and 80 columns.
- *Full inverse video.



The MULTIFLEX Video-80 card allows the user of an APPLE II computer to have an 80x24 text display with upper and lower case characters. This board allows the user to switch from a 40 column display to a 80 column display, and run PASCAL, CP/M and show APLESOFT programs in 80 columns.

\$99

Multiflex Drive for Apple

FEATURES:

- *SA400L base drive.
- *APPLE compatible.
- *Complete with case.
- *90 day warranty.

The MULTIFLEX APPLE-compatible disk drive is a standard Shugart SA400L which has been modified to work with the APPLE II/II + Ile computers. It is compatible and handles all the special protection disk operating systems that are in use (including those that use "half-tracking"). This drive, in a case, complete with a 90-day warranty is available with or without a controller card

Drive with controller \$549
Drive only \$349



16K RAM Card \$75

Expand your 48K APPLE to 64K. The MULTIFLEX 16K RAM Card allows other languages to be loaded into your APPLE from disk or tape. Allows APPLE CP/M users to run CP/M 56.



Multiflex Z-80 Card

This card allows the user to run Z80/8080 programs on his APPLE II/II + /Ile computer. Specifically, it allows him to run the CP/M operating system, with all its attendant software, such as word processors, accounting packages etc.

\$150

(CP/M not included)

Multiflex Semi Disk

FEATURES:

- *Fully compatible with APPLE computers
- *256K of fast dynamic RAM.
- *Works like 2 disk drives.

The MULTIFLEX SEMI DISK is a disk emulator board for the APPLE II range of computers. With its 256K bytes of RAM, it looks to the computer like two very fast disk drives. This makes the use of various data base programs, and other software that use more than one drive extremely easy because the wait time until the next module is loaded is minimal, thus increasing the productivity of the user immensely.

\$379

No software included

Multiflex EPROM Programmer

FEATURES:

- *EPROM programmer for APPLE computers.
- *Programmes 2716, 2732, 2732A, 2764.
- *ZIF socket for the EPROM.
- *Complete with software.
- *Built-in programming supply.

The MULTIFLEX EPROM Programmer Card for the APPLE II/II + /Ile computers allows the user to create his own software and then store it on an EPROM for use in another system. This card, with its on-board programming supply, can program 2716 (2K x 8), 2732 or 2732A (4K x 8), and 2764 (8K x 8). Included with the card is a disk full of software, which using menus allows the user to program or verify EPROMs, check if they are blank, set pointers anywhere in memory, and save or load memory ranges to/from the disk drive, making this unit a very versatile piece of hardware for the hardware developer or the hobbyist.

\$99

Apple II Printer Cards

MICROTEK APPLE DUMPLING CARD:

\$170

This card gives the user full control of his printer directly from his APPLE II/II + /Ile keyboard, including graphics and text screen dumps. It comes complete with a cable for a printer with a standard Centronics-style Interface.

ORANGE MICRO GRAPPLER +:

\$235

The Grappler+ Interface is uniquely capable of performing a wide range of both text and graphic commands, such as: Dual Hi-Res graphics; keyboard programming; DIP switch printer selection; Inverse, Rotated, or double sized graphics; skipover-perf; Left and right margin variation; and Variable line length.

PURE DATA PDA-232 SERIAL CARD:

\$95

The PURE DATA PDA-232 is a complete serial card for the APPLE II/II + /Ile computers. Its on-board software allows to make the APPLE into a dumb terminal, allows the APPLE to be accessed remotely or as a simple I/O device to allow connection to a printer, modem etc. It also allows for software and/or hardware baud rates and character types.

Check with our ads in Electronics Today and Computing now or call us for information on availability.

Monitors

BMC BM-12AU: \$125
A 12" green phosphor monitor with a 12 MHz bandwidth, which is ideal for the APPLE computers (in either 40 or 80 column mode).

ZENITH ZVM-121: \$165
A 12" green phosphor monitor with a 13 MHz bandwidth and a 40/80 column screen width selector switch works with just about any home microcomputer on the market today.

AMDEK COLOUR-1: \$569
A 13", medium resolution, composite video colour monitor with a built-in speaker, which gives a great colour picture with just about any computer.

ELECTROHOME RGB COLOUR MONITOR/BOARD SET:
The Electrohome ECM 1302 colour RGB monitor and SUPERCOLOUR interface board allows the user of an APPLE II computer to get a high quality colour picture out of his computer.
Call for price

Diskettes

5 1/4":	per box of 10
Maxell MD-1 (SSDD)	\$55.00
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Control Data (SSDD)	\$70.00
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Maxell FD-2 (DSDD)	99.00
Ectype (SSDD)	65.00

Quantity discounts available

Memory Chips



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2114L - 200 ns (1kx4 static)	2.49
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2016 - 150 ns (2kx8 static)	8.75
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2708 - (1kx8) EPROM	5.75
2716 - (2kx8 EPROM single + 5V)	4.95
2732 - (4kx8 EPROM single + 5V)	8.69
2532 - (4kx8 EPROM single 5V)	8.95
2764 - (8kx8) EPROM single 5V)	13.95

Modems

HAYES SMARTMODEM: \$399
This is an RS232C, 300 baud, direct connect, intelligent modem. It can answer calls, dial numbers, receive and transmit data and disconnect... all automatically. The SMARTMODEM is also a true direct connect modem - that means that it plugs directly into a modular telephone jack, not a specialized telephone. Thus much less noise and more reliable reception.

HAYES MICROMODEM II: \$499
This unit has all the features of the Hayes SMARTMODEM, but on a single card which plugs directly into one of the expansion slots of an APPLE II/II+/IIE computer. It comes complete with software to allow you to use the modem as soon as you plug it in, or develop your own applications software.

NOVATION APPLE-CAT: \$569
An intelligent modem which plugs right into your APPLE II/II+/IIE computer. All auto functions are supported, as well as an RS232 port. A BSR x10 controller, a telephone handset and an extra board to enable 1200 baud service are all options for this unit. It also comes complete with self-prompting software.

NOVATION AUTO-CAT: \$399
A truly automatic direct-connect modem using a state-of-the-art, all-digital, crystal controlled design. All you need to do is plug it to your computer and a modular telephone jack and away you go!



NOVATION ACOUSTIC CAT: \$249 (300 BAUD)

ECONO MODEM
300 baud, acoustic coupler, attractively packaged, (uses +5, +12, -12 voltages from your computer).
Limited time offer only: \$59

MULTIFLEX MODEM: \$149
The MULTIFLEX Modem is a 300/600 baud, direct connect, originate/answer modem. Based on the MC6860 IC, its design make it inexpensive and extremely reliable, and allows for many functions such as auto answer and disconnect. Its small size allows it to be install in just about any location so that there is a great deal of flexibility about this unit.

Multiflex Low-Cost Logic State Analyzer

You've just completed a microprocessor system, and it doesn't work. What next? You can use an oscilloscope to check for clock signals and the like, but if everything appears to be in order you can't go much further without sophisticated equipment. In these situations, professionals turn to their logic state analyzers, each of which cost thousands of dollars. MULTIFLEX has the answer for all those people who don't want to take a mortgage on their house just to get a computer working. The MULTIFLEX Logic State Analyzer has all the essential features of those more expensive units at a fraction of the cost. This is a high-quality piece of test equipment, suitable for industrial or scientific use, but its price is well within the price range of a hobbyist.

Easy to understand and operate, the Logic State Analyzer allows you to monitor 16 points in a digital system (ie. data and/or address bus, or control lines) which carry continually changing signals. You can select a bit pattern you expect will appear at these points. Once the pattern appears the Analyzer will trigger and record ("freeze") the next 1023 bit patterns so that they can be examined step by step even though data is no longer available in the unit being examined. For software development the Analyzer is invaluable, especially in dedicated systems.

If you design a microprocessor system for a specific function, and you have no monitor, assembler or other such software, the best and often only way to debug the system is to use a logic analyzer. It will let you look closely at the data flow as a program is executing, or monitor the address lines to make sure that the instructions are being executed in the proper sequence. The various control lines such as memory read and write, DMA, interrupts, or enable and disable signals can also be examined. You can, of course, monitor any combination of these signals, such as the data bus and half of the address bus, or half of each plus 4 control lines. The combinations are endless.

A special feature of the MULTIFLEX Logic State Analyzer is that any number of units can be interconnected for dealing with larger input words. With two Analyzers, you can monitor the address and data bus of an 8-bit processor at the same time and have 8 spare signals to monitor the control lines, I/O signals or signals from external devices. Anyone who will be doing any systems debugging should take a close look at this unit, since its features and low price tag make it an asset.

**Kit with case \$295
A&T \$395**



Exceltronix

Software for Apple® Computers

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Spellstar (req. Z80 Card) 224.95
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Wordstar (req. Z80 Card) 424.95

MUSE:

Address Book \$57.95
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ON-LINE SYSTEMS:

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APPLE:

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OMEGA MICROWARE:

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The Inspector 84.95
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Bag of Tricks \$49.95
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SENSIBLE SOFTWARE:

Super Disk Copy III \$39.95

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Disk 64.95

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largest ranges of
software in
Canada.**

Multiflex 64K/Static RAM Card Kit

This is one of the new high technology boards in the MULTIFLEX line of IEEE 696/S-100 compatible computer board kits. Using the new 2K x 8 static RAM chips, the user can have 64K worth of RAM in his system without having to worry about the timing problems caused by refreshing. In the standard kit the user is supplied with CMOS 6116 chips so that with the optional battery backup circuit, memory can be retained up to one year after a power down situation occurs. Other features include a deselect feature for each 2K chip (in the range C000H to FFFFH) so that the RAM card does not conflict with system EPROMs and the fact that any RAM chip can be replaced by a standard 2716 EPROM. A battery charger circuit is provided for the batteries used in the power down back-up circuit. Also, the board may be disabled during memory-mapped I/O operations by use of the S-100 "phantom" signal. This board is a very inexpensive way to add 64K worth of RAM to your S-100 system.



Kit with 16K \$325
Kit with 32K \$400
Kit with 64K \$499
A&T with 64K \$599

Multiflex Floppy Disk Controller Kit

The MULTIFLEX floppy disk controller is a state-of-the-art IEEE 696/S-100 compatible board. It allows the user to interface, simultaneously, up to four (4) 8 inch or 5 1/4 inch disk drives in any combination to his system with the flexibility of single/double sided and single/double density operation. If desired, all operations can be done using DMA techniques with the optional on-board controller or under processor control. Latest technology has been used in this design. The board is designed around the FD2793 controller chip for easy use under any operating system. However, this board is especially designed for easy use with the CP/M or MP/M operating system (available as an option) and the MULTIFLEX Z80 computer kit. With all these features and its reasonable cost, this board is one of the best buys in a floppy disk controller board on the market today.

Kit \$295. A&T \$395
DMA Kit \$29.00
CP/M (with BIOS) \$169

Multiflex Economy Video Board

This is yet another of the exciting new IEEE 696/S-100 compatible products from MULTIFLEX Tech. Inc. This board is an intelligent, I/O mapped, 80 x 24 Video Display Board. Based on the 8275 programmable CRT controller, the 8257 programmable DMA controller, and a Z80 processor, this board has many extremely useful features that are extremely simple for the user to implement. Provided on board is 8K of static RAM which gives the user 3 1/2 screens of text. With simple commands, the user can easily scroll around in this buffer, clear the present page and home, home on the present page and go to the beginning of the buffer. There are also 4 field attributes (blink, reverse video, underline, and highlight) which can be turned on and off by software. Other software commands include a carriage return, line feed, clear to end of line; transmit cursor location; transmit character at cursor location; position cursor; disable control functions; reset control register; as well as all the standard functions such as tab return, line feed, and backspace. Also included in the software is a debug/setup program which completely tests the board and allows the user to set up various parameters on it. The output from the board is in either composite video or a video signal with separate horizontal and vertical sync signals (either normal or inverted). All this makes this board a superb value in an S-100 video board.

Kit \$295
A&T \$375

Zilog CPU Card Kit

MULTIFLEX is pleased to announce its new IEEE 696/S-100 based processor card kit using the ZILOG series of processors and support chips. The Z80 processor can be jumper selected to run at 2 or 4 MHz. Also selectable, on 4K boundaries is the reset/power-on jump. There are 2 Z80-PIO parallel port chips on board which provide 32 fully programmable I/O lines. One (1) RS232 port and 1 TTL-level serial port are also provided for by use of a Z80-DART integrated circuit. If the user wishes to have synchronous serial data transfer, he can simply replace the Z80-DART with a Z80-SIO/0 and he will have all the standard features of the DART along with synchronous data transfer. There is no RAM provided for on-board, however there is a space for an EPROM which can be selected to be either a 2716 (2K x 8) or a 2732 (4K x 8). Also, the board takes full advantage of Z80 vectored interrupts and priority arbitration.

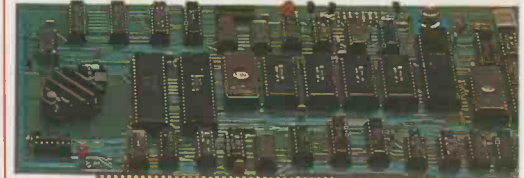
Kit \$275
A&T \$350



Floppy Disk Controller Kit



Zilog CPU Card Kit



Economy Video Board

MULTIFLEX VIDEO CHARACTER DISPLAY BOARD

The MULTIFLEX Video Character Display Board is a superb value in the IEEE 696/S-100 video board market. It's features include an on-board Z80 microprocessor, 6845 CRT controller, 12K of screen RAM, and up to 16K of program EPROM. A 4K EPROM character generator and a 4K RAM character generator are also provided for. The 80 x 24 screen allows 4 attributes (inverse video, blinking, underlining and highlighting) to be applied to each character. Text display is not the only thing you can do with this board, since it allows for up to a 256 x 192 graphics display as well.

Also available is an optional piggyback board, which provides 2K more of program RAM, a Centronics-style printer port with 2K of print spooling buffer, a full RS232 serial port, and a full colour video interface in 16 colours, with output in either RGB or NTSC form. A light pen interface is also provided.

Multiflex Video Character Display Board Kit:

Main Board Kit \$295
Piggyback Colour Board kit \$195
Both A&T \$649

Excellent selection of CMOS, TTL, Linear, Transistors and Passive Components.



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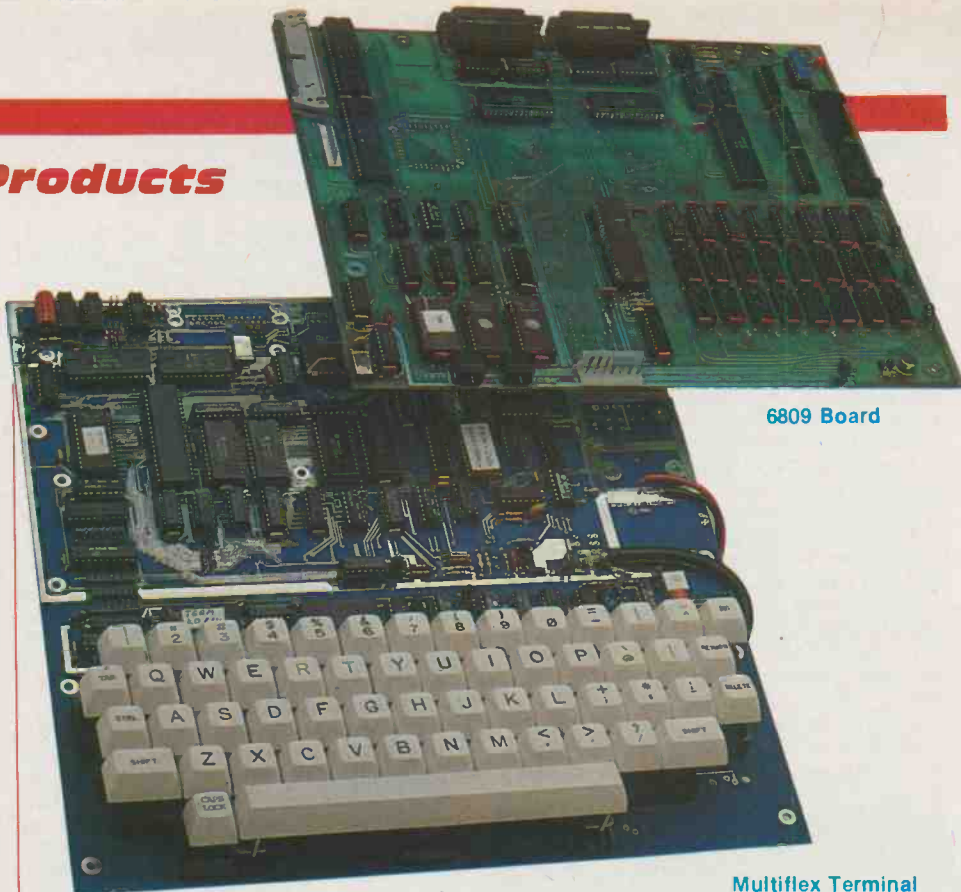
Multiflex Products

Multiflex Economy Video Display Terminal Kit

Now available from MULTIFLEX is an economy video display terminal. Originally designed as a low cost access unit for our soon to be operational computerized mail-ordering and bulletin board system, this terminal is a semi-intelligent system which is controlled by a Z80A microprocessor and a 6845 CRT controller chip. The keyboard is fully ASCII encoded and the character generator contains the full 128-character set as well as a 128-character alternate set both of which are in the 5x7 dot matrix format. The screen display is 80 characters by 24 lines if the unit is hooked to an external monitor (not included) or 64 by 24 if run through an RF modulator to a TV. There are 3 software selectable attributes (dim, reverse video, and alternate character set) which can be chosen one at a time for the whole screen. This attribute can then be switched on and off for each individual character. A 2K buffer is provided for normal operation. However when the optional 6K memory upgrade is purchased, 4 screen pages can be loaded from the host machine, edited locally, and then downloaded back to the host again saving on connect time and phone line bills. Also included are 2 RS232 ports: one for a modem and one so that a printer can be attached to the terminal. The baud rates on these ports are software programmable and can range from 110 to 9600 baud. The MULTIFLEX Video Display Terminal has provision for an on board modem freeing a serial port. With all these features, you would expect to pay a lot for this kit, but all this is available to you, complete with a case, for an extremely low price.



Kit \$259
Kit & Case \$289
A&T plus case \$369



6809 Board

Multiflex Terminal

U of T 6809 Single Board Computer

The 6809 Single Board Computer, designed at the University of Toronto and distributed exclusively by EXCELTRONIX, is a compact hardware unit which was designed originally as a lab board for teaching students about microprocessor systems. Its many features, however, make it an ideal unit for stand-alone control applications or software development systems as well.

The system is designed around the Motorola MC6809 microprocessor. This is an 8-bit processor with full 16-bit internal architecture, 2 Index registers, 2 stack pointers, 2 8-bit or 1 16-bit accumulators, a direct page register and a wide range of addressing modes, including a program-counter-relative mode. This mode allows the user to write completely position independent software, important in systems software development.

There is provision for up to 48K bytes of dynamic RAM on-board. The refreshing of this RAM is controlled by an 8202 Dynamic RAM Controller. This chip allows for completely transparent refreshing of the RAM (ie. no wait states to slow the system down). There is also provision for up to 12K of EPROM using either 2532 or 2716 chips.

There are 4 complete I/O circuits built onto the board. 2 of them are serial (RS232); one is used for a terminal (which is required for use of the board with the supplied monitor software), and the other one is user defineable, but it is set up to

communicate with either a modem or a printer. Also on-board are 2 6522 VIA chips. These provide 2 parallel ports per chip along with 2 16-bit timer/counters. One of the parallel ports and one of the timers are used by the monitor software to provide a cassette interface (which operates at 300 baud). The second parallel port on that chip is wired into a connector which is ideal for interfacing a parallel printer or keyboard. The 2nd VIA is not used at all and is completely free for the user. For further expansion of the system, a fully buffered version of the CPU signals (data, address, control lines and a signal indicating whether or not the current address is located on the board) is available at a cable connector.

The software provided with the system is in a 2532 EPROM and allows the user to: test the memory; dump blocks of memory; examine and modify single memory locations; read or write from the cassette port; set and examine breakpoints; single step and/or execute machine language programs and set and examine the processor registers. All this is accomplished through a 9600-baud terminal interface (one of the serial ports) included is a full screen editor/assembler which allows the user to work in 6809 assembly language rather than machine language. All this makes this board an ideal trainer, control unit or software development unit for just about anyone.

Kit with 16K \$769
A&T with 48K \$499

Special Pricing is available when both items on this page are purchased together

Printers

OKI DATA Printers:

ML82A \$599

- 120 c.p.s.
- 9 x 9 Dot Matrix
- 9" platten

ML92 \$789

- 160 c.p.s.
- 9 x 9 Dot Matrix
- 4 character sizes

ML84 \$1495

- 136/231 c.p.s.
- 9 x 9 Dot Matrix
- 13½" platten
- 2 character sizes
- Serial or parallel interfac

Star Gemini — Series Printer:

Star Micronics Ltd. has now announced a brand new series of printers: the GEMINIs!. These printers are EPSON MX series compatible, and have two additional features: a built-in 2.3K byte buffer and proportional spacing with correspondence quality print. This makes this unit suitable for just about any purpose that you could require a printer for. There are two models: the GEMINI-10, with an 8½" platten, and the GEMINI-15 which has a 15" platten. Both of these machines run at 100 cps with an 100% duty cycle.

Epson FX — Series Printers:

EPSON has upgraded their very popular MX-series of printers and made the new series: the FX's. A number of new and exciting features are built into these machines, such as 160 cps print speed, proportional spaced printing, quad-density bit-map graphics, quiet mode printing so that the print can be used in an environment where noise is a problem, and user defined characters sets (up to 256 characters).

Smith-Corona TP-1 \$850



The Smith-Corona TP-1 is the ultimate in low-cost letter-quality printing. This daisy wheel printer is available with either a parallel or a serial interface so that it can be attached to just about any computer

easily. The speed of the unit is 12 cps and it prints at 10 cpi. The TP-1 was designed for the person who needs a daisywheel printer but doesn't have a lot of money to spend and that's just what it delivers.



EPSON MX100



EPSON FX80

PRINTERS

EPSON MX80 (8.5" dot matrix) c/w GRAFTRAX +	\$759.00
EPSON MX80 F/T (8.5" dot matrix) c/w GRAFTRAX +	869.00
EPSON MX100 (15" dot matrix) c/w GRAFTRAX +	995.00
EPSON FX-80 (8.5" dot matrix)	925.00
STAR Gemini-10 (8.5" dot matrix)	615.00
STAR Gemini-15 (15" dot matrix)	795.00
Okidata u82A (8.5" dot matrix)	599.00
Okidata ML92 (9" dot matrix)	789.00
Okidata ML84 (13.5" dot matrix)	1495.00
Smith-Corona TP-1 (13" daisy wheel)	850.00

PRINTER ACCESSORIES

EPSON 8145 2K Serial Board	\$189.00
EPSON 8155 4K Serial Board	250.00
EPSON MX80 Ribbon	15.00
EPSON MX100 Ribbon	25.00
EPSON MX80 Printhead	75.00
EPSON MX100 Printhead	100.00
8.5 x 11" Printer Paper	45.00
15 x 11" Printer Paper	60.00

Call for prices on interface boards for particular computers!



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New Products Available Soon

Disk Drive and Controllers for TRS-80® Model III at an unbelievable Price

IBM® Compatible Peripheral Boards

Disk Drive and peripheral for the PET®

Complete Satellite TV Receiving System for less than \$1000!

New Double Density Osborne 1 Personal Computer

The OSBORNE 1 Personal Business Computer was designed, built and priced with just one objective: to make you more productive in your work, business or profession. The OSBORNE 1 system is delivered with the hardware and software you need to get to work right away. The programs supplied with the OSBORNE 1 are easy to learn, and easier to use. The OSBORNE 1 is totally CP/M compatible which allows access to thousands of software packages that have been developed to run under this disk operating system.

The standard features include: * a Z80A microprocessor running at 4 MHz * 64 Kbytes of RAM * dual double density floppy disk drives each capable of storing 158 Kbytes of information (approx. 55 pages of typed, double-spaced text) * an RS232C asynchronous serial port for connection to serial printers, or any other device using this industry standard interface * a modem interface port for easy attachment of a modem which permits inter-computer communication * an IEEE 488 interface for data communication to test instruments or parallel printers * a clear, 5 inch, 24 row green screen, which will display a 52 character window on a 128 character line with automatic scrolling * a standard typewriter style keyboard * a numeric keypad * cursor control keys * 10 programmable function keys * a fully por-

Osborne \$2395



Special: \$2549 Including 12" Monitor & Video Adapter

table case * a complete, well written users manual * and five (5) disks full of software!

The software packages included are: **CP/M:** The world's most widely used disk operating system, which is now considered an industry standard. Not only do you get the disk operating software, also included is an ASCII file editor, an 8080 assembler, a **Dynamic Debugging Tool (DDT)** for use in machine language debugging/disassembling, a file transfer program, and lots more.

WORDSTAR MAILMERGE: This powerful, easy-to-use word processor has been ranked one of the best on the market. MAILMERGE is an added feature for producing form documents and labels, and merging separate files of data into a single document.

SUPERCALC: SUPERCALC is a management-oriented software tool that provides the user with the means to manage and manipulate data interactively in the spread-sheet format.

OSBORNE 1™

CBASIC: A commercially oriented BASIC compiler/interpreter which comes with the compiler, a run-time monitor and a cross referencer for listing all the variables in the source program.

MBASIC: (BASIC 80) The industry standard BASIC by MICROSOFT which supports enhanced features such as random disk I/O, line editing, single and double precision floating point math, and direct CPU, I/O or memory control.

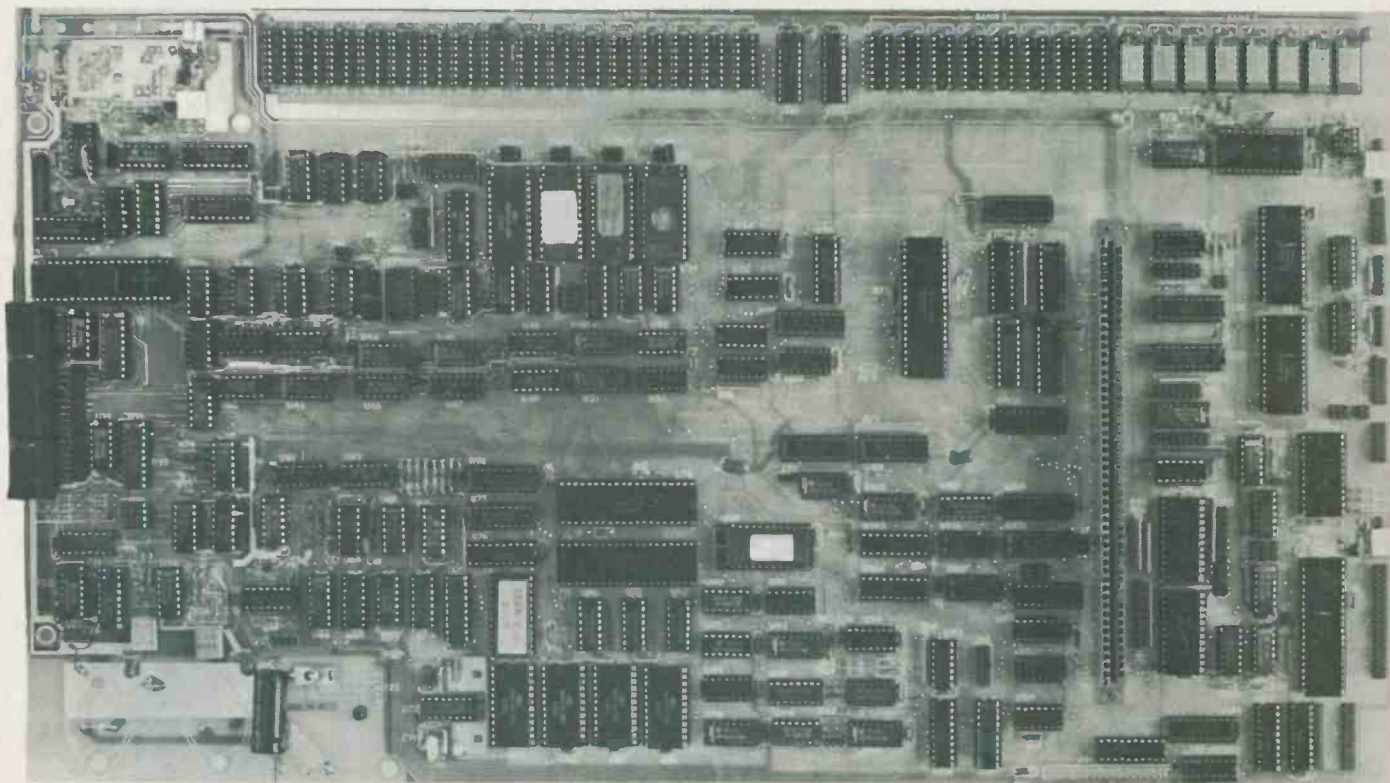
Osborne I Hardware

Osborne 1 with Double Density	\$2395.00
MULTIFLEX Video Adapter	19.00
Serial Printer Cable	35.00
Parallel Printer Cable	40.00

Multiflex Products

Multiflex Single Board Computer

Kit with 64K \$599
A&T with 64K \$795
CP/M (with BIOS) \$169



FEATURES:

- *Full IEEE S-100 bus for easy expansion.
- *Up to 256K of on-board dynamic RAM.
- *Processor speed 4 MHz.
- *Memory management for up to 16M bytes of memory.
- *3 16 bit timer/counters.
- *2 RS232C serial ports.
- *24 line parallel port.
- *Real time (time-of-day) clock.
- *Floppy disk controller.
- *80x24 video display.
- *512x512 bit-map graphics
- *Print spooler.
- *Optional RF modulator.
- *Priority interrupts.
- *Fully CP/M compatible.
- *Many jumper-selectable hardware options.

