

CANADA'S NEW ELECTRONICS MAGAZINE

# electronics today

OCT. 77

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electronic workshop

ALSO

## VFETS FOR EVERYONE

SPECIAL TECHNICAL FEATURE

## LOUDHAILER

CONSTRUCT YOUR OWN



ELECTRONICS  
IN PHOTOGRAPHY

NEW SERIES:

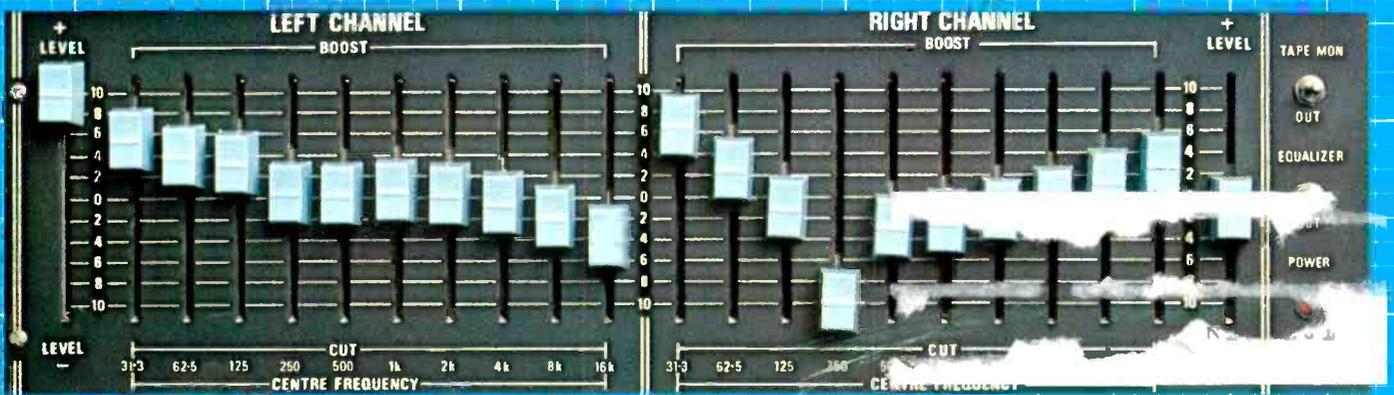
# microbiography

TECHNICAL SURVEY  
OF  
M.P.U. FAMILIES



GYRATOR BASED DESIGN

# GRAPHIC EQUALISER



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## Meet the stay-at-home

Realistic® NAVAHO™ TRC-440 is an AM base station CB for home or office use. We designed it without the frills but with plenty of guts... so you can get into base station CB at a minimal cost without sacrificing the quality. Inside, the NAVAHO has features like multiple IF filters for superior selectivity and adjacent channel rejection; full-time ANL to cut pulse interference; push-pull audio for clean, highly-intelligible sound; hysteresis-type adjustable squelch that automatically compensates for fading to reduce signal 'chopping.' With PLL circuitry for precise frequency accuracy...no crystals to buy! Outside, we added a lighted channel selector and S/RF meter (so you can determine your signal strength); an up-front speaker, dynamic plug-in Communications mike and headphone jack. For an economical base station, it's unbeatable! Stay at home — and keep in touch — with a NAVAHO TRC-440.

21-1540 Only 179.95 at your nearby Radio Shack store.

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# electronics today

international

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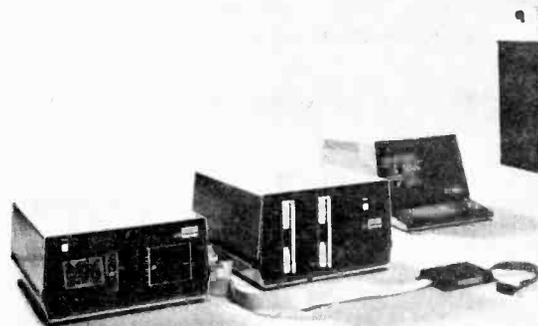
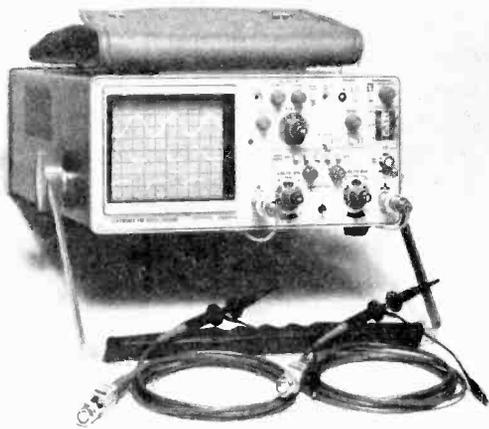
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## NEW! NEW! NEW!

It's not often that we get to meet the heads of any of the world's leading electronics companies and when that rare occasion does arrive it is interesting to see the direction of the thoughts and aims of their company. It was therefore enlightening to discuss the future of electronics in general and Tektronix in particular with Earl Wantland, President and Chief Executive Officer and Leon Orchard, General Manager of Tektronix Service Instrument Division at the recent opening of Tektronix Canada Ltd., new Canadian Headquarters in Barrie, Ontario.

The opening also formed the stage for the world launch of the model 442 oscilloscope and the Canadian launch of the model 8002 Microprocessor Lab. The 442 scope has been specifically designed with the microprocessor era in mind and has a performance matched to this field of servicing without the high performance required for servicing full blown computer systems.

The 8002 Microprocessor Lab is a designers aid which has the ability to be used with any of the presently available microprocessors and able to adapt to new types as they become available. Designing a mpu into an electronic system poses new and unique problems for electronic engineers who must now become computer programmers as well as circuit design engineers.

Until now a typical product design incorporating a microprocessor has required several man-months of software program design, followed by hardware design, and then finally integrating the two into the final product.

The Tektronix 8002 has solved the problem and drastically reduced the design time by allowing the engineer to design his program on an emulator cpu (central processing unit) and then transferring the program into a prototype unit step by step, analyzing and debugging at each step.

While some development aids recently have been offered by a few

microprocessor manufacturers, they have been limited to use with only a single microprocessor unit. The Tektronix 8002 is the first universal, high level microprocessor design lab capable of supporting existing as well as future microprocessors from different manufacturers. Examples of existing microprocessors which the 8002 can presently support include the Intel 8080, Motorola 6800, Zilog Z80, and Texas Instruments 16 BIT TMS 9900.

The products are not designed for the hobbyist — the scope being about \$1,500 U.S. and the basic 8002 about ten times that figure — however, they do demonstrate the importance Tek are putting on the "microprocessor explosion" (as one of their executives put it). It is obvious that Tek are heading into a future they expect to be the fastest period of development in this century and they have the openmindedness and ability to be part of that development.

For more information please contact: *Tektronix Canada Ltd., P.O. Box 6500, Barrie, Ontario L4M 4V3.*

## GIMIC OR RICH MAN'S TOY!

An optional miles-to-empty gauge is being offered by Ford on its 1978 Lincoln Continental Mark V. The unit provides a three digit readout gas-discharge display at the push of a button and automatically lights when the miles-to-empty drop below 50.

The device employs an l.s.i. logic circuit which receives data from two transducers, one in the fuel tank and one connected to the transmission to

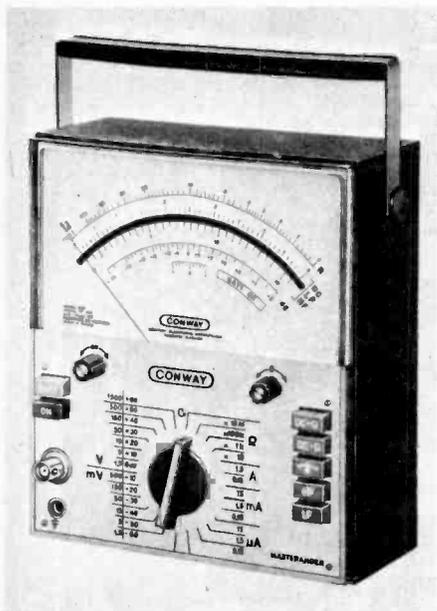
provide vehicle speed.

From the information received the logic circuitry calculates distance travelled, fuel used and m.p.g. From this data it provides the miles-to-empty figure. All that sophistication to provide a "gimic" to prevent you running out of fuel when a reserve in the tank with a simple switch over system could be used?

Surely electronics can be employed in a more useful way — as the control for an anti-skid device for instance!

## DELAYED ITEM!

Audio signals can now be delayed up to 205 milliseconds in a single solid state device. Matsushita Electronics Corp. have developed a charge coupled device (bucket brigade) which can provide approximately 8 times the previously attainable delay. The device, type no. MN3005, has 4096 steps and is expected to find immediate use in electronic musical instruments and other audio equipment to provide longer reverberation and echo times



## MASTERMETER!

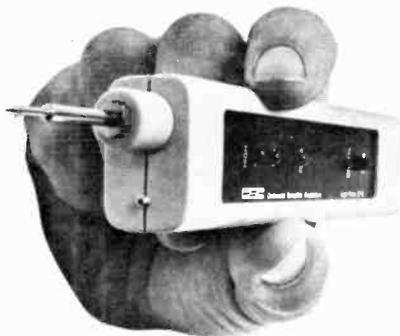
A wide range electronic multimeter is now available from Conway Electronic Enterprises. The Master-anger MKII/A has an input impedance of 100 megohms and covers a d.c. and a.c. voltage range of 50  $\mu$ V to 50,000V. Current ranges are from 50nA to 150A a.c./d.c.; resistance and insulation from 0 to 10,000 megohms.

A special probe incorporating a bridge network is employed for temperature measurements from -150°C to +500°C. In addition to all this dB and dBm can be measured and the unit can be driven by internal batteries or from a power line of 90 to 250V at 40 to 400 Hz. Price is \$288 including standard test probes, leather carrying case and federal sales tax.

For more information contact Conway Electronic Enterprises Ltd., 88-90 Arrow Road, Weston Ontario, M9M 2L8.

## PROBING

Two new "probes" for digital fault finding and testing have recently been announced by C.S.C. The Logic Probe 2 (LP-2) is a compact, self-contained instrument, measuring only 147 x 25 x 18mm. Drawing its power from the circuit under test, LP-2 provides pulse detection and pulse stretching functions for an instant readout of logic levels, positive and negative transitions,



pulse symmetry (duty cycle), as well as abnormal circuit conditions . . . with all major logic families, including TTL, DTL, HTL and CMOS. Cost of the LP-2 is approximately \$40.

The second device is a Digital Pulser (DP-1) also drawing its power from the circuit under test this device detects the circuit's condition — high or low state — triggering the unit to produce an opposite polarity pulse. Rapid, stimulus-response type trouble-shooting is accomplished by using the pulser to inject signals at key points in TTL/DTL, CMOS and other popular circuits.

Testing with a single pulse, or with 100 pulses per second is possible via a simple pushbutton control on the DP-1, allowing the selection of single-shot or continuous modes. An LED indicator monitors the operating mode by flashing once for a single pulse, or continuous illumination for a pulse train.

Pulse width in the DP-1 is selectable to accommodate CMOS (10  $\mu$ sec + 30%) or TTI/DTL (1.5  $\mu$ sec + 30%) logic families. It provides CMOS circuits with a 50 mA source to logic 1, and a sink to logic 0. For TTL/DTL circuits, the DP-1 can be used as a 100 mA source up to 3.5V and a sink to .6V, for up to 60 loads. Cost of the DP-1 is approximately \$100. For more information contact Len Finkler Ltd., 25 Toro Rd., Downsview, Ontario, M3J 2A6.

## MARKET STUDY

Results of a preliminary market study in the electronic calculator market carried out by Sharp Electronics have some interesting features. For instance they predict "a significant stabilization in prices . . .

there is no doubt that we will see more attention being paid to cosmetic elements . . . an industry-wide increase in unit sales of about 20 per cent. We expect that Sharp will exceed that figure. As for projections of industry-wide dollar volume, we project an industry-wide dollar increase of 10 per cent, and we expect to better that figure.

"We are convinced that the consumer calculator market is going to continue to expand rapidly and we are involved in a total commitment to provide the most advanced and attractive product that it is possible to manufacture for this broad and highly diversified market. The proof is obvious. The size of our line is 30 models and a substantial amount of money has been invested in technology, market research, sales support, public relations and advertising.

"We expect desk-top calculators will have a larger share of the market in 1977, and we also expect that the replacement purchases will represent a growing market with great potential. We estimate that the 1977 calculator market in Canada today is about \$73 million."

## M.P.U. COPIER

Another example of the use of a microcomputer has recently been announced. The Xerox Corp. will be marketing a microcomputer-controlled copier — the 5400. The microcomputer is employed to diagnose trouble and reduce the number of service calls. It also controls the operation of an attached sorter.

The 5400 will use similar image forming technology to the 9200 high volume copier.

For more microprocessor news see the Microfile section in this issue.

## MASTERMIND — JULY 1977

It has been brought to our attention that the name Mastermind is a registered Trade Mark. We apologize to Invicta Plastics of Cadby, Leicester, England, the owners of this trade mark, for our unauthorised use of this in the July 1977 issue. It was not our intention to infringe their rights and we acknowledge their exclusive rights to the Mark.

# AUDIOPHILE

## NEW PRODUCTS

More power, less distortion, extremely competitive prices, and entry into both the turntable and cassette deck markets are the highlights of the new 1978 audio component line from H.H. Scott Inc.

The Scott stereo receiver line will include five models ranging from the budget-priced 18 watt R307 to the top-of-the-line R376 with 75 watts per channel. Feature improvements include flywheel tuning, lower harmonic distortion, and increased sensitivity.

The Scott stereo integrated amplifier line sees the addition of the 60 watt A457. Harmonic distortion figures are again improved across the line. Another addition is the T527 stereo tuner with IHF sensitivity of 10.33 dBf at 1.8uV.

Five new turntables are all two-speed single-play models, with automatic return and aluminum die cast platters. The three lower-priced models are belt-drive and the remainder, direct-drive. All but the



budget PS-17 feature strobe lights.

For 1978, Scott has also entered the cassette tape deck market, initially introducing the CD-67 and CD-87, two front loading systems.

More details on the Scott range are available from *Paco Electronics Ltd.*, 45 Stinson St., Ville St. Laurent, Quebec H4N 2E1.

Also available from Paco is a new range of Peerless "Mix and Match" loudspeaker components. The range

consists of 4 woofers, one midrange and two tweeter speakers with four different crossover circuits which can be made up into five recommended speaker systems cabinets are not provided but sizes and basic construction details are given.

Suggested prices start at approximately \$60 for a single, basic two way system and go up to around \$160 for a single three way system using the best available components.

## NOISE REDUCTION

New audio items from the well respected Burwen Research Inc. Two new noise reduction or elimination devices are now available they are the DNF 1201A dynamic noise filter which costs approx. \$600 and the Transient Noise Eliminator TNE 7000.

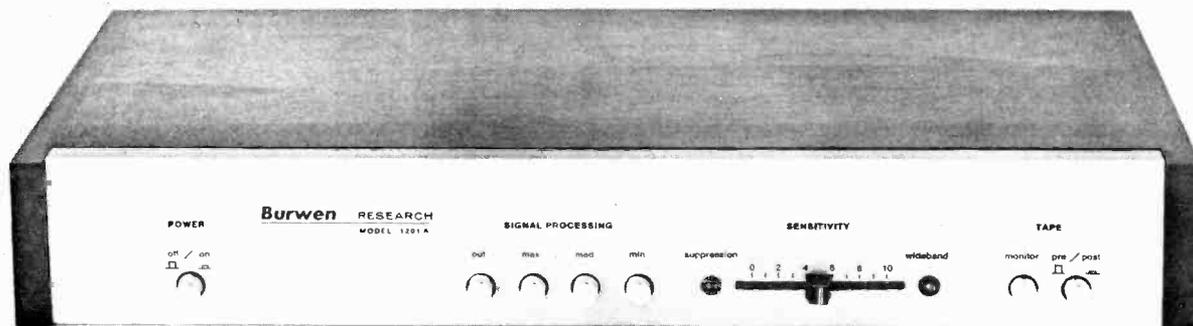
The DNF 1201A is basically a low-pass variable filter the cutoff frequency of which varies between 500 Hz and 300kHz in accordance with the needs of the signal. Transients can extend the bandwidth in 600 microseconds whilst reduction is automatically adapted to the signal

and varies between 50 milliseconds and 1.5 seconds.

The TNE 7000 is designed to eliminate occasional ticks and pops, and to reduce the hash on older records to something more like tape hiss. Ticks are detected by measuring the high frequency content of the vertical stylus motion from a stereo record. When the high frequency level changes more rapidly than it does in natural music, a tick is sensed and the system output is switched off. Unlike other systems which may switch off the signal for as long as 3 milliseconds, this system turns off the signal only for the duration of the tick, typically 100

to 600 microseconds. This short blanking duration reduces the amount of transient noise generation that would otherwise result from the removal of the tick. Furthermore, the blanking period is filled by a voltage which produces a smooth transition from the musical signal before the tick to the musical signal after the tick. This advance system thus produces a minimum of error in the musical signal and, at the same time, is sensitive enough to eliminate most of the small ticks.

Further information on these systems is available from *A. Allen Pringle Ltd.*, 30 Scarsdale Road, Don Mills, Ontario, M3B 2R7.



# eti microfile

The microprocessor scene watchers have been buzzing recently with the almost simultaneous release of information on two consumer oriented "complete" systems.

## COMMODORE PET 2001

Using the all-in-one box approach, the "PET computer 2001" contains 9 inch (pardon me, 23 cm) video display, cassette recorder and two keyboards — one for alpha characters, the other for numbers. But there's a lot more to this carefully prepared product.

Here's the rundown:

Processor: 6502 (MOS Technology)  
Resident Software (ROM) 8K BASIC Interpreter

4K Operating System  
1K Diagnostic Routine  
1K Machine Language Monitor  
RAM

4K or 8K expandable to 32K

Commodore claims their BASIC is the fastest yet implemented on a micro, and it includes all standard Dartmouth, and many extended BASIC statements including string handling and sophisticated I/O statements, with file management. In addition provision is made to allow writing of and linkage to user developed machine language routines.

The screen-keyboard set-up is quite novel, with a display of 40 columns by 25 lines of 8 x 8 dot matrix characters. These may be alphanumeric, or one of a collection of 64 graphic symbols allowing graphs, drawings and even playing cards to be displayed. You are also armed with a winking cursor, fully controllable, and can reverse any of the characters (white on black or black on white).

The hardware itself is quite nicely done, with only 3 pcb's in the basic machine, one for cassette recorder, one for video monitor, and one snap out boardful of processor guts. The machine also interfaces to the IEEE — 488 bus system for information interchange, up until now greeted with only mild enthusiasm by high priced test equipment manufacturers. This product could give the bus a shot in the arm.

Now where can you get one, and how much?

Commodore in the U.S. has been absolutely inundated with orders, and they're not exactly hustling machines "up" here. On top of this

there's C.S.A. approval to be won. You may be holding your breath until January or later. It's possible that a couple may be on view at your local micro-emporium before then, but for sale?

You can order a PET from Commodore in the U.S. for the following prices — 4K model US\$595.00; with 8K RAM US\$795.00. Delivery is within 90 days. No peripherals are available yet, but may come next year.

Commodore Business Machines Ltd.,  
3370 Pharmacy Ave.,  
Agincourt, Ontario



*This futuristic looking unit is the much talked about PET from Commodore — note the unusual keyboard layout.*

## RADIO SHACK TRS-80

Radio Shack has also just jumped on the byte wagon (band bus?) with the introduction of a low priced system in the U.S. And guess what it's got!

The TRS-80 system actually comes in four parts, 12" video monitor, cassette recorder, and power supply boxes being separate from the keyboard unit which also contains the mpu and main circuitry. (The separate power supply may make for faster CSA approval).

The system is based on the Z80 chip, and includes 4K ROM containing BASIC, plus graphics, 4K dynamic RAM, and I/O ports.

Various options are available, the parts above come to (surprise surprise) US\$599.95. However, the keyboard may be obtained by itself for US\$399.95. No word yet on

availability in Canada.

Information from:

Radio Shack  
Dept. TRS-80  
205 North West Seventh St.,  
Fort Worth  
Texas 76101, U.S.A.



*Radio Shack's consumer oriented four piece package.*

## NEW STORE

Business is still booming in the personal computer field — at least it seems to be, as another Toronto based computer store has recently opened.

This one, called the Home Computer Centre, opened in mid September and is located at 6101 Yonge which is up near the 401 for those coming in from other areas.

The store will mainly concentrate on complete systems with an emphasis on communication between systems and with remote cpu's. There will be technically qualified staff available most days to answer your questions and help you "play" with the systems! The principals tell us that they should have one of the elusive PET's in the store by the time you read this.

The main sales target will be concentrated on two areas, one is the home computer and its peripherals and the other is the small business application. The store will also provide maintenance, repairs, system software and hardware designs to customers.

We are always pleased to hear of the opening of new computer stores, and formation of clubs, so if you're involved — drop us a line!

**Next month** we hope to bring you a few technical details on the Heathkit H8 and H11 systems pictured on this month's cover.