The MULTIFLEX Single Board Computer is among the new breed of state-of-the-art Canadian computer products. With a Z80 series microprocessor, 64K of dynamic RAM, a full featured floppy disk controller and a 80x24 video section, all on the board, this unit makes an ideal low-cost system for the CP/M operating system.

The memory section has a number of unique features rarely to be found on any other machine. The circuitry is provided on-board for up to 256K of dynamic RAM (using 4164 64K x 1 chips). Jumper options allow the user to select one of three options with regard to wait states (no wait states, wait states on operation code fetches, or wait states on all memory accesses) so that the user can configure his system to his requirements. Four jumper-configurable sockets are furnished as well. Any mix of 6116/2016 (2K x 8 RAM); 2716 (2K x 8 EPROM); 2732 (4K x 8 EPROM) or 2764 (8K x 8 EPROM) can be placed in this socket, which can be enabled to shadow any other memory which would be addressed in these locations. It is also possible to disable these sockets in software, if the user wishes to do so. Full memory management is available on the board which can turn the Z80's standard 64K address space into the full 16 Mbyte 24-bit address space allowed by the S-100 bus standard. This memory management applies to the 256K RAM on-board, all other on-board memory, and all memory on the S-100 bus.

The board also contains a full-featured floppy disk controller. Based on the WD1793 IC, this section will handle any combination of 8" or 5 1/4" drives, whether they be single or double density or single or double sided. The newest technology was also used in designing the data separator circuit. This circuit is all-digital, allowing extremely reliable use in the double density mode. The floppy controller is fully compatible with both CP/M, giving the user full flexibility as to what operating system he wants to run.

For interfacing to the real world, the user is again given the flexibility to configure the system to his own needs. Supplied are 3 independent software and/or hardware controlled 16-bit timer counters, 2 of which are used to generate the baud rates for the 2 on-board RS232C serial ports. Both of these ports are programmable for either synchronous or asynchronous operation. A full 24-line software controlled parallel port and a real time (time-of-day) clock, which can be backed up with batteries if the user so wishes.

The real-time clock, the floppy controller, the timers, and any other



Exceltronix

Multiflex Single Board

I/O port can be chosen to operate in a software selectable priority interrupt scheme. A second interrupt controller allows the on-board interrupts to be vectored with and other interrupts from external S-100 bus boards in a jumper selectable priority.

There is a full video section on the MULTIFLEX Single Board Computer as well. A second Z80 processor is used along with a 6845 CRT controller, giving the user a variety of features. Up to 8K of EPROM can be used to control the section, allowing emulation of a variety of terminals or room for custom display routines. 8K of static RAM is also provided for, this being used for the display buffer,

the Z80's work area, and a print buffer. The print buffer can be used for the built-in Centronics-type printer port in the section. An ASCII keyboard port is also provided. The character generator on the board provides up to 256 characters and symbols, which are user-programmable since they are in a 2732 EPROM. The video output is available in two forms: a composite video signal, and the separate sync and video signals, allowing the board to be used with a variety of monitors. As well, circuitry for an optional RF modulator is provided on-board, for easy connection to a TV set. The actual display format in text is 80 characters by 24 lines.

But, a 192 by 256 pixel graphics mode is also made available to the user. The resolution of this graphics mode can be changed by the user by providing additional software. A full, general, graphics interface (for joysticks, digitizing tablets, touch panels, etc) and a light pen input are provided so that user—friendly software is easy to implement on the system.

Overall, the MULTIFLEX Single Board Computer, with its numerous features can be many things to many users, from a full-featured Z80 development system to a very powerful CP/M based computer.

Multiflex 5¼" & 8" Systems.

We, at MULTIFLEX, are pleased to announce two new assembled and tested configurations of our new Single Board Computer systems. **These systems are based on the MULTIFLEX Single Board Computer, a description of which is given on page 11.**

THE TRAVELLING SYSTEM:

The first configuration is a portable, unit. It will provide for two slim-line 5¼ inch double-sided, double-density disk drives, mounted side-by-side vertically, a nine inch video monitor in the middle, and internally at the other end, room for an optional S-100 backplane which can plug into the Single Board Computer (it is terminated in a S-100 female card-edge connector). The backplane can hold up to 4 additional S-100 boards (extra memory, A/D + D/A, colour video, etc.). A switching power supply can be mounted internally and a hinged external keyboard along the front is part of the package. All this will result in a portable system which runs CP/M and all its compatible software.

\$1850

THE BUSINESSMAN'S SYSTEM:

The second system is a full configuration business system. Included is a fully configured **Single Board Computer** complete with 256K bytes of RAM, a 4MHz Z80A processor, and all of the other exciting features of this remarkable system, including the CP/M operating system. Also included are two 8" slim-line double sided,



double density disk drives (SA860) and a powerful switching power supply. External connectors are provided for an ASCII keyboard, an external video monitor, extra external disk drives, two RS232C ports, and a Centronics-style printer connector. All of this gives the serious system user all the advantages of a fully loaded CP/M system in one small package.

\$2895

THE SYSTEMS INTEGRATOR PACKAGE:

This configuration is suitable for systems developers or hobbyists wanting a powerful packaged system.

It consists of three of our S100 cards: CPU Board with 64K of RAM on board, economy video board, floppy controller board and our six slot backplane. It also includes a keyboard and CP/M and a portable 12" Zenith green screen monitor. It comes complete with two 8" double sided, double density disk drives, and a very powerful switching power supply. This system allows the user to develop and test easily what ever circuitry he wants within his system. All the standard external connectors are provided, so that expansion and connection of external devices is simple.

\$2950

Multiflex Super System



All this for an incredible \$1195

Nowhere in Canada, can you find a computer value such as this one. The **MULTIFLEX Super System** is the ideal computer for the person who wants to get the most for his system dollar.

The package consists of: the **MULTIFLEX Z80 Computer Kit** c/w 64K of dynamic RAM, the **MULTIFLEX Economy Video Board**, the **MULTIFLEX Floppy Disk Controller Board**, 1 5/4" disk drive (either a SA400L or an SA200), and CP/M complete with the **MULTIFLEX BIOS**. All of this makes a fully expandable CP/M-based IEEE 696/S-100 system, that is on par with any on the market, but which costs much, much less.

The **MULTIFLEX Z80 Computer Kit** is the heart of this powerful system. Its special features include an EPROM programmer (which will handle any EPROM from a 2716 up to a 27128), 4 S-100 slots, a 40-chip wire-wrap area, 2 built-in parallel ports, up to 3 optional RS232 ports, a hex keypad, 16 function keys, a hex address/data display, a Z80 processor (and which can run at 4 MHz), 64K of dynamic RAM, optional memory management, an optional real-time clock, and room for up to four IEEE 696/S-100 cards.

The **MULTIFLEX Economy Video Board** gives the user an 80 character display on a standard composite video monitor. The board emulates a standard terminal, which allows the user to configure his software to run extremely easy on his system. A

number of attributes, such as inverse video, highlighting, underlining, and blinking characters. There is enough on-board RAM to allow for up to 3 1/2 pages of text to be stored on the board, making local editing a breeze. A keyboard also contained on the board for easy interfacing of just about any ASCII keyboard.

The **MULTIFLEX Floppy Disk Controller Board** is a full featured floppy disk controller board. It allows use of 8" or 5 1/4" drives, whether they be single or double density or single or double sided, in any combination (up to a maximum of 4 drives total). The board is based on the WD2793 disk controller IC and the FDC9216B integrated disk data separator IC, which makes this board extremely reliable and versatile.

The other items in the package include a 5 1/4" single-sided, double-density disk drive (either an SA400L or an SA200) and the CP/M 2.2 operating system complete with the **MULTIFLEX BIOS**. This BIOS allows the user to mix and match his disk drives and even read (or write) the OSBORNE 5 1/4" disk format, which gives the user a more extensive selection of software.

The **MULTIFLEX Super System** is ideal for the computer enthusiast, hobbyist, educational institutions or the serious computer user who is looking for a low-cost way to enter the world of CP/M computing, with an expandable and versatile system.

* BASIC EXTRA OPTIONS

Multiflex Keyboard (with duplicated numeric keypad)	\$120
Keyboard (without numeric keypad)	\$99
Keyboard Case (for either of above)	\$35
Power Supply (5V 6A, +15 3.7A, -15V 3.7A) Includes case and RF filter. Ideal for this system.	\$139
Zenith 12" Green Monitor (10% off this price if purchased with system)	\$165

Huge Selection of Options Available

Hardware

1. Piggyback board with 2 serial ports and real time clock (kit) \$120.00
2. Economy RS232 expansion board (kit) \$35.00
3. DMA (kit) \$29.00
4. High resolution graphics board. Details on request
5. DC-DC convertor for programming EPROMs \$19.95

Plus Many More — Runs Virtually all S-100 Cards.

Software

1. BASIC (running under CP/M)
 2. WORDSTAR (Word Processor)
 3. SUPERCALC (Spread Sheet)
- Plus Many More.



Exceltronix

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Multiflex 68000 System

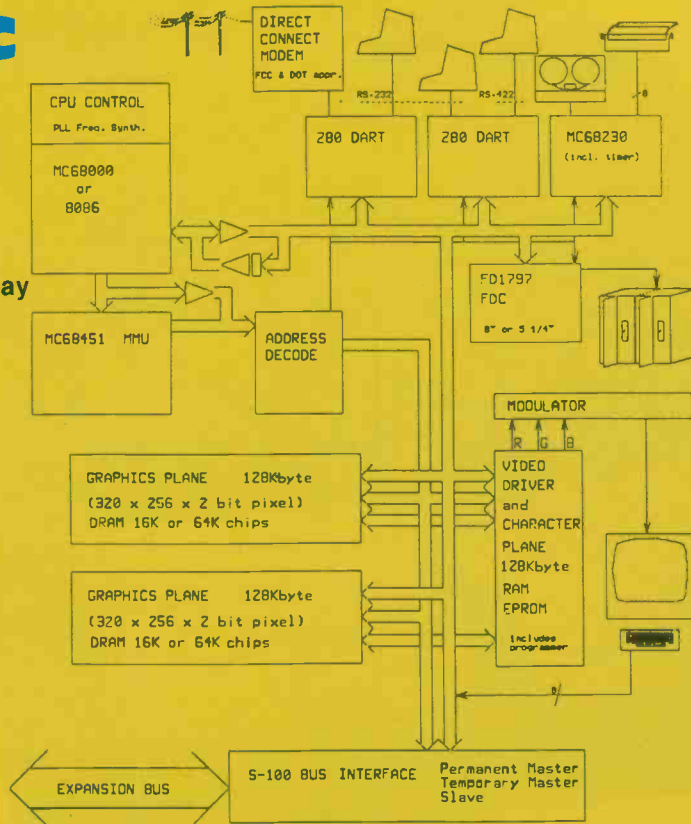
FEATURES:

- *Works with either of the two major 16-bit microprocessors: the MC68000 or the 8086.
- *Speed from 2-12 MHz.
- *Maximum of 16M bytes of memory.
- *4 serial ports on-board.
- *24-bit counter/timer on-board.

- *Centronics printer interface.
- *Cassette interface.
- *Full floppy disk controller.
- *82x25 text display.
- *320x256 pixel, 4 colour graphics.
- *RGB or composite monitor interface.
- *Various operating systems available (CP/M-86, XENIX, MS-DOS).

**Basic
Kit
\$695**

Price and specification may change without notice.



The **MULTIFLEX 68000/8086** Single Board Computer allows the user to enter the exciting new world of 16-bit computing at an impressively low price, with the option of making his system very powerful very easily.

The most important feature of this system is the processor, or rather the choice of processors. There is a choice of two: a Motorola MC68000 or the Intel 8086. Both of these processors run at speeds ranging from 2 - 12 MHz. This choice allows the user to pick the processor to fit his specific needs.

The 68000 is Motorola's venture into the world of 16-bit microprocessors. The 17 internal registers are divided into two groups; a group of 8 32-bit data registers (which can be used in 8, 16 or 32 bit segments) and a group of 7 address registers and 2 stack pointers. There are two stack pointers so that the system software and user's software can

maintain separate stack and not interfere with one another. A separate 16-bit data path and 24-bit address path are built into the 68000, so that no external de-multiplexing is necessary, which help keep the throughput of the processor high. This allows this microprocessor to be used in a multitasking or high-level language environment with great ease.

The 8086 microprocessor is an upwards-compatible member of the 8080 series of microprocessors. This means that there is software compatibility (at the source code level) between this 16-bit unit and the earlier 8-bit microcomputers. The register layout of this machine is similar to the 8080, but the registers are 16-bits wide instead of 8-bits. Directly, with its multiplexed address/data bus, the 8086 can address up to 1 Mbyte of memory.

The basic system comes with a

comprehensive 68000 monitor in EPROM which creates an ideal basis for the user, who wants to learn how to use a 16 bit system and who wants to eventually expand it.

A full 16 Mbytes of memory can be addressed by the combination of the processor and the 68451 Memory Management Unit. Of this memory, there are 7 sockets (each of 16K bytes size) which can be set up for either RAM or EPROMs. Also 5 of these sockets can be strapped to program EPROMs. The maximum on-board RAM is 300K bytes. The fully extended S-100/IEEE 696 bus on the board allows for another 15M bytes worth of memory. All of this memory give the user complete flexibility for whatever application he has in mind.

This board also has an amazing assortment of I/O features. Four serial ports are included on the board, each with individually programmable baud rates. Two of these ports are setup with RS232 drivers, one with a RS422 driver, and one is set up for an optional onboard direct connect modem. Also onboard is a parallel port controller that is wired up as a Centronics-type printer port and also handles a cassette interface. A 24-bit programmable timer is also included so that user timing functions (such as a real time clock) can be set up. Also included on-board is a full-featured floppy disk controller. This controller will handle up to 4 drives (either 8" or 5 1/4") in either double density or single density modes with either double or single density drives.

The video section on the **MULTIFLEX 68000/8086** Single Board Computer is another very impressive feature of this system. An RGB monitor, a composite video monitor, and an RF modulator are all provided on-board. For text display, the user gets an 82 character by 25 line screen (41 x 25 through the RF modulator). All characters on this display can have up to 4 attributes (Inverse video, Highlight, Underline, and Blink) and each character be in one of 4 colours. The character generator for all characters is in RAM, so that user defined characters are a breeze to create and use. Also supported are full 4-colour graphics with a 320 x 256 pixel resolution. There is an ASCII parallel keyboard interface on the board as well.

All of these features make the **MULTIFLEX 68000/8086** Single Board Computer Canada's leader in the new 16-bit computer technology.

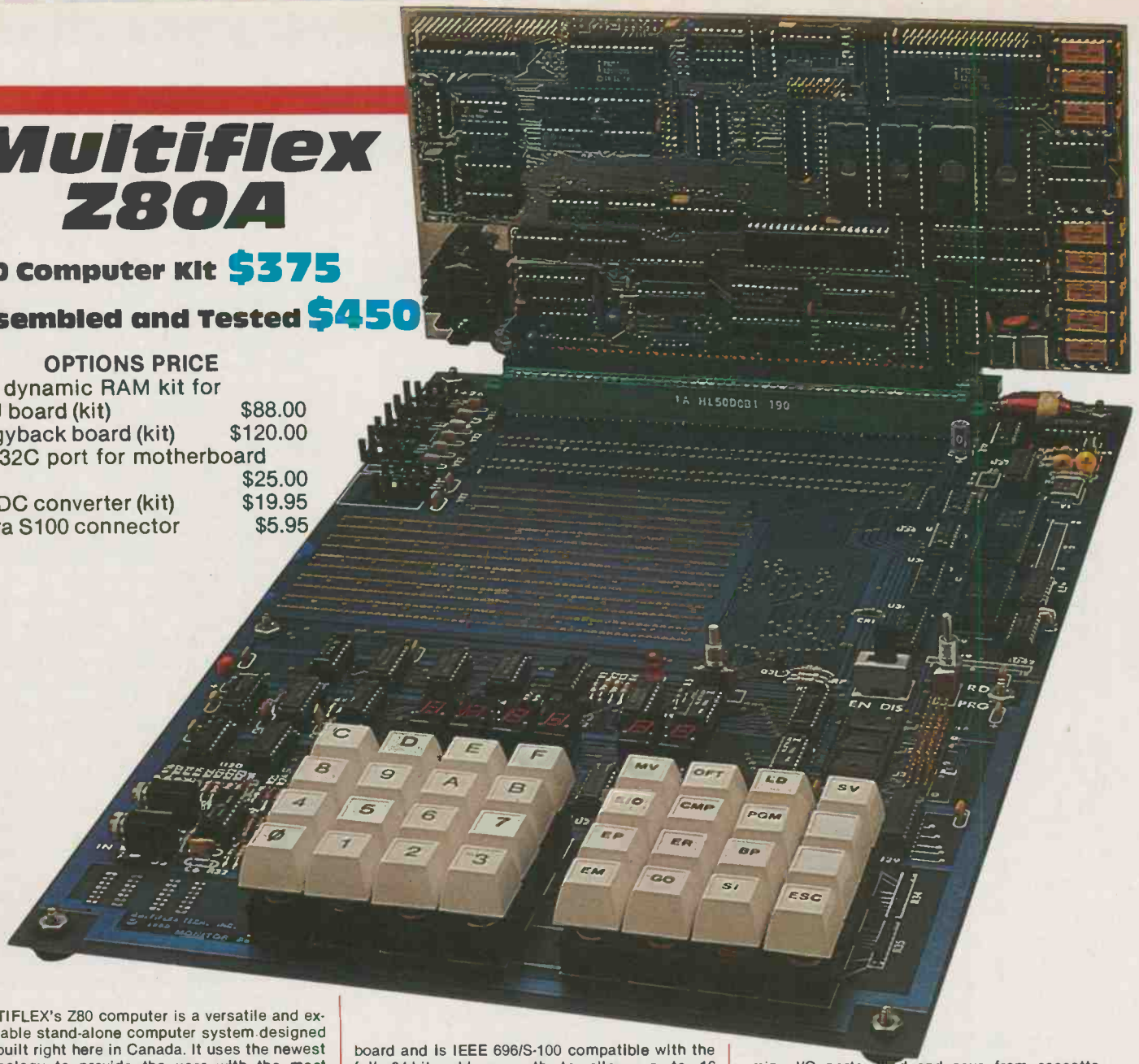
Multiflex Z80A

Z80 Computer Kit **\$375**

Assembled and Tested **\$450**

OPTIONS PRICE

64K dynamic RAM kit for CPU board (kit)	\$88.00
Piggyback board (kit)	\$120.00
RS232C port for motherboard (kit)	\$25.00
DC-DC converter (kit)	\$19.95
Extra S100 connector	\$5.95



MULTIFLEX's Z80 computer is a versatile and expandable stand-alone computer system designed and built right here in Canada. It uses the newest technology to provide the user with the most capabilities for the smallest price-tag. Its adaptability to any situation and extremely low cost allow it to be used in many applications ranging from a trainer to a complete CPM-based computer comparable to the best on the market, at a fraction of the price.

The actual layout of the system is a two board design. One board (the "motherboard") contains a 24-line parallel I/O chip for interfacing to the external world, an RS232C serial port with baud rates selectable from 110 to 9600 baud, a hex address and data display, a hex keypad, 14 monitor function keys, 2 user definable keys, a 40-chip wire wrap area with full access to all the bus signals, on-board provision for regulators so that the board can be supplied with standard S-100 voltages, an EPROM programmer which will handle 2708 (1Kx8), 2716 (2Kx8), 2732 (4Kx8) 2532 (4Kx8), 2764 (8Kx8) and the brand new 27128 (16Kx8) EPROMs, a DC-to-DC converter to supply the programming voltage to the EPROM programmer and four (4) slots for IEEE S-100 compatible boards for further expansion. This is an extremely useful and important feature as it allows expansion of the system with all boards using this industry-standard bus structure, which are available from MULTIFLEX, as well as from hundreds of manufacturers worldwide.

The other board is the CPU card. This card plugs into one of the S-100 slots on the mother-

board and is IEEE 696/S-100 compatible with the full 24-bit address path to allow up to 16 megabytes of memory to be addressed. The processor used is the Z80 (running up to 6 MHz) and there is provision on-board for 64K of dynamic memory (using 4164 chips) which will operate without wait states. Provided for as well is a 2K to 32K (selectable in 2K blocks) common resident area in memory for use with multiple memory banks. There are also 4 sockets on board which will handle 2732 (4Kx8) or 2764 (8Kx8) EPROMs or the new 6116/2016 (2Kx8) static RAMs (all of which can be software deselected if desired) to allow the user complete versatility in setting up the board to meet his own specifications. Also on board is 1 parallel port with 24 lines of I/O and 3 16-bit counter/timers for applications which require the unit to keep track of real time. Another feature of the CPU board is that it was designed by our engineers to run the CPM 2.2 disk operating system so that if a floppy disk controller board is added to the system a fully configured CPM machine can be set up for a very low cost as described on page 13.

The monitor software that comes with the kit is a well-written extensive package which allows the user to have complete versatility in machine language programming and execution as well as control of all the features on the board. The monitor functions include: examine/modify memory locations, memory block moves, compare 2 blocks of memory, examine CPU registers, ex-

amine I/O ports, load and save from cassette, calculate relative branch offsets, set breakpoints, single step programs, execute programs, and program EPROMs. Each of these processes is invoked by a single keypress. Also available to the user are 2 spare keys definable for special functions as required by specific applications and application programs.

Available as an option, there is a piggyback board which attaches to the CPU board and gives the user a real-time/time-of-day clock with battery back-up, memory management for up to 16M of memory in 4K blocks, 2 RS232C ports which have independent software selectable baud rates, vectored interrupts for the onboard I/O and clock devices, and a general interrupt controller designed to handle multiple interrupts for up to 7 other boards.

All these features make this a very impressive stand-alone unit and, when combined with other S-100 boards either from the MULTIFLEX line or from most other manufacturers, give the user the potential for a very powerful microcomputer system.

The standard kit includes the CPU board with a Z80A (4MHz) processor, 2K of RAM (a 6116), and 4K of EPROM (a 2732) as well as the motherboard with all the features mentioned above except the RS232C port and the DC-to-DC converter. Also supplied are sockets for all IC's and 1 S-100 connector.

History of Radar

The Instruments of darkness tell us truths, Win us with honest trifles, to betray's In deepest consequence.

Macbeth

Roger Allan examines the growth of radar from a weather system to one of the most important technologies of WWII, including some surprising facts about German research.

THE FIRST KNOWN usage of radar and radar jamming properties for the purposes of survival occurred in Central America a long time ago when the *Melese Laodamia* Moth evolved a system whereby, upon hearing acoustic signals from a bat hunting for its prey, it could reply with signals of its own which effectively jammed the radar. These moths have been in the radar jamming game for some millions of years, and probably started it all.

However radar, as we know it, is the science of locating distant objects by radio and had its beginnings in the very early days of radio. The scattering of radio waves by material objects — the fundamental process of radar — was first observed by Hertz in his classic experiments conducted in 1886 when he demonstrated the existence of radio waves. But it was not until 1904 that the Royal German Patent Office granted a patent to cover the basic radar idea, subsequently patented in a number of countries, to the young German inventor Christian Hulsmeyer. His device comprised a wireless transmitter and receiver mounted side by side, so that:

“waves projected from the transmitter can only actuate the receiver by being reflected from some metallic body, which at sea would presumably be another ship.”

Hulsmeyer called his invention the ‘Telemobiloscope’ (or the German equivalent), and it was designed to ring a bell whenever the receiver picked up echo signals. As there was then



Bell Laboratories engineers testing waveguide antennas in New York, 1939. These were discovered by British scientists and were a pioneering contribution to WWII radar technology.

no way in which radio waves could be amplified, his device could not have had a range of more than a few hundred yards at best, and further could not have determined the direction in which the echoes were being received. No one bought a Hulsmeyer Telemobiloscope, and it faded into obscurity.

The Early Days

The first usage of the Hertzian scattering property was by Appleton and Barnett working at Cambridge University in Britain who in 1924 used it to determine the height of the reflecting regions of the upper atmosphere using a process known as the *frequency modulation method*. In this process the transmitted frequency is increased linearly at a definite rate. The wave returned from the ionosphere (the subject of the experiment) at a range R is delayed by a time interval $2R/c$, where c is the velocity of the radio wave. The latter wave therefore differs in frequency from the wave then being transmitted upwards and the two waves incident on the receiver interfere, producing a beat. The measurement of the beat frequency determines the range.

The following year the Americans Breit and Tuve introduced the *amplitude modulation method*, in

which they radiated pulses of $1/1000$ th second duration in a vertical direction. The time of transit of the radio waves being constant and known, they were able to determine directly the height of the ionosphere. This pulse beat method is currently the most practical and widely used, though for some specialist applications the frequency modulation method may still be most appropriate.

The first reported observation of the reception of radio waves scattered by actual aircraft in flight was made in 1932 by British Post Office engineers, but they regarded this as interference and failed to realize its possibilities.

American and French developments in radar technology prior to and for most of the war years was at best spotty, involving a complicated history of experiment, early total failure and qualified success. As the French developments ended with the fall of France, and the American efforts were largely copies of or improvements on British systems, they will not be mentioned here, other than to say the American efforts were concentrated in the hands of Bell Laboratories and the Microwave Committee of the U.S. National Defense Research Committee.

The British efforts were rather more extensive than their allies, and

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- 7010-S 1¾" H x 4¼" W x 5¼" D

MODEL	RANGE (FROM 10 Hz)	TIME BASE		AVERAGE SENSITIVITY		GATE TIMES	MAX RESOLUTION			SENSITIVITY CONTROL	EXT CLOCK INPUT/ OUTPUT	METAL CASE
		FREQ	STABILITY-DESIGN	BELOW 500 MHz	ABOVE 500 MHz		12 MHz	60 MHz	MAX FREQ			
7010-S	600 MHz *1 GHz	10 MHz	±1 PPM-TCXO *±0.1 PPM-OCXO	10 mV -27 DBM	20 mV -21 DBM	(3) 1, 1, 10 SEC	1 Hz	1 Hz	10 Hz	Yes	No	Yes
8010-S	600 MHz *1 GHz	10 MHz	±1 PPM-TCXO *±0.05 PPM-OCXO	10 mV -27 DBM	20 mV -21 DBM	(4) 01, 1, 1, 10 SEC	1 Hz	1 Hz	10 Hz	Yes	Yes	Yes
8013-S	1.3 GHz	10 MHz	±1 PPM-TCXO *±0.05 PPM-OCXO	10 mV -27 DBM	20 mV -21 DBM	(4) 01, 1, 1, 10 SEC	1 Hz	1 Hz	10 Hz	Yes	Yes	Yes

*AVAILABLE OPTION



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M3J 2S2

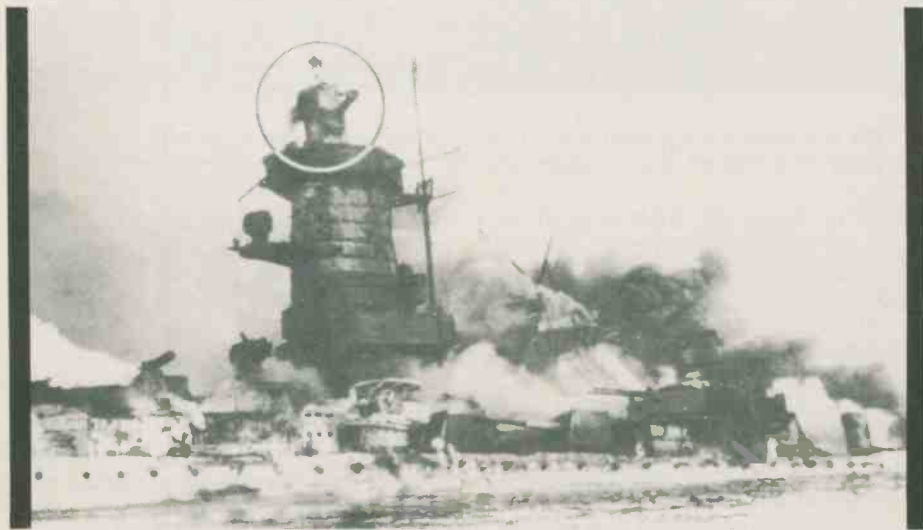
Circle No. 10 on Reader Service Card.

History of Radar

their story is fairly well known even to the general layman.

Essentially, the development of British radar dates from the establishment by the Air Ministry during the winter of 1934-35 of a committee for the scientific survey of air defence. This committee received, among other suggestions, a carefully worked out plan for the radio pulse-echo detection of aircraft submitted by the Scottish physicist then heading the radio department of the National Physical Laboratory, Robert Watson-Watt, later knighted for his contributions to radar.

The first experimental system of the type proposed by Watson-Watt was set up in the late spring of 1935 on a small island off the east coast of England. By the fall of 1935 the main features of a chain of warning stations to protect England had been worked out, and construction of the first five stations was begun in 1936. By March 1938 these stations, which protected the Thames estuary, and were known as the CH stations (for Chain Home) were complete and under Royal Air Force personnel.



The *Graf Spee* after being scuttled by the German Navy in 1939. The circle shows the radar aerials mounted on the front of the main director tower.

Development then shifted to air-borne radar equipment. Two types were designed: a set for the detection of surface vessels or surfaced submarines by patrol aircraft (called ASV for air-to-surface vessel) and equipment to enable nightfighter aircraft to home on enemy aircraft (called AI for aircraft interception).

An experimental ASV system was successfully demonstrated during British fleet manoeuvres in September 1938. Experimental AI equipment was demonstrated to the Chief of RAF Fighter Command in

August 1939, just a month before the outbreak of WWII.

The focussing of radar energy into shaped beams is especially important in the case of air-borne radar, for energy reflected when the radar beam strikes the ground or sea beneath the plane can mask entirely the much weaker echoes of the targets sought. Shaped beams can be obtained by the use of very large antennas or very short radio wave lengths of a few centimetres.

By early 1940 the multicavity magnetron had been developed to the point where it gave about ten kilowatts of pulse power. The invention of this tube made microwave radar practical for the first time.

Wartime radar developments by the British were numerous and far reaching with many different types developed.

Aircraft Warning Systems

The earliest sets used were those of the CH system. These large installations used radio waves about ten

metres in length and gave their display on a scope. Target bearing was found by comparing the intensity of the target signal received on one fixed receiving array with the intensity of the echo from the same target received on another fixed array aimed in a different direction: the elevation of a target plus its altitude was measured in a similar way. These CH radar stations remained the principal reliance of the British radar defence during the war, and were used in 1944 and 1945 for the detection of German V-2 rocket launching positions.



The German *Freya* radar site, photographed by the British in 1941. German radar technology was far more advanced than is usually believed, but was not used for the same strategic purposes as the Allied units.

Later aircraft warning sets used shorter radio wave lengths, usually about 1.5 to 3 metres. At this wavelength, a relatively narrow beam can be produced by an antenna array small enough for installation on ship-board, or for use in a transportable ground equipment array. At the same time, the use of a radar beam requires continuous scanning in azimuth in order to cover all directions from the station.

In early 1944 there was introduced a microwave early warning radar, operating on a wave length of 10 cm, which was highly successful. The radar beam produced by this set was only 1° wide in azimuth; in consequence the ability of the set to resolve closely spaced targets on its PPI (Plan Position Indicator) display was very much better than that of earlier equipment having broader beams. The large RAF raids, comprising more than 500 aircraft, could be separated with each aircraft seen separately.

Identification Equipment

When a radar indicator shows echoes from dozens or even hundreds of aircraft, it becomes important to know which of these aircraft are friendly and which hostile. This led to the early development of IFF equipment (Identification Friend or Foe) in which all friendly aircraft were equipped with a transponder which gave a coded response when the aircraft carrying it was in the beam of a radar set. Arrangements were made to display this response on a scope which was either that used by the challenging radar set, or on a special scope

History of Radar

associated with the radar. Aircraft showing an IFF response were taken to be friendly, aircraft not showing such a response were doubtful. Either they were hostile, or they were friendly planes whose transponders were out of order or not turned on.

Control of Aircraft Interception

The observation was made by the British that since a hostile plane and a friendly fighter can be seen on the indicator of a single radar, it might be possible for a ground controller, viewing the radar scope, to coach the fighter into position to make an interception. The development of the Plan Position Indicator greatly facilitated such ground control of interception. Special radar equipment, called GCI for Ground Control Interception was introduced early in the war with great effect.

When the Germans abandoned daytime attacks on England at the end of 1940, the technique of ground control became more exacting. It was no longer sufficient to bring the defensive fighters into the general vicinity of the enemy aircraft and then to rely on the pilot's vision to complete the interception. A skillful ground controller could, under favourable circumstances, bring a fighter close enough to his target to enable a visual contact to be made even at night, though with extreme difficulty.

AI Radar

To help overcome the difficulties mentioned above, nightfighters were provided with air-borne radar sets with a range of a few miles. The ground controller coached the nightfighter into a position a mile or two behind the hostile plane, a little below and on the same course. He then instructed the radar observer in the nightfighter to turn on his AI equipment. If the early phases of the interception had been successfully carried out, the hostile aircraft gave a signal on the AI radar and combat was joined.

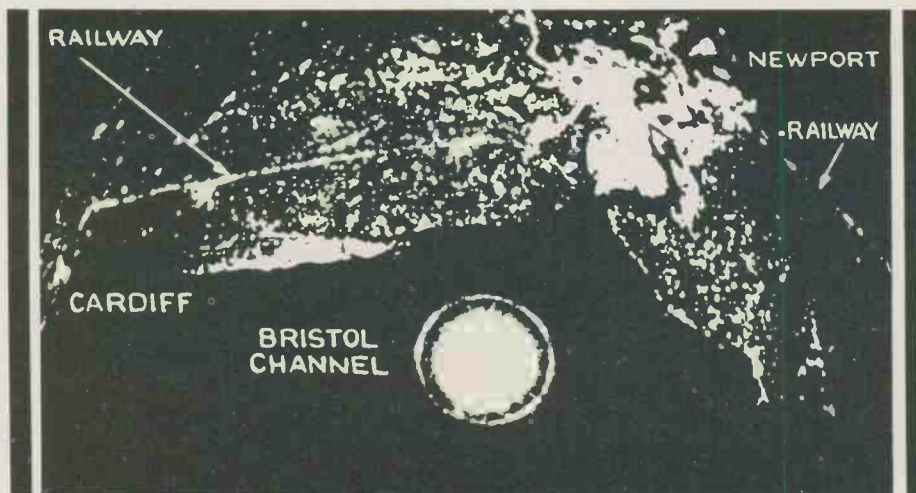
By the time reliable microwave AI equipment had been developed by the Allies they enjoyed such thorough air superiority that it did not play a major tactical role. The early British 1.5 metre AI equipment used in 1940 and 1941 had many drawbacks, but it was sufficiently effective to enable the RAF to master the night bombing capability of the Luftwaffe.

Air-Borne Radar for Bombing Purposes

During trials of AI and ASV radar it was found that microwave equipment with its narrow beam could give a sufficiently good picture of the terrain beneath the aircraft to enable navigation. Cities and built up areas returned a much stronger signal than open ground, and hills, rivers, railway lines and coast lines were especially well defined. Called H₂S (for Home Sweet Home — the pilots also using it to

constant range from one station, called the 'cat'. The other station, called the 'mouse' sent to the aircraft signals indicating the exact moment of bomb release necessary to hit the previously chosen target.

Oboe was highly accurate; with good ground and air crews the operational errors were less than 250 yards from an altitude of 30,000 feet. Its limitations were that, since it depended on the ability of ground stations to see the signals from a beacon in the bombing aircraft, it would not work



The H₂S radar navigational system. The terrain below the aircraft was shown in sufficient detail to guide the pilot to a target and home again.

return to base) the RAF used it to guide its pathfinder aircraft. These pathfinders dropped flares on the target at which the main force aimed by ordinary optical means or by Oboe (mentioned below).

Beacon Bombing Systems

Radio beacons give an immediate response to a radar challenge and as such can provide an excellent means for measuring the range to a point whose nature is known. Two such measurements based on a single point enable the exact position of such a point to be found by triangulation. Since range can be measured conveniently and accurately by pulse-timing methods, very precise positions can be determined.

Two different bombing systems were based on this principle during WW II. In one of them, called Oboe, the aircraft carried a radio beacon. The beacon was challenged by two ground stations, and the range of the aircraft from each station measured. Signals were sent to the plane by radio to keep it on a circular course of

over the optical horizon (about 250 miles at 30,000 feet), that it demanded a high degree of co-ordination between two widely separated ground stations, and could only handle one aircraft at a time.

In the second type of beacon bombing system, H, beacons were placed on the ground at accurately located spots and the integration and display equipment was carried in the bombing aircraft. Each aircraft could challenge the ground stations independently of all the other planes that might be doing so at the same time.

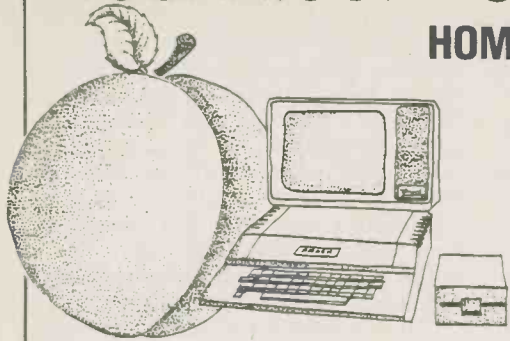
German Developments

Customary histories of radar, primarily for reasons of national pride, tend to concentrate on British and American efforts, while leaving the German devices pretty much as unknown quantities. In fact, until the latter stages of the war, the Germans had the best of the lot — they just didn't use them as well as they might and didn't have enough of them.

German efforts date back to 1933 when Dr. Rudolph Kuhnold, the

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History of Radar

head of the German signals research department, while working on sonar, decided that the same sort of process might work for aircraft detection. Initially, Kuhnold's work involved a device which operated on a frequency of 2,000 metres and didn't work — due to difficulties in tube design, his machine only put out 0.1 watt of power. Later the same year, however, the Dutch Philips company designed a tube capable of generating 70 watts — much more powerful than any built before. Rebuilding his device to fit the new tube, Kuhnold in March of 1934 set it up overlooking Kiel harbour and was able to pick up the battleship *Hessen* lying at anchor 600 yards distant.

The prototype was improved and set up near Lubeck where Kuhnold ran a demonstration for German naval officials, picking up echoes from a ship seven miles away and from a passing sea plane which happened to cross through his beam about 700 yards distant. Impressed, the officials awarded a development grant to the Gema company for further development. In the next ten months, Kuhnold independently invented pulse transmissions and was able, in September 1935, to demonstrate a system to Admiral Raeder which picked up coastlines at 12 miles and ships at seven.

The code name for this device was the DT-Gerat, which ostensibly

stood for *Dezimeter Telegraphie* which would link the system with the network of point-to-point wireless communication stations publicised by the German Post Office. In the next year, the Gema company altered the frequency of DT to 150 MHz, extending its range to thirty miles. With further modification, this system became the *Freya* radar operating at 125 MHz — the most important German early warning system up to the middle of the war. The first deliveries of *Freya* to the German navy took place in 1938 and, while providing good early aircraft warning, was useless as a gunlaying device. The Gema company then produced the *Seetakt* version of *Freya* which was mounted on a number of warships, notably the *Graf Spee* and the *Bismarck*.

Not to be left behind, the Telefunken organisation entered the field of radar development, producing the *Wurzburg* radar in 1938. It was a small, highly mobile set with the ability to plot aircraft to within very fine limits at ranges up to twenty-five miles, operating on 560 MHz. It was designed as a gunlaying apparatus.

Comparisons

A comparison of abilities at the commencement of hostilities might be useful. The *Freya* had a maximum

range of 75 miles, gave full 360 degree cover and was fully mobile, but it could not measure the actual altitude of approaching aircraft. The British CH had a maximum range of 120 miles and could determine an aircraft's altitude, but it could only gaze over a 120 degree arc and required four 300 foot high permanent transmitter aerials. The *Wurzburg* was small, highly mobile, with a range of 25 miles and the best resolving power of any of the systems.

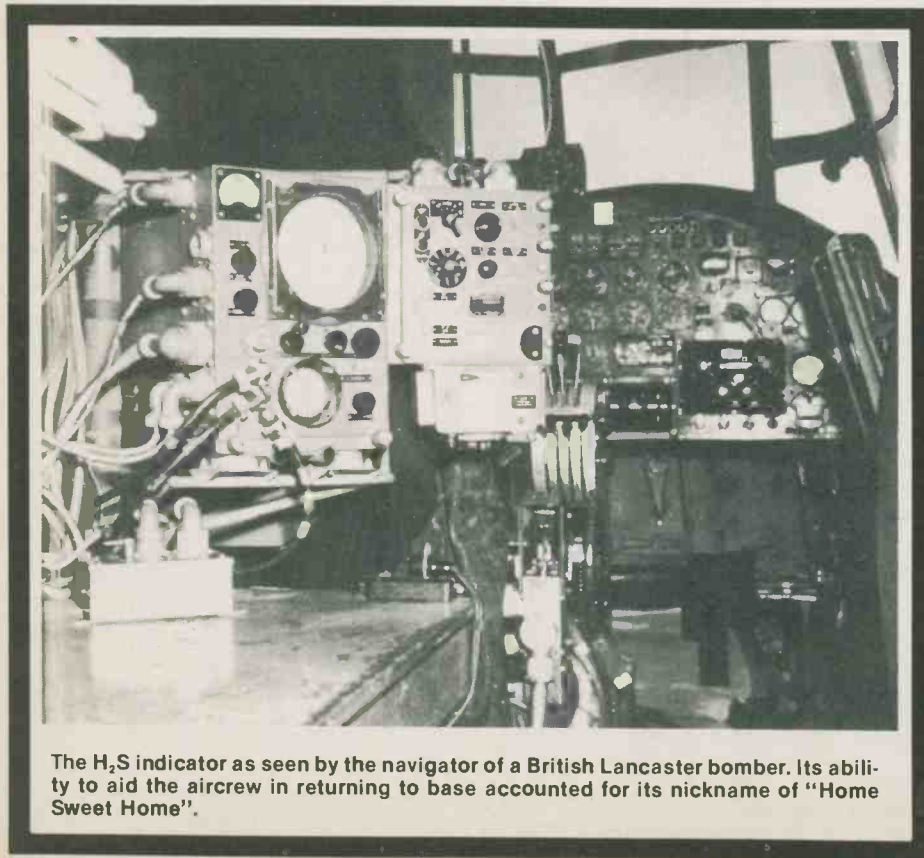
The introduction of the *Wurzburg* gunlaying radar took longer than anticipated, and without radar the gunners still had to seek out their target using searchlights and an optical range predictor. This created problems in usage until the end of 1940 when *Wurzburg* production got in stride and was paired with a *Master* searchlight. In this coupling, the radar would spot the aircraft and automatically guide the *Master* searchlight (which emitted a faint blue colour) which would lock onto the aircraft regardless of what evasive manoeuvres the plane underwent. Four other searchlights, of the customary white colour, would then be switched on and likewise lock on the plane, permitting the flak gunner ample opportunity to fire.

Further, the *Wurzburg* sets fell short of what was required. The trouble was that its range was so short that it was often impossible to find the attacking bombers' altitude in time for night fighters (when not coupled with a *Master*) to reach it, and unless the interception was quickly completed, the bomber passed out of the *Wurzburg's* range unscratched.

Ground reflection also made it difficult to follow aircraft flying below 6000 feet. The Telefunken company set about dealing with these problems, and during the spring of 1941 introduced a new device, called the *Giant Wurzburg*. Essentially, all they had done was to increase the *Wurzburg's* reflector disk from ten feet to twenty-five feet — this had the effect of narrowing the beam width while more than doubling its range, enabling it to detect aircraft over forty miles away. It had a static mounting.

Fighter Control

To convert the range and bearing information derived from the radar into a form in which it could be used by the fighter controller, the German airforce developed the *Seeburg* table. It looked rather like a dias with two



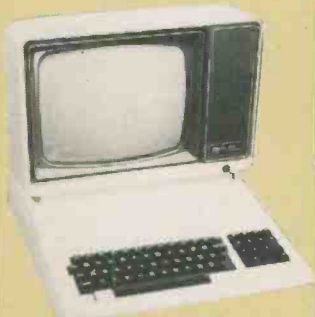
The H,S indicator as seen by the navigator of a British Lancaster bomber. Its ability to aid the aircrew in returning to base accounted for its nickname of "Home Sweet Home".

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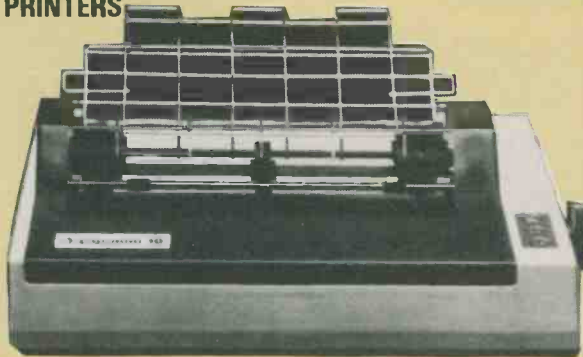


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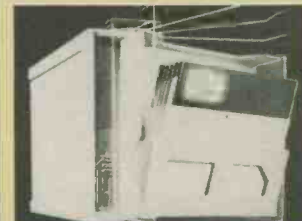
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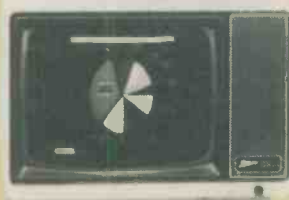
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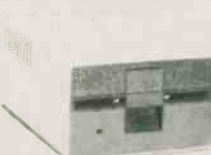
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Strips of aluminum foil were dropped from aircraft to jam enemy radar. The strips were cut to a small size, but returned as much radar signal as an entire aircraft.

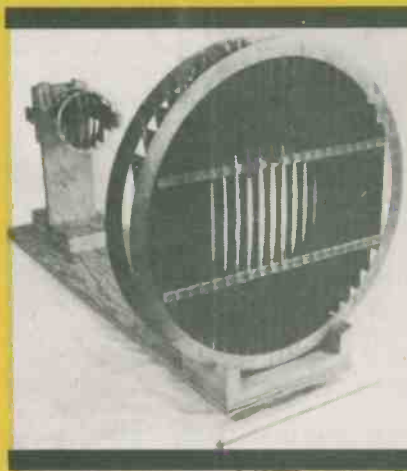
flights of steps leading up to a table at the centre. The table top consisted of a frosted glass screen with a map of the area and a grid painted on it. Beneath this screen was a second table, round which sat two men operating light projectors, one to project a spot of red light indicating the bomber's position and the other to project a blue spot, indicating the fighter's position, onto the screen above. Each man was connected to one *Wurzburg* set by telephone. As the two coloured spots of light jerked across the frosted glass screen, a man at the top of the dias followed them with a coloured wax crayon. The fighter controller could see the progress of the interception and broadcast instructions to the fighter aircraft by radio telephone.

In 1942 it was decided that what worked with *Wurzburg* should also work with *Freya*, and so *Mammut* was built by the I.G. Farben company. Essentially, it was an enlarged *Freya* with a reflector ninety feet wide and thirty-five feet high — about the size of a tennis court. The structure did not rotate, but found the direction of the target by swinging the beam electronically through a limited arc of 100 degrees. The huge reflector squashed the beam into a narrow pencil, which could reach aircraft 200 miles away.

Like *Freya*, *Mammut* could not measure altitude, and so a second new radar was introduced in the same year, *Wasserman*, built by the Gema company, which gave accurate height, range and bearing of an aircraft up to 150 miles away. It

employed an aerial mounted on a rotating tower with a reflector 130 feet high and twenty feet wide. *Wasserman* was the finest early warning radar to be produced by either side during WW II.

In the same year a third new form of German radar was introduced manufactured by Telefunken and named *Lichenstein*. It was an airborne radar, designed to be fitted to night fighters to enable their crews to engage Allied bombers even in the darkest night. It worked on 490 MHz and had a maximum range of two miles and a minimum range of 200 yards or so. The minimum range was



An 18 inch waveguide lens, developed during WWII. These considerably reduced the size of radar aerials for airborne use. The smaller lens behind it is a directional feed.

important, since fighters had to get quite close to their target before firing. That there is a minimum at all becomes evident from technical considerations: the radar transmits a pulse, and while it does so, the extremely sensitive receiver has to be switched off; otherwise it would suffer damage. The receiver cannot pick up echoes from targets nearby, because the transmitter is still radiating its brief pulse and the receiver is still switched off. This dead distance between the radar set and its nearest visible target is proportional to the length of the transmitted pulse. 200 yards is very good.

The remainder of the war primarily consisted of minor improvements to the basic designs, improvements in aerial configuration, particularly for on-board radar systems, and a decrease in the wavelengths used.

Typical of the rather peculiar methods which were sometimes employed by wartime British intelligence in trying to untangle German radar efforts is the story of how Dr. R. V. Jones derived some circumstantial evidence that the Germans had portable radar in 1940. British intelligence knew that the Germans had a device called *Freya* but what it was no one knew. Jones researched the mythological background of the goddess *Freya*, and initially came up blank. She was the Nordic goddess of Beauty, Love and Fertility. Jones delved deeper into her background and found that *Freya's* most prized possession was an exquisite necklace called *Brisingamen*, but to acquire it she had had to sacrifice her honour and be unfaithful to the husband she loved. *Heimdall*, the watchman of the gods, guarded *Brisingamen* for her, and *Heimdall* could see one hundred miles in every direction, by day and by night. Jones reported to the Chiefs of Staff: "It is unwise to lay too much stress on this evidence, but these are the only facts that seem to have any relation to our previous knowledge. Actually, *Heimdall* himself would have seemed the best code name for R.D.F. (radio direction finding, eg. radar) but perhaps it would have been too obvious. It is difficult to escape the conclusion therefore that the *Freya-Gerat* is a form of portable R.D.F."

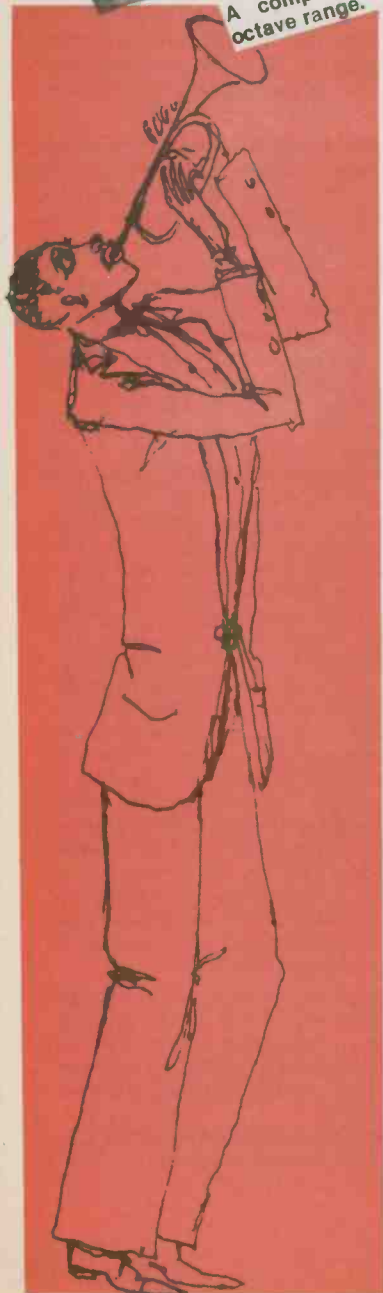
Freya may possibly be associated with *Wotan* — she was at one time his mistress — although it would have been expected that Hitler would have in this case chosen *Frigga*, *Wotan's* lawful wife."

Strange are the ways of the wartime intelligence community!

Electromusic Techniques Part 1



A compact synthesiser with a three-octave range.



Tim Orr emerged from his workshop this month just long enough to hand over this bundle of circuits for the ardent build-it-yourself musician.

VIRTUALLY ALL of the electronic music synthesisers that have been produced to date employ analogue circuits to generate the synthesised sounds. The process is known as subtractive synthesis, and operates by dynamically filtering out parts of the spectrum of a signal that is often rich in harmonics. The results are instant, easy to modify and relatively inexpensive to implement. It is not possible to produce an arbitrary output spectrum, and so it is very difficult to synthesise realistic copies of naturally generated sounds. This can be done using a digital technique known as harmonic synthesis, whereby the sound is constructed by precisely defining the amplitude and phase of each of the harmonics. These are then added together to produce the output. However, natural sounds are constantly varying and so the data defining all the harmonics must also vary. Harmonic synthesis can produce very realistic sounds and is in itself a powerful technique for generating completely new sounds, but the hardware is a combination of sophisticated microprocessor and digital technology and so is outside the scope of this article.

When we hear a sound we unconsciously analyse it for useful information; "Who wants another drink?" for example. Nobody knows how the human brain analyses incoming sounds, but it does it with incredible speed and sophistication. It can extract precise information from sounds (speech perception), it can experience pleasure from a rich harmony, or it can even learn to ignore certain sounds, such as a ticking

clock. The brain is very good at perceiving pitch (or at least it thinks it is; it is also a fairly good liar); see Fig. 1. When you hear a pure tone you will get a strong impression of its pitch. You will not be able to define its frequency in Hertz, but you will be able to remember its pitch. A sawtooth has a strong harmonic structure but even so you will get the same pitch perception. The ringing tone has virtually no energy at the fundamental frequency and yet it is still possible to correctly perceive the pitch of the signal, although it is more difficult than for the pure tone.

Most musical instruments produce a range of notes. Some instruments, like violins, can produce a continuous range of frequencies; because, unlike the guitar, there are no frets along the neck of the instrument. Keyboard instruments have fixed tuning; the piano, for example. The keyboard is an excellent choice for controlling a synthesiser, as it is easily converted so that it generates suitable electrical signals and it is widely accepted by musicians. Equal temperament tuning is used, that is, there are twelve notes per octave and they are spaced at intervals of the twelfth root of two (that is 1.0594631) along an exponential curve, as in Fig.2.

When You Hear The Tone . . .

The keyboard is used to define the fundamental pitch of a sound, but the actual shape of the waveform will determine its harmonic structure (Fig. 3). A sinewave is a pure tone and has no harmonics. A halfwave-rectified sine wave contains a fundamental plus a series of even harmonics. A fullwave-rectified sine wave is composed entirely of even harmonics. The squarewave and the triangle are both composed of a series of odd harmonics; in fact if you lowpass filter a square wave you can produce a triangle. The triangle is a fairly pure tone, with little of the energy in the waveform contained in its harmonics. The sawtooth is a rich waveform, having both odd and even harmonics.

The harmonic structure of all these waveforms extends to infinity, but the drawings only show the first 15 harmonics. If we call the harmonic number n , then the harmonic amplitude is easy to define. The rate at which the harmonic amplitude decreases is $1/n$ for the sawtooth and square wave and $1/n^2$ for the half and fullwave rectified sine wave and the triangle. Figure 4 shows a sawtooth being constructed from harmonics.

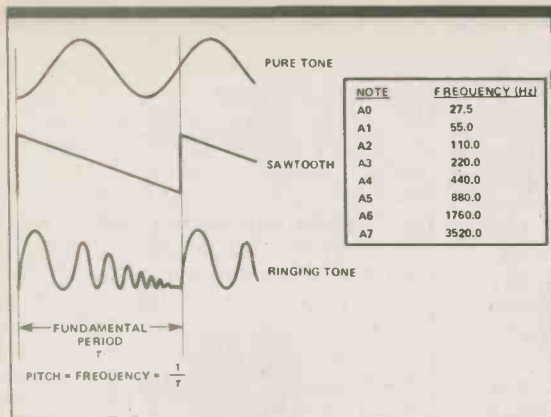


Fig. 1 Pitch perception.

The sum of the harmonics is beginning to look like a sawtooth. As more harmonics are added (with the correct phase and amplitude) the sum will converge upon the correct sawtooth shape. An interesting effect can be produced by changing the mark/space ratio of the square wave. This modifies the odd harmonic spectrum and introduces even harmonics. The mark/space ratio is often dynamically modified as a synthesis process.

Frequency modulation is often employed in synthesizers to produce vibrato and other dramatic pitch change effects. Figure 5 shows some of the effects of frequency modulation. As the modulation depth is increased, frequency sidebands are generated. Their spacing and amplitude are determined by the modulation depth and the modulation and carrier frequencies. To precisely calculate them involves some complex maths and Bessel functions (which I have forgotten all about). To make matters worse, synthesizers usually use voltage controlled oscillators with an exponential transfer function, which tends to exponentially distort the sideband positions. But so what! Music synthesizers are all about making music and not the calculation of sidebands. If a particular electronic device produces a useful musical effect, then use it, don't analyse it.

The output from an oscillator is known as an excitation signal. This defines the pitch of the signal, and to a certain extent the harmonic content of the final signal. It is common practice to filter the excitation signal (Fig. 6). The frequency response of the filter is referred to as a formant. The formant modifies the harmonic spectrum of the excitation, producing a colouration of the sound. The formant is usually a mobile filter and this makes it possible to dynamically alter the sound colour. If the formant has a sharp resonant peak, then the

output signal will ring as it passes the harmonics of the excitation.

Another parameter that characterises a sound is its amplitude contour or envelope (Fig. 7). A sound that has a sharp attack and a slow release is similar to a plucked instrument. Other envelopes will make the sound seem like something else.