# Number One ETI CIRCUITS

The first in a new series  
of 'ideas books' for the experimenter

## Contents

### ALARMS

Basic Alarm  
Photo Intruder Alarm  
Intruder Alarm  
Photo Electric Relay  
Low Temperature/Lights out  
Temperature Sensor  
Coolant level  
Water Level  
Electronic Lock  
Car Battery Watchdog  
Simple Car Alarm  
Simple Lock

### AMPLIFIERS & PREAMPLIFIERS

High Input Impedance  
High Impedance Buffer  
Low Output Impedance  
High Input Impedance  
Low Frequency Extender  
Virtual Earth Preamp  
IC Tape Head Preamp  
Simple Stereo Tape Player  
2.5 Watt  
20 Watt Slave  
10 Watt  
Loudspeaker Microphone  
Voltage Controlled Amp  
Wide Band Amplifier  
Video Power Amp  
Broadband Amp

### SIGNAL PROCESSORS

Fuzz Box  
Guitar Fuzz  
Fuzz Box  
Waa Waa  
Disco Autofade  
Simple Autofade  
Information Transfer  
Optical Pulse Conditioner  
TV Sound Pickoff  
Cracklefree Potentiometer  
Voltage to Frequency  
Sine to Square Wave  
Precision AC to DC  
Voltage Processor  
Universal Meter  
Double Precision  
Fast Half Wave  
Simple Chopper  
Noise Rejecting SCR Trigger  
Phase Shifter

### SIGNAL GENERATORS

Simple  
Variable Duty cycle  
Fast Edge  
FET  
Improved Multivibrator  
Variable Duty cycle  
Stable R C  
Cheap (CMOS)  
Simple TTL XTAL  
Uncritical XTAL  
Pulse  
Zero Crossing  
Simple Pulse  
Needle Pulse  
Stable Linear Sawtooth  
Zener  
Noise  
Pink

Simple Relaxation  
Triangle with independent slope  
Exponential  
Widerange Multivibrator  
Multiple Waveform  
Linear Sweep  
Step Frequency  
Beeper  
7400 Siren  
Simple Siren  
Ship Siren  
Two Tone  
Toy Siren  
Kojak, Startrek, Z Cars  
Sound Effects  
Sound Effects

### FILTERS

Bandpass  
Low & High Pass  
Rejection Notch  
Bandpass  
Cartridge EQ & Rumble  
Hum Stopper  
Tape Hiss Reduction  
Simple Crossover

### DIGITAL

Thermometer  
Heads or Tails  
Binary Calculator  
Voltmeter  
Seven Segment to Decimal  
Die  
Random Binary  
CMOS Die  
Multiplexer Hints  
Learning Memory  
CMOS Clock

### POWER SUPPLIES

Constant  
Temperature Stable  
Constant  
Voltage Controlled  
Precision Voltage Divider  
Dual Polarity  
Simple Balanced  
Voltage Divider  
Low Regulated  
Short Circuit Protected  
Simple TTL Supply  
ZN414 Supply  
Stable Reference  
Transformerless inverter  
DC to DC AC  
Voltage Multiplier  
Automobile Converter  
Shaver Adaptor  
DC-DC  
High Voltage From Battery  
Variable -ve or -ve output  
Simple  
12V from Battery Charger  
Bucket Regulator  
Adjusting Zener Voltage  
Variable Zener  
Zener Boosting of Regulators  
High Power  
Electronic Fuse  
Better Fuse  
Regulator & Fuse  
Fast Acting  
SCR Crowbar  
Voltage Polarity  
NI CAD Discharge  
Current Limiting

### TEST

Diode Checker  
GO/NO GO Diode Tester  
Zener Check  
GO/NO GO Transistor Tester  
Quick JFET Test  
Current Gain Tester  
Basic Transistor Tester  
Simple Transistor/SCR  
SCR Tester  
Crystal Check  
Crystal Checker  
Good/Bad Battery Tester  
Battery Tester  
Op-Amp Tester  
Op-Amp Checker  
Cheap Logic Probe  
Audible TTL Probe  
Audible Slow Pulses  
Logic Probe  
Logic Analyser  
I and O Display Probe  
Simple High Impedance  
Voltmeter  
Audio/RF Tracer  
Thermocouple Thermometer  
Metering Stabilised supplies  
Simple Frequency Meter

### TIMERS & DELAYS

Low Standby Drain  
741 Timer  
Self Triggering Timer  
Pulse Timer  
Pulse Delay  
Voltage Controlled Monostable  
Sequential Relays  
Door Chime Delay

### SWITCHING

Touch Triggered Bistable  
Touch Sensitive Switch  
Electronic Switch  
Sound Operated 2 Way  
SPST Switch Flip Flop  
Two Signals on one Wire

### INDICATORS

Line-o-Light  
3 Step Level  
Light Level  
Bargraph Display  
Fuse Failure  
Blown Fuse  
Back Up Lamp  
DC Lamp Failure  
FM Tuner Station  
Current Flow  
Disco Cue

### FLASHERS

Dancing Lights  
Low Frequency Strobe

Flasher  
Ultra Simple

### POWER CONTROL

LDR Mains Control  
Floodlamp Control  
Zero Crossing Sync  
Train Controller  
Low Differential Thermostat  
Simple Temperature Control  
Full Wave SCR Control

### AUTOMOBILE

Brake Lamp Failure  
Courtesy Light Delay  
Simple Hazard Light  
Light Extender & Reminder  
Four Way Flasher  
Headlamp Dipper  
Wiper Delay  
Suppressed Zero Voltmeter  
Rev Counter/Tachometer  
Auxiliary Battery

### DETECTORS & COMPARATORS

Peak Detect & Hold  
Window Detector  
Peak Program  
Positive Peak  
Reaction Comparator

### RADIO FREQUENCY

Crystal Marker  
100 kHz Marker  
RF Voltmeter  
RF Detector  
LED RF Indicator  
RF Amplifier Protection  
FET-Radio  
Op-Amp Radio

### MISCELLANEA

Phase Locked Loop  
Touch Doorbell  
Phase Lock Control  
Audio Mixer  
Virtual Earth Mixer  
Plop Eliminator  
Loudspeaker Protection  
Digital Capacitance Probe  
Digital Tape Recorder Adaptor  
Breakdown Diode Substitution  
Dual Function Charger  
Dual Mode Amp

Capacitor Substitution  
Electronic Capacitor  
Speeding Up Darlington's  
Shutter Saver  
Thyristor Sensitivity  
Sound Operated Flash  
Strength Tester  
Logic Noise Immunity

### TIPS

Identifying 74 Series  
Supply Pins  
Soldering IC's  
Tinning With Solder Wick  
PCB Stencils  
Front Panel Finish  
DIL Drilling  
Fluorescent Starting  
Avoiding insulated Heat Sinks  
TTL Mains Interface  
Boost Your Mains  
High Resistance on Low Meters  
High Voltage Electrolytics  
Transistor Identification  
Template & Heat Sink for  
Power Transistors  
Transistor Socket  
Solder Flow Problems  
Odd Resistor Values  
Resistors in parallel  
CMOS DIL Handling  
Identifying Surplus ICS  
Extending Battery Life  
Battery Snaps  
Power Supply or Battery  
Battery Checking  
Muck Remover  
Transformers in reverse  
Loudspeaker Checking  
Improving UJT Linearity  
Signal Tracer  
Crystal Earpieces  
Cheap Varicaps  
Zener Lifts Capacitor Rating

### DATA

741 Op-Amp Data  
BC 107-109 Data  
BC 177-179 Data  
CMOS & TTL Data  
2N3055 Data  
MJ2955 Data  
Bipolar Data Tables  
Bipolar FETs Rectifiers  
Diodes Pinouts Zener Misc

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Toronto, Ont. M4H 1B1

# GRAPHIC

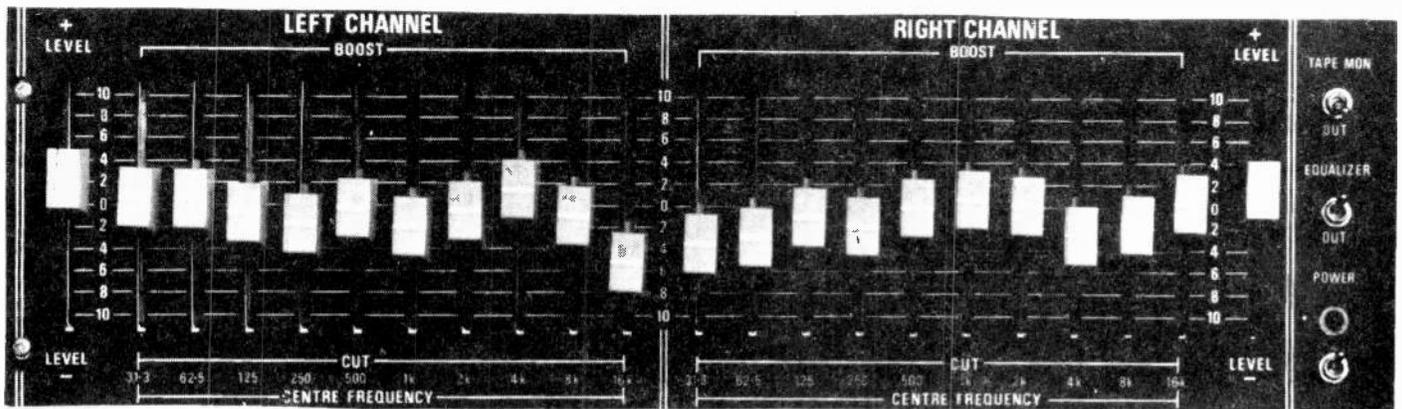
GRAPHIC EQUALIZERS are popular with both the professional and domestic user alike. However until the presentation of our earlier equalizer (ETI 427) the cost of such a device was very high and this limited its wide use. We have now redesigned the equalizer to simplify the construction and it now has no coils and one additional filter has also been added.

available cannot give correct reproduction in an inadequate room. It is a sad fact that very few rooms are ideal, and most of us put up with resonances and dips, convinced that this is something we have to live with.

Whilst the octave equalizer will not completely overcome such problems, it is possible to minimize some non-

particular system. One adjusts the equalizer to provide a uniform response, the settings of the potentiometer knobs then graphically display the areas where the speaker etc is deficient.

There is a snag, however, one must have an educated ear in order to properly equalize a system to a flat response. It is not much use equalizing to your own preference of peaky bass



The advantages of an equalizer are not generally well known but are as follows.

Firstly an equalizer allows the listener to correct deficiencies in the linearity of either his speaker system alone, or the combination of his speaker system and his living room.

As we have pointed out many times in the past, even the best speakers

linearities of the combined speaker/room system.

In a concert hall it is also possible to use the unit to put a notch at the frequency where microphone feedback occurs, thus allowing higher power levels to be used.

Thirdly, for the serious audiophile, an equalizer is an exceedingly-valuable tool in evaluating the deficiencies in a

etc in order to evaluate a speaker.

Ideally, a graphic equalizer should have filters at 1/3 octave intervals, but except for sound studios and wealthy pop groups, the expense and size of such units are too much for most people.

The equalizer described here has 10 octave spaced filters but if desired it could be modified to give 1/2 or 1/3

# EQUALISER

# GRAPHIC EQUALISER

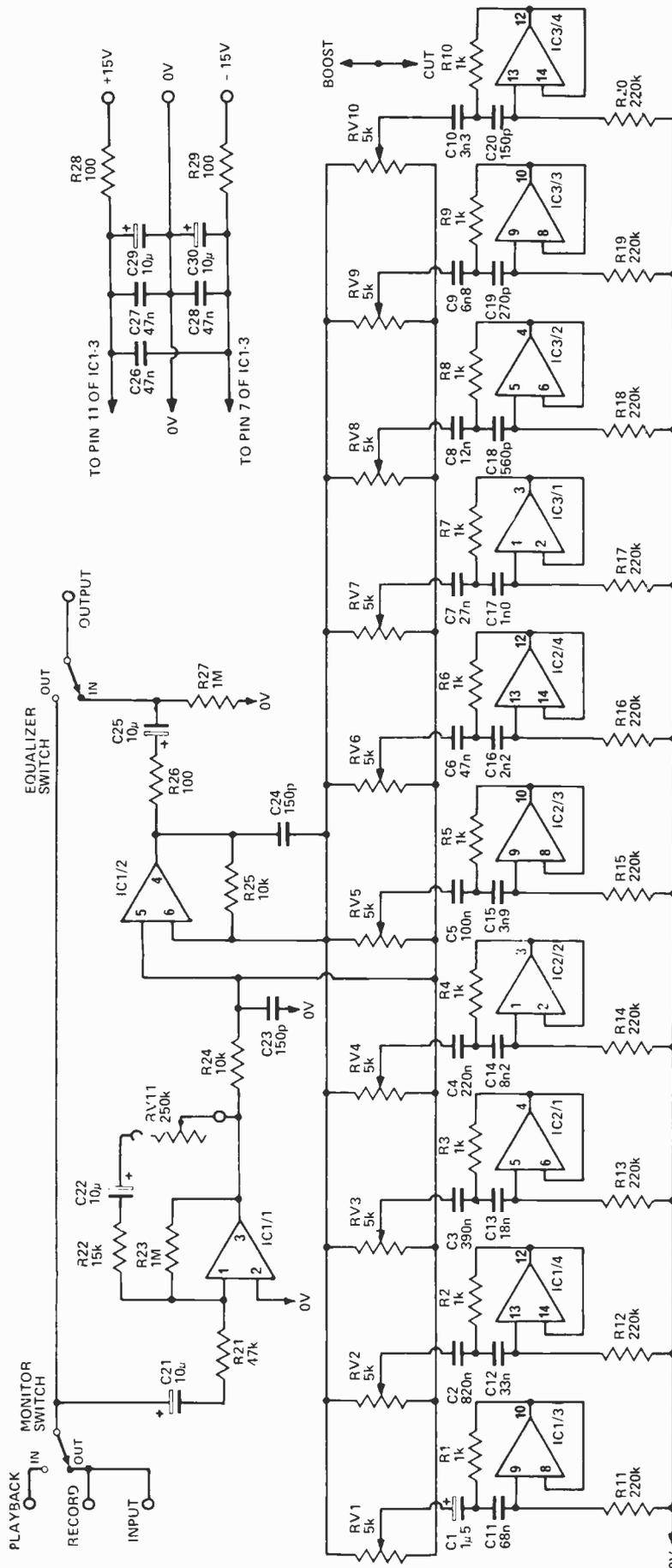


Fig. 1. Circuit diagram of one channel of the equalizer.

## HOW IT WORKS

This equalizer is basically similar to that used in the previous unit with the addition of an extra filter in each channel. The previous unit also used coils (inductors) these have been replaced by gyrators to simplify construction. We will explain more about gyrators later but at the moment just assume that they are an inductor.

The equalizer stage is a little unusual in that the filter networks are arranged to vary the negative feedback path around the amplifier. If we consider one filter

circuit. With the slider of the potentiometer at the top end (Fig. A) we have 1 k ohms to the 0V line from the negative input of the amplifier, and 5 k between the two inputs of the amplifier. The amplifier, due to the feedback applied, will keep the potential between the two inputs at zero. Thus there is no current through RV.A. The voltage on the positive input to the amplifier is therefore the same as the input voltage since there is no current through, or voltage drop across resistor RA.

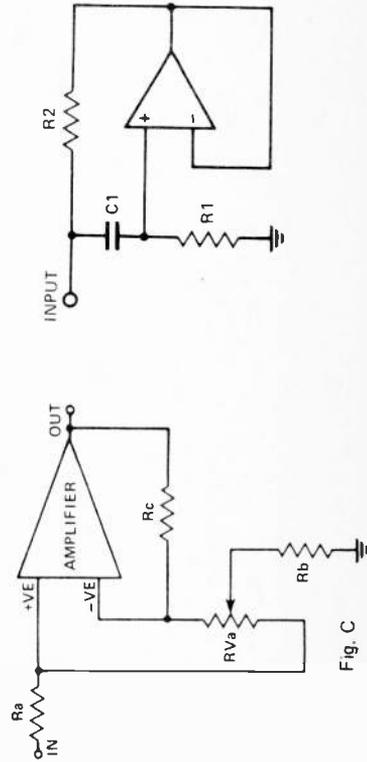


Fig. C

section impedance of the LCR network will be 1 k ohms at the resonant frequency of the network. At either side of resonance the impedance will rise (with a slope dependant on the Q of the network which is 3) due to the uncanceled reactance. This will be inductive above resonance and capacitive below resonance. We can therefore represent the equalizer stage by the equivalent circuit below.

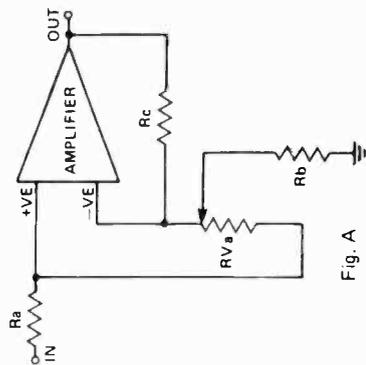


Fig. A

It must be emphasized that this equivalent circuit represents the condition with one filter only, at its resonant frequency. Additionally letters have been used to designate resistors to avoid confusion with components in the actual

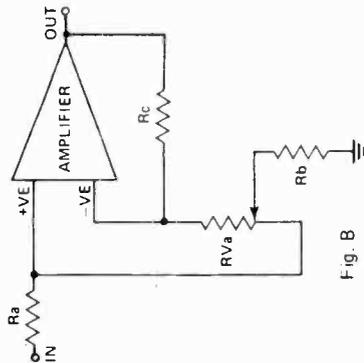


Fig. B

The output of the amplifier in this case is approximately the input signal times  $(10,000 + 10000)/100$  giving a gain of 11 (20dB approx.). If the slider is at the other end of the potentiometer, (Fig. B), the signal appearing at the positive input, and thus also the negative input is about 0.1  $(1000 (10,000 + 1000))$  of the input. There will still be no current of the potentiometer and in RC, thus the output will be 0.1 of the input. That is, there will be a loss of 20 dB.

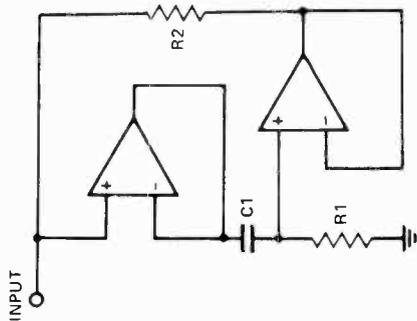
If the wiper is midway, both the input signal and the feedback signal are attenuated equally, and the stage will have unity gain.

With all filter sections in circuit the maximum cut and boost available is reduced, but  $\pm 14$  dB is still available.

In the actual circuit we have used the first op-amp (IC1/1) as a buffer for the input and also as the overall gain control stage. With the values shown the gain is adjustable over a range of -9 to +14 dB. By replacing R22 by a link RV11 will act like a normal volume control. Now to the gyrator.

The only difference between an inductor and a capacitor — electrically, that is, not mechanically — is the phase relationship between the current and voltage. In the gyrator we use an op-amp to reverse the phase relationship of a capacitor and make it appear like an inductor. In the circuit below the inductance is given by the formula

$$L = R1 \times R2 \times C1 \text{ Henries where } C \text{ is in } \mu\text{-farads}$$



of the amplifier. The use of a second amplifier will increase the resistance to many megohms while the same formula holds for inductance.

Like a real inductor there is a series resistance (winding resistance) or R2 and a parallel resistance R1 (in a coil this is due to winding capacitance). The lowest value of R2 depends on the amplifier used but for standard op-amps it would be about 100 ohms. At the high end the value of R1 is limited by input current.

octave spacing as large values of inductance are easily obtained with gyrators (active inductors).

### Construction

Assemble the PCB's as per the overlays, leaving off the sliders for now. Check everything carefully to make sure it's correct, as once they are mounted onto the board you'll never be able to get to anything!

To fit these potentiometers, solder a generous 2 inch length of tinned wire to each of the end contacts, and one of the slider pins. Offer up the pot to the board, push the

Now build up the PSU, and test it thoroughly before wiring it to the boards. Mount the transformer as far from the circuit boards as possible, and if possible screen it with a metal enclosure. On the original shallow metalwork shown here screening the PSU added considerably to the overall quality of sound.

### Third octave filters

While we have not built up a third octave unit we see no reason why it will not work. Additional stages can simply be added except that the Q of the circuits must be changed to narrow the

band. At the moment the impedance of the capacitor and inductor (gyrator) is about 3000 ohms at the centre frequency and this should be increased to about 8000 ohms for the third octave unit. The capacitors and inductors can be calculated by

$$C = \frac{1}{2 \pi f X_C} \quad L = \frac{X_L}{2 \pi f}$$

where  $X_C = X_L = 8000 \Omega$

and  $f = \text{centre frequency}$

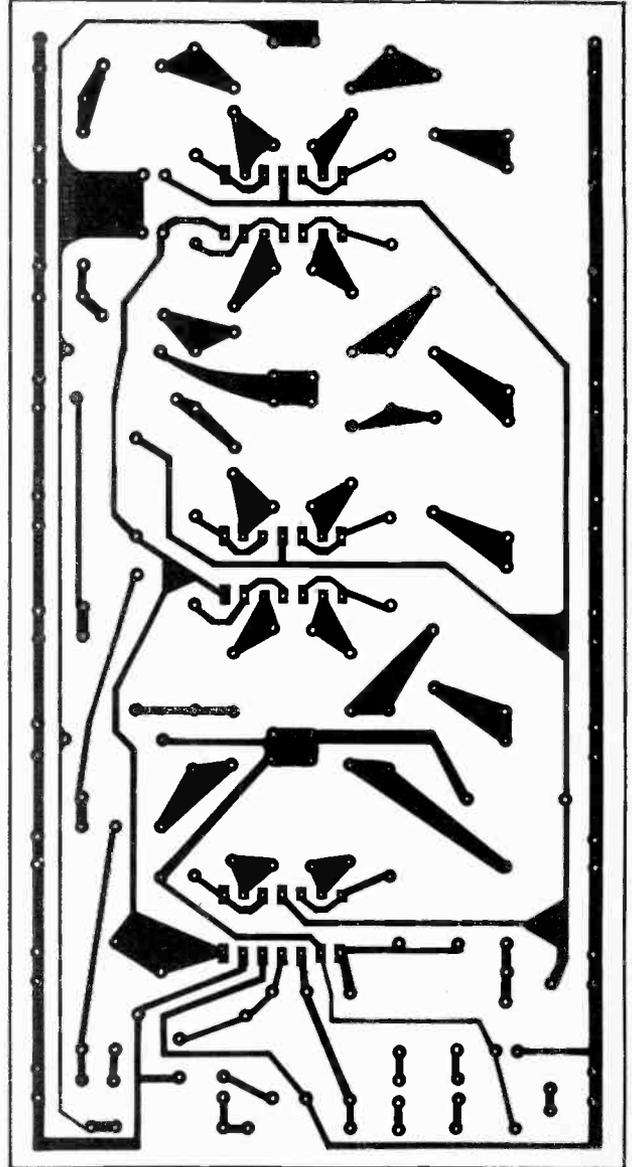
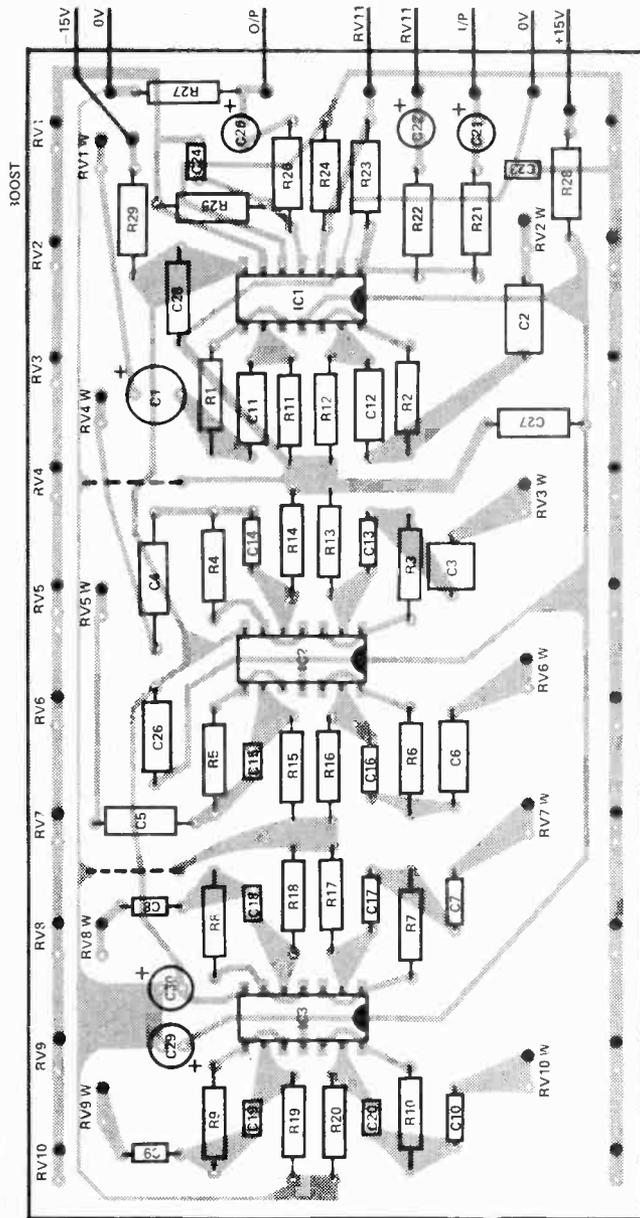
It is recommended to reduce loading IC1/2 that the potentiometers be increased to 10k.