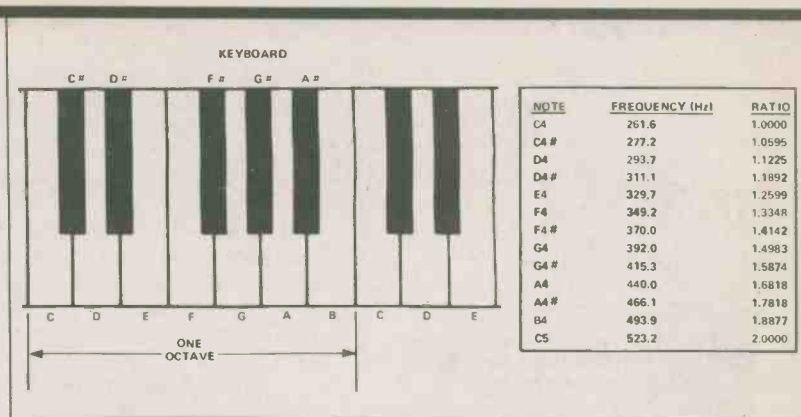


Fig. 2 Keyboard layout with table showing equal temperament tuning.

Building Blocks

Most synthesizers are constructed from standard building blocks, and most of these blocks are voltage controlled. This is a very powerful concept, because it enables you to control a unit with a combination of control voltages and/or audio signals. Building blocks can be patched

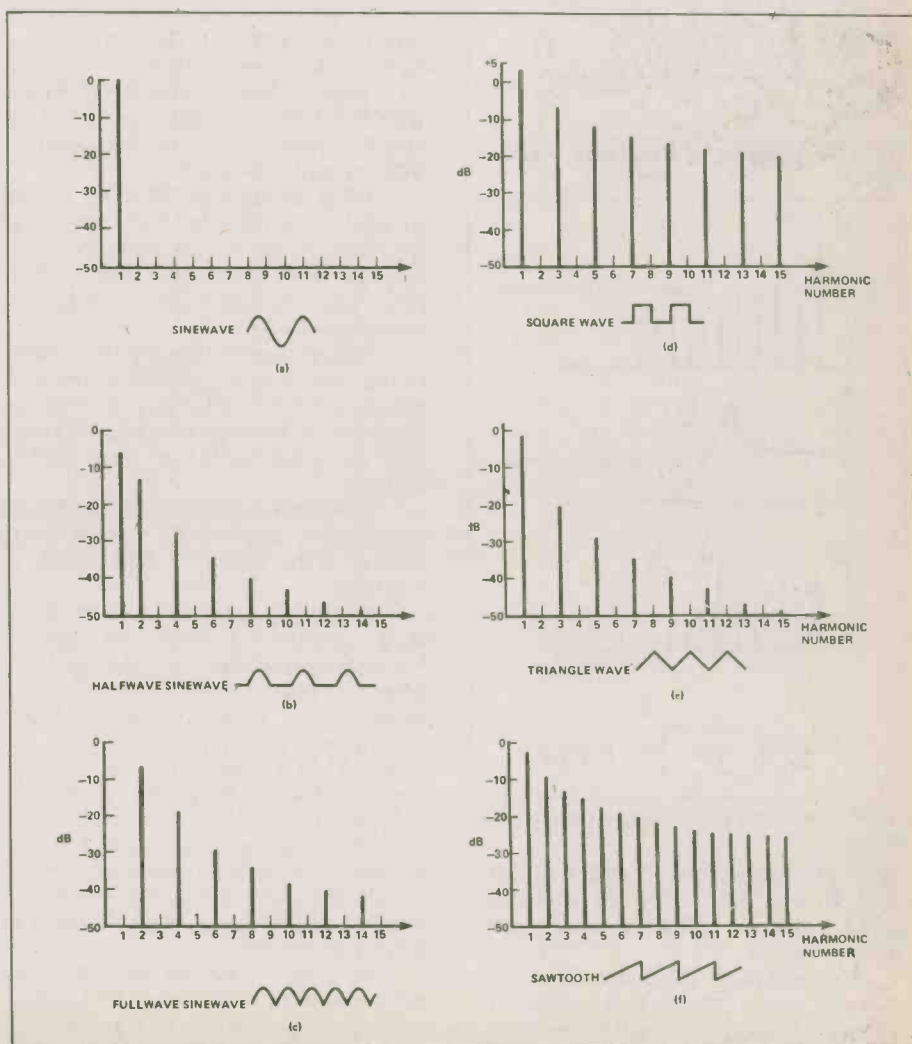


Fig. 3 Harmonic structure of various standard musical waveforms.

Electromusical Techniques Part 1

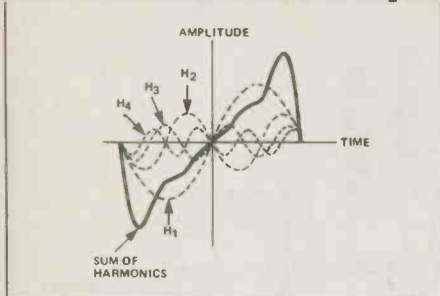


Fig. 4 Adding the first four harmonics to construct a sawtooth waveform.

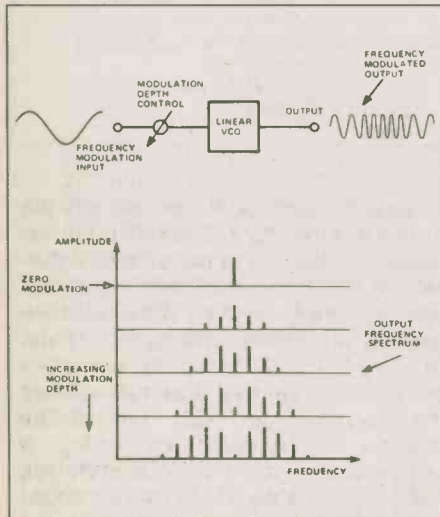


Fig. 5 The effects of frequency modulation.

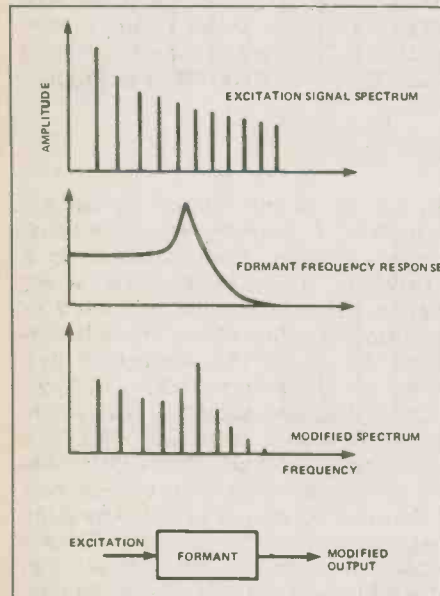


Fig. 6 The effect of filtering an excitation signal.

together in any arbitrary order to produce any system that is wanted. Some standard building blocks are detailed below.

Voltage Controlled Oscillator Used to generate the pitched excitation signals. Often a VCO will generate a wide range of waveforms. The control sensitivity is usually +1V/octave.

Therefore a one twelfth of a volt change will alter the oscillator pitch by one semitone. The exponential control law is a very powerful concept. If a VCO is being driven so that it produces a melody, then adding +1V to the control input will transpose the melody up by one octave. Thus musical transpositions are very simple to produce. Often more than one VCO will be used, so that a rich chord is obtained.

Voltage Controlled Filter This is used as a formant for the excitation signal. The VCF is generally a lowpass filter, but it can often be a multi-mode device with lowpass, highpass, bandpass and notch responses. The VCF also has a Q (resonance) control. The control sensitivity is +1V/octave for the frequency parameter, and undefined for the Q.

Voltage Controlled Amplifier The VCA controls the level of audio signals. The control law can be linear or logarithmic. The VCA is usually controlled by an ADSR unit and is employed to generate signal envelope contours. The device is a two quadrant multiplier.

Attack, Decay, Sustain, Release unit The ADSR is used to generate the signal envelope contour and also the VCF sweep waveform.

Ring Modulator This is a four quadrant multiplier or balanced multiplier. The output voltage is the product of the two input signals. It is often used to generate discordant or clangorous sounds.

Noise source Generates random noise, which can be used in the synthesis of non-pitched sounds such as explosions. Filtered or sampled noise can be used as a random control voltage.

Low Frequency Oscillator These oscillators are used to generate vibrato in the VCO or a filter sweep in the VCF.

Keyboard Musical control interface, generating pitch voltages of +1V/octave and also a gate signal to indicate that a note is pressed. A monophonic keyboard only allows one note at a time to be pressed, but if more than one can be pressed simultaneously then the system is polyphonic.

There are several other building blocks such as flangers, sequencers, frequency shifters, and pitch detectors, but there isn't enough space to deal with them.

Polyphonic synthesizers tend to be voice-based; i.e. all the building blocks are pre-routed to form a voice (Fig. 8). Modular systems are not pre-routed to form a voice (Fig. 8).

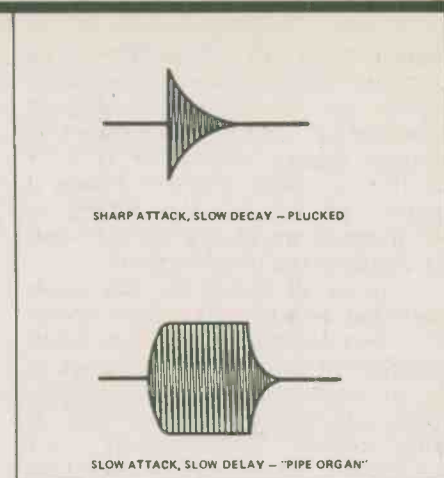


Fig. 7 Two typical amplitude contours, or envelopes.

Modular systems are not pre-routed and have to be patched, either with lots of jack-to-jack patch leads or via a matrix patch board using patch pins. Patch leads are relatively inexpensive, but the leads get in the way and it is often difficult to see just what you have patched. Matrix patch boards are easy to understand, but they suffer from crosstalk and a large board (60 by 60) might cost \$1000.

Diode Data

The silicon diode has an exponential transfer function, that is the diode current increases exponentially for linear increments in the diode voltage (Fig. 9). This can be used to turn linear changes from, say, a keyboard into exponential or musical intervals in a VCO. The required musical range is probably no more than 200 to 1 and so a suitable operating current would be 0.5 uA to 100 uA, thus avoiding the non-exponential parts of the curve. The silicon diode is temperature dependent (it is often used as a thermometer) and so great care must be

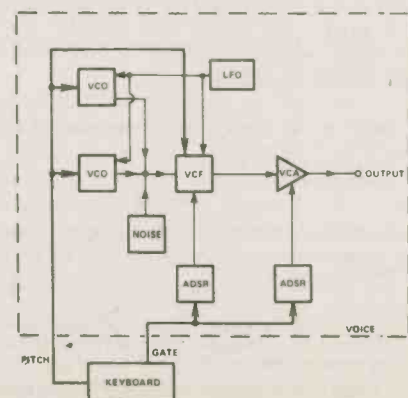


Fig. 8 The standard synthesizer voice.

used to avoid thermal problems. The junction voltage changes by -1.9 mV/ $^{\circ}$ C, but a semitone change is equivalent to 1.5 mV, therefore a 1° C change could result in a 1.27 semitone change in pitch! Figure 9 shows two temperature effects in operation; there is a large shift and the slope of the line changes.

Figure 10 illustrates the equations that determine the diode operation. Two facts emerge from these equations. First, an 18 mV change in V_{BE} will double the current I_e and second, this parameter has a temperature coefficient of $-0.33\%/^{\circ}$ C. Both the temperature problems can be resolved by using a circuit similar to that shown in Fig. 11. Transistor Q1 is run at constant current (12 μ A) by the op-amp. Q2 is used as the exponentiator transistor. The emitter of Q2 is held at a voltage

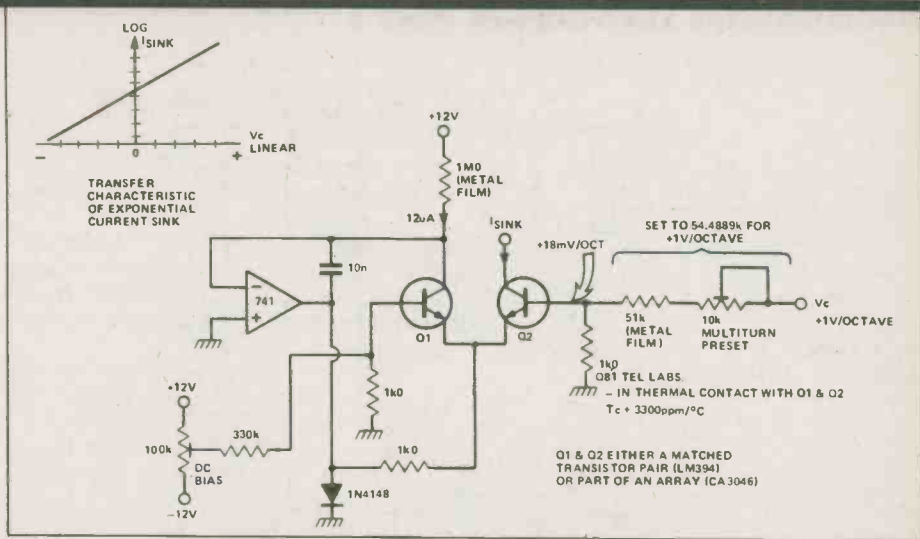


Fig. 11 An exponential current sink.

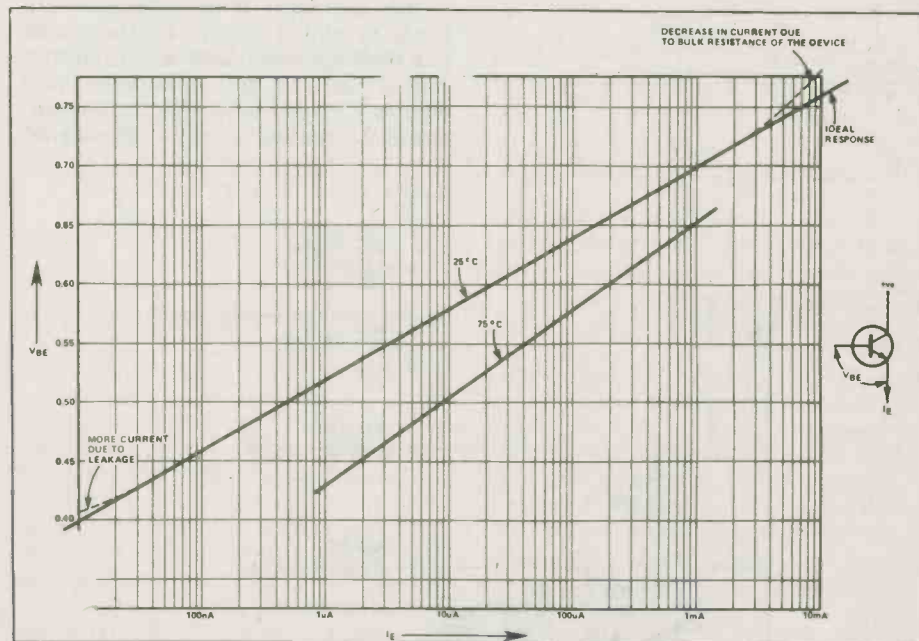


Fig. 9 Silicon diode transfer characteristics.

WHERE
 I_0 IS THE EMITTER SATURATION CURRENT
 K IS BOLTZMANN'S CONSTANT
 q IS THE CHARGE ON AN ELECTRON
 T IS THE TEMPERATURE IN $^{\circ}$ K

HOWEVER, $\frac{KT}{q}$ IS 26 mV AT 28.58° C (301.73° K IS ROOM TEMPERATURE).
 THEREFORE, $I_c \approx I_0 e^{V_{BE}/26}$

WHERE V_{BE} IS MEASURED IN mV
 REARRANGING THE EQUATION,
 $26 \cdot \ln \left(\frac{I_c}{I_0} \right) = V_{BE}$

THEREFORE, AN OCTAVE CHANGE IN I_c IS CAUSED BY A 18.021827 mV CHANGE IN V_{BE} (AT 28.58° C). HOWEVER, IF THE TEMPERATURE WERE $+1^{\circ}$ C HIGHER, THEN V_{BE} WOULD HAVE TO BE INCREASED IN SIZE TO A NEW VALUE OF
 $26 \cdot \ln \left(\frac{302.73}{301.73} \right)$

SO, FOR AN OCTAVE CHANGE IN I_c AT THE NEW TEMPERATURE, V_{BE} MUST CHANGE BY 18.08155 mV, AN INCREASE OF 0.059723 mV. THIS CAN BE EXPRESSED AS A PERCENTAGE CHANGE PER $^{\circ}$ C :-
 TEMPERATURE SENSITIVITY = $\frac{0.059723 \times 100}{18.021827} = 0.33139\%/^{\circ}$ C

Fig. 10 Exponential transistor characteristics.

of about $-0V6$. Any voltage change at the base of Q2 will result in an exponential change in the collector current of Q2. Q1 and Q2 are in thermal contact and so any temperature change will affect both equally. Thus the -1.9 mV/ $^{\circ}$ C factor is cancelled out by Q1 acting as a compensating thermometer for Q2. The slope change is removed by using a temperature sensitive resistance (Q81 — Tel Labs) which has an equal but opposite temperature coefficient to the diode junction. This resistor is often in thermal contact with the matched transistors. If this circuit is connected to a linear current controlled oscillator, a musical VCO is produced.

VCO Circuits

Figure 12 is the circuit for an exponential VCO using an exponential current source. The oscillator is a standard triangle-square wave device. IC2 is a current-controlled integrator; the slow rate at its output is equal to I_{ABC}/C . This voltage is buffered by IC3 which drives a Schmitt trigger IC4. The output of IC2 ramps up and down between the two hysteresis levels which are determined by the two clamping diodes connected to the output of IC4. Any stray capacitance on the output of IC4 will slow down the Schmitt trigger and this will make the VCO go flat at high frequencies. Also the propagation time delay around the oscillator will cause a flattening out to the response at high frequencies. These effects can be nulled out but they may not even affect things if the VCO frequency is kept relatively low.

A good VCO is shown in Fig. 13. It is a monolithic device with triangle, sawtooth and pulse outputs, and has a Sync input for slaving it to another

Electromusic Techniques Part 1

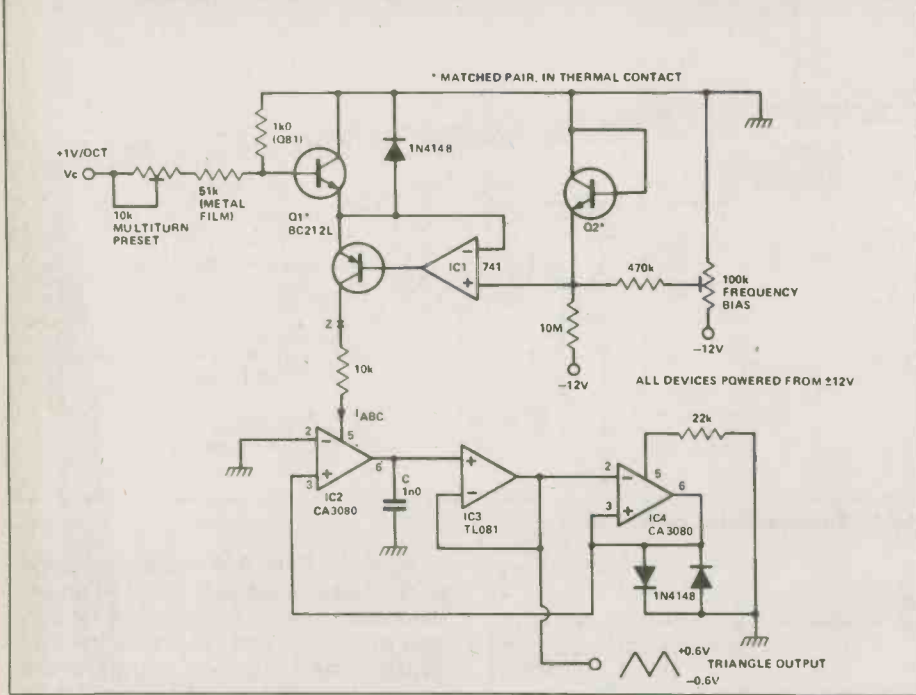


Fig. 12 An exponential VCO.

oscillator. Originally it appeared as the heart of the ETI Synthesiser 1 project, August 1982. (Back issues are available; see the contents page for ordering information.)

LFO Circuits

A couple of LFO units are shown in Fig. 14. All four output waveforms can be usefully employed to sweep VCOs and VCFs. Often the waveforms are mixed together to produce strange frequency modulations. When the sawtooth is fed into one side of a ring modulator and noise into the other, a beat track can be generated; it sounds a bit like a cymbal being hit.

Noise Generators

In 'the old days' noise sources were made by amplifying the noise current of a diode junction that was zenering. These were a bit unreliable, and always involved selecting the device. However, noise can be generated

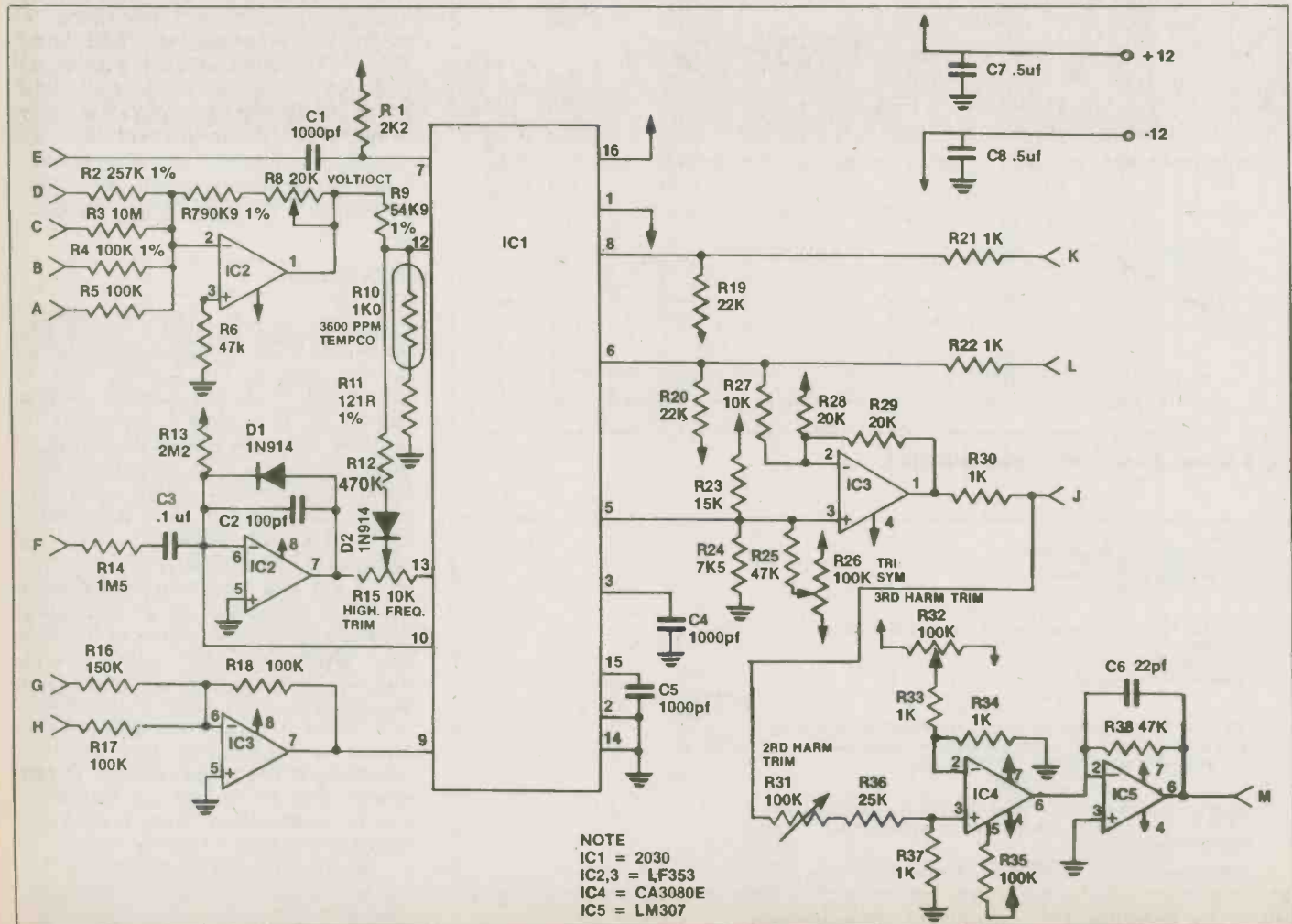
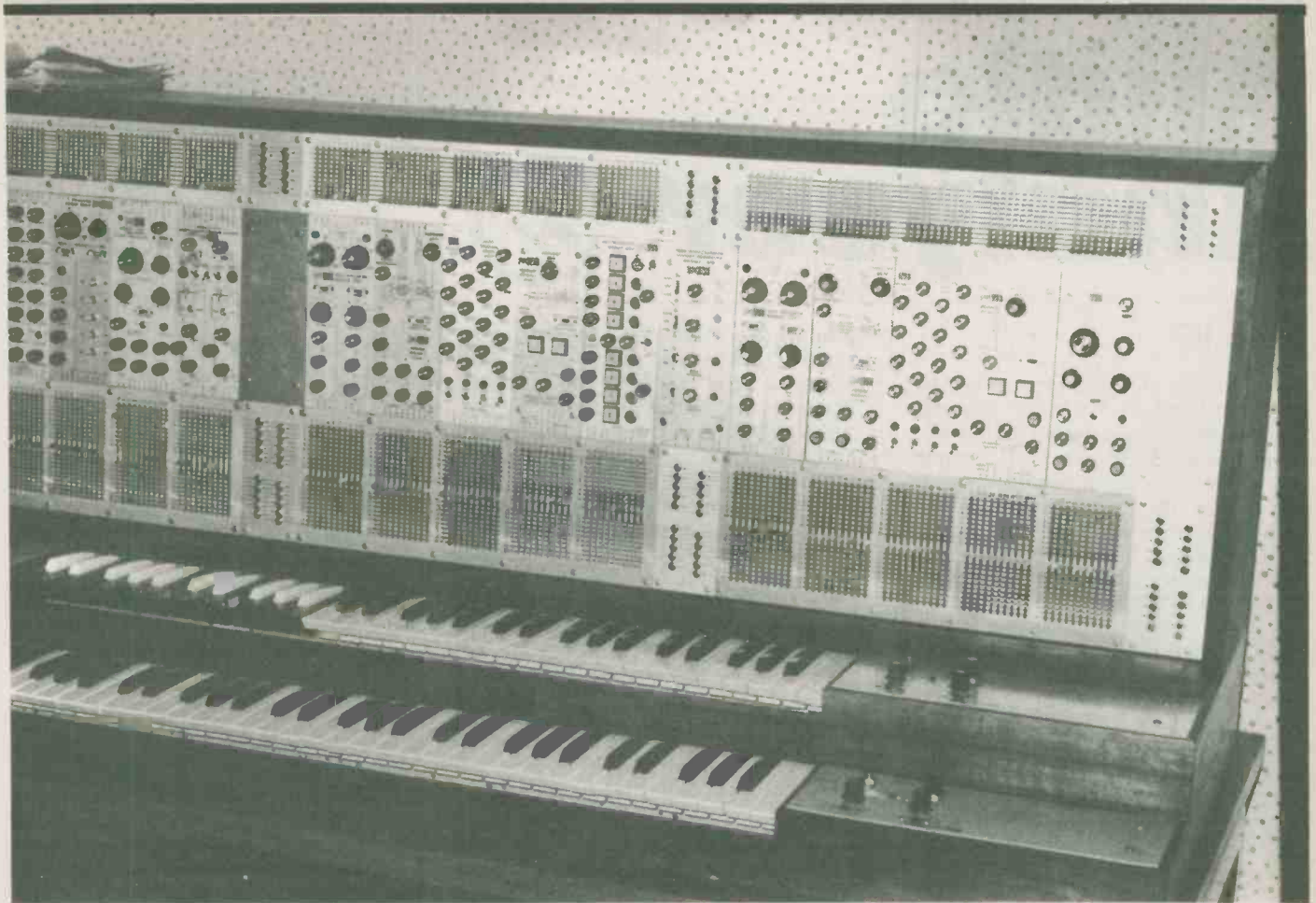


Fig. 13 A VCO using a monolithic device.



Acres of knobs and patch points - a large studio type synthesiser.

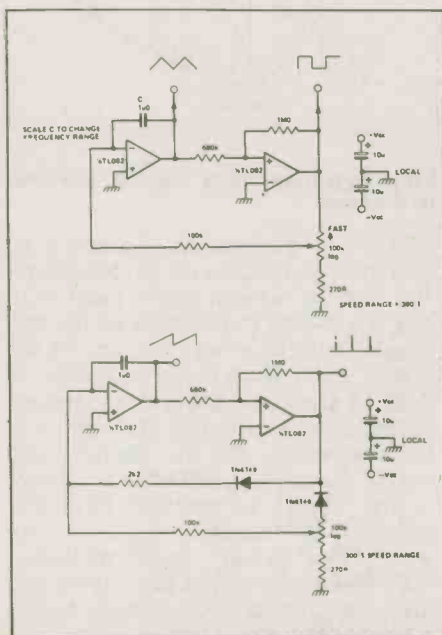


Fig. 14 A triangle/square wave LFO (top) and a sawtooth/pulse LFO (bottom).