# GRAPHIC EQUALISER

## PARTS LIST

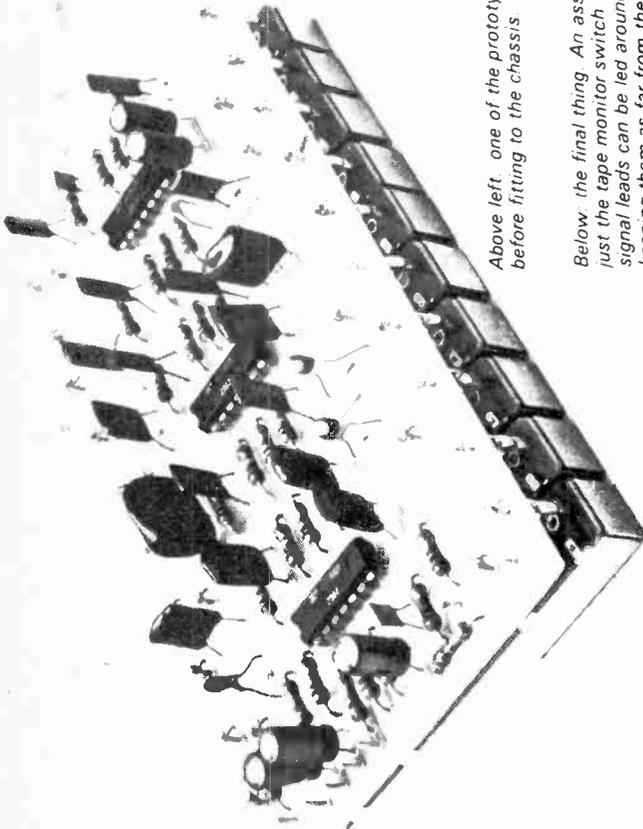
- RESISTORS all 1/2W 5%
- R1-R10 1k
  - R11-R20 220k
  - R21 47k
  - R22 15k
  - R23,27 1M
  - R24,25 10k
  - R26,28,29 100
  - R30 1k8
- POTENTIOMETERS
- RV1-RV10 5k lin
  - RV11 250k log
- CAPACITORS
- C1 1u5 tantalum
  - C2 820n polyester
  - C3 390n "
  - C4 220n "
  - C5,33,34,35,36 100n "
  - C6 47n "
  - C7 27n "
  - C8 12n "
  - C9 6n8 "
  - C10 3n3 "
  - C11 68n "
  - C12 33n "
  - C13 18n "
  - C14 8n2 "
  - C15 3n9 "
  - C16 2n2 "
  - C17 1n0 "
  - C18 560p ceramic
  - C19 270p "
  - C20,23,24 150p "
  - C21,22,25,29,30 10u 25V
  - C26-C28 47n polyester
  - C31,32 1000u 25V
- SEMICONDUCTORS
- IC1-IC3 4136
  - IC4 4195
  - LED 1 TIL 209
- TRANSFORMER
- T1 120/24ct at 100mA or more
- MISCELLANEOUS
- Metalwork and case to suit
  - Three DPDT toggle switches
  - Three wire line cord and plug.
  - For stereo operation double quantity of all components except PSU parts.

Component overlay and foil pattern for the main pcbs in the equaliser. Two of these are required for stereo. The pins are to be wired to the slider controls once everything is fitted onto the board. Foil pattern shown full size at 152mm width.



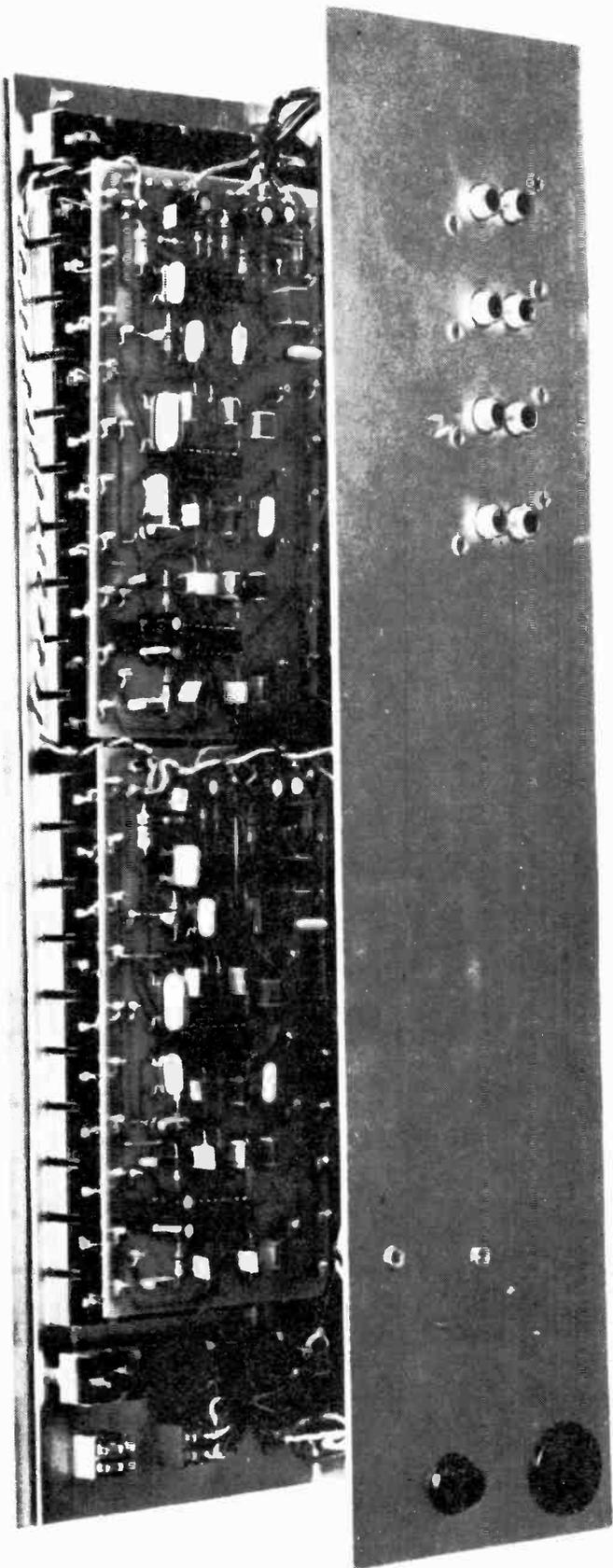
# SPECIFICATION

<b>Frequency response</b> Equalizer out Equalizer in and all controls at zero	Flat 10Hz - 20kHz $\pm 1/2$ dB
<b>Range of controls</b> Individual filters Level control	$\pm 13$ dB $\pm 14$ dB - 9dB
<b>Maximum output signal</b> at <0.1% distortion	6 volts
<b>Maximum input voltage</b>	10 volts
<b>Distortion</b> at 2 volts out, controls flat	100Hz 1kHz 6.3kHz 0.02% 0.02% 0.04%
<b>Signal to noise ratio</b> re 2 volts out, controls flat	82 dB
<b>Input impedance</b>	47 k
<b>Output impedance</b>	100 ohms

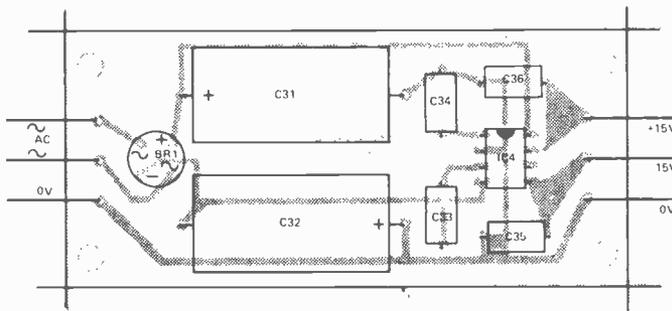
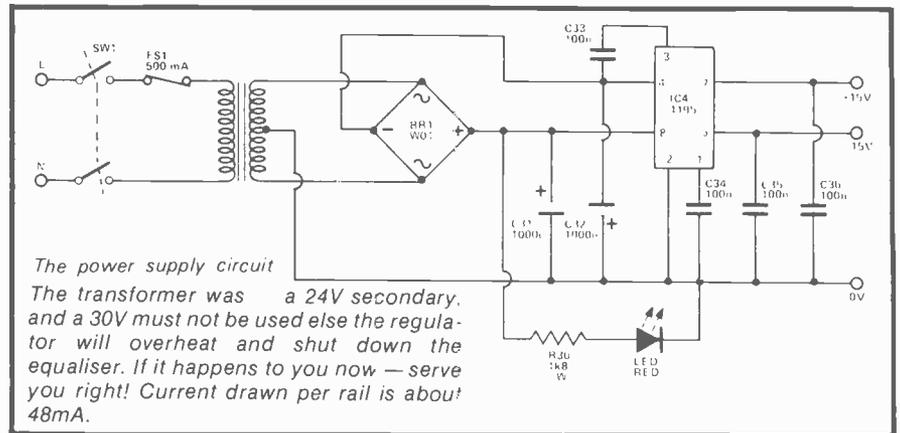


*Above left: one of the prototype board assemblies before fitting to the chassis*

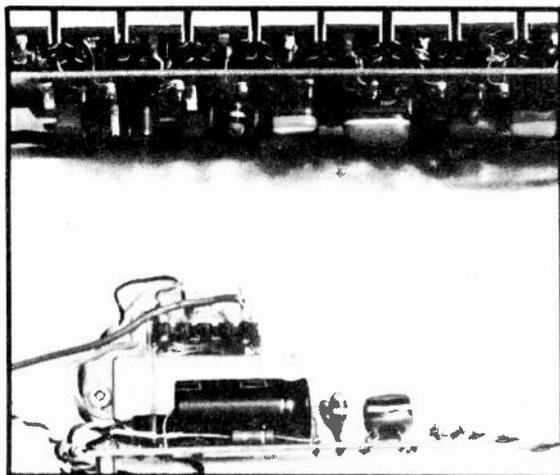
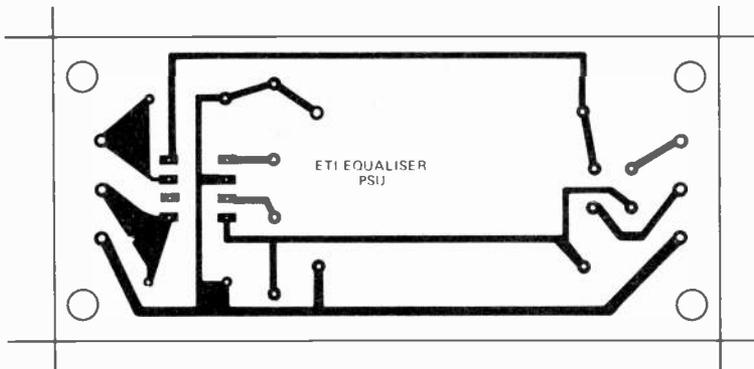
*Below: the final thing. An assembled equaliser with just the tape monitor switch to be wired in. All the signal leads can be led around beneath the sliders, keeping them as far from the PSU as possible*



# GRAPHIC EQUALISER

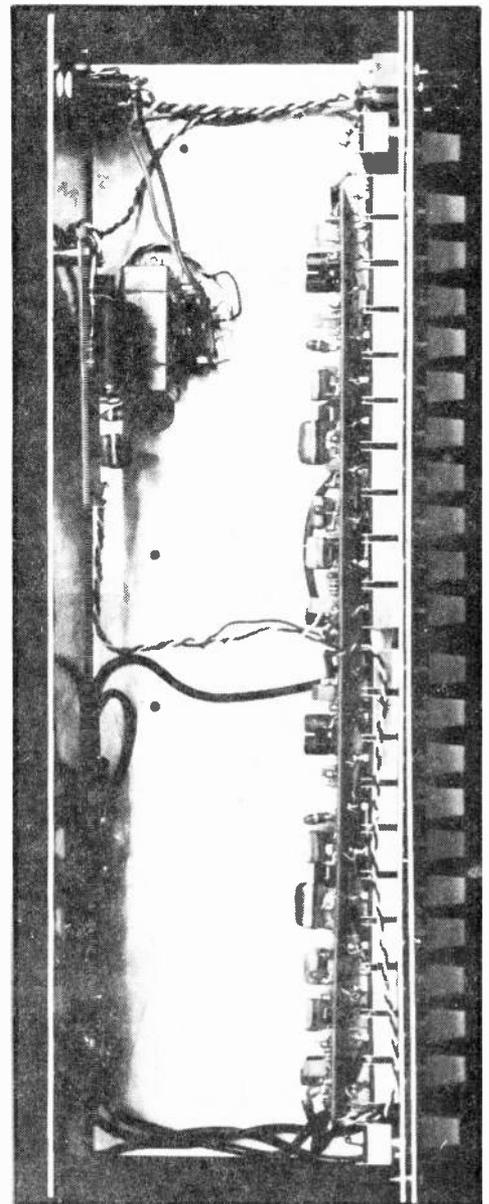


Component overlay and foil pattern for the power supply. The LED dropper resistor is wired from C32. The foil pattern is shown full size i.e. 88mm width.



The power supply board in situ. Note the LED dropper resistor wired from the reservoir capacitor. The support pillars are missing from one end of the PCB here, as they help support the screen around the transformer and this had to be removed. For some reason our camera wouldn't work through aluminium.

Below The beast assembled and lying beneath our camera. Note that here the screening has been removed from around the power supply so you can see what's gone where. The LED wiring can be seen as a twisted pair running from the regulator board top left.



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10/77

# VACUUM TUBES FOR

BY WALLY  
PARSONS

IN 1906, Lee DeForest first used high-vacuum tubes as amplifiers in the repeaters of the first transcontinental telephone network, officially opened in 1915. In 1924, Bell labs first demonstrated electrical recording. The next year Victor and Columbia each released its first electrical recording. In that same year Victor sold 42,446 Orthophonic acoustical Victrolas, but only 11 of its new all electric phonographs.

Over the years the ratio has changed, to put it mildly, with an ever-increasing search for perfection, accompanied by numerous milestones along the way: new circuits, transducers, tube types, semi-conductors. The newest milestone is the subject of this article, a new power amplifier technology.

But before describing this new technology, some basic review might be in order, both for readers new to electronics, and for those who may have forgotten certain fundamentals, as we all do in a time of fast changing technology.

## TUBES

In the beginning, man created vacuum tubes, and they were indeed wonderful devices.

A vacuum tube has all its working parts enclosed in a vacuum, and is, in a sense, a field effect device, in that current is controlled by the electric field on its control electrode. Electrons are emitted by thermionic action from a heated cathode and attracted to the anode by that electrode's high positive potential. Since its physical structure allows only one electrode to provide a source of electrons, current can flow in only one direction and under only one condition of polarity. Therefore, it functions as a diode, conducting either continuously under one condition of polarity, or on alternate half-cycles of an AC voltage. Current is essentially proportional to applied voltage. (Fig. 1)

If a grid structure is placed between these electrodes, it can also be used to control current flow. A negative potential will repel electrons, opposing their flow to the anode, and by placing it close to the cathode, a small change in grid potential will have the same effect on anode current as a much larger change in anode potential. If a load is inserted in series, a voltage is developed, and power dissipated. Therefore, the device will amplify.

It can be seen that this action is direct, and electron flow can be made to respond rapidly to changes in control potential. Moreover, in switching applications it can switch an inductive load rapidly, because the back EMF developed sees an extremely high impedance and no reverse current flows.

Fig. 2 shows the relationship of anode voltage, grid volts, and anode current for a triode tube. It can be seen that anode current can be controlled by both anode volts and grid volts. If a load resistance is inserted in the anode circuit, current changes will cause voltage changes across the load. These can be plotted in the form of a load line as shown, and also as a transfer curve for the specific load.

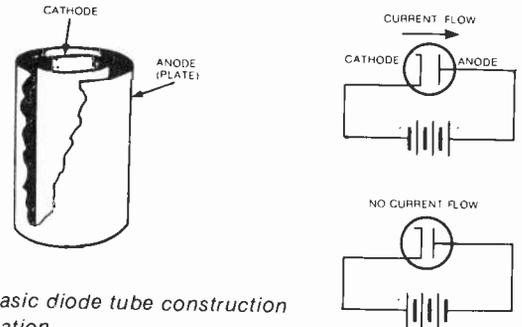


Fig. 1 Basic diode tube construction and operation.

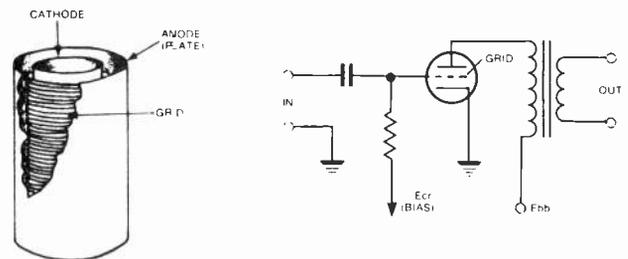
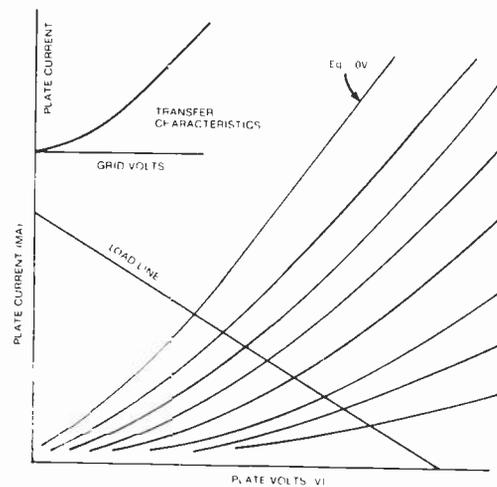


Fig. 2 Triode construction, circuit and characteristics.



It is obvious that the amplification of this device is quite linear, but gain and output are limited as shown by the semi-vertical slope of the curves, and also by the fact that plate voltage cannot be swung close to the zero volts level.

Inserting a second grid between the control grid and anode, or plate, and applying a fixed positive voltage somewhat lower than on the plate further accelerates

electrons, but because of the grid's open structure, most of them continue on to the plate. But note that the screen voltage takes precedence over the plate in controlling current. And we can swing the plate voltage further for more output, and get higher gain as well.

The addition of the second grid with a fixed high potential results in a current flow essentially independent of anode voltage, but still subject to the action of the control grid. (Fig. 3). Trouble occurs, however, when we try to produce a plate voltage swing lower than the screen voltage. Electrons are moving so fast that when they strike the plate they dislodge other electrons, which are attracted to the higher potential screen grid, thus reducing current through the load.

Then someone had the bright idea of installing yet another grid between the screen and plate, and tying in to the cathode. Because it is at cathode potential, it literally pushes the secondary emission electrons back to the plate, resulting in a family of curves as in Fig. 4. (Pay close attention to these curves because we'll be looking at similar ones later on).

Distributed loading is also possible by dividing the load between screen and anode, and results in Fig. 4a. This kind of flexibility makes possible some tube designs of exceptional linearity.

## PROBLEMS

This would look pretty good except for a few problems. To begin with, the tube, like a light bulb, converts more electricity to heat than to useful work. To get a lot of work out of it means it uses up lots of energy, which in this day and age is wasteful. To give an idea of how much heat is generated, consider the two 75 watt class AB amplifiers plus other assorted components which quite literally keep my studio at 25°C without any additional heating on the coldest day of winter. Or a television receiver (hybrid) producing an image to rival the best colour film — when it isn't down for repairs to the circuit board or other devices suffering from heat prostration.

Secondly, also like a light bulb, a tube's performance deteriorates from the moment power is applied. Thus, direct coupled circuits can give real headaches in maintaining correct operating characteristics.

And then there's the output transformer. In order to match the thousands of ohms impedance to a low impedance load such as a loudspeaker, a transformer is virtually a necessity. And with the kind of inefficiencies involved we can't afford

Fig. 3 The addition of a second grid showing circuit and characteristics.

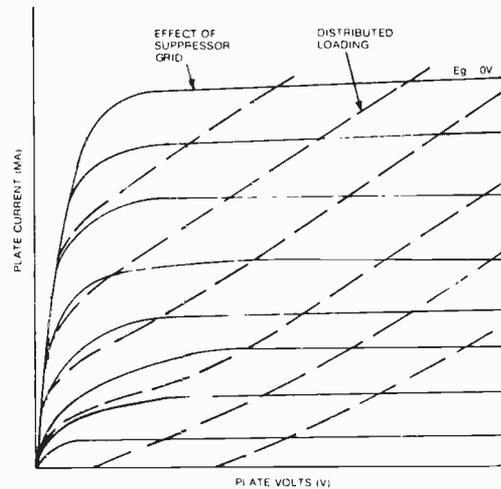
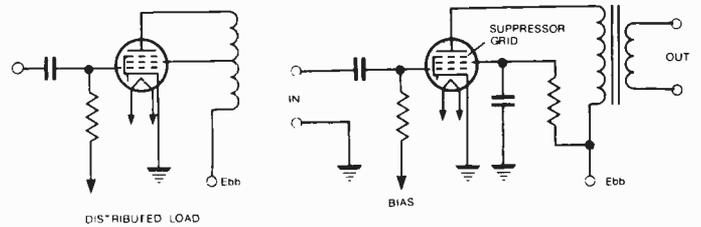
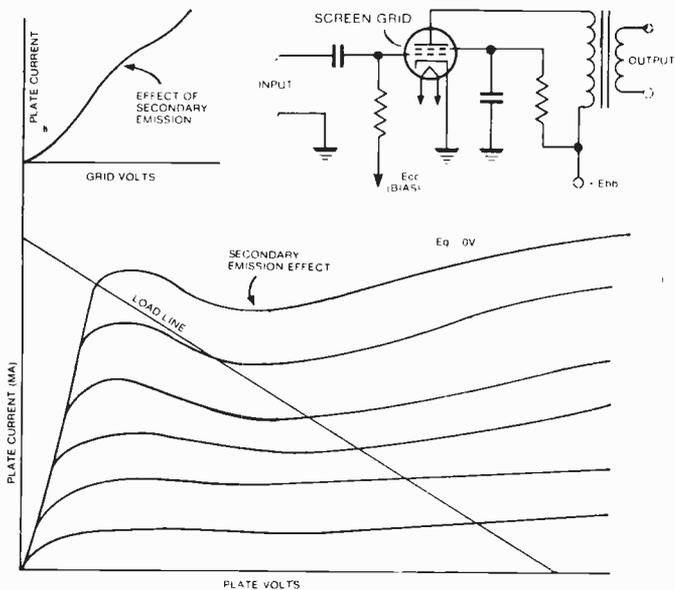


Fig. 4 Circuits and characteristics of the tube of Fig. 3 with additional grid connected to the cathode.

the impedance mismatches if we try to get away without using transformers. And we can't use gobs of feedback to reduce the resulting distortion. It's bad enough that, if we don't opt for a delicately balanced direct coupled circuit we have a low frequency roll-off and 90° phase shift at every R-C coupling point, but also add the additional phase shift and internal resonances of the transformer. In practice, we are limited to between 20 and 26dB of overall feedback. Obviously, a high level of open loop linearity must be designed into such an amplifier.