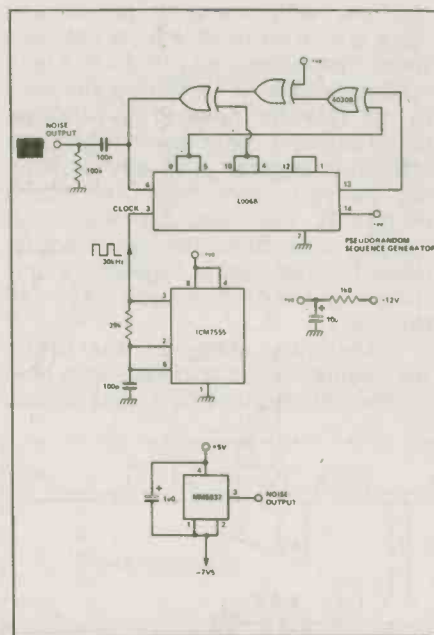


Fig. 15 A digital noise source (top) and a noise generator chip (bottom).

digitally with a maximum length pseudorandom sequence generator (Fig. 15). The noise spectrum is relatively flat and always the same. If you slow down the clock rate you can get some interesting sounds; I think that this is used on some TV games. If a longer shift register is used, say 30 or 40 stages (the 4006 is 18 stages long), and the noise source is turned on, a tone is initially heard which gradually changes into noise as the sequence becomes more scrambled up. You can purchase a monolithic noise generator (pseudorandom); it is the MM5837 made by National Semiconductor, also sold by AMI with the part number S2688.

ETI

Audio Analyser



Construction

Construction of this project is not for the faint-hearted! To make this project handheld has meant using two fairly dense PCBs. So you can put away your gas-fired soldering irons and pliers; delicacy, finesse and a steady hand are required. Use an iron with a small bit and make sure you don't leave huge blobs of solder that bridge the PCB tracks. IC sockets are not just recommended; we insist upon them. Fit the components to the boards in the usual way, filter board first, taking great care to observe component polarity where this is important. Don't miss out any of the wire links; and don't try to finish it all in one evening, or two. Time 'saved' during construction will be wasted on fault-finding, later!

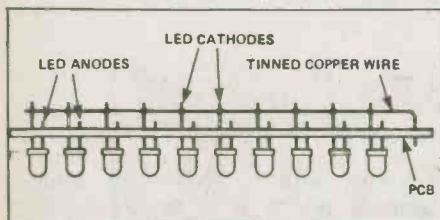


Fig. 1 Wiring the LED matrix; It is best to check all the LEDs before soldering them in, because replacing one will be very difficult once the boards are assembled.

The nice men who designed the 4017 didn't put its sequential outputs 'sequentially' on the IC pins and this often leads to tricky PCB layouts when using the IC. Fortunately we can cheat, because all we need in this project is to look at each of the 10 channels separately — so long as they appear on the right display columns it doesn't matter what the actual order is. This is why the filters don't run in sequence down the PCB — it's purely for convenience.

To avoid the use of a double-sided PCB for the display matrix, a rather cunning technique has been adopted. Solder in one row of LEDs only and cut off one pin only — the

ones whose solder pads are linked by copper tracks. Now solder a length of tinned copper wire to the pad indicated, bend it over so it touches the other LED pins about 1/4" away from the board, then solder all the pins to it and trim them off. Then do the next row, and so on. Mistakes made here will be almost impossible to correct later, so check that every LED in every row is the right way round before you solder it. The most certain method is to use Figure 2; flats, dots and 'one leg is shorter than the other' can all

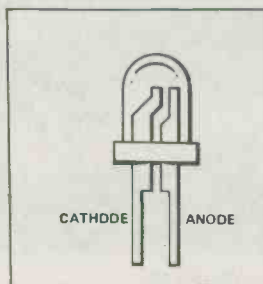


Fig. 2 Pin connections of a LED.

lead you astray.

The two PCBs are bolted together with stand-off pillars and have a number of wire links between them. The easiest way to do this is to solder lengths of tinned copper wire to the relevant pads of the display board and cut them down slightly to different lengths, gradually increasing as you move down the board (Figure 3). Then you can insert the longest link onto the filter board, move the two closer together, insert the second and so on, until they're all through.

Assembly starts by test-fitting the display board and making a hold for the display. It's a good idea to glue

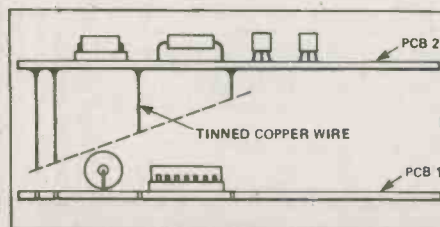
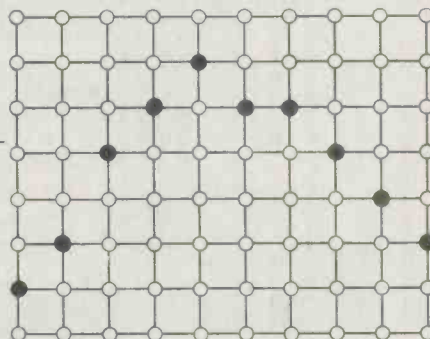


Fig. 3 Fitting the links between the two boards.



a piece of red plastic or polarising filter behind it to improve the contrast of the LEDs. Fix the pillars to the display board and screw into the case — the transistors and tantalum capacitors will probably have to be bent over to give clearance. Now slide the main board over the wires, as described above, solder all the links and trim them. Now the wiring for the off-board components can be completed.

We found the cheapest way of getting an electret mic element was to buy a cheap electret cassette recorder mic (about \$6) and cut the

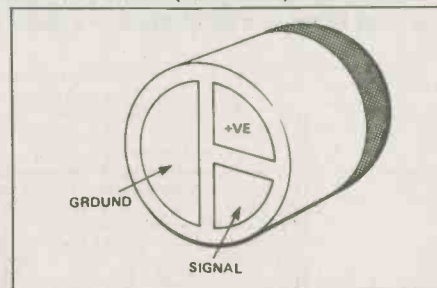
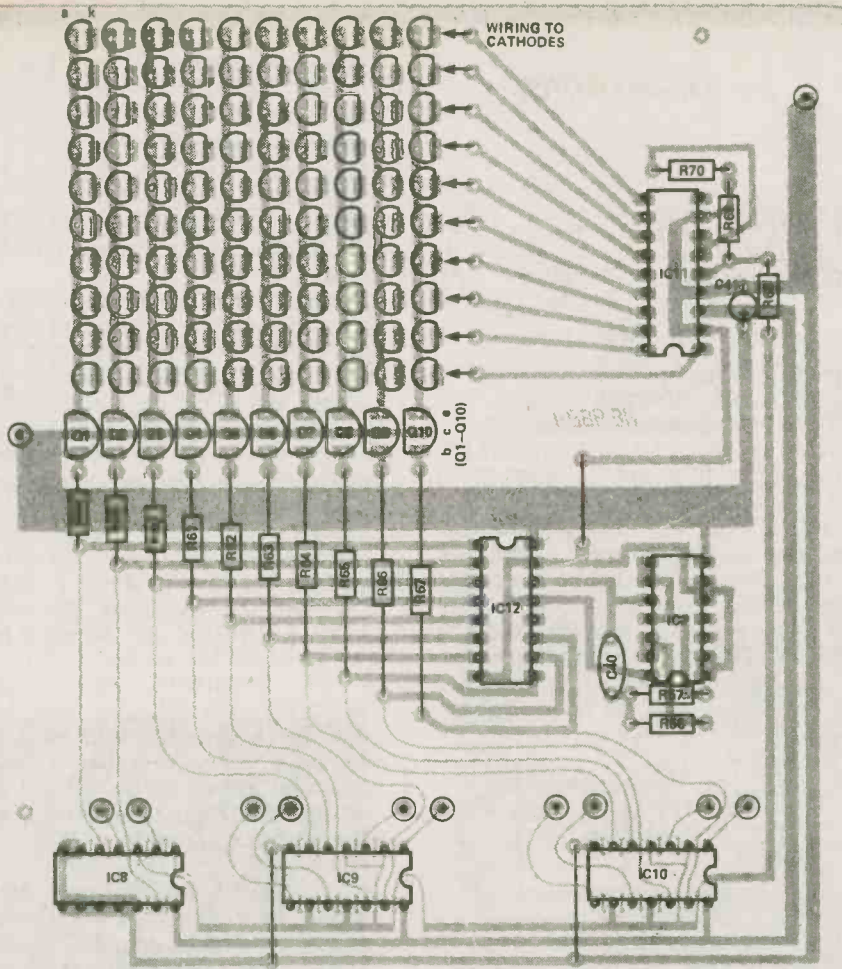


Fig. 4 Connections to an electret microphone.

end off it. Do this very carefully as you mustn't damage the insulation on the internal wiring; you'll need it to link the mic to the PCB. Glue the mic into a suitable-sized hole cut in the end of your case and connect it to the PCB as shown on the overlay; the existing battery terminals of the mic will tell you which are the positive and negative supplies, while the third wire is the signal connection (probably screened by the ground wire). If you don't feel your constructional abilities are up to this, just plug a mic into the external jack socket; not as compact but much easier.

If choosing an alternative case, bear in mind that you'll want easy access to the batteries; the current con-

NOTE: CIRCLED PADS INDICATE LINK WIRES BETWEEN THE PCBs (SEE TEXT)



sumption of the unit is quite high and you'll either have to replace your alkalines regularly or, if you've been sensible, recharge the Nicards.

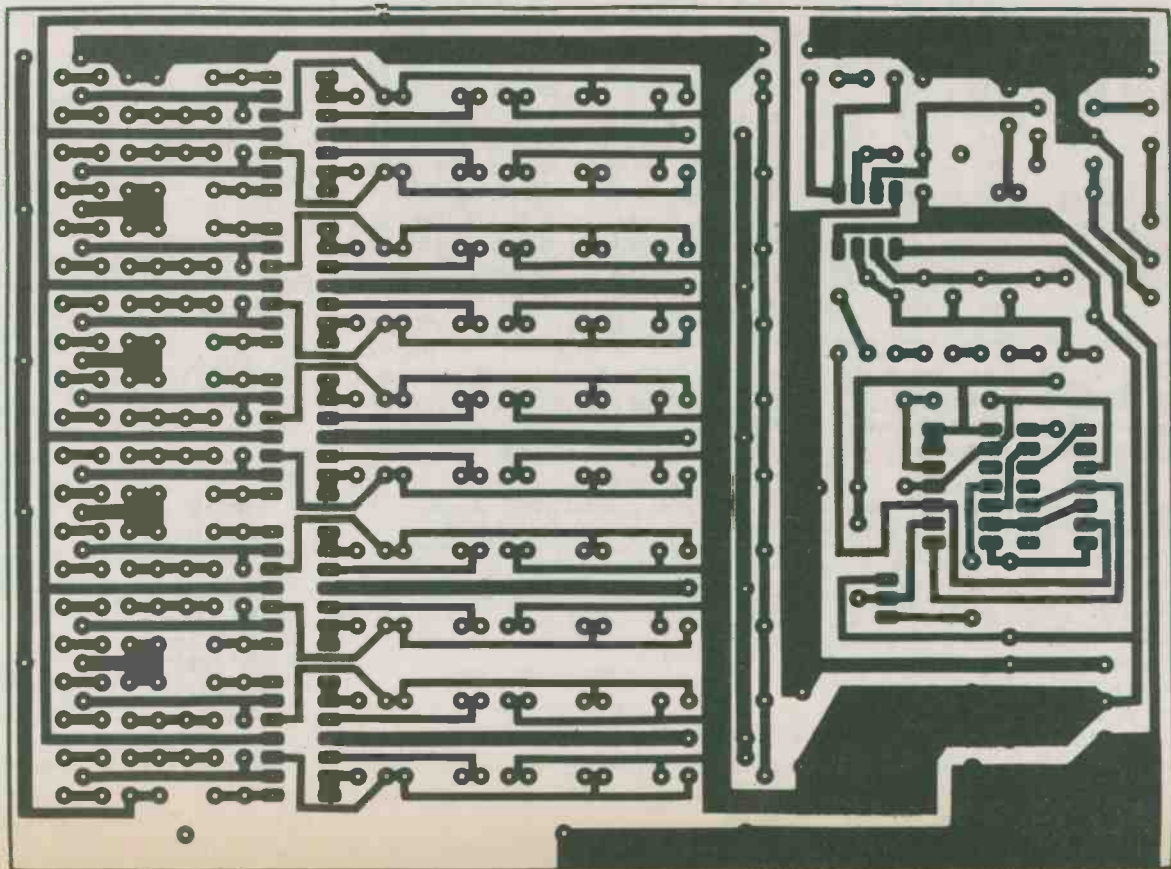
Anyone who attempts to improve on our PCB design is on his own. Anyone who attempts to build the circuit on Veroboard will be recommended for committal to a mental institution.

Setting up and Use

The unit can be set up using either the built-in pink noise generator or, better still, with a sine wave oscillator. Adjust PR10 to about 75% of its travel (wiper towards the clockwise direction). With the unit switched on and the sine wave oscillator connected to the external input, by sweeping the oscillator frequency, each column should come up in sequence. Adjust the sine wave frequency and the analyser level control until the 16 kHz column is peaking at a column height of about eight LEDs.

Now, using the same amplitude and without touching the level control, adjust the signal generator frequency until the 8 kHz column peaks

Component overlay for the display board.



The foil pattern for the filter board.

Audio Analyser

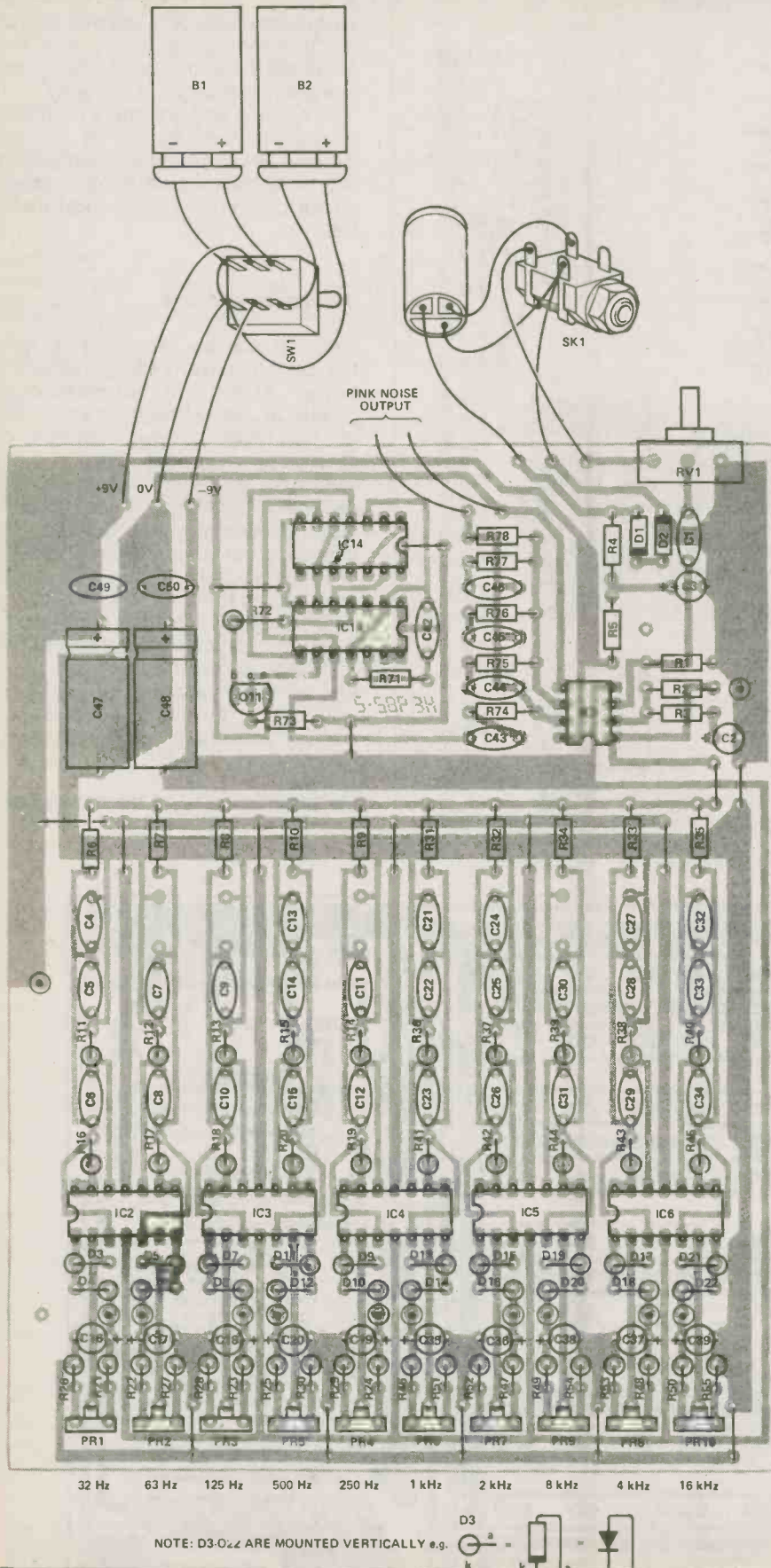


Fig. 7 The filter board component overlay.

and adjust PR9 to give the same height. Repeat this adjustment for each of the filters. Due to component tolerances the actual peak of a filter may not correspond exactly to its nominal centre frequency. The 16 kHz filter has the greatest loss which is the reason for starting with it near its maximum gain.

If a sine wave oscillator isn't available, connect the pink noise output to the external input and adjust the presets to give an even response across the 10 channels. Each column should be approximately the same height; due to the nature of noise, the top of the columns may jump up and down slightly and this should be averaged out by eye. If one of the columns appears dimmer than the rest, replace the transistor that drives that column; if only a single LED appears dim then it must be replaced by as



Fig. 5 View of the LED display from the foil side.

we've pointed out, the method of construction make this a bit tricky. It's a good idea to either buy good quality LEDs or test them individually for duds before commencing construction.

To measure a room set-up, feed the pink noise into the hi-fi or PA system via a cable from the listening position and adjust the graphic equaliser controls until a flat response is indicated.

A final point; the microphone us-

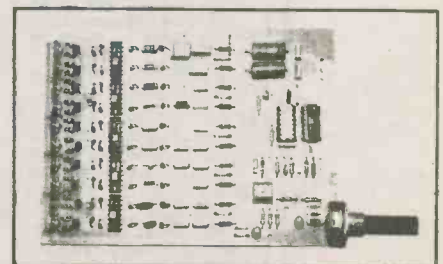
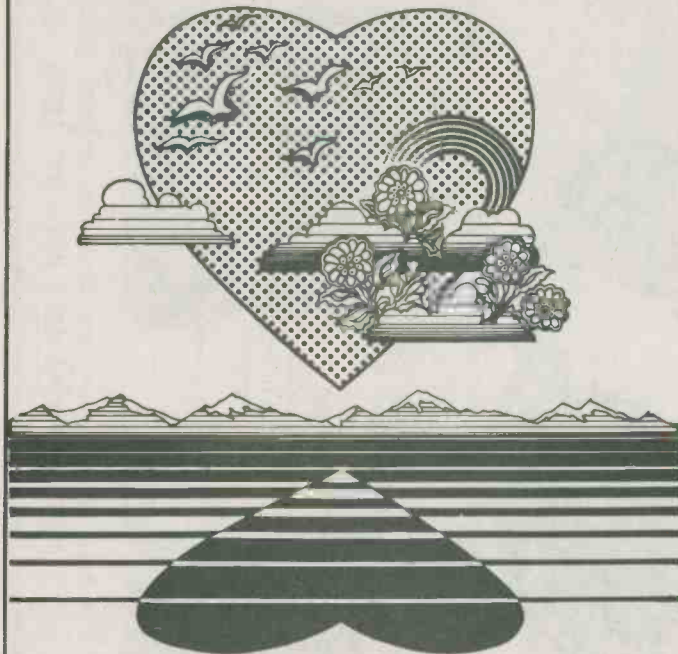


Fig. 6 The completed display board.

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THERE was that home-built body scanner that made a few errors . . .



THEN there was that 64K personal computer using 12AX7's that Hydro wouldn't let you power up . . .

THE one-kilowatt power amplifier that wasn't good for anything but arc welding . . .

In cases like these, we recommend ETL, the magazine for electronics enthusiasts: projects, designer articles, tech-tips and how-it-works articles, as well as news and stories of general interest to the hobbyist and technician.

Whether you prefer lots of soldering iron time or just like keeping up, ETL does its best to serve you, except maybe for body scanners.

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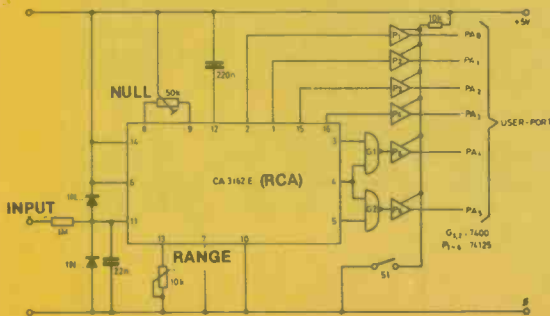
COMPUTING TODAY

THIS MONTH'S Computing Today features another of those fine old PET traditions, the not remarkably coherent machine code programs. Submitted by Heino Velder, this program will transform your PET into a digital voltmeter with huge numbers upon the screen. The huge numbers are taken care of by a BASIC printing routine.

The voltage to be measured is digitized by the circuit in figure 1, essentially a simple six bit digital to analog converter which feeds the user port of the PET. The machine code program, living in the PET's second cassette buffer, sets up a translation table in RAM, sets the direction registers for the VIA chip that drives the PET's port and samples the data coming in. The values to be displayed on the screen are loaded into RAM locations 0, 1 and 2 in page zero, essentially the USR JMP instruction and address, which are not used here. The BASIC display routine can pick these up by PEEKing these locations and passing what it finds along to the printing subroutines.

The actual workings of the machine language routines are a bit too complex to get into here; you can probably puzzle them out for yourself if you want, but this should not be necessary to get the program running.

Have a blast.



```

.. 033A A0 05 LDY #005
.. 033C 20 97 03 JSR #0397
.. 033F A9 03 LDA #003
.. 0341 85 01 STA #01
.. 0343 A9 00 LDA #000
.. 0345 85 00 STA #00
.. 0347 A2 0B LDX #00B
.. 0349 86 02 STX #02
.. 034B A9 00 LDA #000
.. 034D 8D 7C 02 STA #027C
.. 0350 A0 05 LDY #005
.. 0352 A2 00 LDX #000
.. 0354 B1 00 LDA (#00),Y
.. 0356 C5 02 CMP #02
.. 0358 D0 01 BNE #035B
.. 035A E8 INX
.. 035E 88 DEY
.. 035C 10 F6 BPL #0354
.. 035E EC 7C 02 CFX #027C
.. 0361 90 88 BCC #036E
.. 0363 8E 7C 02 STX #027C
.. 0366 A5 02 LDA #02
.. 0368 5D 7E 02 STA #027E
.. 036B C6 02 DEC #02
.. 036D 10 E1 BPL #0350
.. 036F AD 7E 02 LDA #027E
.. 0372 18 CLC
.. 0373 69 30 ADC #030
.. 0375 C9 3A CMP #03A
.. 0377 D0 02 BNE #037B
.. 0379 A9 2D LDA #02D
.. 037B C9 3B CMP #03B
.. 037D D0 02 BNE #0381
.. 037F A9 05 LDA #005
.. 0381 48 PHA
.. 0382 18 CLC
.. 0383 A9 10 LDA #010
.. 0385 65 00 ADC #00
.. 0387 C9 40 CMP #040
.. 0389 D0 BA BNE #03A5
.. 038B 68 PLA
.. 038C 68 PLA
.. 038D 85 02 STA #02
.. 038F 68 PLA
.. 0390 85 01 STA #01
.. 0392 68 PLA
.. 0393 85 00 STA #00
.. 0395 58 CLI
.. 0396 60 RTS
.. 0397 78 SEI
.. 0398 A9 C0 LDA #0C0
.. 039A 8D 43 E8 STA #E843
.. 039D A9 FF LDA #0FF
.. 039F 20 B9 03 JSR #03B9
.. 03A2 99 00 03 STA #0300,Y
.. 03A5 A9 EF LDA #0EF
.. 03A7 20 B9 03 JSR #03B9
.. 03AA 99 10 03 STA #0310,Y
.. 03AD A9 DF LDA #0DF
.. 03AF 20 B9 03 JSR #03B9
.. 03B2 99 20 03 STA #0320,Y
.. 03B5 86 DEY
.. 03B6 10 DF BPL #0397
.. 03B8 60 RTS
.. 03B9 8D 7A 02 STA #027A
.. 03BC AD 12 E8 LDA #E812
.. 03BF C9 EF CMP #0EF
.. 03C1 D0 06 BNE #03C9
.. 03C3 58 CLI
.. 03C4 68 PLA
.. 03C5 68 PLA
.. 03C6 68 PLA
.. 03C7 68 PLA
.. 03C8 60 RTS
.. 03C9 AE 4F E8 LDX #E84F
.. 03CC 8A TXA
.. 03CD 09 CF ORA #0CF
.. 03CF CD 7A 02 CMP #027A
.. 03D2 D0 E8 BNE #03DC
.. 03D4 8A TXA
.. 03D5 29 0F AND #00F
.. 03D7 60 RTS

```

```

100 PRINT "D"
110 POKE 827,5:POKE 849,5:POKE 884,0
120 SYS 826
130 FOR I=0 TO 2:D=PEEK(I)+1:A=I*6:PRINT "MID$(D,1,3)"
140 ON D GOSUB 160,230,300,370,440,510,580,650,720,790,860,930
150 NEXT:GOTO 110
160 PRINTTAB(A); "  "
170 PRINTTAB(A); "  "
180 PRINTTAB(A); "  "
190 PRINTTAB(A); "  "
200 PRINTTAB(A); "  "
210 PRINTTAB(A); "  "
220 RETURN
230 PRINTTAB(A); "  "
240 PRINTTAB(A); "  "
250 PRINTTAB(A); "  "
260 PRINTTAB(A); "  "
270 PRINTTAB(A); "  "
280 PRINTTAB(A); "  "
290 RETURN
300 PRINTTAB(A); "  "
310 PRINTTAB(A); "  "
320 PRINTTAB(A); "  "
330 PRINTTAB(A); "  "
340 PRINTTAB(A); "  "
350 PRINTTAB(A); "  "
360 RETURN
370 PRINTTAB(A); "  "
380 PRINTTAB(A); "  "
390 PRINTTAB(A); "  "
400 PRINTTAB(A); "  "
410 PRINTTAB(A); "  "
420 PRINTTAB(A); "  "
430 RETURN
440 PRINTTAB(A); "  "
450 PRINTTAB(A); "  "
460 PRINTTAB(A); "  "
470 PRINTTAB(A); "  "
480 PRINTTAB(A); "  "
490 PRINTTAB(A); "  "
500 RETURN
510 PRINTTAB(A); "  "
520 PRINTTAB(A); "  "
530 PRINTTAB(A); "  "
540 PRINTTAB(A); "  "
550 PRINTTAB(A); "  "
560 PRINTTAB(A); "  "
570 RETURN
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600 PRINTTAB(A); "  "
610 PRINTTAB(A); "  "
620 PRINTTAB(A); "  "
630 PRINTTAB(A); "  "
640 RETURN
650 PRINTTAB(A); "  "
660 PRINTTAB(A); "  "
670 PRINTTAB(A); "  "
680 PRINTTAB(A); "  "
690 PRINTTAB(A); "  "
700 PRINTTAB(A); "  "
710 RETURN
720 PRINTTAB(A); "  "
730 PRINTTAB(A); "  "
740 PRINTTAB(A); "  "
750 PRINTTAB(A); "  "
760 PRINTTAB(A); "  "
770 PRINTTAB(A); "  "
780 RETURN
790 PRINTTAB(A); "  "
800 PRINTTAB(A); "  "
810 PRINTTAB(A); "  "
820 PRINTTAB(A); "  "
830 PRINTTAB(A); "  "
840 PRINTTAB(A); "  "
850 RETURN
860 PRINTTAB(A); "  "
870 PRINTTAB(A); "  "
880 PRINTTAB(A); "  "
890 PRINTTAB(A); "  "
900 PRINTTAB(A); "  "
910 PRINTTAB(A); "  "
920 RETURN
930 PRINTTAB(A); "  "
940 PRINTTAB(A); "  "
950 PRINTTAB(A); "  "
960 PRINTTAB(A); "  "
970 PRINTTAB(A); "  "
980 PRINTTAB(A); "  "
990 RETURN
READY.

```

Computing in Britain

ANOTHER FIRST for Scotland's "silicon glen" has been claimed with the announcement that a new fourth generation personal business computer codenamed "Project Apricot" is to be produced in Glenrothes New Town, Fife, in a \$20 million project.

Brainchild of Birmingham-based Applied Computer Techniques (ACT) it will be manufactured in a 4,650 square metre purpose-built factory on the new town's Southfield industrial estate and it is reckoned that its June-scheduled launch will be one of the world's biggest ever micro-computer manufacturing start-ups.

While details of the new product will remain a closely guarded secret until the official launch, ACT say that the micro-computers will incorporate a unique hardware/software mechanism that will greatly simplify the current level of technical expertise required to operate business computers.

The new computer will be aimed at the business user and be complementary with the US-produced Sirius 1 machine which has put ACT at the top of the UK business computer market tree in the space of 18 months.

The Glenrothes project will be the company's first venture into computer manufacture, though they already operate a computer print company, and their new product, Apricot, will cost "significantly less" than the Sirius, which is priced around the \$5,000 mark.

Every machine will come complete with a range of software covering the most common business applications and production is expected to rise to 4,000 units a month next year, with about 50 per cent being exported.

"There is clearly a niche in the market place for a portable business computer of advanced specification and we intend to meet that demand," said managing director Roger Foster.

"The decision to make such a forceful entry into manufacturing was founded on our high level of software expertise and the success we have had in distributing micro-computer hardware and software.

"This strength is reflected in ACT's no 1 position in sales of the 16-bit Sirius 1 micro-computer in the UK and with Apricot we will go from

no 1 in the UK into the top 20 suppliers of 16-bit personal computers in the world by 1984."

The company looked at a number of locations before settling on Glenrothes as the ideal site because it already has many high technology companies and a highly skilled workforce.

Microcomputers Unaffected by Climate

Order book values have reached \$20 million only one month after the launch of the Andromeda Zita range of go-anywhere portable micro-computers by Information and Technology Computer Services Group (ITCS) of Staines, near London.

Total orders have risen to 2000 units following the signing of a contract with Key Information Technology, a wholly-owned company of the YBA Kanoo Group of Saudi Arabia. They are one of the largest merchant houses in the Middle East and will ensure distribution throughout the Arabian Gulf. The contract is for an initial order of 500 machines.

The Andromeda Zita is claimed to be the world's first Winchester hard-disk based portable micro-computer and the first to be able to operate in extremes of climate - such as those in the Middle East. It weighs only 15.8 kg in its waterproof, hermetically-sealed case, and is ready for use anywhere with a built-in keyboard and 254 mm screen.

At present manufacture of the computers is carried out at Staines, Ashford (near London) and at Glenrothes in Scotland. To meet demand the company is having to increase production targets eightfold to 40 units per day, which will involve taking on additional staff and expanding production facilities.

The company has been in existence for only 14 months and expects that about 70 per cent of its production will be for export. Managing director of ITCS, David Lewis-Pryce, believes that the success of his company's computers proves that British high technology can compete successfully with that of the United States and Japan.

Hybrid Computer

Interactive Data Systems, a computer company based at Milton Keynes in the English midlands has produced a new hybrid computer which, it believes, is unique in the computer market.

The machine is a low cost micro computer which can run on both 8-bit and 16-bit software - most computers run on 8-bit.

There are two processors in the computer and it is possible to switch between them, depending on the required use.

The company is planning to distribute some 20,000 of these machines a year throughout Europe and the Middle East.

Educational establishments are expected to be particularly interested and a significant order has already been received from a University in Holland.

Software such as word processing, integrated accounts, stock control, financial modelling and data base is available with the computer.

The keyboard layout is standard with a separate numeric keypad. French and German layouts are also available.

Said Interactive Managing Director James Spencer: "At a cost of \$4,000 it would be difficult to find a more versatile machine. We are confident it is a winner."

The IDS 2009 comes with 128k of Random Access Memory, (RAM) expandable to 640k. Internal Bus Structure is S100, enabling the addition of up to two extra boards.

Disk Storage options are either single sided - each with 200k capacity - or double sided with 400k capacity. A 101 Megabyte Winchester and 200 mm IBM compatible floppy disk drives will be available later in 1983.

The machine comes with 240 mm green screen and separate DIN standard keyboard, with 12 programmable function keys and cursor control keys.

MBasic -86 comes as standard with the IDS 2009 and a complete range of programming languages operating under CP/M or MS-DOS is available.

COMPUTERS (HARDWARE)

THE ESSENTIAL COMPUTER DICTIONARY AND SPELLER AB011 \$10.45

A must for anyone just starting out in the field of computing, be they a businessman, hobbyist or budding computerist. The book presents and defines over 15,000 computer terms and acronyms and makes for great browsing.

A BEGINNER'S GUIDE TO COMPUTERS AND MICROPROCESSORS — WITH PROJECTS. TAB No.1015 \$14.45

Here's a plain English introduction to the world of microcomputers — its capabilities, parts and functions — and how you can use one. Numerous projects demonstrate operating principles and lead to the construction of an actual working computer capable of performing many useful functions.

BP66: BEGINNERS GUIDE TO MICROPROCESSORS AND COMPUTING E.F. SCOTT, M.Sc., C.Eng. \$7.55

As indicated by the title, this book is intended as an Introduction to the basic theory and concepts of binary arithmetic, microprocessor operation and machine language programming.

There are occasions in the text where some background information might be helpful and a Glossary is included at the end of the book.

BP72: A MICROPROCESSOR PRIMER E.A. PARR, B.Sc., C.Eng., M.I.E.E. \$7.70

A newcomer to electronics tends to be overwhelmed when first confronted with articles or books on microprocessors. In an attempt to give a painless approach to computing, this small book will start by designing a simple computer and because of its simplicity and logical structure, the language is hopefully easy to learn and understand. In this way, such ideas as Relative Addressing, Index Registers etc. will be developed and it is hoped that these will be seen as logical progressions rather than arbitrary things to be accepted but not understood.

BEGINNERS GUIDE TO MICROPROCESSORS TAB No.995 \$11.45

If you aren't sure exactly what a microprocessor is, then this is the book for you. The book takes the beginner from the basic theories and history of these essential devices, right up to some real world hardware applications.

HOW TO BUILD YOUR OWN WORKING MICROCOMPUTER TAB No.1200 \$16.45

An excellent reference or how-to manual on building your own microcomputer. All aspects of hardware and software are developed as well as many practical circuits.

BP78: PRACTICAL COMPUTER EXPERIMENTS E.A. PARR, B.Sc., C.Eng., M.I.E.E. \$7.30

Curiously most published material on the microprocessor tends to be of two sorts, the first treats the microprocessor as a black box and deals at length with programming and using the "beast". The second type of book deals with the social impact. None of these books deal with the background to the chip, and this is a shame as the basic ideas are both interesting and simple.

This book aims to fill in the background to the microprocessor by constructing typical computer circuits in discrete logic and it is hoped that this will form a useful introduction to devices such as adders, memories, etc. as well as a general source book of logic circuits.

HANDBOOK OF MICROPROCESSOR APPLICATIONS TAB No.1203 \$16.45

Highly recommended reading for those who are interested in microprocessors as a means of accomplishing a specific task. The author discusses two individual microprocessors, the 1802 and the 6800, and how they can be put to use in real world applications.

MICROPROCESSOR/MICROPROGRAMMING HANDBOOK TAB No.785 \$16.45

A comprehensive guide to microprocessor hardware and programming. Techniques discussed include subroutines, handling Interrupts and program loops

BP102: THE 6809 COMPANION M. JAMES \$8.10

The 6809 microprocessor's history, architecture, addressing modes and the instruction set (fully commented) are covered. In addition there are chapters on converting programs from the 6800, programming style, interrupt handling and about the 6809 hardware and software available.

AN INTRODUCTION TO MICROPROCESSORS EXPERIMENTS IN DIGITAL TECHNOLOGY HB07: SMITH \$16.45

A "learn by doing" guide to the use of integrated circuits provides a foundation for the underlying hardware actions of programming statements. Emphasis is placed on how digital circuitry compares with analog circuitry. Begins with the simplest gates and timers, then introduces the fundamental parts of ICs, detailing the benefits and pitfalls of major IC families, and continues with coverage of the ultimate in integrated complexity — the microprocessor.

DESIGNING MICROCOMPUTER SYSTEMS

HB18: POOCH AND CHATTERGY \$18.00

This book provides both hobbyists and electronic engineers with the background information necessary to build microcomputer systems. It discusses the hardware aspects of microcomputer systems. Timing devices are provided to explain sequences of operations in detail. Then, the book goes on to describe three of the most popular microcomputer families: the Intel 8080, Zilog Z-80, and Motorola 6800. Also covered are designs of interfaces for peripheral devices, and information on building microcomputer systems from kits.

S-100 BUS HANDBOOK HB19: BURSKY \$26.00

Here is a comprehensive book that exclusively discusses S-100 bus computer systems and how they are organized. The book covers computer fundamentals, basic electronics, and the parts of the computer. Individual chapters discuss the CPU, memory, input/output, bulk-memory devices, and specialized peripheral controllers. It explains all the operating details of commonly available S-100 systems. Schematic drawings.

BASIC MICROPROCESSORS AND THE 6800 HB06: \$24.45

Provides two books in one: a basic guide to microprocessors for the beginner, and a complete description of the M6800 system for the engineer.

Each chapter is followed by a problem section.

DIGITAL INTERFACING WITH AN ANALOG WORLD TAB No.1070 \$16.45

You've bought a computer, but now you can't make it do anything useful. This book will tell you how to convert real world quantities such as temperature, pressure, force and so on into binary representation.

MICROPROCESSOR INTERFACING HANDBOOK: A/D & D/A TAB No.1271 \$16.45

A useful handbook for computerists interested in using their machines in linear applications. Topics discussed include voltage references, op-amps for data conversion, analogue switching and multiplexing and more.

HOW TO TROUBLESHOOT AND REPAIR MICROCOMPUTERS AB013 \$13.45

Learn how to find the cause of a problem or malfunction in the central or peripheral unit of any microcomputer and then repair it. The tips and techniques in this guide can be applied to any equipment that uses the microprocessor as the primary control element.

TROUBLESHOOTING MICROPROCESSORS AND DIGITAL LOGIC TAB No.1183 \$16.45

The influence of digital techniques on commercial and home equipment is enormous and increasing yearly. This book discusses digital theory and looks at how to service Video Cassette Recorders, microprocessors and more.

HOW TO DEBUG YOUR PERSONAL COMPUTER AB012 \$13.45

When you feel like reaching for a sledge hammer to reduce your computer to fiberglass and epoxy dust, don't. Reach for this book instead and learn all about program bug tracking, recognition and elimination techniques.

COMPUTERS (SOFTWARE)

BP109: THE ART OF PROGRAMMING THE 1K ZX81 M. JAMES AND S.M. GEE \$8.10

This book shows you how to use the features of the ZX81 in programs that fit into the 1K machine and are still fun to use. Chapter Two explains the random number generator and uses it to simulate coin tossing and dice throwing and to play pon-toon. Chapter Three shows the patterns you can display using the ZX81's graphics. Its animated graphics capabilities, explored in Chapter Four, have lots of potential for use in games of skill, such as Lunar Lander and Cannon-ball which are given as complete programs. Chapter Five explains PEEK and POKE and uses them to display large characters. The ZX81's timer is explained in Chapter Six and used for a digital clock, a chess clock and a reaction time game. Chapter Seven is about handling character strings and includes three more ready-to-run programs — Hangman, Coded Messages and a number guessing game. In Chapter Eight there are extra programming hints to help you get even more out of your 1K ZX81.

BP114: THE ART OF PROGRAMMING THE 16K ZX81 M. JAMES & S.M. GEE \$10.40

The book starts by introducing the 16K RAM pack and the printer. It continues by explaining how the extra storage is used and presents a memory test program to check that the 16K RAM pack is operational. Chapter Three covers some utilities that you will find useful in writing longer programs. Chapter Four is an interlude from serious applications, presenting four games programs that make the most of the extended graphics capabilities now available to you. Chapters Five to Eight deal with writing and debugging large programs, storing them on cassettes and printing out both programs themselves and their results. These chapters also introduce programs for editing data bases and statistical analysis for financial management and covers text and graphics printing. Chapter Nine takes a look at randomness. Chapter Ten introduces machine code and explains why you might like to use it.

BEGINNER'S GUIDE TO COMPUTER PROGRAMMING TAB No.574 \$16.45

Computer programming is an increasingly attractive field to the individual, however many people seem to overlook it as a career. The material in this book has been developed in a logical sequence, from the basic steps to machine language.

HOW TO PROFIT FROM YOUR PERSONAL COMPUTER: PROFESSIONAL, BUSINESS, AND HOME APPLICATIONS LEWIS \$19.45

HB01 Describes the uses of personal computers in common business applications, such as accounting, managing, inventory, sorting mailing lists, and many others. The discussion includes terms, notations, and techniques commonly used by programmers. A full glossary of terms.

THE JOY OF MINIS AND MICROS: DATA PROCESSING WITH SMALL COMPUTERS STEIN AND SHAPIRO \$18.00

HB03 A collection of pieces covering technical and management aspects of the use of small computers for business or science. It emphasizes the use of common sense and good systems design for every computer project. Because a strong technical background is not necessary, the book is easy to read and understand. Considerable material is devoted to the question of what size computer should be used for a particular job, and how to choose the right machine for you.

USING MICROCOMPUTERS IN BUSINESS VEIT \$16.45

HB04 An essential background briefing for any purchaser of microcomputer systems or software. In a fast-moving style, without the usual buzz words and technical jargon, Veit answers the most often asked questions.

BASIC FROM THE GROUND UP SIMON \$19.45

HB15 Here's a BASIC text for high school students and hobbyists that explores computers and the BASIC language in a simple direct way, without relying on a heavy mathematical background on the reader's part. All the features of BASIC are included as well as some of the inside workings of a computer. The book covers one version of each of the BASIC statements and points out some of the variations, leaving readers well prepared to write programs in any version they encounter. A selection of exercises and six worked out problems round out the reader's experience. A glossary and a summary of BASIC statements are included at the end of the book for quick reference.

BASIC COMPUTER PROGRAMS FOR BUSINESS: STERNBERG (Vol. 1) \$18.45

HB13 A must for small businesses utilizing micros as well as for entrepreneurs, volume provides a wealth of practical business applications. Each program is documented with a description of its functions and operation, a listing in BASIC, a symbol table, sample data, and one or more samples.

BP86: AN INTRODUCTION TO BASIC PROGRAMMING TECHNIQUES S. DALY \$8.25

This book is based on the author's own experience in learning BASIC and in helping others, mostly beginners, to program and understand the language. Also included are a program library containing various programs, that the author has actually written and run. These are for biorhythms, plotting a graph of Y against X, standard deviation, regression, generating a musical note sequence and a card game. The book is complemented by a number of appendices which include test questions and answers on each chapter and a glossary.

THE BASIC COOKBOOK. TAB No.1055 \$10.45

BASIC is a surprisingly powerful language — if you understand it completely. This book, picks up where most manufacturers' documentation gives up. With it, any computer owner can develop programs to make the most out of his or her machine.

PET BASIC — TRAINING YOUR PET COMPUTER AB014 \$20.45

Officially approved by Commodore, this is the ideal reference book for long time PET owners or novices. In an easy to read and humorous style, this book describes techniques and experiments, all designed to provide a strong understanding of this versatile machine.

—PROGRAMMING IN BASIC FOR PERSONAL COMPUTERS AB015 \$13.45

This book emphasizes the sort of analytical thinking that lets you use a specific tool — the BASIC language — to transform your own ideas into workable programs. The text is designed to help you to intelligently analyse and design a wide diversity of useful and interesting programs.

COMPUTER PROGRAMS IN BASIC AB001 \$15.45

A catalogue of over 1,600 fully indexed BASIC computer programs with applications in Business, Math, Games and more. This book lists available software, what it does, where to get it, and how to adapt it to your machine.

PET GAMES AND RECREATION AB002 \$17.45

A variety of interesting games designed to amuse and educate. Games include such names as Capture, Tic Tac Toe, Watchperson, Motie, Sinners, Martian Hunt and more.

BRAIN TICKLERS AB005 \$9.00

If the usual games such as Bug Stomp and Invaders From the Time Warp are starting to pale, then this is the book for you. The authors have put together dozens of stimulating puzzles to show you just how challenging computing can be.

PASCAL TAB No.1205 \$16.45

Aimed specifically at TRS-80 users, this book discusses how to load, use and write PASCAL programs. Graphic techniques are discussed and numerous programs are presented.

PASCAL PROGRAMMING FOR THE APPLE

AB008 \$20.45
A great book to upgrade your programming skills to the UCSD Pascal as implemented on the Apple II. Statements and techniques are discussed and there are many practical and ready to run programs.

APPLE MACHINE LANGUAGE PROGRAMMING

AB009 \$20.45
The best way to learn machine language programming the Apple II in no time at all. The book combines colour, graphics, and sound generation together with clear cut demonstrations to help the user learn quickly and effectively.

Z80 USERS MANUAL

AB010 \$21.45
The Z80 MPU can be found in many machines and is generally acknowledged to be one of the most powerful 8 bit chips around. This book provides an excellent 'right hand' for anyone involved in the application of this popular processor.

HOW TO PROGRAM YOUR PROGRAMMABLE CALCULATOR

AB006 \$12.45
Calculator programming, by its very nature, often is an obstacle to effective use. This book endeavours to show how to use a programmable calculator to its full capabilities. The TI 57 and the HP 33E calculators are discussed although the principles extend to similar models.

Z-80 AND 8080 ASSEMBLY LANGUAGE PROGRAMMING

HB05 \$16.00
Provides just about everything the applications programmer needs to know for Z-80 and 8080 processors. Programming techniques are presented along with the instructions. Exercises and answers included with each chapter.

BASIC COMPUTER PROGRAMS IN SCIENCE AND ENGINEERING

HB08 \$18.00
Save time and money with this collection of 114 ready-to-run BASIC programs for the hobbyist and engineer. There are programs to do such statistical operations as means, standard deviation averages, curve-fitting, and interpolation. There are programs that design antennas, filters, attenuators, matching networks, plotting, and histogram programs.

MICROCOMPUTERS AND THE 3 R'S

HB09 \$16.45
This book educates educators on the various ways computers, especially microcomputers, can be used in the classroom. It describes microcomputers, how to organize a computer-based program, the five instructional application types (with examples from subjects such as the hard sciences, life sciences, English, history, and government) and resources listings of today's products. The book includes preprogrammed examples to start up a microcomputer program; while chapters on resources and products direct the reader to useful additional information. All programs are written in the BASIC language.

GAME PLAYING WITH BASIC

HB10 \$17.45
The writing is nontechnical, allowing almost anyone to understand computerized game playing. The book includes the rules of each game, how each game works, illustrative flowcharts, diagrams, and the output produced by each program. The last chapter contains 26 games for reader solution.

SARGON: A COMPUTER CHESS PROGRAM

HB12 \$26.00
"I must rate this chess program an excellent buy for anyone who loves the game." Kilobaud.

Here is the computer chess program that won first place in the first chess tournament at the 1978 West Coast Computer Faire. It is written in Z-80 assembly language, using the TDL macro assembler. It comes complete with block diagram and sample printouts.

A CONSUMER'S GUIDE TO PERSONAL COMPUTING AND MICROCOMPUTERS, SECOND EDITION

HB14 \$16.45
The first edition was chosen by Library Journal as one of the 100 outstanding sci-tech books of 1978. Now, there's an updated second edition!

Besides offering an introduction to the principles of microcomputers that assumes no previous knowledge on the reader's part, this second edition updates prices, the latest developments in microcomputer technology, and a review of over 100 microcomputer products from over 60 manufacturers.

THE BASIC CONVERSIONS HANDBOOK FOR APPLE, TRS-80, AND PET USERS

HB17 \$13.45
Convert a BASIC program for the TRS-80, Apple II, or PET to the form of BASIC used by any other one of those machines. This is a complete guide to converting Apple II and PET programs to TRS-80, TRS-80 and PET programs to Apple II, TRS-80 and Apple II programs to PET. Equivalent commands are listed for TRS-80 BASIC (Model I, Level II), Applesoft BASIC and PET BASIC, as well as variations for the TRS-80 Model III and Apple Integer BASIC.

SPEAKING PASCAL

HB16 \$19.45
An excellent introduction to programming in the Pascal language! Written in clear, concise, non-mathematical language, the text requires no technical background or previous programming experience on the reader's behalf. Top-down structured analysis and key examples illustrate each new idea and the reader is encouraged to construct programs in an organized manner.

BP33: ELECTRONIC CALCULATOR USERS

HANDBOOK \$24.25
M.H. BABANI, B.Sc.(Eng.)
An invaluable book for all calculator users whatever their age or occupation, or whether they have the simplest or most sophisticated of calculators. Presents formulae, data, methods of calculation, conversion factors, etc., with the calculator user especially in mind, often illustrated with simple examples. Includes the way to calculate using only a simple four function calculator: Trigonometric Functions (Sin, Cos, Tan); Hyperbolic Functions (Sinh, Cosh, Tanh) Logarithms, Square Roots and Powers.

THE MOST POPULAR SUBROUTINES IN BASIC

TAB No.1050 \$10.45
An understandable guide to BASIC subroutines which enables the reader to avoid tedium, economise on computer time and makes programs run faster. It is a practical rather than a theoretical manual.

PROJECTS

BP48: ELECTRONIC PROJECTS FOR BEGINNERS

\$5.90
F.G. RAYER, T.Eng.(CEI), Assoc.IERE
Another book written by the very experienced author — Mr. F.G. Rayer — and in it the newcomer to electronics, will find a wide range of easily made projects. Also, there are a considerable number of actual component and wiring layouts, to aid the beginner.

Furthermore, a number of projects have been arranged so that they can be constructed without any need for soldering and, thus, avoid the need for a soldering iron.

Also, many of the later projects can be built along the lines as those in the 'No Soldering' section so this may considerably increase the scope of projects which the newcomer can build and use.

221: 28 TESTED TRANSISTOR PROJECTS

R.TORRENS \$5.50
Mr. Richard Torrens is a well experienced electronics development engineer and has designed, developed, built and tested the many useful and interesting circuits included in this book. The projects themselves can be split down into simpler building blocks, which are shown separated by boxes in the circuits for ease of description, and also to enable any reader who wishes to combine boxes from different projects to realise ideas of his own.

BP49: POPULAR ELECTRONIC PROJECTS

\$6.25
R.A. PENFOLD
Includes a collection of the most popular types of circuits and projects which, we feel sure, will provide a number of designs to interest most electronics constructors. The projects selected cover a very wide range and are divided into four basic types: Radio Projects, Audio Projects, Household Projects and Test Equipment.

EXPERIMENTER'S GUIDE TO SOLID STATE ELECTRONIC PROJECTS

AB007 \$10.45
An ideal sourcebook of Solid State circuits and techniques with many practical circuits. Also included are many useful types of experimenter gear.

BP71: ELECTRONIC HOUSEHOLD PROJECTS

\$7.70
R. A. PENFOLD
Some of the most useful and popular electronic construction projects are those that can be used in or around the home. The circuits range from such things as '2 Tone Door Buzzer', Intercom, through Smoke or Gas Detectors to Baby and Freezer Alarms.

BP94: ELECTRONIC PROJECTS FOR CARS AND BOATS

\$8.10
R.A. PENFOLD
Projects, fifteen in all, which use a 12V supply are the basis of this book. Included are projects on Windscreen Wiper Control, Courtesy Light Delay, Battery Monitor, Cassette Power Supply, Lights Timer, Vehicle Immobiliser, Gas and Smoke Alarm, Depth Warning and Shaver Inverter.

BP69: ELECTRONIC GAMES

\$7.55
R.A. PENFOLD
In this book Mr. R. A. Penfold has designed and developed a number of interesting electronic game projects using modern integrated circuits. The text is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.

BP95: MODEL RAILWAY PROJECTS

\$8.10
Electronic projects for model railways are fairly recent and have made possible an amazing degree of realism. The projects covered include controllers, signals and sound effects: striboard layouts are provided for each project.

BP93: ELECTRONIC TIMER PROJECTS

\$8.10
F.G. RAYER
Windscreen wiper delay, darkroom timer and metronome projects are included. Some of the more complex circuits are made up from simpler sub-circuits which are dealt with individually.

110 OP-AMP PROJECTS

MARSTON \$13.45
HB24
This handbook outlines the characteristics of the op-amp and present 110 highly useful projects—ranging from simple amplifiers to sophisticated instrumentation circuits.

110 IC TIMER PROJECTS

GILDER \$11.45
HB25
This sourcebook maps out applications for the 555 timer IC. It covers the operation of the IC itself to aid you in learning how to design your own circuits with the IC. There are application chapters for timer-based instruments, automotive applications, alarm and control circuits, and power supply and converter applications.

110 THYRISTOR PROJECTS USING SCRs AND TRIACS

MARSTON \$13.45
HB22
A grab bag of challenging and useful semiconductor projects for the hobbyist, experimenter, and student. The projects range from simple burglar, fire, and water level alarms to sophisticated power control devices for electric tools and trains. Integrated circuits are incorporated wherever their use reduces project costs.

110 CMOS DIGITAL IC PROJECTS

MARSTON \$11.75
HB23
Outlines the operating characteristics of CMOS digital ICs and then presents and discusses 110 CMOS digital IC circuits ranging from inverter gate and logic circuits to electronic alarm circuits. Ideal for amateurs, students and professional engineers.

BP76: POWER SUPPLY PROJECTS

\$7.30
R.A. PENFOLD
Line power supplies are an essential part of many electronics projects. The purpose of this book is to give a number of power supply designs, including simple unregulated types, fixed voltage regulated types, and variable voltage stabilised designs, the latter being primarily intended for use as bench supplies for the electronics workshop. The designs provided are all low voltage types for semiconductor circuits.

There are other types of power supply and a number of these are dealt with in the final chapter, including a cassette power supply, Ni-Cad battery charger, voltage step up circuit and a simple inverter.

BP84: DIGITAL IC PROJECTS

\$8.10
F.G. RAYER, T.Eng.(CEI), Assoc.IERE
This book contains both simple and more advanced projects and it is hoped that these will be found of help to the reader developing a knowledge of the workings of digital circuits. To help the newcomer to the hobby the author has included a number of board layouts and wiring diagrams. Also the more ambitious projects can be built and tested section by section and this should help avoid or correct faults that could otherwise be troublesome. An ideal book for both beginner and more advanced enthusiast alike.

BP67: COUNTER DRIVER AND NUMERAL DISPLAY PROJECTS

\$7.55
F.G. RAYER, T.Eng.(CEI), Assoc. IERE
Numeral indicating devices have come very much to the forefront in recent years and will, undoubtedly, find increasing applications in all sorts of equipment. With present day integrated circuits, it is easy to count, divide and display numerically the electrical pulses obtained from a great range of driver circuits.

In this book many applications and projects using various types of numeral displays, popular counter and driver IC's etc. are considered.

BP73: REMOTE CONTROL PROJECTS

\$8.60
OWEN BISHOP
This book is aimed primarily at the electronics enthusiast who wishes to experiment with remote control. Full explanations have been given so that the reader can fully understand how the circuits work and can more easily see how to modify them for other purposes, depending on personal requirements. Not only are radio control systems considered but also infra-red, visible light and ultrasonic systems as are the use of Logic ICs and Pulse position modulation etc.

BP99: MINI—MATRIX BOARD PROJECTS

\$8.10
R.A. PENFOLD
Twenty useful projects which can all be built on a 24 x 10 hole matrix board with copper strips. Includes Doorbuzzer, Low-voltage Alarm, AM Radio, Signal Generator, Projector Timer, Guitar Headphone Amp, Transistor Checker and more.

BP103: MULTI-CIRCUIT BOARD PROJECTS

\$8.10
R.A. PENFOLD
This book allows the reader to build 21 fairly simple electronic projects, all of which may be constructed on the same printed circuit board. Wherever possible, the same components have been used in each design so that with a relatively small number of components and hence low cost, it is possible to make any one of the projects or by re-using the components and P.C.B. all of the projects.

BP107: 30 SOLDERLESS BREADBOARD PROJECTS —

BOOK 1 \$9.35
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which electronic circuits can be built and tested. The components used are just plugged in and unplugged as desired. The 30 projects featured in this book have been specially designed to be built on a "Verobloc" breadboard. Wherever possible the components used are common to several projects, hence with only a modest number of reasonably inexpensive components it is possible to build, in turn, every project shown.

BP106: MODERN OP-AMP PROJECTS

\$8.10
R.A. PENFOLD
Features a wide range of constructional projects which make use of op-amps including low-noise, low distortion, ultra-high input impedance, high slew-rate and high output current types.

BP110: HOW TO GET YOUR ELECTRONIC PROJECTS

WORKING \$8.10
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.

BP110: HOW TO GET YOUR ELECTRONIC PROJECTS WORKING

R.A. PENFOLD \$8.10
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.

CIRCUITS

BP80: POPULAR ELECTRONIC CIRCUITS — BOOK 1

R.A. PENFOLD \$8.25
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.

BP98: POPULAR ELECTRONIC CIRCUITS, BOOK 2

R.A. PENFOLD \$9.35
70 plus circuits based on modern components aimed at those with some experience.

THE GIANT HANDBOOK OF ELECTRONIC CIRCUITS

TAB No.1300 \$28.45
About as twice as thick as the Webster's dictionary, and having many more circuit diagrams, this book is ideal for any experimenter who wants to keep amused for several centuries. If there isn't a circuit for it in here, you should have no difficulty convincing yourself you don't really want to build it.