A great deal of engineering energy was spent designing Output Transformerless Amplifiers, but few were very successful, and those that were often created more problems than they solved. So if you're a masochist or a compulsive tinkerer, fine. Or if you're a perfectionist. Some legendary amplifiers were built using tubes. The Williamson, (I still have one, in daily use, and it still sounds great), Quad, Leak Point One, MacIntosh Unity Coupled. The Quad, for example delivered all of 15 watts — and was rock stable driving an electrostatic (Quad, of course) at five performance levels. Mac's drove a lot of disc cutters (at 60 watts) to produce discs which still sound spectacular.

But many were anxious to do something with the new-fangled transistors, and we did.

## TRANSISTORS

The bi-polar transistor is an entirely different kind of beast. It is composed of three materials, either a *p*-type semiconductor between two *n*-types, or an *n*-type between two *p*-types, as shown in simplified form with bias voltages Fig. 7a. A semi-conductor such as silicon or germanium possesses a crystalline structure in the form of a diamond lattice with each atom having four adjacent neighbours, held together by what are known as co-valent bonds, each bond involving a shared pair of electrons. These electrons are not available for conducting current, and, as a result, conduction is very semi, indeed, the resistance being around 100 million times that of copper.

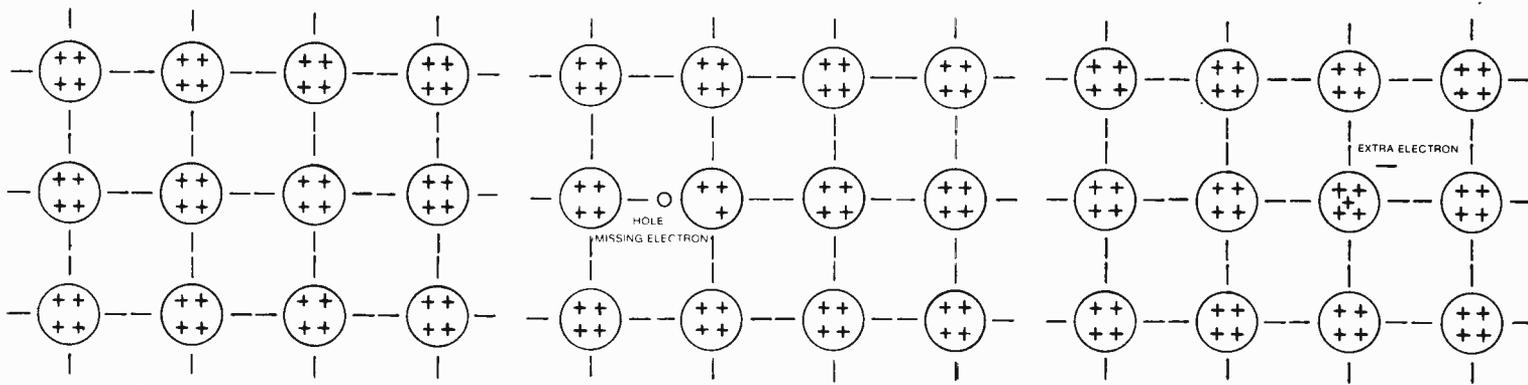


Fig. 5a. Basic lattice structure

Fig. 5b. P-type lattice structure

Fig. 5c. N-type lattice structure

However, if either during crystal growth or by diffusion we introduce an impurity such as phosphorus or arsenic, four of its electrons form bonds while the fifth is only lightly held and is available for conduction. This is an *n*-type material. If we add an impurity such as aluminum, only three valence electrons are available. Therefore, one of the valence bonds is not completed, resulting in a vacancy or hole in the lattice structure (Fig. 5). An electron from an adjacent electron pair bond may absorb enough energy to break its bond and fill the hole. This doesn't look like much of a big deal, but the result is quite dramatic.

It should be noted that the atomic structure is in equilibrium and there is no net change. However, if a free electron breaks its bond it leaves behind a positive net charge; if it completes a bond by entering a hole, a negative net charge results. Current flow is produced by bringing about this carrier mobility. What was originally a very high resistance is now, under the right conditions, able to conduct substantial current. Just as a small impurity (e.g. sulphuric acid) added to non-conductive pure water, makes electrolytic conduction possible, as in electro-plating, or an automobile battery.

When *p* and *n*-type materials are joined together, a *p-n* junction is formed (Fig. 6). Some of the free electrons from the *n*-type material diffuse across the junction and recombine with holes of the *p*-type material. The opposite process takes place with holes from the *p*-type material, producing a space charge or depletion region on either side of the junction, giving the *p*-type material a slight negative charge, and the *n*-type a slight positive charge. This process is finally limited by the resulting potential gradient.

But if a battery is connected as shown in Fig. 6a free electrons from the *n*-type material are attracted to the positive terminal, while holes from the *p*-type material are attracted to the negative terminal, widening the space charge region and increasing the potential gradient until it approaches that of the external battery. There is now little or no voltage difference across each region and little or no current flow. The junction is reverse biased.

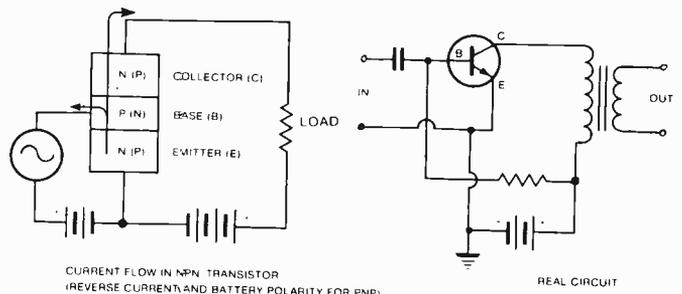
If we reverse these polarities (Fig. 6b) electrons in the *p*-type material break their bond and enter the battery creating new holes, while electrons from the battery negative terminal

enter the *n*-type material and diffuse toward the junction. The space charge region narrows and the energy barrier becomes insignificant, so that excess electrons from the *n*-type material can penetrate the junction and move via the *p*-type holes to the positive battery terminal, for as long as voltage is applied. The junction is now forward biased.

### WORK!

Now we'll make these materials do some work.

In the device shown in Fig. 7, the forward-biased emitter-junction injects electrons into the base region. The impurity, or doping levels chosen are such that almost all the emitter current is composed of these electrons, and very few holes injected into the emitter. The base region is very thin so that nearly all injected electrons diffuse to the edge of the depletion region of the reverse-biased base-collector junction where the field sweeps them across the collector bulk. Since for an equal current, more power is developed across a high resistance than a low resistance, amplification occurs as a result of current being transferred from the low-resistance emitter-base junction to the high resistance collector junction.



CURRENT FLOW IN NPN TRANSISTOR (REVERSE CURRENT AND BATTERY POLARITY FOR PNP)

REAL CIRCUIT

Fig. 7a. Current flow in a semiconductor and circuit diagram.

The curves show that, as with the pentode tube, current is controlled mostly by the control electrode (base), but in this case the controlling parameter is current, not voltage. We have an inherently low-impedance device, and since it requires current into its input impedance, its signal source

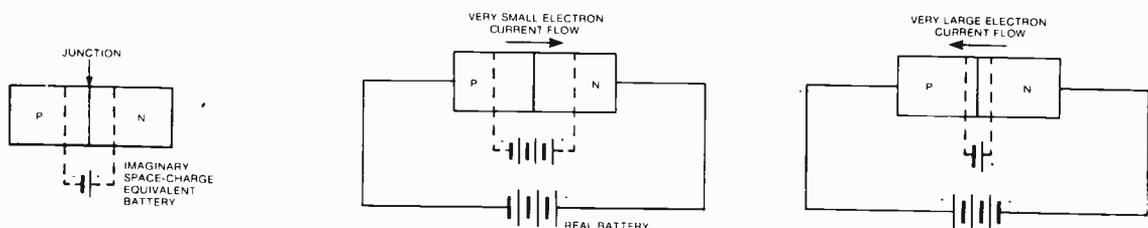


Fig. 6. Showing "space charge", reverse bias and forward bias.

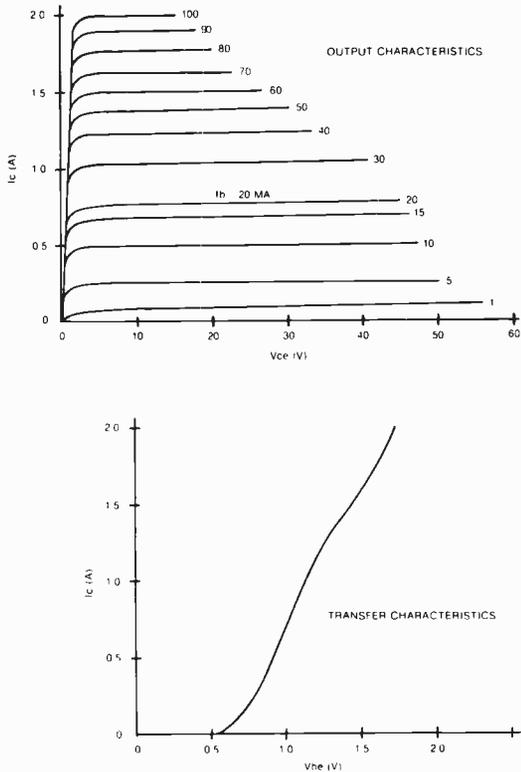


Fig. 7b. Output and transfer characteristics of the 2N3054.

must be capable of delivering power. Even an ideal transistor requires input current, unlike an ideal vacuum tube. This reduces efficiency (after all,  $x$  volts across  $\infty$  draws 0 Amp current, which means zero watts input) but we don't have to heat up a cathode to shake a few electrons loose, so our overall efficiency is vastly greater.

### DISADVANTAGE

The major disadvantage of this type of device lies in the nature of the depletion layers at the junctions, particularly the emitter-base. When current flows in a transistor, excess charge is stored in the base region. If the base-emitter junction is changed from a forward to reverse bias state, as in the negative swing of a class B or AB stage, or when a class A stage is overdriven, the junction cannot immediately switch to the reverse blocking state due to the presence of these excess charge carriers. They have the effect of allowing current to flow in reverse as if forward biased, until these charge carriers are removed.

In addition, there is a capacitance effect associated with the barriers of a reverse-biased junction, which possesses a finite charge-discharge time. The result is a switching transient during part of a cycle, sometimes erroneously referred to as crossover distortion (the latter occurs in any device in push-pull and is due to a discontinuity in the transfer function, usually caused by incorrect bias). This can be reduced by reducing the junction area but this reduces the dissipation capability. In fact, a transistor design favouring one characteristic usually does so at the expense of others.

Also as temperature rises in the device (due to current flow, for example) carrier mobility at the junctions increases, causing further increase in current. The current increase further raises temperature, which raises current — wheels within wheels, perpetual motion, whatever. The resulting thermal runaway quickly destroys the device. And all in a matter of milliseconds — ZAP!

In large area transistors, current tends to become non-uniform in distribution. The temperature rise in the high current region leads to localized thermal runaway until equilibrium is reached by a sharp drop in collector voltage, called secondary breakdown, frequently with total destruction to the device. This is more true at high voltage and low current than the reverse, and frequently means that rated dissipation cannot be reached. This leads to overdesign, unnecessarily high voltage and dissipation ratings (and remember, a design which favours one characteristic often does so at the expense of others) plus elaborate protective circuits.

High levels of feedback are generally used to control distortion and this in conjunction with the excess charge condition in the base leads directly to transient overload, and resultant transient intermodulation. Output is delayed during this charge/discharge, which delays application of feedback. It simply isn't available. The input signal is not immediately reduced by feedback, and passes through at high initial level. At this point it seems that the millenium has not quite arrived after all.

### THE FET

Since a semi-conductor is precisely that, a battery connected across the ends of a  $p$ -type or an  $n$ -type bar will cause current to flow through the material, just as it does through a vacuum tube. We discussed earlier the characteristics of a  $pn$  junction. If for example, a  $p$ -type material is joined to the surface of an  $n$ -type bar, located between the battery terminals, a  $pn$  junction is formed, and if this junction is reverse biased, a space charge or field is produced of opposite polarity which will inhibit current flow, just as the control grid inhibits current flow in a vacuum tube. Changing this reverse voltage causes a large current change, and therefore amplification results.

A simple junction FET is shown in Fig. 8. With a given drain

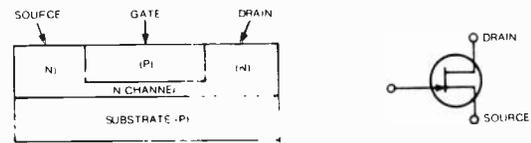


Fig. 8 N-channel JFET construction and symbol.

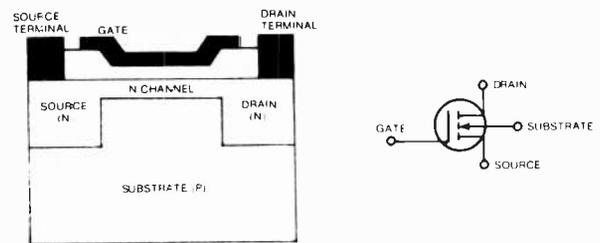


Fig. 9a. N-channel depletion horizontal MOSFET construction and symbol.

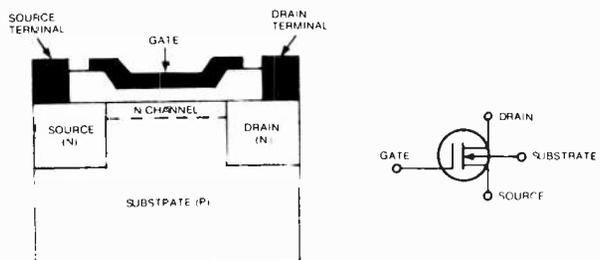


Fig. 9b. N-channel enhancement horizontal MOSFET construction and symbol.

— source voltage, maximum current flows under zero gate voltage conditions, and at some reverse voltage, determined by device geometry and doping levels, no current will flow. Also, as in the vacuum tube, load characteristics are not reflected to the input circuit, because current is not controlled by carrier injection as in bipolars, but by voltage levels.

A variation is the Metal Oxide Semi-conductor Field Effect Transistor. (MOSFET) (Fig. 9) a far more versatile device whose technology is virtually the cornerstone of modern computer technology, although it has had less use to date in linear applications such as audio amplification.

MOSFETS come in two basic types. In both types the gate consists of a metal electrode separated from the channel by a thin oxide layer. In the depletion type current flow is controlled by the electrostatic field of the gate when biased. Voltage relationships are the same as for the J-FET, except that when the J-FET is forward biased current will flow through the junction (after all, it is a *pn* junction). This does not contribute to amplification, and may even destroy the device. When a depletion MOSFET is so biased it may result in increased current flow, and, provided current, dissipation, and breakdown ratings are suitable, the device may be driven on both sides of the zero volts point as with vacuum tubes. Unlike vacuum tubes, under these conditions, the gate draws no current, therefore does not require the driver to deliver power.

The enhancement type MOSFET shown in Fig. 9b, is more widely used. The source and drain are separated by a substrate of opposite material, and under zero gate volts no current flows. However, when sufficient forward bias is applied to the gate the region under the gate changes to its opposite type (e.g. *p*-type becomes *n*-type) and provides a conductive channel between drain and source. Carrier level, and conduction is controlled by the magnitude of gate voltage. Although J-FETS, and especially MOSFETS, have certainly delivered on their original promise, in one area they are particularly conspicuous by their absence, and that is in the area of power. Unfortunately, the channel depth available for conduction is limited by the practical limits on gate voltage. The lower current density has been the primary limitation due to the horizontal current flow.

## VMOS

Recent years have seen the introduction and commercial use of Vertical Channel J-FETS, notably by Sony and Yamaha (Fig. 10). The vertical channel permits a very high width-length ratio, permitting a decreased inherent channel resistance and high current density. Unfortunately it exhibits

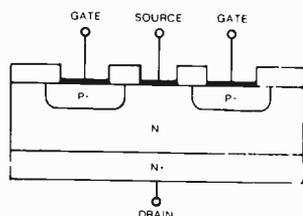


Fig. 10. Vertical junction FET construction.

the same disadvantages as the small signal J-FET, plus, in available devices, a very high input capacitance, ranging from 700pf to around 3000pf, limiting high frequency response. In addition, since they must be biased into the off condition, bias must be applied before supply voltage and removed after the supply if it is to be operated anywhere near its maximum ratings. This problem doesn't exist with vacuum tubes because of heater warm-up time, although some "instant-on" circuits impose heavy turn-on surges.

This necessitates a complex power supply, and indeed Yamaha, for example, uses more devices in the supply than it does in its amplifier circuits. However, the construction does make possible the design of complementary types and Nippon Electric and Sony both have high power devices available. Unfortunately, neither company seems anxious to make detailed information available, so there is little to disclose here beyond the fact that they are said to have characteristics similar to those of triode tubes.

However, the Vertical MOSFETS by Siliconix are readily available, at reasonable prices, and the manufacturer most generous in providing data. The following information is extracted from their application note AN76-3, Design Aid DA 76-1, plus device data sheets.

## THE DEVICE

Notice in Fig. 11, that the substrate and body are opposite type materials separated by an epi layer (similar to high speed bi-polars). The purpose of this structure is to absorb the depletion region from the drain-body junction thus increasing the drain-source breakdown voltage. An

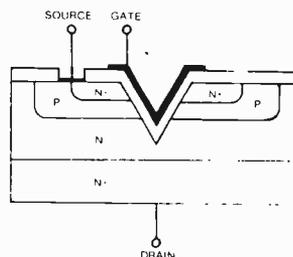


Fig. 11. Vertical MOSFET construction (Siliconix).

alternative would have involved an unacceptable trade-off between increasing the substrate-body depth to increase breakdown voltage but increasing current path resistance and lengthening the channel. In addition, feedback capacitance is reduced by having the gate overlap *n*-epi material instead of *n*<sup>+</sup>.

In manufacture, the substrate-drain and epi layer are grown, then the *p*-body and *n*<sup>+</sup> source diffused into the epi layer, in a similar manner as the base and emitter of a diffusion type transistor. A V groove is etched through the device and into the epi layer, an oxide layer grown, then etched away to provide for the source contact and an aluminum gate deposited. It is apparent that this type of device allows current flow in one direction only; this is not always so with a similar type of horizontal FET, where source and drain may be identical in structure and of the same material. Therefore, no reverse current flows (we hope) when used in switching applications, as was also the case with vacuum tubes.

In-circuit operation is refreshingly simple: Supply voltage is applied between source and drain, with the drain positive with respect to the source, under which conditions no current flows, and the device is off. This is an enhancement type device, and is turned on by taking the gate positive with respect to the source and body. The electric field induces an *n* channel on both surfaces of the body facing the gate, and allows electrons to flow from the negative source through the induced channel and epi and through the substrate-drain. The magnitude of current flow is controlled almost entirely by the gate voltage, as seen in the family of curves (Fig. 12) with no change resulting from supply voltage changes above 10V.

## ADVANTAGES

The vertical structure results in several advantages over horizontal MOSFETS.

1) Since diffusion depths are controllable to close tolerances, channel length, which is determined by diffusion depth, is precisely controlled. Thus, width/length ratio of the channel, which determines current density, can be made quite large. For example, the VMP1 channel length is about 1.5 $\mu$ s, as against a minimum of 5 $\mu$ s in horizontal MOSFETS, due to the lower degree of control of the shadow masking and etching techniques used in such devices.

2) In effect, two parallel devices are formed, with a channel on either side of the V groove, thus doubling current density.

3) Drain metal runs are not required when the substrate forms the drain contact, resulting in reduced chip area, and thus reduced saturation resistance.

4) High current density results in low chip capacitance. Also, unlike horizontal MOSFETS, there is no need to provide extra drain gate overlap to allow for shadow mask inaccuracies, so feedback capacitance is minimized.

In comparison with bi-polars, especially power devices, the advantages are even more impressive.

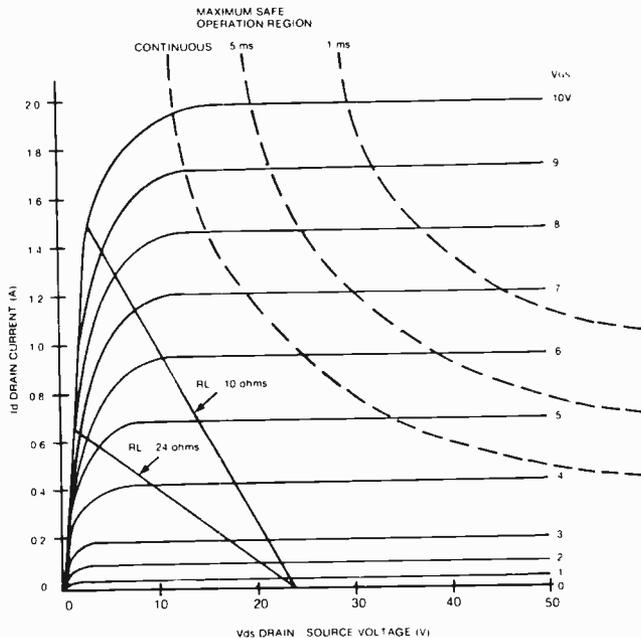


Fig. 12a. Output characteristics VMP1

destroy the device by exceeding its maximum ratings, but a brief near-overload does not result in an uncontrollable runaway condition. Usually, simple fusing and/or thermistor protection is sufficient for maximum safety, and even this may be unnecessary with conservative design. Absence of secondary breakdown means that full dissipation can be realized even at higher supply voltages. In this respect they resemble vacuum tubes.

## AVAILABLE DEVICES

Seven devices representing three families are available. Types VMP-1, VMP-11, and VMP-12 are 2A, 25W dissipation

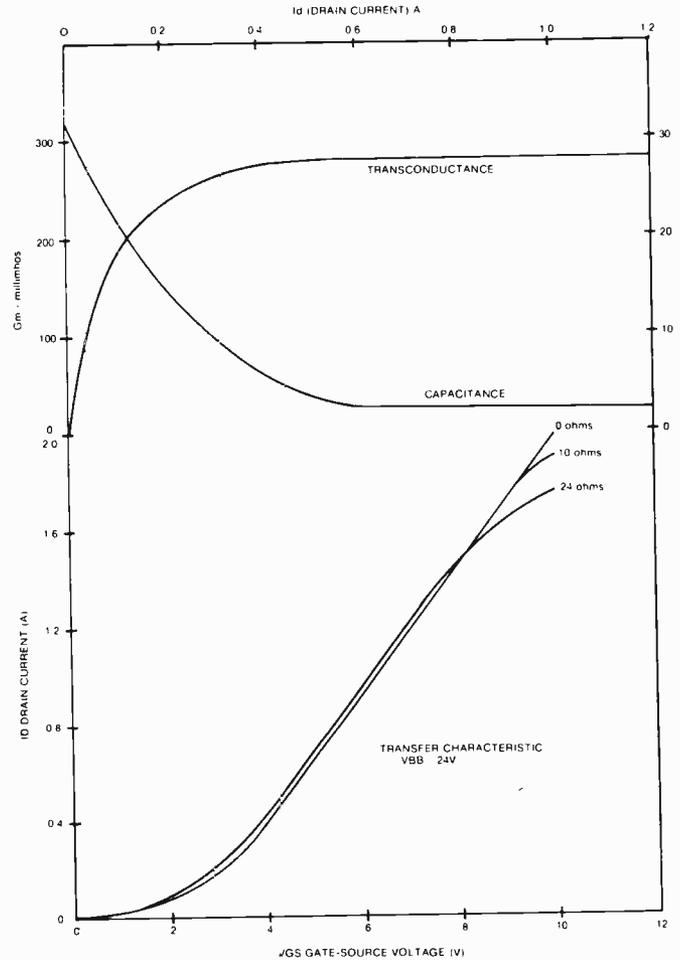


Fig. 12b. Other VMPI characteristics.