BP39: 50 (FET) FIELD EFFECT TRANSISTOR PROJECTS

F.G. RAYER, T.Eng.(CEI), Assoc.IERE \$5.50
Field effect transistors (FETs), find application in a wide variety of circuits. The projects described here include radio frequency amplifiers and converters, test equipment and receiver aids, tuners, receivers, mixers and tone controls, as well as various miscellaneous devices which are useful in the home.

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

BP87: SIMPLE I.E.D. CIRCUITS

R.N. SOAR \$5.90
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.

BP42: 50 SIMPLE I.E.D. CIRCUITS

R.N. SOAR \$3.55
The author of this book, Mr. R.N. Soar, has compiled 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components — the Light Emitting Diode (I.E.D.). A useful book for the library of both beginner and more advanced enthusiast alike.

BP82: ELECTRONIC PROJECTS USING SOLAR CELLS

OWEN BISHOP \$8.10
The book contains simple circuits, almost all of which operate at low voltage and low currents, making them suitable for being powered by a small array of silicon cells. The projects cover a wide range from a bicycle speedometer to a novelty 'Duck Shoot'; a number of power supply circuits are included.

BP37: 50 PROJECTS USING RELAYS, SCR'S & TRIACS

F.G. RAYER, T.Eng.(CEI), Assoc.IERE \$5.50
Relays, silicon controlled rectifiers (SCR's) and bi-directional triodes (TRIACs) have a wide range of applications in electronics today. This book gives tried and practical working circuits which should present the minimum of difficulty for the enthusiast to construct. In most of the circuits there is a wide latitude in component values and types, allowing easy modification of circuits or ready adaptation of them to individual needs.

BP44: IC 555 PROJECTS

E.A. PARR, B.Sc., C.Eng., M.I.E.E. \$7.55
Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are Basic and General Circuits, Motor Car and Model Railway Circuits, Alarms and Noise Makers as well as a section on the 556, 558 and 559 timers.

BP24: 50 PROJECTS USING IC741

RUDI & UWE REDMER \$4.25
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.

BP83: V MOS PROJECTS

R.A. PENFOLD \$8.20
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 V MOS 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.

BP65: SINGLE IC PROJECTS

R.A. PENFOLD \$6.55
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.

BP97: IC PROJECTS FOR BEGINNERS

F.G. RAYER \$8.10
Covers power supplies, radio, audio, oscillators, timers and switches. Aimed at the less experienced reader, the components used are popular and inexpensive.

BP88: HOW TO USE OP AMPS

E.A. PARR \$9.35
A designer's guide covering several op amps, serving as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.

IC ARRAY COOKBOOK

JUNG \$14.25

HB26 \$14.25
A practical handbook aimed at solving electronic circuit application problems by using IC arrays. An IC array, unlike specific-purpose ICs, is made up of uncommitted IC active devices, such as transistors, resistors, etc. This book covers the basic types of such ICs and illustrates with examples how to design with them. Circuit examples are included, as well as general design information useful in applying arrays.

BP50: IC LM3900 PROJECTS

H.KYBETT, B.Sc., C.Eng. \$5.90

The purpose of this book is to introduce the LM3900 to the Technician, Experimenter and the Hobbyist. It provides the groundwork for both simple and more advanced uses, and is more than just a collection of simple circuits or projects.

Simple basic working circuits are used to introduce this IC. The LM3900 can do much more than is shown here, this is just an Introduction. Imagination is the only limitation with this useful and versatile device. But first the reader must know the basics and that is what this book is all about.

223: 50 PROJECTS USING IC CA3130

R.A. PENFOLD \$5.50

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.

224: 50 CMOS IC PROJECTS

R.A. PENFOLD \$4.25

CMOS IC's are probably the most versatile range of digital devices for use by the amateur enthusiast. They are suitable for an extraordinary wide range of applications and are also some of the most inexpensive and easily available types of IC.

Mr. R.A. Penfold has designed and developed a number of interesting and useful projects which are divided into four general categories: I — Multivibrators II — Amplifiers and Oscillators III — Trigger Devices IV — Special Devices.

THE ACTIVE FILTER HANDBOOK

TAB No.1133 \$14.45

Whatever your field — computing, communications, audio, electronic music or whatever — you will find this book the ideal reference for active filter design.

The book introduces filters and their uses. The basic math is discussed so that the reader can tell where all design equations come from. The book also presents many practical circuits including a graphic equalizer, computer tape interface and more.

DIGITAL IC'S — HOW THEY WORK AND HOW TO USE THEM

AB004 \$11.45

An excellent primer on the fundamentals of digital electronics. This book discusses the nature of gates and related concepts and also deals with the problems inherent to practical digital circuits.

MASTER HANDBOOK OF 1001 PRACTICAL CIRCUITS

TAB No.800 \$20.45

MASTER HANDBOOK OF 1001 MORE PRACTICAL CIRCUITS \$24.45

TAB No.804 \$24.45
Here are transistor and IC circuits for just about any application you might have. An ideal source book for the engineer, technician or hobbyist. Circuits are classified according to function, and all sections appear in alphabetical order.

THE MASTER IC COOKBOOK

TAB No.1199 \$18.45

If you've ever tried to find specs for a so called 'standard' chip, then you'll appreciate this book. C.L. Hallmark has compiled specs and pinout for most types of ICs that you'd ever want to use.

ELECTRONIC DESIGN WITH OFF THE SHELF INTEGRATED CIRCUITS

AB016 \$13.45

This practical handbook enables you to take advantage of the vast range of applications made possible by integrated circuits. The book tells how, in step by step fashion, to select components and how to combine them into functional electronic systems. If you want to stop being a "cookbook hobbyist", then this is the book for you.

AUDIO

BP90: AUDIO PROJECTS

F.G. RAYER \$8.10

Covers in detail the construction of a wide range of audio projects. The text has been divided into preamplifiers and mixers, power amplifiers, tone controls and matching and miscellaneous projects.

205: FIRST BOOK OF HI-FI LOUDSPEAKER ENCLOSURES

B.B. BABANI \$3.55

This book gives data for building most types of loudspeaker enclosure. Includes corner reflex, bass reflex, exponential horn, folded horn, tuned port, klipschorn labyrinth, tuned column, loaded port and multi speaker panoramic. Many clear diagrams for every construction showing the dimensions necessary.

BP47: MOBILE DISCOTHEQUE HANDBOOK

COLIN CARSON \$5.90

The vast majority of people who start up "Mobile Discos" know very little about their equipment or even what to buy. Many people have wasted a "small fortune" on poor, unnecessary or badly matched apparatus.

The aim of this book is to give you enough information to enable you to have a better understanding of many aspects of "disco" gear.

HOW TO BUILD A SMALL BUDGET RECORDING STUDIO FROM SCRATCH

TAB No.1166 \$16.45

The author, F. Alton Everest, has gotten studios together several times, and presents twelve complete, tested designs for a wide variety of applications. If all you own is a mono cassette recorder, you don't need this book. If you don't want your new four track to wind up sounding like one, though, you shouldn't be without it.

BP51: ELECTRONIC MUSIC AND CREATIVE TAPE RECORDING

M.K. BERRY \$5.50

Electronic music is the new music of the Twentieth Century. It plays a large part in "pop" and "rock" music and, in fact, there is scarcely a group without some sort of synthesiser or other effects generator.

This book sets out to show how electronic music can be made at home with the simplest and most inexpensive of equipment. It then describes how the sounds are generated and how these may be recorded to build up the final composition.

BP74: ELECTRONIC MUSIC PROJECTS

R.A. PENFOLD \$7.70

Although one of the more recent branches of amateur electronics, electronic music has now become extremely popular and there are many projects which fall into this category. The purpose of this book is to provide the constructor with a number of practical circuits for the less complex items of electronic music equipment, including such things as a Fuzz Box, Waa-Waa Pedal, Sustain Unit, Reverberation and Phaser-Units, Tremolo Generator etc.

BP81: ELECTRONIC SYNTHESISER PROJECTS

M.K. BERRY \$7.30

One of the most fascinating and rewarding applications of electronics is in electronic music and there is hardly a group today without some sort of synthesiser or effects generator. Although an electronic synthesiser is quite a complex piece of electronic equipment, it can be broken down into much simpler units which may be built individually and these can then be used or assembled together to make a complete instrument.

ELECTRONIC MUSIC SYNTHESIZERS

TAB No.1167 \$11.45

If you're fascinated by the potential of electronics in the field of music, then this is the book for you. Included is data on synthesizers in general as well as particular models. There is also a chapter on the various accessories that are available.

TEST EQUIPMENT

BP75: ELECTRONIC TEST EQUIPMENT CONSTRUCTION

F.G. RAYER, T.Eng. (CEI), Assoc. IERE \$7.30

This book covers in detail the construction of a wide range of test equipment for both the Electronics Hobbyists and Radio Amateur. Included are projects ranging from an FET Amplified Voltmeter and Resistance Bridge to a Field Strength Indicator and Heterodyne Frequency Meter. Not only can the home constructor enjoy building the equipment but the finished projects can also be usefully utilised in the furtherance of his hobby.

99 TEST EQUIPMENT PROJECTS YOU CAN BUILD

TAB No.805 \$16.45
An excellent source book for the hobbyist who wants to build up his work bench inexpensively. Projects range from a simple signal tracer to a 50MHz frequency counter. There are circuits to measure just about any electrical quantity: voltage, current, capacitance, impedance and more. The variety is endless and includes just about anything you could wish for!

HOW TO GET THE MOST OUT OF LOW COST TEST EQUIPMENT

AB017 \$10.45
Whether you want to get your vintage 1960 'TestRite' signal generator working, or you've got something to measure with nothing to measure it with, this is the book for you. The author discusses how to maximize the usefulness of cheap test gear, how to upgrade old equipment, and effective test set ups.

THE POWER SUPPLY HANDBOOK

TAB No.806 \$16.45
A complete one stop reference for hobbyists and engineers. Contains high and low voltage power supplies of every conceivable type as well mobile and portable units.

BP70: TRANSISTOR RADIO FAULT-FINDING CHART \$2.40

CHAS. E. MILLER
Across the top of the chart will be found four rectangles containing brief descriptions of various faults; vis: — sound weak but undistorted; set dead; sound low or distorted and background noises. One then selects the most appropriate of these and following the arrows, carries out the suggested checks in sequence until the fault is cleared.

ELECTRONIC TROUBLESHOOTING HANDBOOK

AB019 \$12.45
This workbench guide can show you how to pinpoint circuit troubles in minutes, how to test anything electronic, and how to get the most out of low cost test equipment. You can use any and all of the time-saving shortcuts to rapidly locate and repair all types of electronic equipment malfunctions.

COMPLETE GUIDE TO READING SCHEMATIC DIAGRAMS

AB018 \$10.45
A complete guide on how to read and understand schematic diagrams. The book teaches how to recognize basic circuits and identify component functions. Useful for technicians and hobbyists who want to avoid a lot of headscratching.

RADIO AND COMMUNICATIONS

BP79: RADIO CONTROL FOR BEGINNERS \$7.30

F.G. RAYER, T.Eng.(CEI), Assoc.IERE.
The aim of this book is to act as an introduction to Radio Control for beginners to the hobby. The book will commence by dealing with the conditions that are allowable for such things as frequency and power of transmission. This is followed by a "block" explanation of how control-device and transmitter operate and receiver and actuator(s) produce motion in a model.

Details are then given of actual solid state transmitting equipment which the reader can build. Plain and loaded aerials are then discussed and so is the field-strength meter to help with proper setting up.

The radio receiving equipment is then dealt with which includes a simple receiver and also a crystal controlled superhet. The book ends with the electro-mechanical means of obtaining movement of the controls of the model.

BP96: CB PROJECTS \$8.10

R.A. PENFOLD
Projects include speech processor, aerial booster, cordless mike, aerial and harmonic filters, field strength meter, power supply, CB receiver and more.

222: SOLID STATE SHORT WAVE RECEIVERS FOR BEGINNERS \$5.20

R.A. PENFOLD
In this book, R.A. Penfold has designed and developed several modern solid state short wave receiver circuits that will give a fairly high level of performance, despite the fact that they use only relatively few and inexpensive components.

BP91: AN INTRODUCTION TO RADIO DXing \$8.10

This book is divided into two main sections one to amateur band reception, the other to broadcast bands. Advice is given to suitable equipment and techniques. A number of related constructional projects are described.

BP105: AERIAL PROJECTS \$8.10

R.A. PENFOLD
The subject of aerials is vast but in this book the author has considered practical designs including active, loop and ferrite aerials, which give good performances and are reasonably simple and inexpensive to build. The complex theory and math of aerial design are avoided.

BP46: RADIO CIRCUITS USING IC's \$5.90

J.B. DANCE, M.Sc.
This book describes integrated circuits and how they can be employed in receivers for the reception of either amplitude or frequency modulated signals. The chapter on amplitude modulated (a.m.) receivers will be of most interest to those who wish to receive distant stations at only moderate audio quality, while the chapter on frequency modulation (f.m.) receivers will appeal to those who desire high fidelity reception.

BP92: ELECTRONICS SIMPLIFIED—CRYSTAL SET CONSTRUCTION \$7.30

F.A. WILSON
Aimed at those who want to get into construction without much theoretical study. Homewound coils are used and all projects are very inexpensive to build.

REFERENCE

THE BEGINNER'S HANDBOOK OF ELECTRONICS

AB003 \$11.45
An excellent textbook for those interested in the fundamentals of Electronics. This book covers all major aspects of power supplies, amplifiers, oscillators, radio, television and more.

ELEMENTS OF ELECTRONICS — AN ON-GOING SERIES

F.A. WILSON, C.G.I.A., C.Eng.,

BP62: BOOK 1. The Simple Electronic Circuit and Components \$8.95

BP63: BOOK 2. Alternating Current Theory \$8.95

BP64: BOOK 3. Semiconductor Technology \$8.95

BP77: BOOK 4. Microprocessing Systems And Circuits \$12.30

BP89: BOOK 5. Communication \$12.30

The aim of this series of books can be stated quite simply — it is to provide an inexpensive introduction to modern electronics so that the reader will start on the right road by thoroughly understanding the fundamental principles involved.

Although written especially for readers with no more than ordinary arithmetical skills, the use of mathematics is not avoided, and all the mathematics required is taught as the reader progresses.

Each book is a complete treatise of a particular branch of the subject and, therefore, can be used on its own with one proviso, that the later books do not duplicate material from their predecessors, thus a working knowledge of the subjects covered by the earlier books is assumed.

BOOK 1: This book contains all the fundamental theory necessary to lead to a full understanding of the simple electronic circuit and its main components.

BOOK 2: This book continues with alternating current theory without which there can be no comprehension of speech, music, radio, television or even the electricity utilities.

BOOK 3: Follows on semiconductor technology, leading up to transistors and integrated circuits.

BOOK 4: A complete description of the internal workings of microprocessor.

BOOK 5: A book covering the whole communication scene.

BP85: INTERNATIONAL TRANSISTOR EQUIVALENTS GUIDE \$12.25

ADRIAN MICHAELS
This book will help the reader to find possible substitutes for a popular user-orientated selection of modern transistors. Also shown are the material type, polarity, manufacturer selection of modern transistors. Also shown are the material type, polarity, manufacturer and use. The Equivalents are sub-divided into European, American and Japanese. The products of over 100 manufacturers are included. An essential addition to the library of all those interested in electronics, be they technicians, designers, engineers or hobbyists. Fantastic value for the amount of information it contains.

BP108: INTERNATIONAL DIODE EQUIVALENTS GUIDE \$8.35

ADRIAN MICHAELS
This book is designed to help the user in finding possible substitutes for a large user orientated selection of the many different types of semiconductor diodes that are available today. Besides simple rectifier diodes also included are Zener diodes, LEDs, Diacs Triacs, Thyristors, Photo diodes and Display diodes.

BP1: FIRST BOOK OF TRANSISTOR EQUIVALENTS AND SUBSTITUTES \$2.80

B.B. BABANI
This guide covers many thousands of transistors showing possible alternatives and equivalents. Covers transistors made in Great Britain, USA, Japan, Germany, France, Europe, Hong Kong, and includes types produced by more than 120 different manufacturers.

BP14: SECOND BOOK OF TRANSISTOR EQUIVALENTS AND SUBSTITUTES \$4.80

B.B. BABANI
The "First Book of Transistor Equivalents" has had to be reprinted 15 times. The "Second Book" produced in the same style as the first book, in no way duplicates any of the data presented in it. The "Second Book" contains only additional material and the two books complement each other and make available some of the most complete and extensive information in this field. The interchangeability data covers semiconductor manufacturers in Great Britain, USA, Germany, France, Poland, Italy, East Germany, Belgium, Austria, Netherlands and many other countries.

TOWER'S INTERNATIONAL OP-AMP LINEAR IC SELECTOR \$13.45

TAB No.1216
This book contains a wealth of useful data on over 5,000 Op-amps and linear ICs — both pinouts and essential characteristics. A comprehensive series of appendices contain information on specs, manufacturers, case outlines and so on.

CMOS DATABOOK

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Into Digital

seven-segment display. The arrangement of the seven-segment display is shown in Fig. 4, and it consists of seven bars of LED material arranged in a figure eight pattern. There is often an eighth segment, a decimal point, but this is not activated by the decade counter so we'll ignore it for the moment.

Now at this point we have a problem of a type which gets more familiar (and more complicated) as we go on with digital electronics. There are four outputs from the 74LS90 counter and there are seven segments to drive. In addition, the signals from the counter are TTL signals, 0V or +5V, and the signal needed at the display to make a segment glow is about 2V. We need some

outputs to the display inputs by resistors, which will limit the amount of current. Without these resistors, the display would be bright, but not for long!

It's straightforward so far, then, but there is one minor complication. There are two varieties of seven-segment displays using LEDs. Each LED in a display has an anode and a cathode. We don't need to have separate connections to each anode and cathode, so we can connect one lot together.

Common-cathode LED displays have one cathode terminal, and the inputs are the separate anode terminals. Common-anode LED displays have one anode terminal, and the inputs are to the separate cathode ter-

sometimes quite hard to get — lots of people advertise it but can't necessarily supply it. If you're unlucky, just reorder for the 7448 instead — it will take more current but it operates in the same way. The display is mounted on columns C and D of the breadboard. The pinout, looking from the top, is shown in Fig. 6 and the mounting position is with pin 1 in line 10C and pin 14 in line 10D. The connections are then as shown in Fig. 5. Check your connections before testing the circuit, and then set SW1 down (to isolate the clock) and SW4 up (to reset the counter). Switch SW2 is connected to the LAMP TEST pin of the 74LS48 (line 20C) and SW3 is connected to the RB input (lines 22C, 21C). Indicator LED 1 on the board is connected to the RB output pin of the 74LS48 — we'll explain these RB inputs and output later on. For the moment, keep the SW2 up and SW3 down.

Switch on, and you should be rewarded with a zero on the display, since the counter is reset to zero. With SW2 down, the remaining segment will light up, because the 'LAMP TEST' input does just that — it switches on each segment of the LED display. That way, you can test displays without having to watch each stage of a count. Put SW2 up again, so that the zero shows, and switch SW1 up, to start the count. The display should now start to go through a normal counting sequence 1,2,3 and so-on up to 9. On the next clock pulse, the gates in the 74LS90 will reset the counter so that the zero shows again.

Suppose you wanted to display tens and hundreds? It's just a matter of repeating these circuits, and the method is shown in Fig. 7, though we haven't room to construct it. The units counter has its QD output connected to the A-input of the next counter, and the ripple-blanking input to the next output as shown. Each counter has its own decoder and seven-segment display.

Ripple-blanking? That's a useful feature of the 74LS48 which we don't need in our circuit, but which is handy when we connect up a lot of counting units together. When the RB connections are 'daisy-chained' (Fig. 7) then the display suppresses leading zeros. In plain English, that means it would never, for example, show 0012, only 12. The zeros which come before any other numbers are simply not displayed — the ripple-blank input acts to gate them off.

Before we leave counting, there's one important point about the 74LS48. At each of the possible input binary numbers from 0000 to 1111,

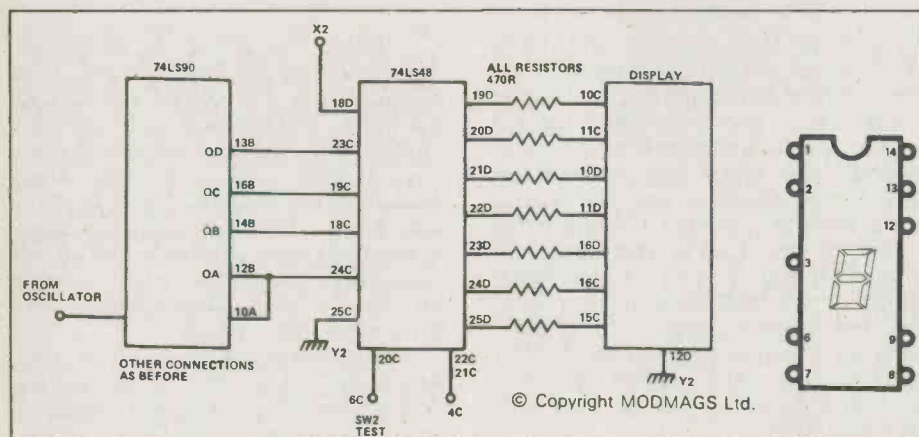


Fig. 5 Counter-decoder-display circuit. Connections to the 74LS90 counter are the same as they were in Fig. 3, but the outputs Qa to Qd are connected to the decoder inputs, and the decoder output are connected through 470R resistors to the display.

method of converting BCD signals into seven segment signals, and TTL levels into LED segment levels. This sort of problem is an interfacing problem, and like most interfacing problems it's solved by using another IC.

The other IC is a BCD-to-seven-segment decoder. Its inputs are the BCD signals from the counter and its outputs are the seven segment lines. These will still deliver signals at TTL levels, so we connect the decoder

minals. Because the display glows when an anode is taken positive or a cathode negative, the two types must use different decoders, or one decoder type, with seven inverters for the opposite type of display.

For our board, the most convenient display is the Litronix, DL728. This is a common-cathode display, and the decoder which goes with it is the 74LS48. We're using 470R resistors to limit the current in each segment to about 6 mA. This is more out of consideration for your power supply than for the display, which could take quite a bit more, up to 20 mA per segment.

Counter Circuit

The circuit for the complete counter and display is shown in Fig. 5. We've used quite a lot of the board for this, and several new components. The 74LS48 is placed with its pin 1 in line 18C and pin 16 in line 18D, replacing a 74LS76. Note that this is a 16-pin chip. Incidentally, the 74LS48 is

DISPLAY		
74LS48	PIN	FUNCTION
	1	ANODE F
	2	ANODE G
	3	NO PIN
	4	CATHODE
	5	NO PIN
	6	ANODE E
	7	ANODE D
	8	ANODE C
	9	ANODE DP
	10	NO PIN
	11	NO PIN
	12	CATHODE
	13	ANODE B
	14	ANODE A
1. QB INPUT		
2. QC INPUT		
3. LAMP TEST		
4. RB OUT		
5. RB IN		
6. QD INPUT		
7. QA INPUT		
8. EARTH		
9. E OUTPUT		
10. D OUTPUT		
11. C OUTPUT		
12. B OUTPUT		
13. A OUTPUT		
14. G OUTPUT		
15. F OUTPUT		
16. +5V		
ONLY ONE CATHODE CONNECTION NEED BE USED		

Fig. 6 Pinouts for the display and for the 74LS 48 decoder.

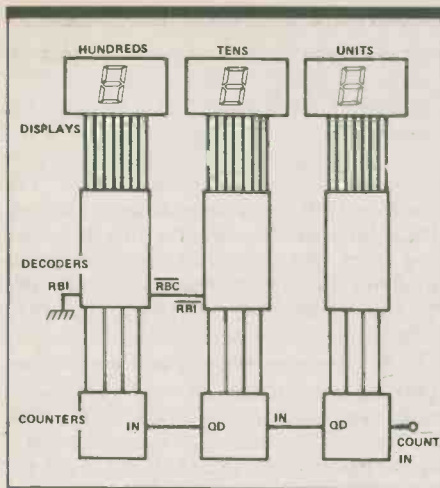


Fig. 7 How a count of up to 99 can be achieved. Each digit needs one 74LS90, equivalent to one 74LS48 decoder, and a seven-segment display. The Qd of the units counter is connected to the input of the tens counter, and the Qd of the tens counter is connected to the input of the hundreds counter. The hundreds and tens decoders have their ripple-blanking connections made so that leading zeros are suppressed.

there is a different set of digits on the seven output lines. This is a simple form of read-only memory chip, because a definite output is always obtained for each input. If we thought of the 74LS48 as a memory circuit, the inputs A, B, C, d would be called the 'address', and the outputs the data. For example, an address of 1000 (eight) gives a data output of 1111111 (all segments lit). Why read-only? Well, there's nothing we can do to change the data which comes out of the 74LS48. An input of 1000 will always give an output of 1111111, and we can't make it 1010101 by any sort of juggling with the chip. The memory circuits which will output a different set of bits at each input address, and if you're familiar with chips like the 74LS48, then memory circuits don't seem quite so unfamiliar.

Back to the Beautiful Movers

Decimal counting and display is just a brief interlude in a lot of binary circuits, and we need now to return to shift registers. We make a shift register from four J-K flip-flops, but nowadays, a shift register would be bought as a complete IC. Shift registers, despite the name, aren't used just for shifting, and we need to know a bit more about their uses nowadays, because microprocessors contain a lot of shift registers.

There are four basic types, labelled SISO, PIPO, PISO, and SIPO. As usual, the letters are the first letters of words, S for serial, P for parallel, I

for input, O for output, and the letters therefore describe how each shift register can be used. In the descriptions which follow, remember that a bit means a binary digit, 0 or 1.

SISO

The SISO shift register is serial in, serial out. A register of this type would have one input and one output, with a clock terminal. A bit at the input is shifted in by a clock pulse, and won't appear at the output until several clock pulses later. How many? That depends on how many flip-flops are in the register; a complete shift through the register will take as many clock pulses as there are flip-flops. It's useful way of delaying a set of bits on their way through a circuit, or of storing bits for a set number of clock pulses.

PIPO

The opposite extreme is the PIPO register, parallel in and parallel out. We can use this one without ever applying clock pulses, simply as a latch to hold some data bits. If a serial input is also provided, this can rotate a set of bits (Fig. 8), so that the bits which you read out are not in the same positions as they were when you put them in. It, too, has its uses.

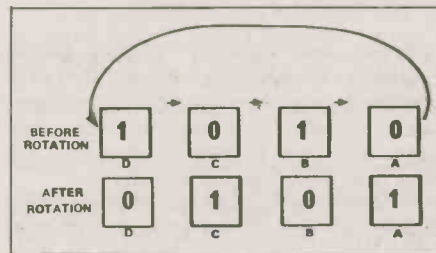


Fig. 8 Rotating a set of bits with a shift register.

SIPO & PISO

The SIPO and PISO are both extremely useful forms of registers. The PISO is parallel in, serial out, so that a complete group of bits can be stored in the register, using one line for each bit, and then read out one by one along a single line. This is how information in groups of bits (like the eight bit unit, or byte, which is used by most microprocessors) can be sent along a single wire to a video terminal, a printer or a cassette recorder. The PISO register is, of

course, only a part of the whole system but its part is the important one — conversion from parallel eight bits to serial one-at-a time.

A SIPO register is the widget you need for the opposite conversion. When you have bits in serial form coming along a single line, and you want to assemble them into groups to deliver to some system which deals with groups (display, microprocessor or whatever), then the SIPO register provides the method. The bits enter the serial inputs, are shifted along the register at each clock pulse, and can be read at the parallel outputs after the correct number of clock pulses. We've simplified all this, of course, because there are usually other problems to solve. You have to be sure that when you send bits out serially, each of them is doing something. There's no point, for example, in sending bits at a rate of 100,000 bits per second to a printer which can cope with only a few hundred bits per second. Taking another example, if you're reading serial bits into a register, you have to make sure that you are grouping them correctly, and not taking some bits from the end of one group and some from the start of the next. There are several ways of ensuring that these actions go smoothly: one of them is the use of bits to identify stop and start, but we don't need to go into these problems right now.

Practical Shifting

What we do need, however, is some first hand experience with a shift register. We could use various IC shift registers to demonstrate all of these actions, or even use a 74LS295, which has both serial and parallel inputs and outputs to demonstrate all four types of registers, but the easiest and least pricy method is just to use the 74LS76s which we already have.

Next, month, we'll show you how to use the 74LS76's to form the various types of shift registers.