1) Input impedance is very high, comparable to vacuum tubes, since it is a voltage controlled device, with no base circuit drawing current from the driver stage. A 7V swing at the gate, at virtually 0A, represents almost 0W of power, but can produce a swing of 1.8A in output current. This represents considerable power gain and will interface directly with high impedance voltage drivers.

2) No minority carrier storage time, no injection, extraction, recombination of carriers, resulting in very fast switching and no switching transient in class B and AB amplifiers. Switching time for a VMP1 is 4nsec for 1A, easily 10-200 times faster than bi-polars, and even rivalling many vacuum tubes.

3) No secondary breakdown, and no thermal runaway. VMOS devices exhibit a negative temperature coefficient with respect to current, since there is no carrier recombination activity to be speeded up with temperature. Thus, as current increases so does temperature, but the temperature rise reduces current flow. It is still possible to

devices intended for switching and amplifier use and differ only in voltage rating (60V, 35V, 90V, respectively). Types VMP2, VMP-21, VMP-22, are 1.5A, 4W devices rated at 60V, 35V, 90V respectively, and are intended mainly for high speed switching, but would also be useful for low power amplifiers and as linear drivers for bi-polars, where the latter offer advantages. And finally, type VMP-4, 1.6A, 35W, specifically intended for VHF amplifier use. All except VMP-4 devices feature gate protection to withstand static discharges and overvoltages, and all are currently available except the VMP-4. One hesitates to pass premature judgement, but if the millenium hasn't arrived yet, at least it might just be on the way. Or, as one automaker's commercials are saying, "Now, that's more like it".

**Next month** we'll examine the VMP-1, VMP-11, VMP-12 family, and figure out ways to put them to good use.

## What to look for in the November issue:

### LASERS AT PLAY

Our cover subject next month is a look at laser light shows etc. It gives a pretty good idea of what's being done with lasers in the entertainment field and how the systems have evolved.

### BUCKET BRIGADE

COMMONLY CALLED 'bucket brigade' by those who are fond of such things, charge coupled devices are roaring onto the market, and seem destined to take a firm hold in several places!

They take the form of ANALOGUE shift registers, and immediately make such things as echo units, phasers and

even TV cameras smaller and better. At the most basic they work by shifting a 'packet' of charge along a long, long line of electrodes under the influence of an external clock signal. Since the size of this 'packet' is variable, you have an analogue device — the variable clock means variable delay, too.

### microbiography

Next month our on-going feature gives details of the third generation in the 8000 family. We will be looking at the 8085 and Z80 so those who are finding information difficult should like this one.

### MPU 4U?

Ever asked yourself 'Why not use an MPU in my next project?'. If, as we suspect, the answer is no then John Miller-Kirkpatrick's article next month is for you.

### Watchdog!



Not a canine approximation. Instead a simple 'robot' which will not allow you to leave the hi-fi or television running when you're not using it. The circuit monitors the audio signal coming from the appliance, and will remove the supply when none appears for a pre-set (long) time period. Operation is 'fail-safe' so that potential fire risks from energised wires are avoided. No more wasted watts!

The articles described here are in an advanced state of preparation, but circumstances may necessitate changes in the issue that appears.

### DIGITAL THERMOMETER

Using the new National temp. control chip (data sheet this issue) with an A/D converter and 7-segment display - our digital thermometer provides an accurate and attractive alternative to those fragile columns of quicksilver,



# microbiography

This month we begin a bus eye view of the original 8008, and a chip off the old block, the popular 8080.

From the relatively recent, but stunningly quick growth in the popularity of microprocessors, the computer hobbyist has been born. But computer hobbyists and interested persons alike have been flooded with a deluge of information on different processors, most of which serves to confuse rather than enlighten.

On this note we start this series, an attempt to look at the entire field of microprocessors and associated products, who makes what, how they work, how they are related, and where they're used.

This month we attack the basics, and start at the start with the daddy of them all — the 8008, followed by the second generation 8080. Next month's part covers the third generation in the 80 series, namely 8085 and Z80 types. Following the 8000 family, we look at the Motorola 6800 camp, with its close relative the 6500 series from MOS Technology/Commodore. From there we plan to progress through the other various processors offered. Stay tuned!

## THE BASICS

First, a brief rundown on the essential features of an mp system — those we will be looking at as we consider each approach to the problem.

Whenever one gets deeply involved in a subject, as mp hobbyists are apt to do, it is easy to lose sight of the global point of view, what an mp system actually is. One picture to remember which quickly puts things in perspective is illustrated by figure 1. It looks ridiculously simple, yet it helps immensely to clarify thinking. An mp system is nothing more than a collection of components with the capability of accepting inputs, acting

upon that information, and as a result producing some outputs.

Let's attach a few more details on a new diagram — figure 2. This is a philosophical look at the basic ideas behind most systems. The chief concept is that the internal mp system and its speed are all important, while all external world (slow) signals are carefully interfaced so as to co-operate with the mp timing. This is the principle of grouping signals with like speed, just as one would not attempt to ride a bicycle or land a 747 on a six lane highway. Both could be done, but only with great sacrifice by the regular users.

Of course there are some cases where an outside device takes over for a while, but generally only with the permission of the processor.

The segment of the system we will be looking at is that part between the 'I' and the 'O', in other words the processor and its support chips.

## INSIDE VIEW

Figure 3 provides a more comprehensive look inside the 'box'. This very general block diagram emphasises the main features of an mp system — data input, data storage, data manipulation and data output.

It is very important also to realize that not only is the CPU capable of data manipulation, it is also in charge of the works. Thus it is a memory and I/O controller by virtue of basic hardware connections.

Armed with this picture we will investigate the different approaches to organizing the basic blocks of figure 3, and the corresponding differences in the internal organization of the mp chip itself. Naturally there will be many similarities between systems. Most of the popular processor sets share such features as 8 bit orientation, similar bus systems and especially support chips which look similar to the outside world, such as parallel and serial I/O devices.

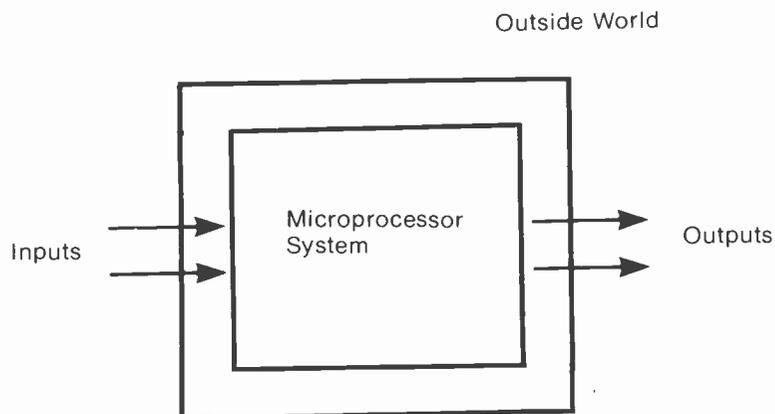


Fig. 1. Simplified basic view of microprocessor system.

# microbiography

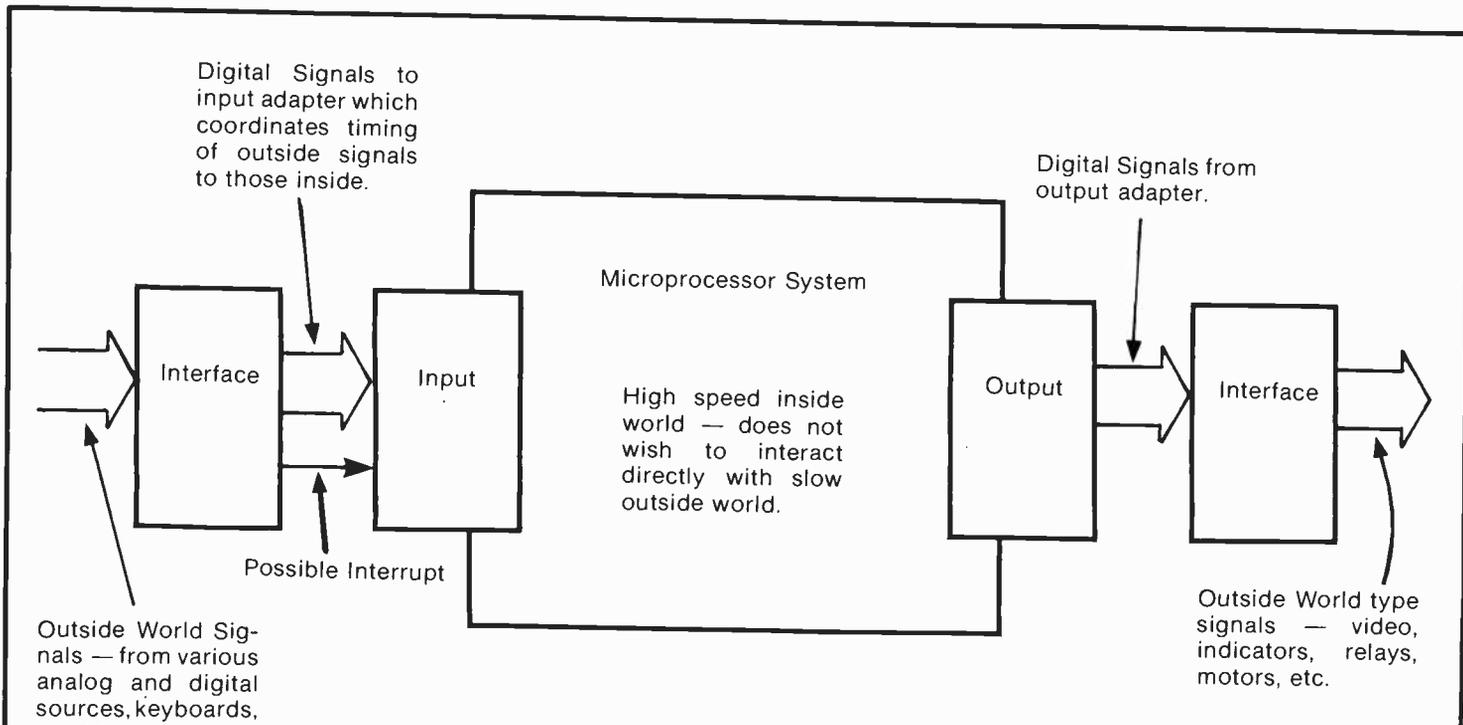


Fig. 2. Complicated simplified view of microprocessor system.  
 Microprocessor system based on the concept that the processor has the highest priority, and will listen or speak to the outside world only under its own decision, except in special circumstances, such as restart conditions. External world may request to "interrupt" the proceedings inside the processor, which then under its own command decides the action to take on this interruption.

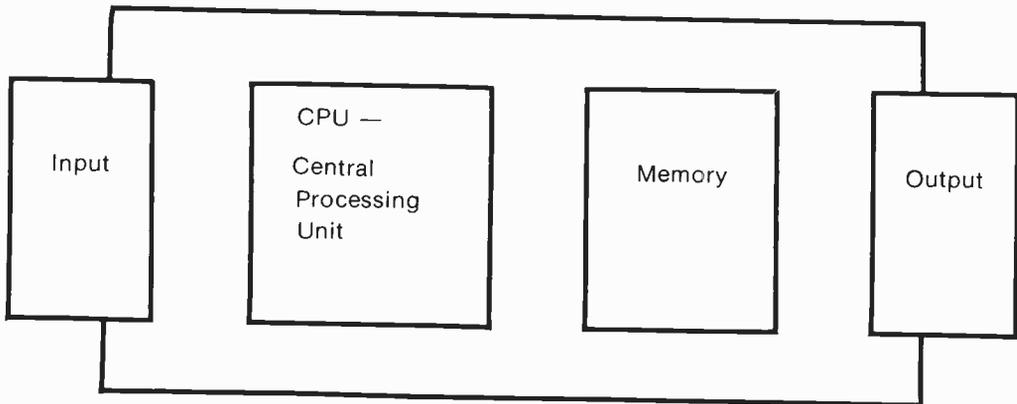


Fig. 3. Inside the system.

## SOFTWARE

In few fields is there such a close tie-up between software and hardware as there is in microprocessors. Hence we cannot possibly look at hardware without seeing the influence on or from the instruction sets and software side.

What is software? Probably the most familiar type of software to most people these days is that written to look after such tasks as accounting, payroll, engineering problems and so forth. Microprocessors can do these tasks too, but it may be difficult to see how the hardware does it. The mpu spends some of its time as a data manipulator, with such operations as adding, subtracting, ANDing and ORing 8 bit bytes, rotating and shifting bytes, and other seemingly low level activities. Suffice it to say that sequences of these instructions can be built up to multiply, handle BCD numbers, do floating point arithmetic, and so on until pretty soon (if you don't have to write the routines yourself!) you have built up a useful high level language capable of actually doing something.

That's fine for the person for whom input and output are numbers and letters, but let's face it, the part of the system that needs the high level language is the human operator! However, mps are often used in a variety of control applications, where inputs are from knobs, switches and sensors, while outputs control parts of a machine, and perhaps indicators. Examples are in elevators, auto ignition systems etc. Here a high level language is not needed, and the programs are implemented directly in machine language. In these uses the mp is doing an impersonation of a very complex logic circuit, one where the hardware AND and OR gates are replaced by the mp's capability to AND and OR data together, and flip-flops are functionally replaced by memory.

We will be looking at the instruction sets of each processor we cover to give an idea of the merits of each at the machine level. It should be pointed out that almost any processor could be made to use a high level language such as BASIC or FORTRAN with enough effort. The question remains as to how fast it can do it, and how lengthy the programs become when converted to machine code. How fast and how long are related factors, and rest on how versatile the instruction set is that was provided by the mpu designers.



## GENERATION 1: 8008

The Intel 8008 was the first 8 bit mp and a fairly simple place for us to start. It will be interesting to see how other processors have developed from this one.

First, take a look at the internal block diagram of the 8008 (figure 4). It is almost entirely filled with 8 and 14 bit registers, whose purpose may be explained by describing what happens during a typical instruction execution.

The first action is an 'instruction fetch'. The program counter (PC) contains the address of the instruction, and the 14 bit number is sent out in two sections through the 8 bit data bus buffer, where external logic 'reconstructs' the 14 bit number and uses it to select the appropriate byte in memory. This 8 bit byte (the instruction) returns along the data bus, through the buffer, into the instruction register. Meanwhile the PC has been incremented, ready for the next instruction.

At this point, the instruction decoder looks at the newly fetched instruction and decides what to do about it. Let us suppose this instruction is to add the present number in the accumulator to the value in the byte following the instruction in memory. Here is an example of 'immediate addressing', because the 'address' of the operand is immediately following the instruction code (or 'op code') which operates upon it.

Now the PC is already incremented, it is again sent out via buffer and external logic to memory, which returns the value desired, this byte being deposited in one of the temporary registers on the left. The value in the accumulator is then transferred to the other temporary register. The two values are added in the arithmetic logic unit, and the result stored back into the accumulator. End of operation.

This points out a typical feature of mpu arithmetic logic operations, which is that an arithmetic logic unit performs the operation, and there is usually an accumulator register which at first contains an/the operand, and finishes up containing the result.

## 8008 INSTRUCTION SET

The 8008 has 48 instructions, divided into five basic groups.

**Index Register Group:** All the registers under the accumulator in figure 4 are known as index registers, because each may be incremented or decremented with single instructions. Other instructions allow transfer of data from register to register, and from memory to register or back. In case of transferring data from memory to register, immediate addressing may be used, or the address of the desired data may be contained in the two bytes following the instruction — 'extended addressing' mode. The instruction decoder knows after fetching the op code the appropriate action to take.

**Accumulator Group:** Seven groups of three instructions allow the accumulator to be added, subtracted, ANDed, or inclusive or exclusive ORed with an index register, immediate data or other memory location. The result ends up in the accumulator. When the ALU is used, certain conditions may occur which are: zero result, negative result, carry bit generated by over or underflow, and parity bit indicating even or odd result. These four 'condition codes' are stored in the four bit register labelled 'flag flip flops'. They may be used arithmetically, such as carry and borrow for addition and subtraction, contain results from instructions which compare the magnitude of two bytes, or for 'conditional' instructions — see below.

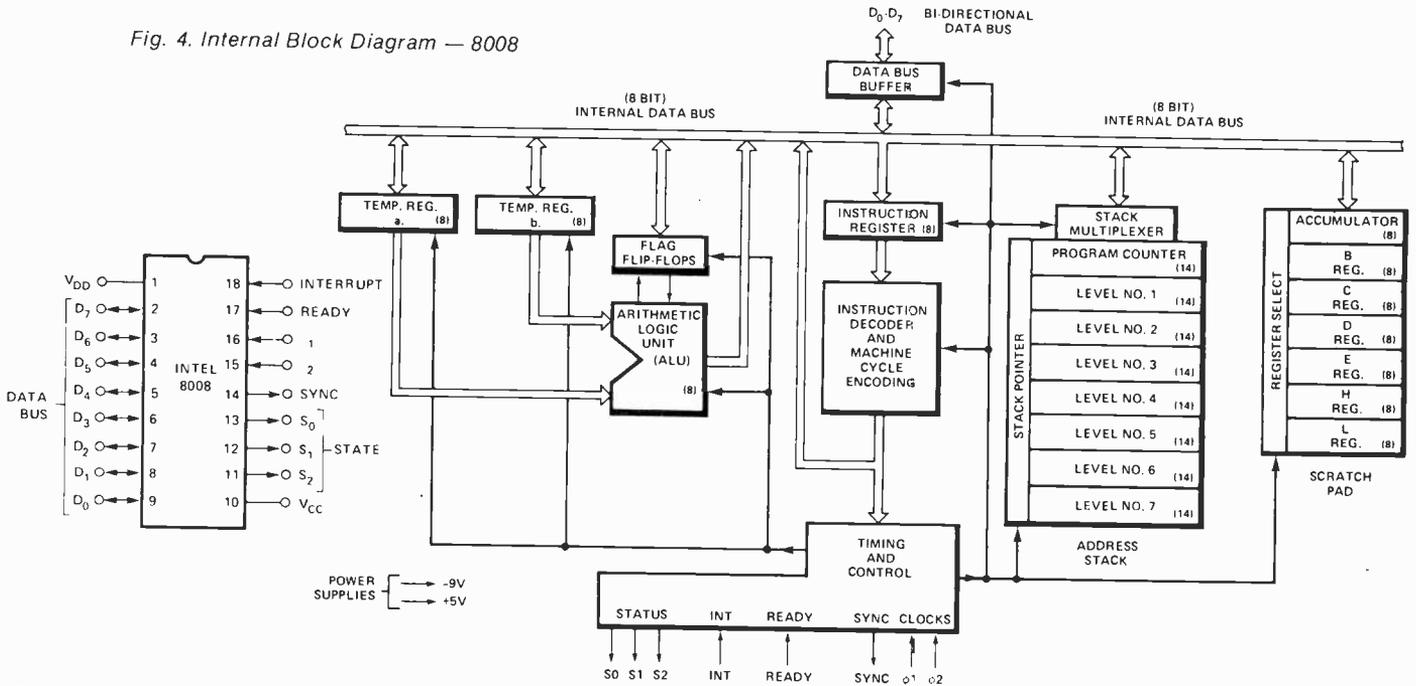
The four remaining instructions allow the accumulator contents to be rotated left or right with or without carry bit (figure 5).



Fig. 5. Pictorial view of rotate operation

# microbiology

Fig. 4. Internal Block Diagram — 8008



## Program Counter and Stack Control:

This section deals with 'Jumps' and 'Subroutines'. A jump is simply a command not to execute the next consecutive instruction, but to go somewhere else in the program and take up operation from there. This corresponds to setting the PC to a new number. Thus the instruction takes three bytes; one for the op code, and two for the new address for the PC. There are nine jump instructions, one unconditional, and the others each dependent on one condition code being '1' or '0'.

A subroutine may be considered as a 'mini-program away from home', perhaps a useful routine used in several different spots in the main program. It has the characteristic that the main program wants to jump to it, but when finished it is desired to return to the next location after the subroutine call. Thus the address of the instruction to return to must be 'remembered' somewhere, this of course being the function of the 'address stack'.

In the event of one subroutine calling another calling another, etc., seven levels in the stack are provided, with the 'pointer' keeping

track of which level in the stack is next in effect. Similarly to the jumps, nine subroutine calls and nine 'return from subroutines' are provided.

**Interrupts:** As previously mentioned, most processors have a means of 'interruption' by external hardware. The input line for this purpose, labelled 'INT', is shown in figure 4. If this line is pulled low, an action similar to a subroutine call takes place, through an instruction known as restart or 'RST'. The way this occurs is quite tricky and bears some explaining.

Suppose there are a number of devices (I/O ports etc.) capable of interrupting. These are each connected into an IC or logic collection which we shall call an 'interrupt controller'. When the interrupt is signalled to the processor, it responds through the interrupt acknowledge line to the interrupt controller. The mp now enters the part of its cycle where it would ordinarily fetch the next instruction. However, external logic causes the memory to ignore this and instead the interrupt controller puts a code onto the bus — the code for RST. The RST op code is made

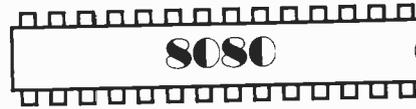
of five bits establishing it as the code for RST, and 3 bits which the interrupt controller determines according to which device is requesting the interrupt.

When the processor receives this RST instruction, it initiates a call-like action, to one of eight locations determined by the 3 bit code. At each of these locations the programmer will have written a routine to handle the particular device whose interrupt signal caused the routine to execute.

This type of interrupt handling scheme is known as a 'vector interrupt' because the reply to the interrupt acknowledge (ie: the RST) contains the information as to which device interrupted, and where to go (vector) for the appropriate routine. This approach is typically fast, but at the expense of hardware complexity. We will see other methods used by different mpu families.

**Input/Output:** Provision is made for 8 input and 31 output ports to be used for I/O of data to/from the system. Note that I/O ports are in this case treated differently from normal memory locations.

**Halt:** One instruction causes the 8008 to stop dead until an 'interrupt' is received.



## 8008 HARDWARE

A variety of details will already be apparent about 8008 hardware. It needs lots of support. First, there's the complication of multiplexing the data and two bytes of address on the one data bus. Signals decoded externally from lines  $S_0$ ,  $S_1$ ,  $S_2$  and 'sync' (figure 4) decide the use of the bus, and generate other control signals such as read or write signals for memory, 'I' or 'O' for I/O ports and so forth. The 'ready' line is used to slow the processor down if slow memory is used, and is 'not ready'. An external two phase clock, typically crystal controlled, is needed along with +5V and -9V supply. 20 or more TTL chips are needed to perform all these functions.

As an example of the speed of the system, one machine cycle takes 20 microseconds (8008) or 12.5 microseconds (8008-1) and each instruction can take two or three cycles if it references memory more than for just the op code fetch. Slow!

## GENERATION TWO — 8080

A speed improvement on the order of ten times and more over the 8008 was obtained with the 8080, and its enhanced versions. Part of this was due to the use of n-MOS rather than p-MOS processes, but a large portion is attributable to the extensively different design. (Figure 6)

Two changes are the most significant — both relate to the use of buses. Notice that the address (expanded to 16 bits to allow up to 64k bytes of memory) now has its own output lines, no longer having to share the data bus, and is all available at once. However, this has been achieved only at the expense of a 40 pin package, compared to the 8008's 18 pins.

The accumulator now feeds directly to the arithmetic logic unit (via a latch) greatly reducing the amount of to-ing and fro-ing along the internal data bus as happens in the 8008.

In addition to these, a few other changes were made. Another flag flip-flop was added, and decimal adjust circuitry facilitates BCD arithmetic.

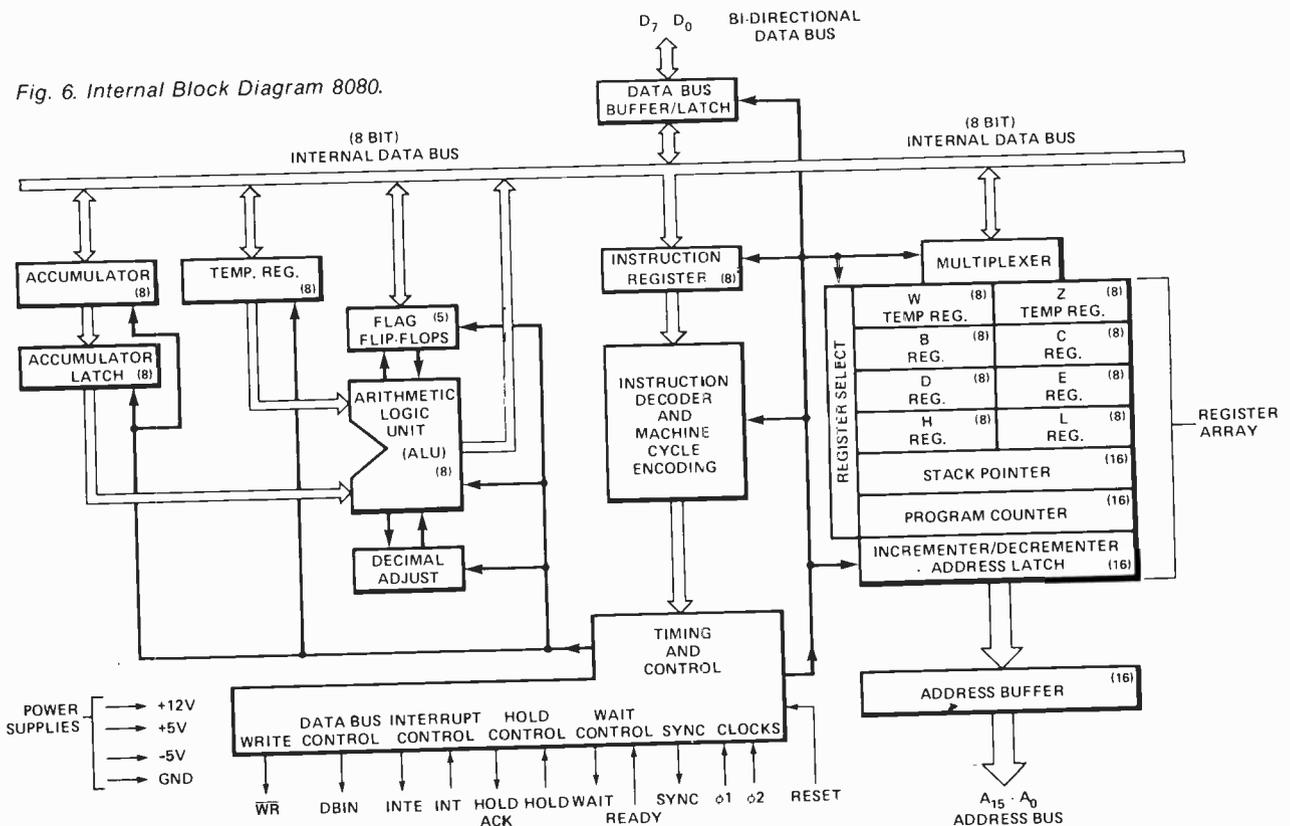
The registers were rearranged, with two 16 bit registers, and three pairs of 8 bit registers. These register pairs may be operated upon as independent 8 bit or combined 16 bit registers.

The program counter functions as before, but the stack has been moved outside the processor into memory, with a 'stack pointer' register inside to keep track of the next available location on the stack. This allows virtually unlimited use of the stack. (No you **can't** have 66 thousand subroutines!)

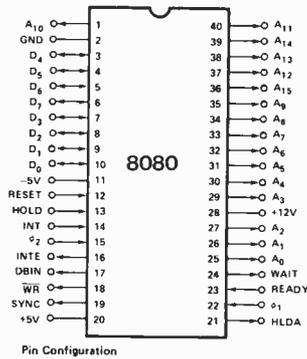
## 8080 INSTRUCTION SET

The same categories of instructions used with the 8008 are also available from the 8080 but with many additions, bringing the total to 78.

Fig. 6. Internal Block Diagram 8080.



# microbiology



Let's first cover the addressing modes used in the 8080 to determine the operand. The first byte of each instruction is the op-code, followed by zero, one or two further bytes.

**Immediate Mode:** The second, or second and third bytes contain the 8 or 16 bits of data.

**Direct:** Bytes two and three contain the exact address in memory where the data is located.

**Register:** The instruction itself specifies the internal register or register pair containing the data.

**Register Indirect:** The instruction itself specifies a register pair whose

contents are to be used as the address for the data.

The number of instructions has been expanded in part by the number of combinations of addressing modes, and the abundance of instructions allowing flexible use of registers. Of particular note is the improved ability to interchange data and address by register transfer operations.

The stack manipulation features have also been expanded. Now that the stack is in memory, instructions are provided to enable its use not just for storing return addresses, but also for accumulator, register, and flag storage. In short, upon calling a subroutine, the entire processor contents may be retained if so desired.

## THE 8080 INSTRUCTION SET

*r* stands for register eg A register  
*rp* stands for register pair, eg B and C registers  
*'data'* means the contents of the second or second and third bytes of the instruction  
*M* stands for memory whose address is in the H and L registers

### DATA TRANSFER GROUP

MOV r1, r2	Move register to register
MOV M, r	Move register to memory
MOV r, M	Move memory to register
MVI r, data	Move immediate (to register)
MVI M, data	Move immediate (to memory)
LXI rp, data 16	Load immediate (to register pair or to stack pointer)
STA addr	Store direct (accumulator to memory)
LDA addr	Load direct (memory to accumulator)
XCHG	Exchange H&L with D&E registers
STAX rp	Store accumulator indirect (with address in registers B&C or D&E)
LDAX rp	Load accumulator indirect (with address in registers B&C or D&E)
SHLD addr	Store H&L direct
LHLD addr	Load H&L direct

### ARITHMETIC GROUP

INR r	Increment register
DCR r	Decrement register
INR M	Increment memory
DCR M	Decrement memory
ADD r	Add register to A
ADC r	Add register to A with carry
SUB r	Subtract register from A
SBB r	Subtract register from A with borrow
ADD M	Add memory to A
ADC M	Add memory to A with carry
SUB M	Subtract memory from A
SBB M	Subtract memory from A with borrow
ADI data	Add immediate to A
ACI data	Add immediate to A with carry
SUI data	Subtract immediate from A
SBI data	Subtract immediate from A with borrow
INX rp	Increment register pair (or stack pointer)
DCX rp	Decrement register pair (or stack pointer)
DAA	Decimal adjust A (gives two BCD digits)
DAD rp	Add B&C, D&E or H&L to H&L

### LOGIC GROUP

ANA r	AND register with A
XRA r	EXCLUSIVE-OR register with A
ORA r	OR register with A
CMP r	Compare register with A
ANA M	AND memory with A
XRA M	EXCLUSIVE OR memory with A
ORA M	OR memory with A
CMP M	Compare memory with A
ANI data	AND immediate with A
XRI data	EXCLUSIVE-OR immediate with A
ORI data	OR immediate with A
CPI data	Compare immediate with A
RLC	Rotate A left
RRC	Rotate A right
RAL	Rotate A left through carry
RAR	Rotate A right through carry
CMA	Complement A
STC	Set carry
CMC	Complement carry

### BRANCH GROUP

JMP addr	Jump unconditional
Jcond addr	Jump on condition specified (carry, no carry, zero, no zero, positive, minus, even or odd parity)
CALL addr	Call unconditional
Ccond addr	Call on condition specified (see above)
RET	Return
Rcond	Return on condition specified (see above)
RST	Restart
PCHL	H&L to program counter

### STACK, I/O AND MACHINE CONTROL GROUP

HLT	Halt
IN port	Input (from port to A)
OUT port	Output (from A to port)
PUSH rp	Push register pair on stack (in memory)
PUSH PSW	Push A and flags on stack
POP rp	Pop register pair off stack
POP PSW	Pop A and flags off stack
XTHL	Exchange top of stack with H&L
SPHL	Move H&L to stack pointer
EI	Enable interrupts
DI	Disable interrupts
NOP	No op

Further additions to the instruction set include disable and enable of interrupts, and a 'no operation' instruction. ('NOP' is used for timing, or to occupy space for later addition of instructions etc.) Also the input and output instructions now use direct addressing to 256 input and 256 output ports.

It should be noted that the entire 8088 instruction set is contained in that of the 8080, and that they are compatible at the machine code level. Thus 8088 programs should run on an 8080, although the stack operation is so different as to make life difficult, and at least inefficient.

### 8080 HARDWARE

Although the number of support chips required, and the bus multiplexing were vastly reduced, some basic support chips are still needed. This is illustrated by figures 7 and 8.

The two phase clock signals needed by the 8080 are not TTL compatible, and have quite strict timing requirements, hence the special clock driver.

As may be noticed in figure 7, some system control lines are derived from the data bus. The use of an outside chip to demultiplex this data bus may seem a nuisance. In fact it is not, because the same chip also buffers the data lines, something

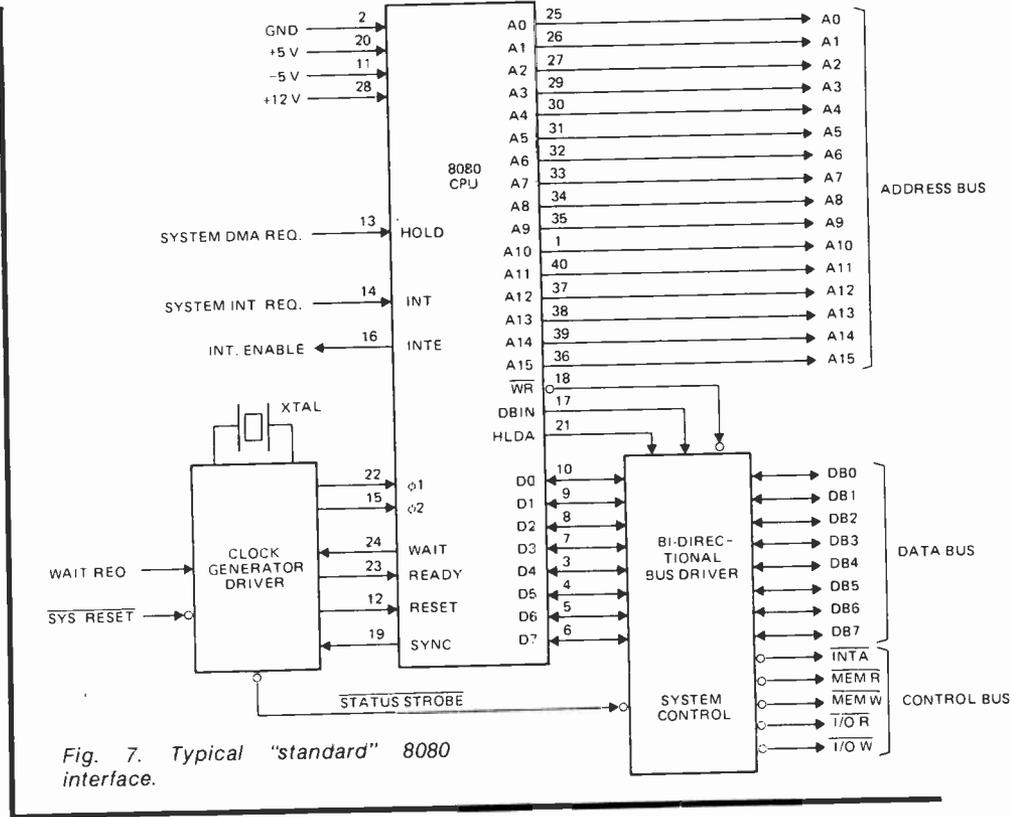


Fig. 7. Typical "standard" 8080 interface.

that is almost always necessary in any case. The reason for this is that drivers capable of more than say one TTL load and a small amount of capacitance are not possible on the same chip as the mpu.

The fairly orderly set of control lines includes the following. Memory and I/O read and write lines (4); interrupt enabled, request and

acknowledged (3); wait request (wait for slow memory etc.); and a new feature, 'hold' (and hold acknowledge) used to instruct the processor to relinquish control of the buses, to allow direct access to the memory by external devices for high speed data transfer.

A typical complete system configuration is depicted in figure 8.

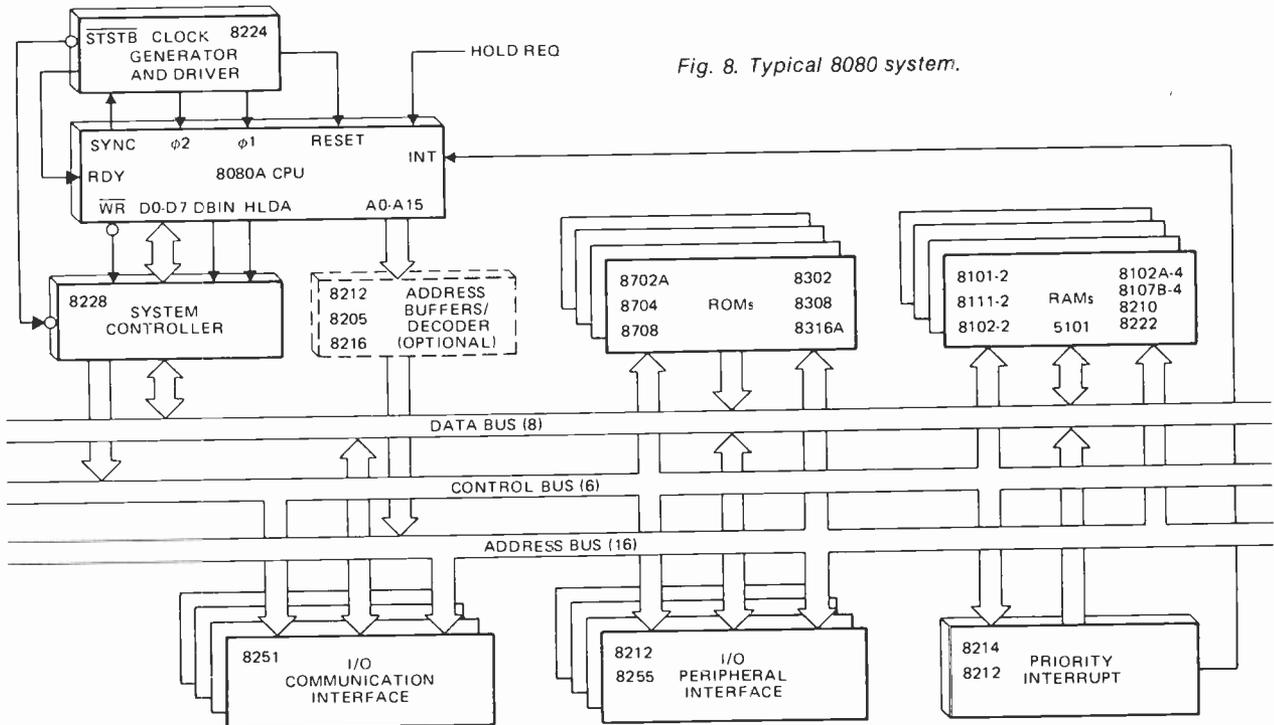


Fig. 8. Typical 8080 system.

# microbiography

## 8080 SUPPORT CHIPS

Intel offer a variety of support chips to hang onto the 8080, herewith a brief rundown of the more interesting.

First of course, there are various shapes and sizes of ROM and RAM, and units for refreshing dynamic RAMs. Other units are:

**8214 Interrupt Priority Unit** — Accepts inputs from up to eight devices and puts them in order of priority. It then compares the priority to a previously set figure. If priority is high enough the unit sends interrupt to mpu, and puts vector onto data bus. (see description of interrupts for 8008, this unit may be used with either mpu)

**8259 Programmable Interrupt Controller** — performs similar function to the 8214, but somewhat more sophisticated and flexible, having the ability to queue interrupts, and easier-to-use hardware.

**8224 Clock Generator** — generates the special clock signals for the mpu.

**8228/8238 System Controllers.** These chips buffer the data bus, as they demultiplex various control signals, see figure 7. The 8238 puts out slightly different write signals for use in larger systems.

**8251 Universal Synchronous/Asynchronous Receiver/Transmitter** — Basically this chip is capable of interfacing the internal parallel data bus to almost any popular format of synchronous or asynchronous data transmission as used to communicate outside the system. Block diagram — figure 9.

**8255 Programmable Peripheral Interface** — interfaces the data bus to the outside world via two 8 bit and two 4 bit data ports. Direction (in or out) of each port can be set by software as needed in the application. All I/O pins are TTL compatible and will directly drive Darlington transistors. Typical applications include input from keyboard, output to printer or display.

**8253 Interval Timer** — Variety of applications. In the most common, the software sets a specific delay, and when time is up an interrupt is sent to the processor. Time delay is achieved by counting pulses of the main clock.

A number of specialized devices follow:

8257 Direct Memory Access Controller

8271 Floppy Disk Interface

8273 Synchronous Data Link Control Protocol Controller

8275 CRT Interface

8279 Keyboard and Numeric/Alphanumeric Display Interface

## CONCLUSIONS

As may have been gathered from this description and from the 8080's popularity, this mpu is a very versatile and general purpose device, combining instructions and interface chips for hardware applications, yet powerful enough for complex software uses. Next month we see how the third generation 8000 types improve on this.

The 8008 and 8080 are Intel originated products. National Semiconductor is the second source for the 8080.

Intel Corp.,  
70 Chamberlain Ave.,  
Ottawa, Ontario K1S 1V9

National Semiconductor District Office  
1111 Finch Avenue West  
Suite 154  
Downsview, Ontario M3J 2E5

We wish to thank Boyd McKinnon of Hamilton Avnet for his assistance in the preparation of this article.

Pin Name	Pin Function
D <sub>7</sub> -D <sub>0</sub>	Data Bus (8 bits)
C/D	Control or Data is to be Written or Read
RD	Read Data Command
WR	Write Data or Control Command
CS	Chip Enable
CLK	Clock Pulse (TTL)
RESET	Reset
TxC	Transmitter Clock
TxD	Transmitter Data
RxC	Receiver Clock
RxD	Receiver Data

Pin Name	Pin Function
RxRDY	Receiver Ready (has character for 8080)
TxRDY	Transmitter Ready (ready for char. from 8080)
DSR	Data Set Ready
DTR	Data Terminal Ready
SYNDET	Sync Detect
RTS	Request to Send Data
CTS	Clear to Send Data
TxE	Transmitter Empty
Vcc	+5 Volt Supply
GND	Ground

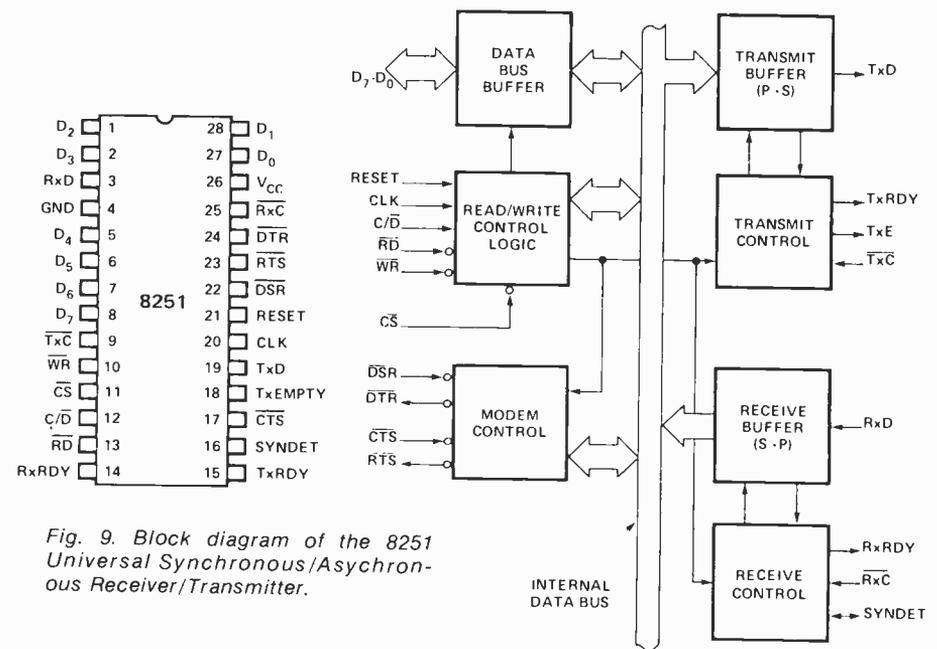


Fig. 9. Block diagram of the 8251 Universal Synchronous/Asynchronous Receiver/Transmitter.