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BIFET & BIMOS Op Amps

Continued from page 30

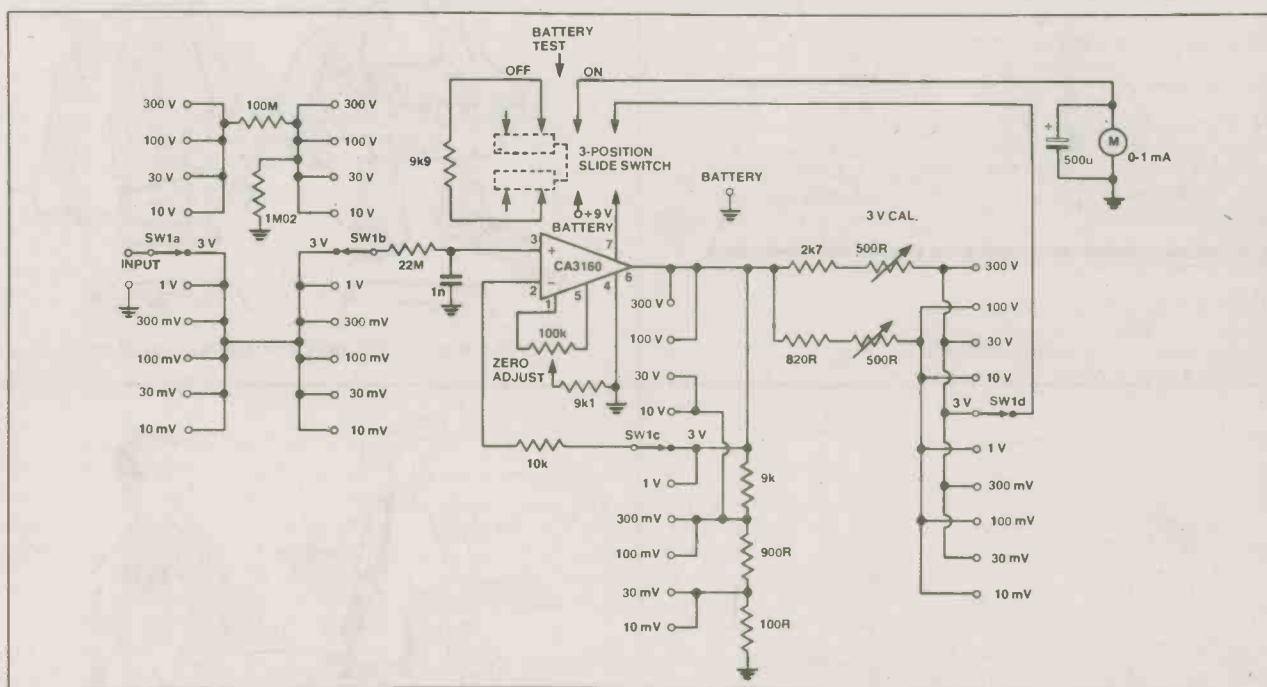


Fig. 19 Example of a multi-range voltmeter measuring from 10 mV to 300 V.

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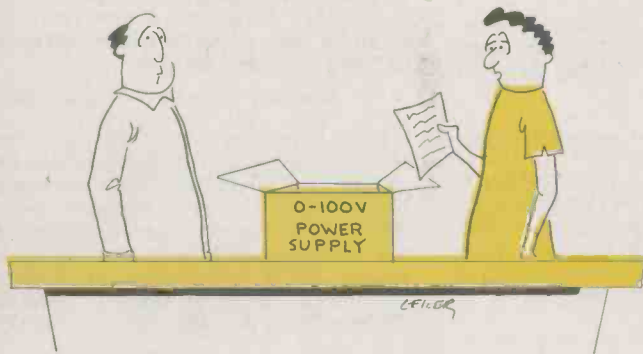
a CA3130 with a frequency compensation capacitor of about 56p between pins 1 and 8.

The aim of this article has not been to introduce readers to all the latest BiFET and BiMOS devices (of which there are large numbers), but

rather to give an indication of the wide selection of circuits that can be made with just a few of the standard types of device which are readily available.

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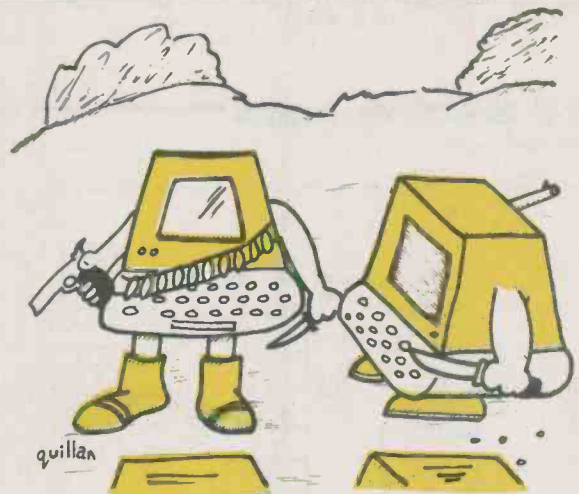
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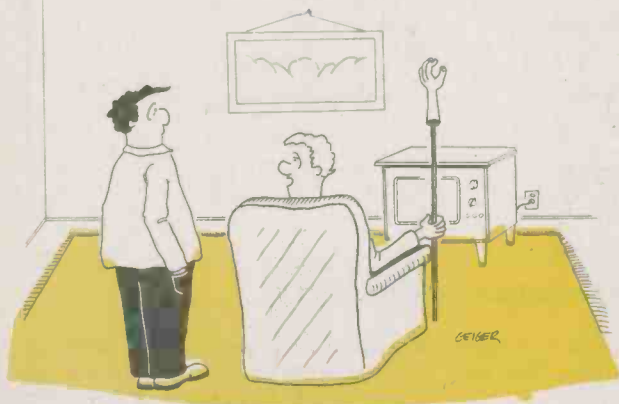
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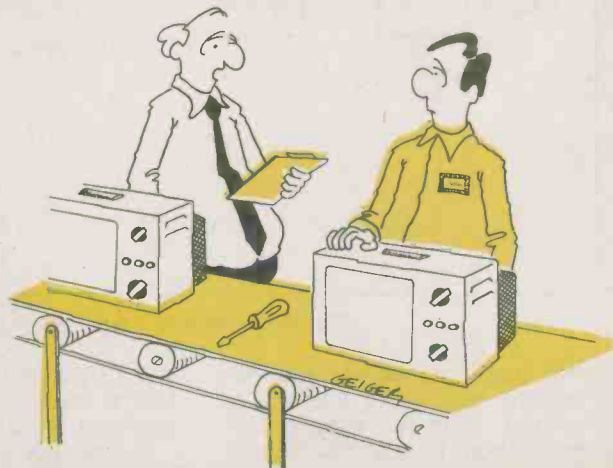
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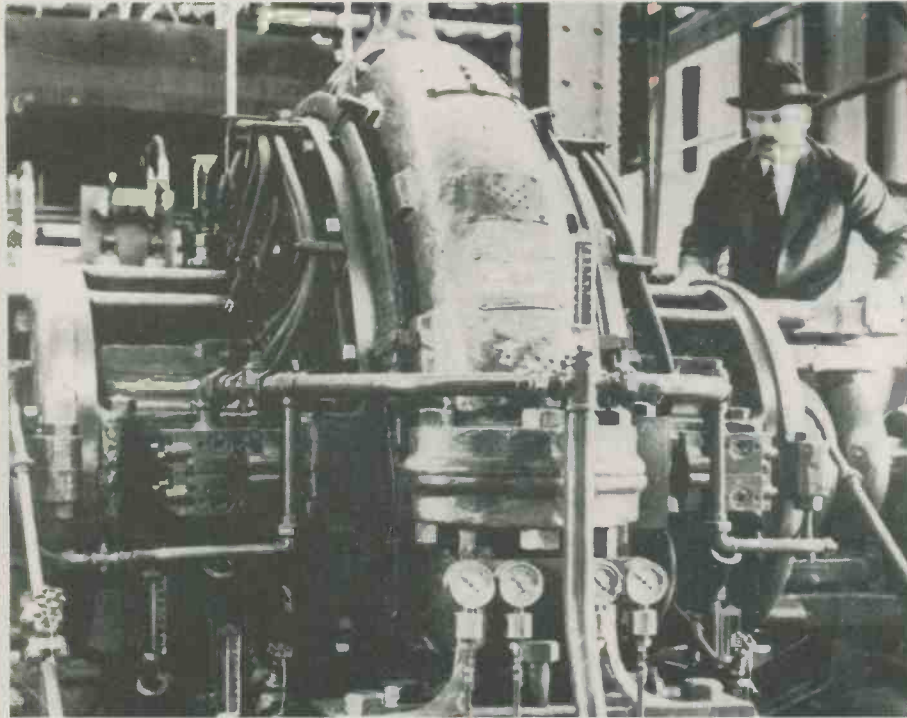
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National Inventors Hall of Fame

Dr. Ernst F.W. Alexanderson, the General Electric Company engineer whose high-frequency alternator gave the United States its

start in the field of radio communication, was inducted recently into the National Inventors Hall of Fame in Arlington, Va.

A native of Sweden, Dr. Alexanderson worked at GE's engineering laboratories in Schenectady, N.Y., from 1901 until 1948. His inventive genius made it possible to transmit

the human voice for many thousands of miles via the first continuous-wave broadcast at 2 KW. He died in 1975.

Dr. Alexanderson was one of five inventors selected this year for the National Inventors Hall of Fame from a field of more than 100 candidates by a panel of judges from 30 scientific and engineering societies. The others were Robert N. Noyce, semiconductor pioneer; Andrew Alford, developer of instrument landing systems for aircraft; Herbert H. Dow, founder of Dow Chemical Company; and George R. Stibits, the "father" of the modern digital computer.

This brings to a total of 48 the number of inventors currently represented in the National Inventors Hall of Fame — including the premier member, Thomas A. Edison, and two other Schenectady GE alumni, Dr. William D. Coolidge and Dr. Charles P. Steinmetz.

Computer Competition Stiffens

According to Reuters news service, competition in personal computers should increase shortly as various manufacturers introduce new models to fill the gap in the \$500 to \$1500 market. Tandy (Radio Shack), IBM, and Apple are working on personal computers in the \$700 to \$1000 range. The IBM, for instance, supposedly will be under \$1000, work through a TV set, and be marketed through large retail chains.

New Magazine for Timex Sinclair Users

A consortium of North American companies has come together to publish the first monthly magazine aimed solely at the 700,000 users of the TS1000 and ZX81. In what is one of the largest magazine launches into the home computer market, TIMEX SINCLAIR USER will have an initial print-run of 100,000.

TIMEX SINCLAIR USER Magazine which will cost \$2.95 and has an annual subscription rate of \$29.95, will cover the full spectrum of user interests: education, business applications, home management, games, family entertainment and at least eight pages of program print outs.

Contact, ECC PUBLICATIONS INC., 49 La Salle Avenue, Buffalo, N.Y. 14217.

We're not making this up . . .

Teleconferencing, whereby executives can see each other via a video/audio hookup across the country, has run into some obstacles which may prevent the service from becoming a smash hit with the boardroom set. According to International Resource Development, Inc., a Connecticut marketing research firm, "an individual who has watched TV over twenty years comes to expect certain behaviour from the people he sees on the screen . . . carefully dressed, coiffed actors with scripted roles. By contrast, the participants in a teleconference tend to have their ties askew, don't always look at the camera, and may pick their noses and seem unsure what to say. This amateurish production is subconsciously translated into an appearance of incompetence." Marketing people see the possibility of \$10 billion in teleconference sales shrinking away as the "medium portrays executives as nerds." And you thought you had problems.

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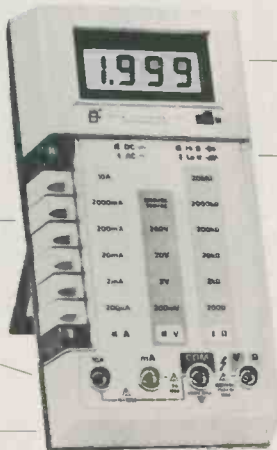
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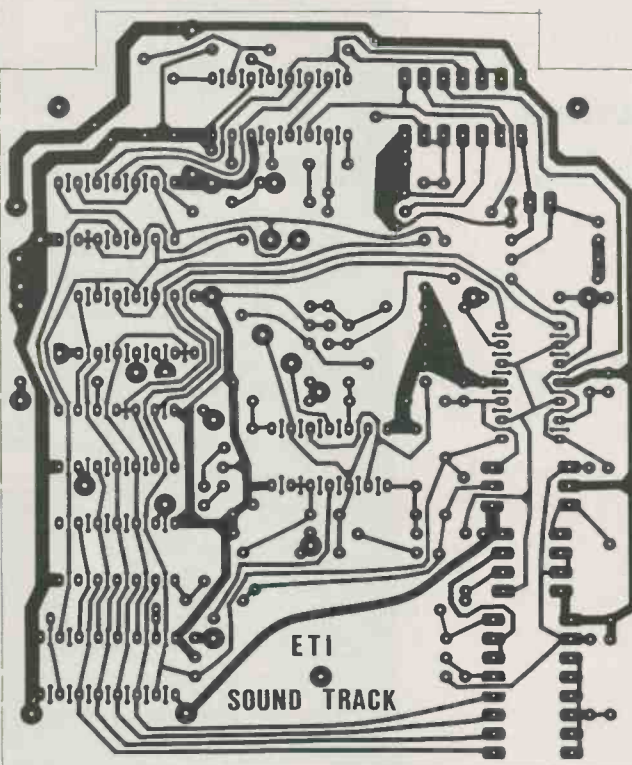
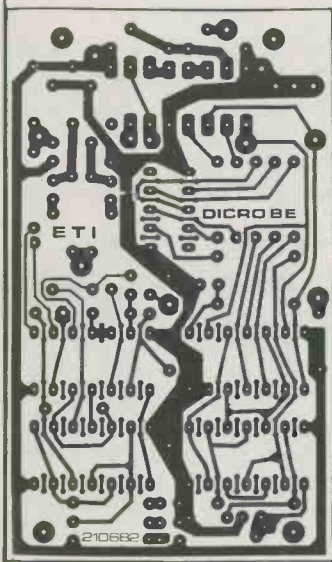
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for your information

PCB Corrections

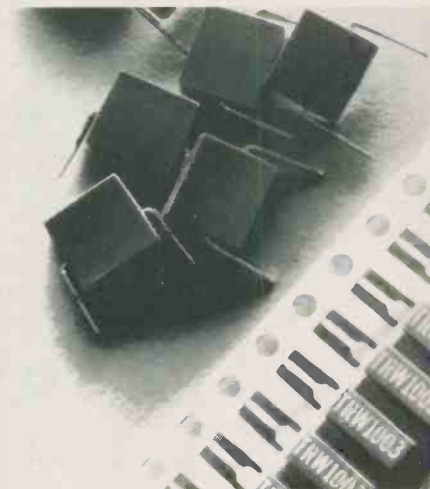
The printed circuit artwork for the Soundtrack and Dual Logic Probe projects in March have been included in this issue. Our apologies to anyone inconvenienced, and our assurance that we've initiated a checklist system to keep track of errant PCB's.



TRW Introduces Laser Produced Capacitor

TRW Capacitor Division is introducing its newest state-of-the-art 2-pin dip capacitor—the micro-thin gauge (MTG) TRW 80 Series.

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For additional information, contact John Gamet, Communications Manager, TRW Capacitor Division, 301 West "0" Street, Ogallala, NE 69153 or telephone (308) 284-3611.

Fuel-efficient Irritation

A British company, Econocruise Limited, is marketing a microprocessor which monitors truck engine parameters and tells the driver when to shift gears for best fuel economy. It also includes a cruise-control system for highway use. Unfortunately, the shift points are indicated by a synthesised voice from out of the dashboard - "change up", "change down". Don't be surprised if you see Econocruises littering the sides of major truck routes.

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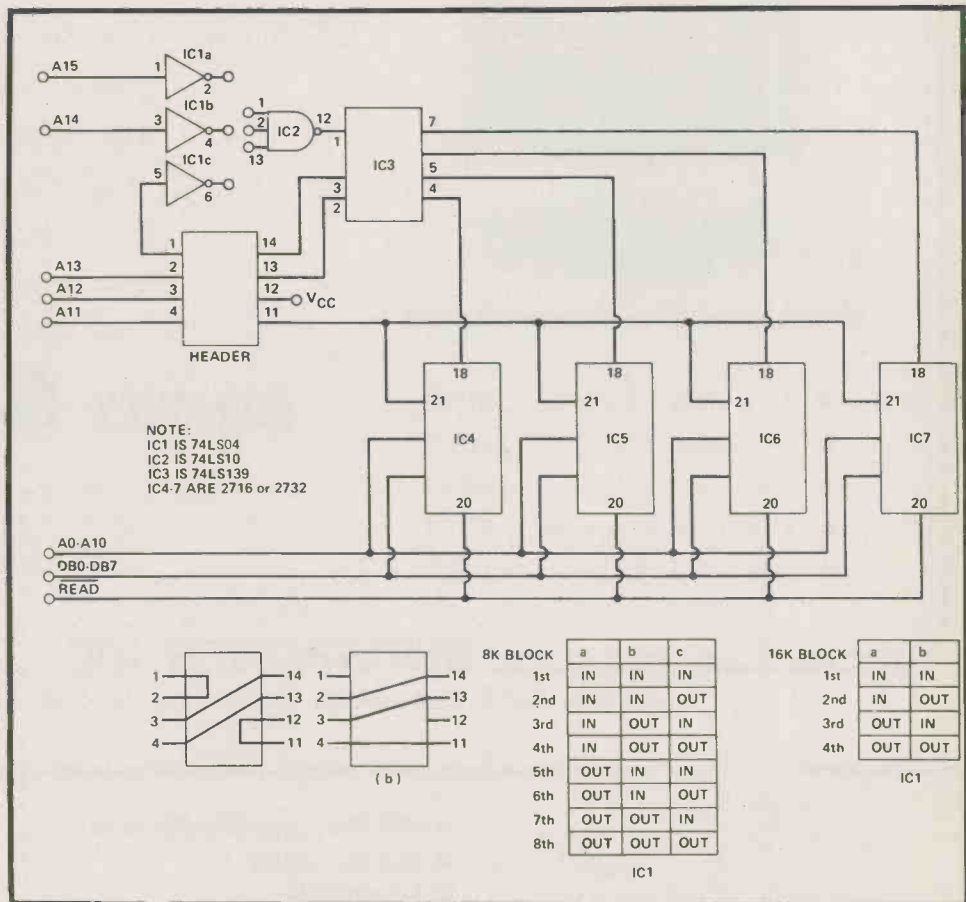
PROM Expansion Card A. Adnitt

This circuit provides a very expandable expansion card for 16 bit address processors and single supply EPROMs. In all expansion cards I have seen they take either four 2K PROMs or two 4K PROMs leaving two empty sockets. Now, by very simple means, an expansion card can be made to give 8K or 16K of memory as shown in the diagram.

If an 8K set-up is first considered with the header wired as shown in Fig. 1a, then pin 21 ($V_{pp}/A11$) of IC4-IC7 is held high, A11 and A12 are used for chip select through the 2-to-4 line decoder (half a 74LS139) and IC1 and IC2 are hard-wired to decode address lines A13, 14 and 15 to select a particular 8K block of memory (see table).

Now, when your operator program outgrows this, a new card is not necessary, just a rewire of the header (Fig. 1b) and the larger EPROMs. In doing this, A11 is taken to IC4-IC7, A12 and A13 are used for chip select through IC3 and now with pins 1 and 2 joined together on IC2, hard wiring with IC1 gives a unique 16K block by decoding address lines A14 and A15. It must be noted, however, that this can only be used for 2716 and 2732 EPROMs as TEXAS 25XX EPROMs have different pin-outs.

By providing 28-pin sockets and additional wiring, the circuit could be reconfigured to take 2764 PROMs — how's that for versatility, as little as 2K to a mammoth 32K of ROM catered for by one card!



Continued on page 84

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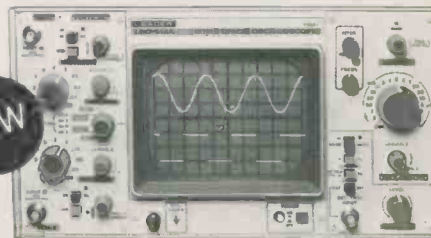
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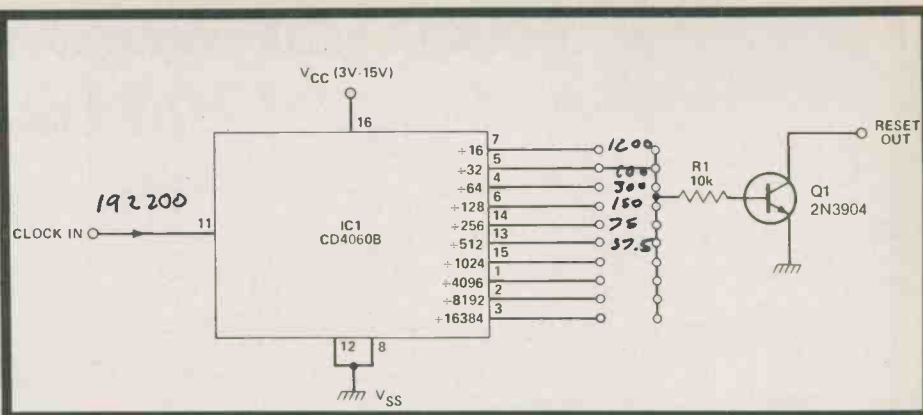
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Tech Tips

Microprocessor Debugging Aid

If you have ever built a microcomputer system, switched on the power, and found that nothing happened, this simple debugging aid may be of interest to you. The problem with troubleshooting microprocessor circuits is the lack of comprehensible signals when probing around the board with an oscilloscope. The answer is simple: the operation of any microcomputer system is predictable, following a pulse applied to the

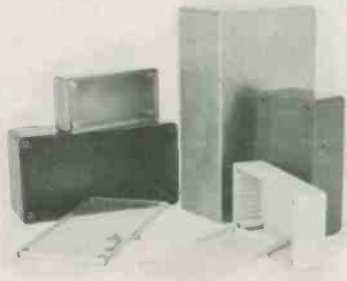


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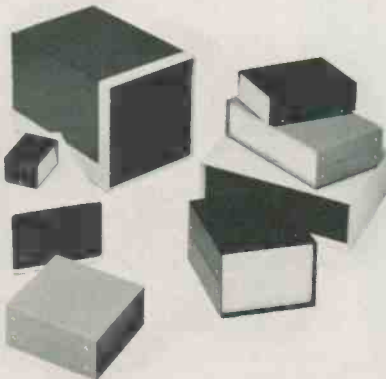


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reset line of that system. A 6502, for instance, will spend six clock cycles sorting itself out internally, then make two memory fetches from the reset vector at address FFFC and FFFD. Using the circuit shown it is possible, when connected to a faulty microprocessor system, to examine the address bus, data bus and control signals for several clock cycles after a reset with a simple oscilloscope. (It will be necessary to trigger the oscilloscope timebase from the reset signal generated by the debugging aid.) The user should be looking for such things as broken printed circuit tracks, solder bridges or even high resistance links between tracks, many of which may be easily detected by tracing the system operation during the first few clock cycles after reset.

The debugging aid consists of a CD4060B CMOS divider integrated circuit which is fed from the clock signal of the micro system under test. The output of the CD4060 drives a transistor which in turn may be used to drive the reset line of the microprocessor. This debugging reset signal may be switched to any one of 10 outputs from the CD4060 allowing a choice of the number of clock cycles to be examined.

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Audio Analyser

Continued from page 62

ed must be fairly flat or its frequency response will affect the measurements you're making. If you use one with a limited bandwidth it's possible to use the presets to compensate; however, to do this properly you'll need to play the pink noise into the mike via a sound system/location you already know to be flat.

ETI

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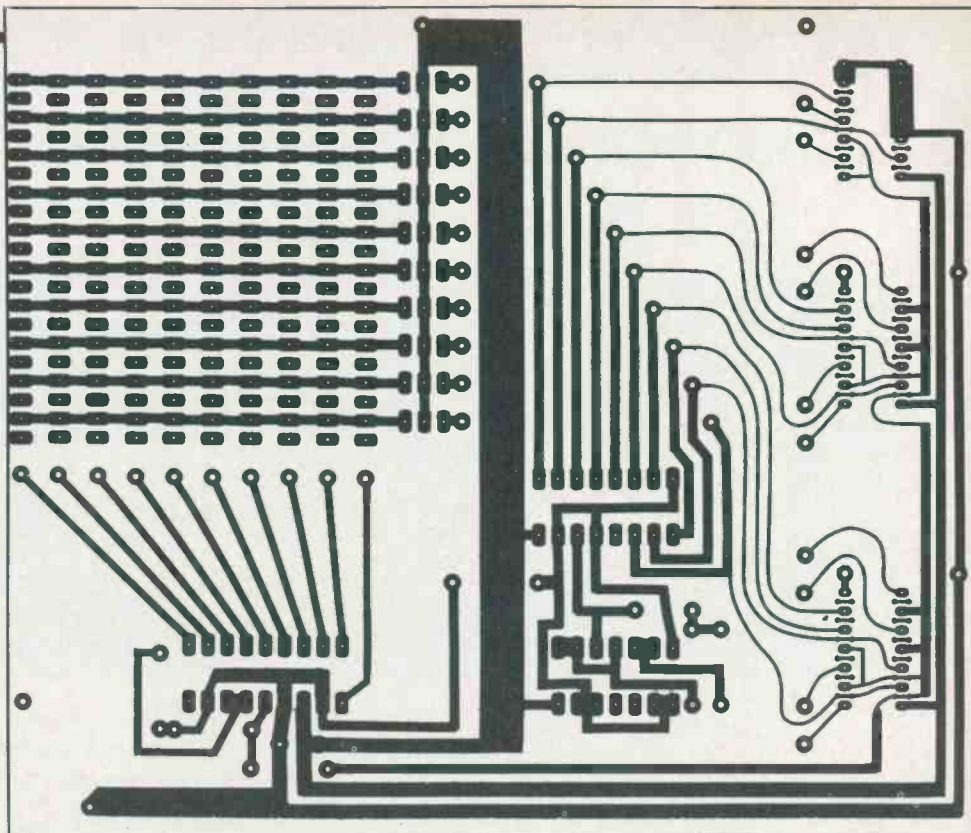
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Canadian Cancer Society
CAN CANCER BE BEATEN? YOU BET YOUR LIFE IT CAN



Digital Capacitance Meter

Continued from page 36

kHz) — do not re-adjust PR2 at this stage.

The astable is not calibrated for the two slow frequencies, which are used with test capacitors over 100 μF in value. Additional timing capacitors, C3 and C4, are simply added to the timing chain by switching them in via SW1. With C4 in circuit and SW2 in position 6, the frequency becomes 90.9 Hz; with C3 in, it becomes 9.09 Hz.

The accuracy of these two ranges depends on the tolerance of C3 and C4. The polyester capacitors recommended have a tolerance of 10%, which is close enough for this end of the range. You could, of course, purchase several of the same nominal value and test them (using this meter!) to find two closest to the specified values.

If you have no oscilloscope, the only method of calibration is to put a close tolerance capacitor in the test socket and adjust the astable circuit

until the correct reading is obtained. It is better not to do this on the lowest range, for stray capacitance may bias the results. Use a 47 nF polyester capacitor on the X1 nF range and adjust PR2 to get a reading of '47' almost every time (you may occasionally get '46' or '48', but errors should be no greater than this). Then use a 4n7 polystyrene capacitor on the X100 pF range and adjust PR1 until '47' is obtained. The meter should then be correct for all the other ranges.

Using The Meter

Plug the test capacitor into the socket and select the required range. If in doubt, select a range greater than the one you expect the capacitor to lie in. Switch on, and press PB1. The value will be displayed instantly (though it actually takes a few milliseconds to get there). On all

ranges, the displayed figure is multiplied by the display range and the scale factor. For example, if the display switch, SW2, is set to x1u, the scale switch to X10 and the display reads '26', the value of the capacitor is $26 \times 10 \times 1\mu = 260 \mu\text{F}$.

If the tens digit is zero, switch to the next lower range and press PB1 again. For the two highest ranges; SW2 must be in position 6 (x1u) and SW1 turned to X10 or X100, as necessary.

Switch the meter off when it is not in use, since the display consumes considerable power. In use, however, the meter works so quickly that the reading can be taken in a couple of seconds and the battery will last for many months.

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The ZX81 uses the same fast microprocessor (Z80A), but incorporates a new, more powerful 8K BASIC ROM — the "trained intelligence" of the computer. This chip works in decimals, handles logs and trig, allows you to plot graphs, and builds up animated displays. And the ZX81 incorporates other operation refinements — the facility to load and save named programs on cassette, or to select a program off a cassette through the keyboard.

Features.

- Unique 'one-touch' key word entry: the ZX81 eliminates a great deal of tiresome typing. Key words (PRINT, LIST, RUN, etc.) have their own single-key entry.
- Unique syntax-check and report codes identify programming errors immediately.
- Full range of mathematical and scientific functions accurate to eight decimal places.
- Graph-drawing and animated-display facilities.
- Multi-dimensional string and numeric arrays.
- Up to 26 FOR/NEXT loops.
- Randomize function.
- Programmable in machine code.
- Cassette LOAD and SAVE with named programs.
- 1K-byte RAM expandable
- Full editing facilities.

ZX81 Professional Keyboard and Case

A full-sized professional keyboard for the ZX81. Features 47 keys and a full-sized space bar. Connects to the ZX81 with no soldering required, via a plug-in flexible connector. You can purchase the keyboard only, or the optional metal case that holds both keyboard and ZX81. Expansion devices (i.e. RAM packs, etc) connect to the ZX81 edge-connector which extends from the rear of the cabinet.

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