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4EH7	2.10	6DW4B	1.70	6LT8	2.70	17DQ6B	4.25
4EJ7	2.00	6DX8	1.70	6LU8	3.90	17JN6	3.35
		6EA8	1.45	6LX8	1.75		
4HA5	1.45	6EC4	3.40			17JZ8	2.40
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5GX7	2.25					21JZ6	3.25
				6Z10	4.00		
5LJ8	2.65	6GB5	3.10	8AW8A	1.80	23Z9	3.45
5U4GB	2.45	6GE5	3.85	8B8	3.05	24LQ6	4.10
5U8	2.95	6GF7A	2.40	8B10	2.75		
		6GH8A	1.55	8BM11	6.35	27GE5	3.45
6AF9	4.10	6GJ7	2.20				
6AJ8	1.75	6GK5	1.80	8CG7	1.60	30AE3	1.65
6AL3	1.60	6GX6	2.40	8DX8	3.40	30KD6	7.15
6ALS	1.50	6GM6	1.45	8GJ7	2.05	31JS6C	4.35
				8JV8	2.05	33GY7A	3.30
6A05A	1.40			8LT8	2.10		
6A08	1.40	6GU7	1.25			35W4	1.35
6AU6A	1.25	6GV8	2.45	8U9	3.30	38E7	4.80
6AV6	1.50	6GW8	2.40	8X9	3.80	38HK7	4.70
		6GX7	2.20	9A08	1.60	40KD6	4.80
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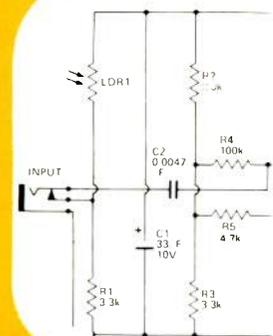
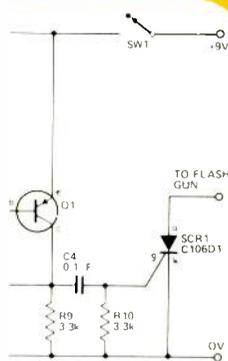
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# ELECTRONICS IN PHOTOGRAPHY

BY IAN SINCLAIR



FOR SOME CONSIDERABLE time now, there have been close links between electronics and photography. Glancing through past issues of ETI, for example, we find a fair number of projects of particular interest to keen photographers, and a look through past copies of "Popular Photography" shows the appreciation of the role of electronics shown by our photographic kindred. This article sets out to describe how electronics is involved in photography today, as it affects the keen amateur and the professional.

Electronics circuits, ranging from the very elementary to the extremely complex, become involved with photography at almost every step in the photographic process; at the camera itself, in the darkroom, and in slide and cine projection. Some of the electronic circuits that are used will be familiar, others less so, and we assume that the readers of this magazine are much more familiar with the electronic circuits than with the photographic processes.

## Exposure Control

One of the earliest applications of simple electronics to the camera was exposure metering and, later, control. The amount of darkening of a given photographic film is decided both by the intensity of the light that reaches the film, and the duration for which the film is exposed. The intensity of light (luminous flux) reaching the film is regulated by the iris of the camera,

a variable opening placed close to the lens, or built into the lens by placing it between the elements (separate glass pieces making up the lens). The timing is decided by the open time of another aperture, the shutter, which opens when the shutter release is pressed, and closes a preset time later. From fairly early days, shutter timings were obtained by using clockwork mechanisms that were reliable and robust. Today with

smaller cameras in use, and more objects of interest moving, the range of shutter speeds has had to be increased to cope, and the regulation of the light level by an iris is used to a greater extent; the shutter speed is set to a value capable of "freezing" movement (of object or photographer) and the iris is used to set the light level for the correct exposure. This is why camera electronics are so devoted to controlling the iris, leaving shutter control in a lesser rôle.

The first efforts concerned metering rather than control; consisting of exposure meters, using selenium cells driving moving-coil meters. The problem of these meters, which can produce excellent results if used properly, is that the light reaching the meter may not be proportional to the light reaching the lens (Fig. 1). The problem becomes more apparent when telephoto lenses are used, since there will be little relationship between the light entering the lens and the light entering the meter. One partial solution, still used, is the "incident light" reading, in which the meter, fitted with a diffusing cone, is pointed at the light source and the resulting reading used in setting the camera aperture.

The combination of colour slide film, which needs fairly exact exposure, with interchangeable lenses, and the single-lens reflex system, called for some improvements in light metering systems. Single lens reflex cameras use a mirror at 45° to the light path to divert the light path to

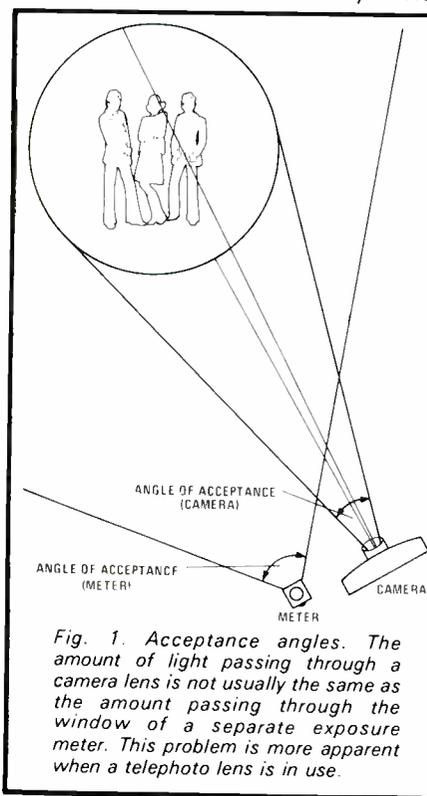
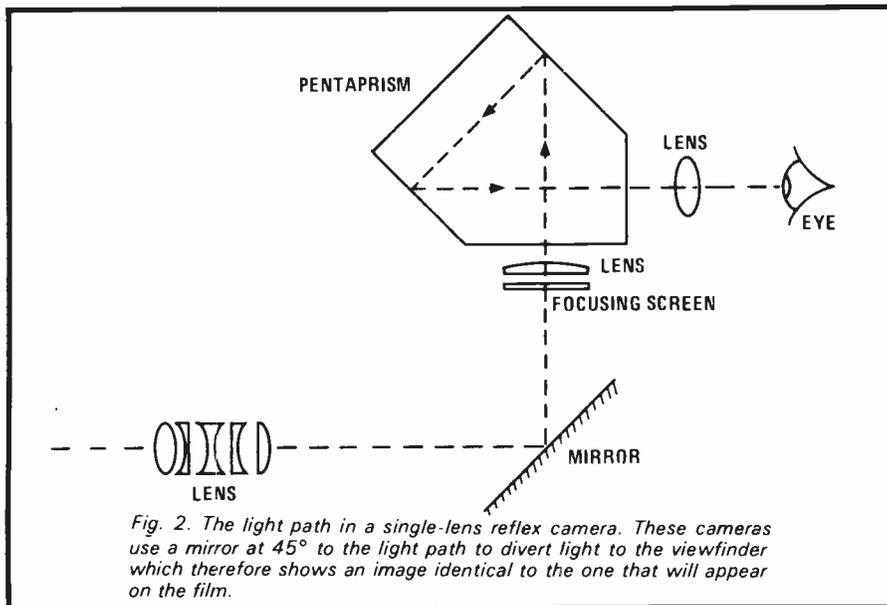


Fig. 1. Acceptance angles. The amount of light passing through a camera lens is not usually the same as the amount passing through the window of a separate exposure meter. This problem is more apparent when a telephoto lens is in use.



the viewfinder (Fig. 2), which therefore shows an image identical to the one that will appear on the film. Since the viewing is done through the lens, there is no parallax problem caused when close-ups are taken, as there would be if a separate viewfinder were used and specialised work such as photomicrography becomes possible.

### TTL Metering

The next logical step is to place the exposure meter somewhere in this reflex viewing system, so that the light coming through the lens also operates the exposure meter. Right away we come up against a problem that still divides good quality cameras into two groups — shall this light reading be taken at one point in the image (a **spot** reading) or should the photocell be affected by the total amount of light entering the lens (an **average** reading). If the reading is a spot one, we must be certain that the spot is located on a piece of the picture we most need to be correctly exposed, so that we can take this reading. If the reading is an average one, we must be sure that the exposure will not be faulty because of a misleading average.

The use of TTL (Through The Lens) metering, whether spot or average, demands the use of cells much more sensitive than the old selenium type. Cadmium sulphide cells have been used for some time; since they are photoresistive, not photovoltaic, they need a battery. They are also much more sensitive to red and infra-red than the eye or the usual run of films so that some light filtering must be used to correct the

balance of the light reaching them.

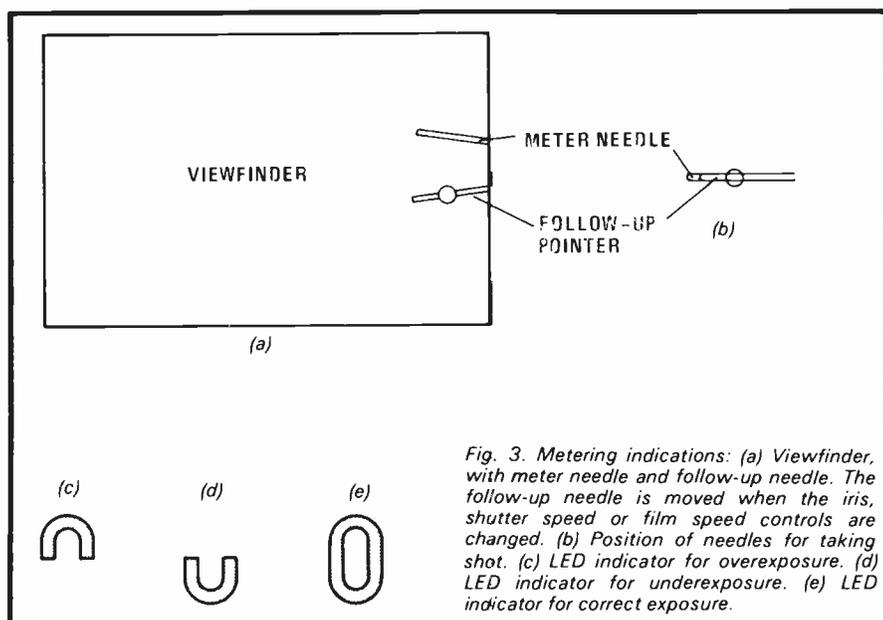
### Indication

The first types of TTL cameras used the cells to indicate correct exposure, which had then to be set by the user after taking the meter reading. Very soon, this developed to a system still used today in which the setting can be done while the image is viewed in the finder. The needle of the exposure meter appears in the viewfinder along with a marker coupled to the iris control. Aligning the marker and the needle by opening or closing the iris control sets the iris to the opening called for by the metering, but the photographer can, from experience of the

type of subject and lighting, modify the setting as needed. A more "electronic" modification of this method, pioneered by Yashica, uses two LED displays (Fig. 3 c,d,e), one shaped as a U, the other as a  $\cap$ . A U displayed means that the iris is set for underexposure, and a  $\cap$  indicates overexposure, and a complete oval indicates correct exposure, for average light reading. Once again, the experienced user can modify the setting.

These systems, though simple, still demand considerable design expertise. The exposure indication is controlled by four quantities: film speed, shutter speed, iris setting and subject illumination, so that variation of any of these quantities will affect the readings. Since the resistance of the cell is determined by the amount of light reaching it, the compensation for film speed and shutter speed must be made by altering other parts of the system, either electrically by potentiometers in the current path, or optical, by neutral density filters in the light path.

With film speed set according to the type of film in use and the shutter speed set for coping with the motion of the subject or camera, the object is viewed and the meter needle position matched by the marker ganged to the iris opening. This scheme has the disadvantage that the image in the viewfinder might be very difficult to see if the iris is at a small aperture



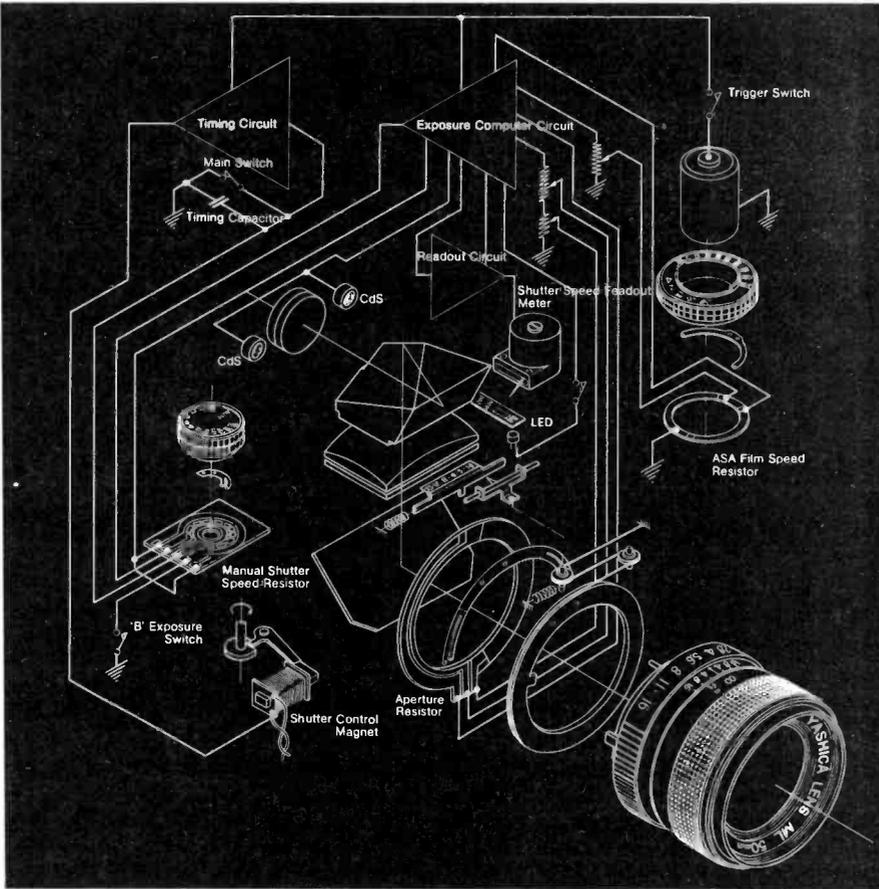


Fig. 4. Yashica FX1 open aperture control system.

(stopped down) so that the next design step was full-aperture finding. This comes in two types, full aperture viewing or full-aperture metering. In each case, the iris can be fully open until the shutter release is pressed; the aperture is then changed to a preset value just before the shutter opens. In full aperture metering, the iris control ring affects the meter sensitivity and presets the iris control without changing the setting of the iris, which remains at full aperture, hence the name, for a bright display in the viewfinder. When the release is pressed, the iris is set, and the shutter operates. In simpler types of camera, viewing for focusing is done at full aperture (and cannot easily be done at reduced aperture) but the iris is stopped down when the metering system is switched in. With this system, the metering can be switched in momentarily to set the iris; if left in place, the system can reset after the release has been pressed.

### Automatic Camera Systems

The final step in this progression is to use the photocell(s) to control the iris directly, with an over-ride to enable the photographer to adjust the

exposure if he wants to. A block diagram of the system used in the Yashica FX1 is shown in Fig. 5. The IC in this system has been developed for Yashica, and comprises a set of comparators into which information on film speed, shutter speed, and iris setting is fed, along with the input from the cells. Since d.c. amplification is easily carried out using ICs, cadmium sulphide cells have now given way to silicon cells which, though less sensitive, can be made much smaller and have a colour

response that matches the films (whether colour or black and white) much better.

### Time Control

For many years, the Compur shutter was the ultimate in timing. Pressing the shutter release opened a set of interlocking shutter blades situated between the lens elements and started a clockwork timer that closed the blades again after the preset time. With additional spring assistance, times of 3 ms or less were obtainable. The demand for interchangeable lenses and faster times led to the development of the focal plane shutter, the first types of which resembled a miniature roller blind with a slit of the same width as the film. This roller blind is set parallel to the film, and when the shutter release is operated, the slit is drawn rapidly across, exposing the film.

The modern focal plane shutter consists of two blades operated electromagnetically rather than by clockwork. This makes the release action smoother, and enables the camera to be operated by remote electrical contacts. The principle used is that pressing the shutter release button activates a solenoid that pulls the blades of the shutter apart, and also starts charging a capacitor through a resistor. At a set level of voltage on the capacitor, the current through the solenoid is switched off, and the blades are closed by a spring or by another solenoid. The timing here is achieved by capacitor charging, a familiar electronic principle, rather than by mechanical gearing, so that the speed is infinitely variable as compared to the set speeds obtainable with mechanical action. To conserve battery charge

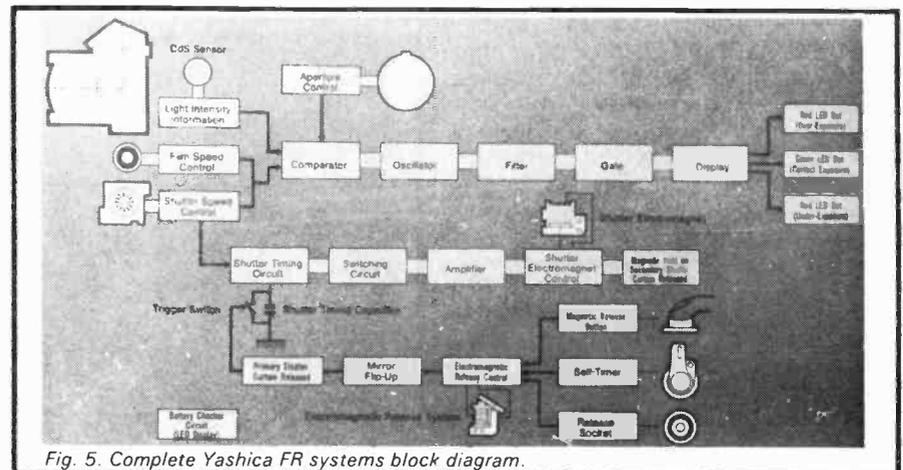


Fig. 5. Complete Yashica FR systems block diagram.

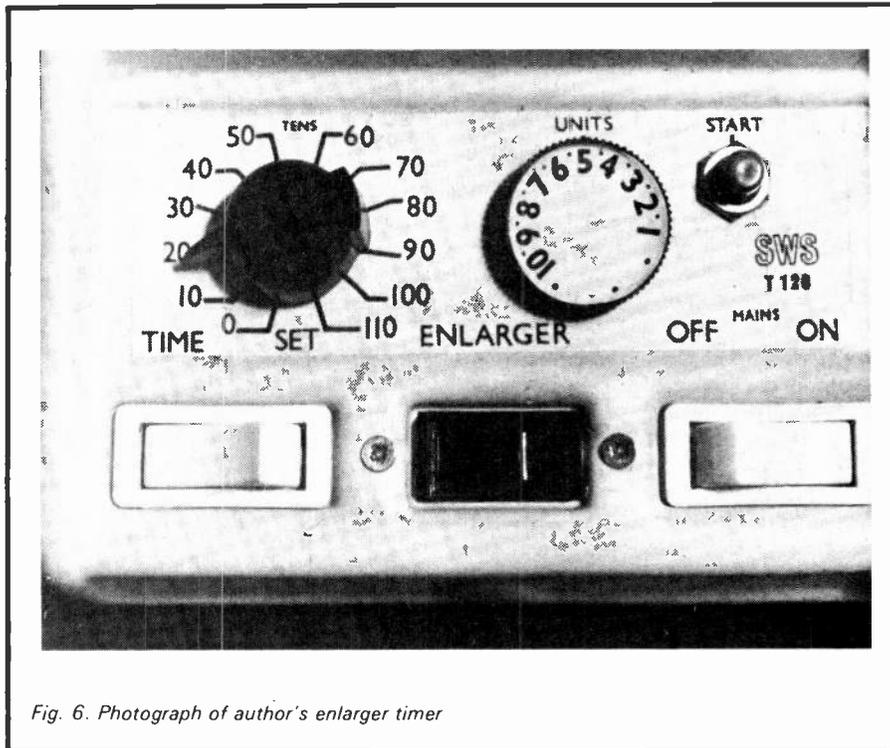


Fig. 6. Photograph of author's enlarger timer

however, the slower speeds are usually of set values obtained by mechanical operation, electrically triggered; this also avoids the problems of very long time constants, which would call for large capacitance and resistance values.

### Darkroom Electronics — light readings

The design and construction of electronic devices for the darkroom is simpler than the corresponding work on cameras, because there are practically no restrictions on size or power supply. Whereas camera electronics must be fitted into the space available on a camera, and operate at the low voltage and current obtainable from small long-life cells such as the manganese alkali or silver oxide types, darkroom electronics equipment can be of any reasonable size and shape and can also be mains operated. The darkroom operations of interest to us are measurements of enlarger light values and the timing of enlargement, possibly along with electronic control of the temperature of chemical baths, and voltage stabilisation of enlarger lamps. The requirements for colour printing are much more stringent than those for black/white printing, so that electronic aids, though very useful for B/W work, are of more use when a large amount of colour printing is done.

With the small format (36 mm x 24 mm) negatives used for so much work nowadays, nearly every print produced is an enlargement.

The enlarger is a high-quality projector arranged vertically so that the photographic enlarging paper (bromide paper) can be laid flat on a base-board and the negative, held in a carrier, used to project an enlarged image on to the paper. The amount of enlargement may be fairly small, such as to the "enprint" size, or very large. In each case, however, the amount of exposure time for the combination of negative and paper size must be determined.

The use of electronic exposure meters simplifies problems of exposure and colour correction considerably. For B/W work, the use of an enlarger exposure meter is most

valuable when technical photography (such as photographing circuits for ETI!) is carried out, since the density of negatives, the contrast range, and the amount of enlargement may vary much more than those of the family snaps. The simplest types of B/W enlarger exposure meters use cadmium sulphide photoresistive cells operating moving coil meters or other indicators. The setting of the speed of the paper, which must be done using a test-strip, since manufacturers do not quote paper speeds for most materials.

For colour adjustment, much more elaborate meters are needed, preferably using silicon cells with amplification. The problem now is not simply that of exposure, but of adjusting the colour of the light in terms of three primary colours (red, green, blue) or their complementary colours, cyan, magenta, yellow. This requires three light readings, one for each colour, and the outputs should be in the form of colour correcting factors that can be supplied in the form of filters. In the simpler types of enlarger, a "filter drawer" is used between the condenser lens (used to make the light from the lamp converge into the projecting lens) and the main lens, and the readings on the colour meter are used to help select the correct filters. On the more expensive enlargers, the correcting filters are built in the form of a "colour head," controlled by three dials on the lamphousing. These are set to correspond with the meter readings, so carrying out the colour correction. Another reading taken from all three sensing cells is then used to determine the exposure time needed.

For the occasional colour print (and the cost in money and work will ensure that the prints will be occasional) the high cost of a colour analyser is quite prohibitive, matching the price of a good oscilloscope, but for regular colour work, particularly when very expensive materials are used, such as in the Cibachrome process, the cost is comparable with the price of the type of enlarger that will have to be used anyway, and can be justified if really excellent results must be attained.

Before leaving the darkroom, we should note that for colour processing, the temperatures of several of the solutions, notably the first developer and colour developer, are critical, needing control to within 0.25°C. This can be done by keeping

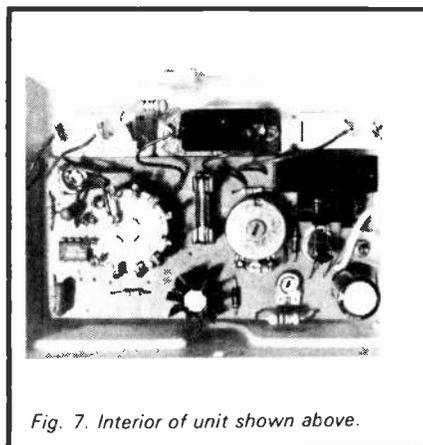


Fig. 7. Interior of unit shown above.

all the bottles, along with the developing tank or drum, in a water bath, and the maintenance of the bath temperature is much easier if thermostatic control can be used. Conventional bimetalic thermostats have much too great a difference between switch-on and switch-off temperatures (differential), but an electronic type using a thermistor to sense temperature and a triac to control heating current can easily provide the amount of control that is needed.

## Other Applications

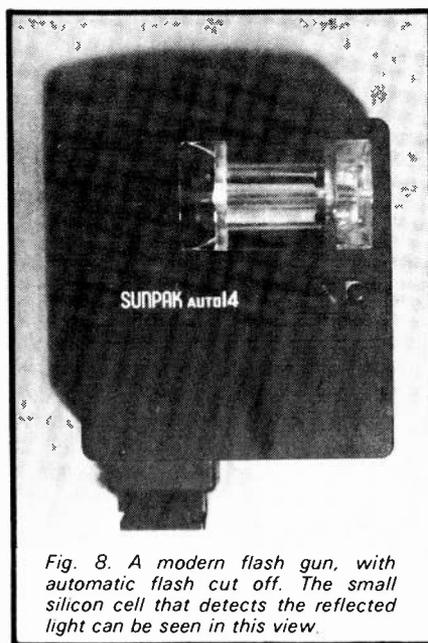
Outside the darkroom, the applications of electronics mainly concern projectors, flashguns, and cine equipment. The capacitor-discharge flash gun, using a transistor inverter circuit to provide a few hundred volts to charge the capacitor, is well established. With the flash gun connected to the camera shutter contacts, the capacitor is discharged through a thyristor when the shutter is wide open, and the current flows through a tube containing Argon and Xenon gases at low pressure. The time of the flash is short, about 100  $\mu$ s or less, which is very short compared to the shutter speed, and the usual arrangement is to have a fixed delay built into the camera, so that the shutter speed must be set to 1/60s, or to a part of the shutter speed dial marked with the letter X. The timing of the exposure is then entirely due to the flash, though complications can arise if the long exposure time allows some exposure in conditions of partial darkness.

A recent development is the triggered shut-off flash (or "computer" flash, as the advertisements dub it). In this system, a silicon cell detects the light reflected back from the subject in the first micro-second or so of the flash, and this cell then charges a second capacitor feeding a comparator. At a fixed value of voltage, the comparator fires a second thyristor that short-circuits the main capacitor, stopping the flash very rapidly. In this way, the camera can be left at a fixed setting and flash photos taken without the usual need to pace out distances and set the aperture of the camera each time. Other flash developments more familiar to the electronics constructor are light-triggered flash used to synchronise one flash gun to the flash

of another, so filling in shadows, and sound-triggered flash, used for some "frozen-action" shots where the speed of sound can be used to provide a variable delay.

## Projection

Slide projectors of the semi-automatic type, using a magazine of slides advanced by a remote-control that incorporates motor-driven focus, have become popular within the last few years now that reasonably-priced models have become available. A more recent development is the fully-automatic projector, with the automatic focus (also featured now on some enlargers). This is based on the principle that the light reflected back from a projection screen is greatest in intensity when the image



*Fig. 8. A modern flash gun, with automatic flash cut off. The small silicon cell that detects the reflected light can be seen in this view.*

is correctly focused. A photocell mounted at the front of the projector picks up the reflected light, and the output of the photocell is taken through a d.c. amplifier to a servo-system operating the focus screw of the lens. Because the photocell is part of a negative feedback loop, the system will settle with the lens in the position giving maximum reflected light, therefore in focus. The system is disabled during slide changing or in the absence of a slide in the carrier, to avoid having the servo-system hunt about for an impossible focus.

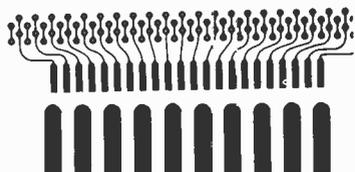
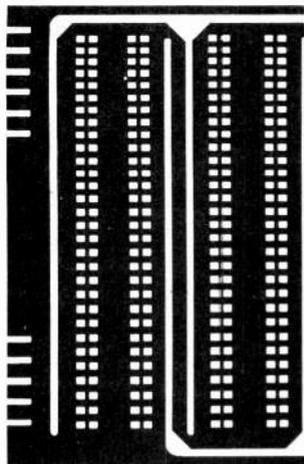
Another application of electronics to slide projectors of the automatic or semi-automatic types is the synchronised tape-slide show. To achieve this, using an ordinary reel-to-reel tape recorder, a synchroniser unit is needed. The sound commentary is recorded on one track of the tape, and synchronising pulses on another track. On playback, each sync pulse is picked up and amplified to generate a pulse of sufficient amplitude to operate the slide-change switch. In this way, the slide changing can be synchronised exactly to the commentary providing that the order of slides in the magazine is unchanged. The pulses are placed on the track by setting up the equipment for recording, and changing the slides at the appropriate times. The pulse at the projector socket is now used to generate the sync signal, and this is recorded on to the tape.

Finally, the closest marriage between photography and electronics occurs in modern cine sound. This is such a specialised field that even to start on cine sound systems would take up much more space than can be justified here, and we can only note that the use of Dolby noise reduction looks like making the optical sound system, in which the sound is recorded in the form of light-and-dark bands on the film, a very serious rival for the magnetic tape stripe systems that have dominated cine sound for years. The important advantage of optical sound is "lip-sync," meaning that the synchronisation of sound and picture is close enough to permit views of people speaking, without the non-sense mouthing words that are not these being heard.

Looking to the future, it seems that the applications of electronics to photography will surely increase. At the time of writing, new colour printing systems are being announced at almost monthly intervals, new cameras appear with still more advanced electronics systems, and elegant applications of electronics appear in instruments that previously used only optical or mechanical techniques. One outstanding possibility for the future is a more electronic image formation process — we are still using the silver halide process for images (along with dye coupling for colours) that was being used over 100 years ago. In these days of electrostatic copiers, could we be at last heading for a film that will wean us away from silver? ●



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# SHORT CIRCUITS

Make yourself heard  
with our

# LOUD HAILER

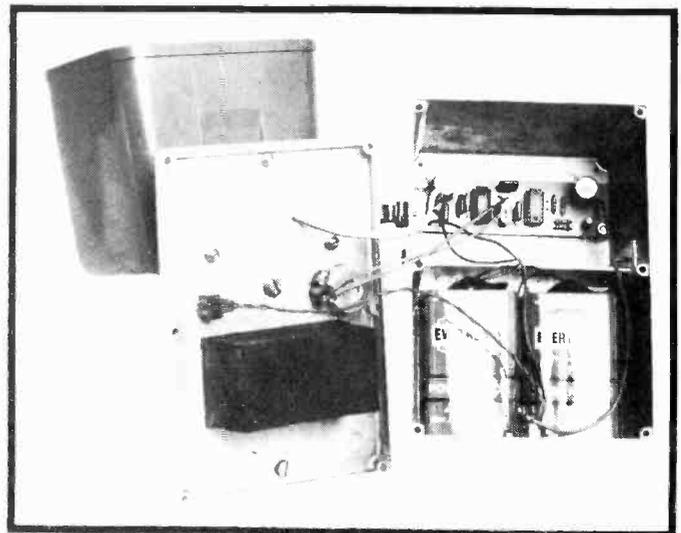
"COME IN NUMBER SIX" is the call heard at boating lakes, however you need large lungs and good health to shout as loud as the professionals. A simpler way for electronics enthusiasts is to build our Loud-Hailer, guaranteed to make you heard above the general noise at fetes, street parties, etc. Most commercial designs are expensive and need to be held up like a megaphone, ours is cheap and can be used in a variety of ways. The electronics and batteries, complete with speaker, are separate from the microphone — this enables you to hold the heavy part in one hand at a comfortable position, and talk through the microphone. You can also hand the microphone to some other person or even conduct an interview!

Using a diecast box makes the unit impervious to inches of water if placed on the ground, and stick-on rubber feet stop it scratching the paint, if placed on a car hood or roof. When held in the hand the volume control can be operated with a thumb (to prevent acoustic feedback), also if the microphone used has no on/off switch the unit's switch can be used. In fact acoustic feedback with our system is not a great problem, as the microphone can be up to 100 feet from the loudspeaker.

## Design

A low impedance microphone was used for a couple of reasons, firstly you can use far longer cable without noise and hum pickup. Second reason is that virtually all cassette recorders are supplied with low impedance microphones, so most of our readers will have one!

The first prototype used 12V as a supply, the final version (shown here) uses 18V. Power output is about 3W at 18V, and if run off a car battery (12V) will give out 2W — still quite loud. A socket can be fitted for external power source if needed with a changeover switch. The output of 3W may not seem very much, but P.A. horn speakers are very efficient and sound loud!



Internal view of the completed loud hailer. Note foam to hold batteries in place.

Fig. 1 Complete circuit diagram

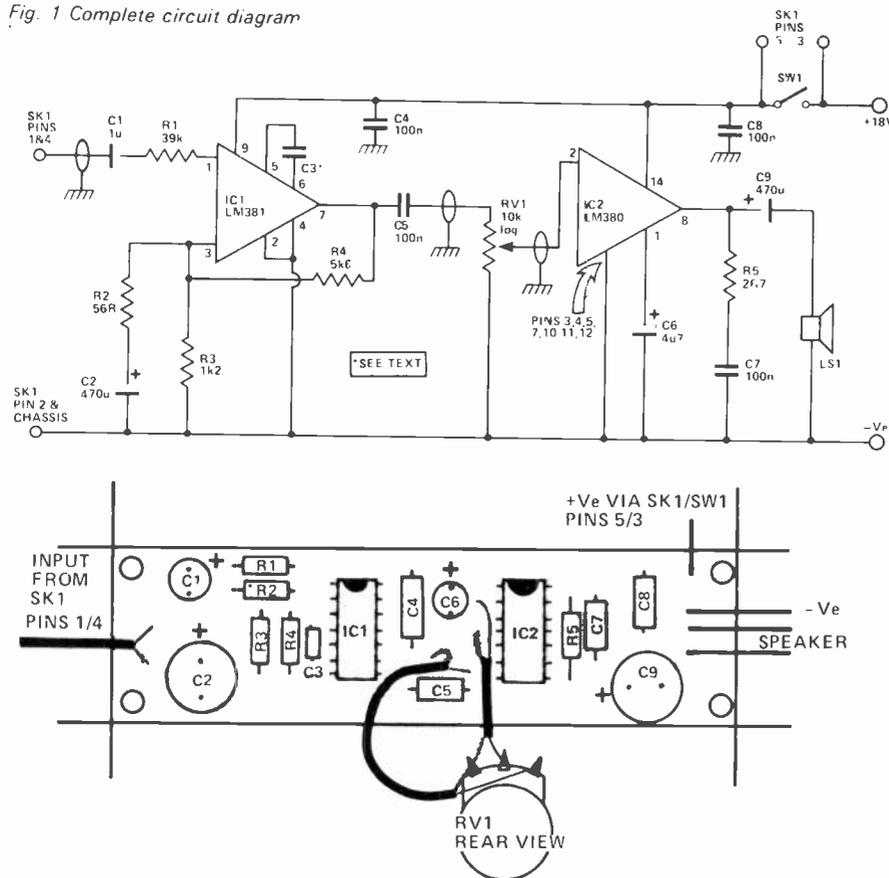


Fig. 2 Component overlay and interwiring

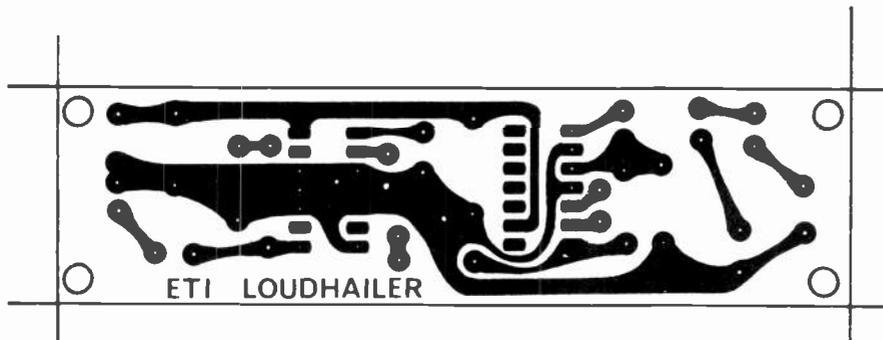
### Construction

The microphone we used and most others, is fitted with 3.5 and 2.5 mm jack plugs — these are changed for a 180° 5 pin din plug, this is to stop ground problems with miniature jack sockets. Pin connections (for plug and socket) are as follows: Pins 1 and 4 live microphone connection. Pin 2 screen of microphone and equipment ground. Pins 3 and 5 used for remote on/off on microphone switch.

Toggle switch SW1 is connected across pins 3 and 5, to act as another on/off control if your microphone has no switch (or you want to use very long single screened cable). Screening is

important, pin 2 on the din socket is shorted to the earth tag on the socket. The input screen is also taken to the board input, the output screen from the LM381 is looped, via the ground end of RV1, to the input screen of the LM380 ie: back to itself. RV1 itself is not grounded separately, just bolted tight to the case. This might seem strange to Hi-Fi boffins, but prevents instability in the circuit — we know because we did it!

The rest of the construction is reasonably straightforward. A large piece of foam is glued to the lid, to prevent the batteries from rolling around inside the box. Finishing touch is a clip for the microphone.



## HOW IT WORKS

The LM381 is a dual low noise preamplifier — only half is used in this application. Most of the compensation network is inside the chip, hence the low parts count outside! Resistors R4 and R5 provide negative input bias current, and establish the dc output level at one-half the supply voltage.

Gain is set by the ratio of R4 to R2 which in this design is 100. C2 establishes the low frequency -3dB point, the value of 470µF used stops the system sounding "boomy". For more bass C2 can be reduced to 100µF.

High frequency roll off is set by C3, with our mike no capacitor was needed. With a condenser electret microphone 100pF was required to reduce the high frequency gain, so if you use a different type C3 can be varied between 10pF and 100pF for best response.

C1 reduces the effect of 1/f noise currents at low frequencies.

The output of the LM381 passes through C5 and RV1 to the LM380 general purpose power amp. R5 and C7 act as a Zobel network on the output to stop instability, when driving reactive loads (like P.A. horn speakers!).

## PARTS LIST

RESISTORS All 1/4w 5% except where stated

R1 39k	R4 5k6
R2 56R	R5 2R7 1/2w 5%
R3 1k2	

### CAPACITORS

C1 1u0 25v
C2 9 470u 16V
C3 See text
C4, 5, 7 8 100n polyester
C6 4u7 16V

### POTENTIOMETER

RV1 10k log rotary

### SEMICONDUCTORS

IC1 LM381  
IC2 LM380

### SWITCH

SW1 Subminiature SPS1

### LOUDSPEAKER

P.A. type horn — 8 ohm, power rating at least 3W.

### MICROPHONE

Low impedance type — around 600 ohms

### BATTERIES

Use 2 large 9V batteries (Eveready 276 for example) or 12 C or D cells.

### CASE & HANDLE

Diecast box 171 x 121 x 106mm  
Handle 107 x 12 7 x 27 4mm

### MISCELLANEOUS

5 pin din plug and chassis socket (180 ) PCB to pattern, nuts, bolts, spacers, etc Screened wire, knob, foam, microphone clip

Fig. 3 PCB pattern (105mm x 30mm)

# Short Circuit

# CONTINUITY TESTER

One of the commonest uses of a multimeter is to prove continuity — it's not the best way of doing it however.

THE PROBLEM WAS IN A TV receiver; a loom of wires connecting one section to another had duplicate colours within the loom so that amid the usual amount of dirt and dark corners it was impossible to trace the course of one particular wire. The answer to the problem was a straightforward continuity tester, a multi-range ohmmeter may be suitable but could cause some trouble in differentiating between zero and a few hundred ohms and also in reading "through" a semiconductor that was in circuit and giving misleading readings.

In the course of servicing a variety of apparatus this question of continuity occurs over and over again; the absence of firm points available for contact clips often means that pointed probes must be pressed into a small joint or onto part of a printed circuit, and while concentrating on the probes it is of course difficult to keep an eye on the meter pointer and in particular to read the value of resistance — or the lack of it.

## Design Considerations

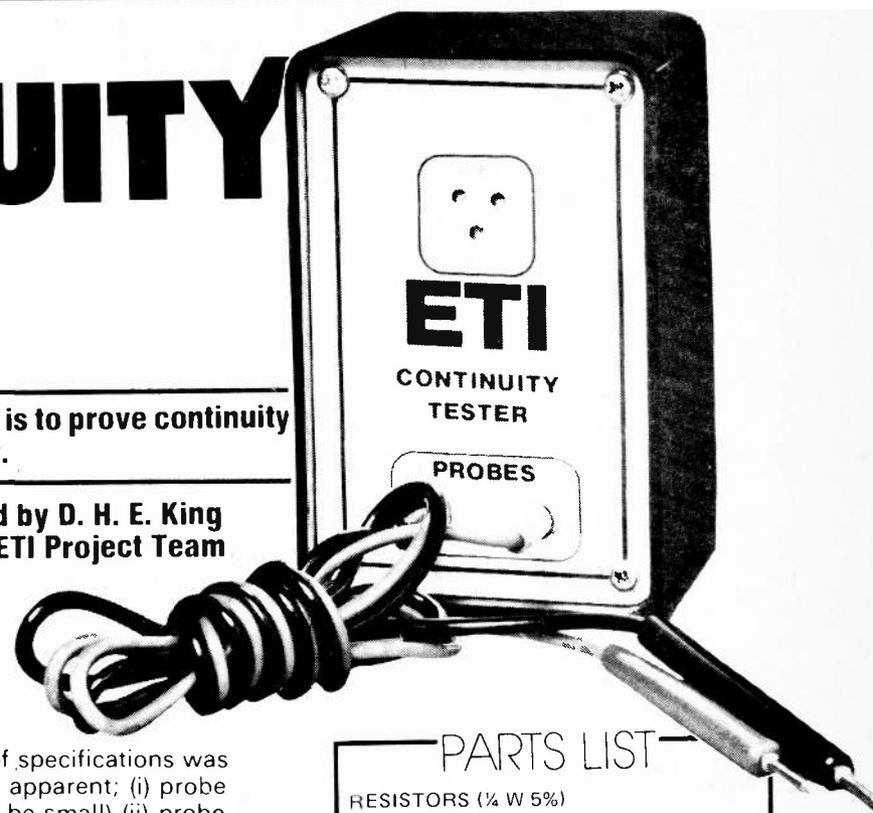
Several simple circuits were tried — a lamp, battery and probes still demanded the attention of the eyes; replacing the lamp by a buzzer was more successful but needed some three to four volts and gave no indication of a series semiconductor junction if the polarity was correct while the current flow was large enough to damage the more delicate devices within the circuit under test. An extension of the principle to operate an astable (multivibrator) type of oscillator gave good audibility but would operate from zero through to several thousands of ohms and so was too general an indication.

Designed by D. H. E. King  
Built by ETI Project Team

A set of specifications was becoming apparent; (i) probe current to be small (ii) probe voltage to be as low as possible, preferably less than 0.3V to avoid seeing germanium or silicon junctions as a continuous circuit; (iii) no on-off switch to be used.

The circuit was the result and several dozen have been constructed and are earning their keep for both "heavy" electricians and electronic technicians.

The output from the speaker is not loud but is more than adequate for the purpose. We used a surplus telephone insert which are often available from component retailers. Small transistor radio loudspeakers with impedances of 25-80 ohms are also available. In both cases the resistance should be brought up to 300 ohms by adding series resistor R8.



## PARTS LIST

### RESISTORS (¼ W 5%)

R1	1 k
R2	2k2
R3,4	22k
R5	2k7
R6,7	56 k
R8	See Text

### CAPACITORS

C1,2	22 n polyester or ceramic
------	---------------------------

### SEMICONDUCTORS

Q1	2N3906 or similar
Q2,3,4,5	2N3904 or similar
ZD1	8V2 Zener Diode, 400mW
D1,2	1N4148 or similar silicon diode

### LOUDSPEAKER

LS1	25-80 R, See Text
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### MISCELLANEOUS

Two 2mm sockets, plugs and probes to suit, connecting wire, 9V battery and clip, Nuts, bolts, pcb spacers. PCB as pattern.

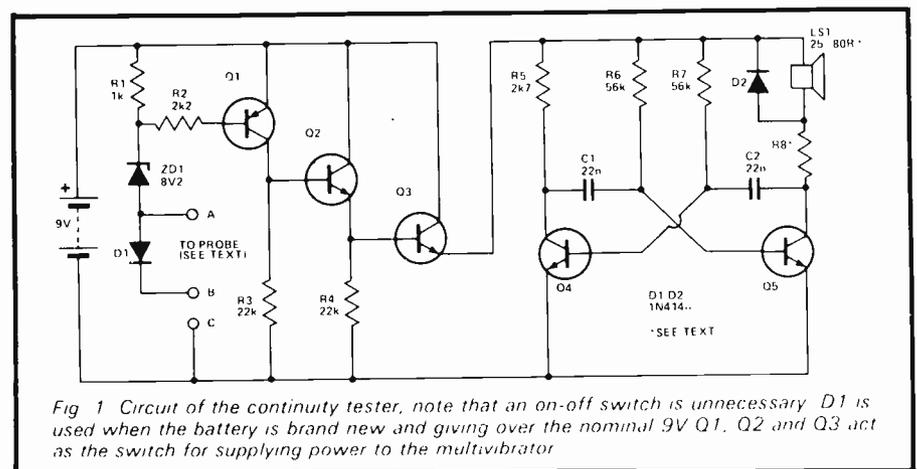


Fig 1 Circuit of the continuity tester, note that an on-off switch is unnecessary. D1 is used when the battery is brand new and giving over the nominal 9V. Q1, Q2 and Q3 act as the switch for supplying power to the multivibrator.

# HOW IT WORKS

Starting with a 9 V supply, when the probes are short-circuited there is 8V2 (8.2 V) dropped across the zener diode ZD1 leaving a maximum of 0V8 (0.8 V) across R1. Application of Ohms law shows that a maximum current of  $0.8/1\ 000 = 0.8\ \text{mA}$  flows via the probes and this satisfies the first design requirement of low probe current.

Q1 is a silicon type and the base-emitter voltage will need to be about 0V5-0V6 (0.5-0.6 V) to forward-bias the junction and initiate collector current. With a maximum of 0V8 available across R1 it is seen that if a semiconductor junction or resistor is included in the outside circuit under test and drops only 0V3 then there will be 0V5 remaining across

R1, barely enough to bias Q1 into conduction.

Assuming that the probes are joined by nearly zero resistance, the drop across R1 is 0V7 - 0V8 and Q1 turns on, its collector voltage rising positively to give nearly 9 V across R3. Q2 is an emitter follower and its emitter thus rises to about 8V3 and this base voltage on Q3 (a series regulator circuit or another emitter-follower if you prefer it) results in some 7V7 being placed across the Q4 - Q5 oscillator circuit. All the transistors are silicon types and unless the probes are joined, only leakage current flows from the battery thus avoiding the need for an on-off switch. When not in use, the battery in the tester has a life in excess of a year.

an "under-voltage" zener volt-drop will leave considerably more than the forecast voltage available at the probes. A silicon diode D1 is therefore connected in series with the zener to decrease the probe voltage by a further 0.6V or so. During final test and just before boxing the completed circuit, the most suitable connection, A or B, is selected for the positive probe wire. The aim is to have the circuit oscillating with short-circuited probes but to stop oscillation with the least amount of resistance or the inclusion of a diode (try both ways) between the probes.

No sensitivity control is fitted although it would be possible to

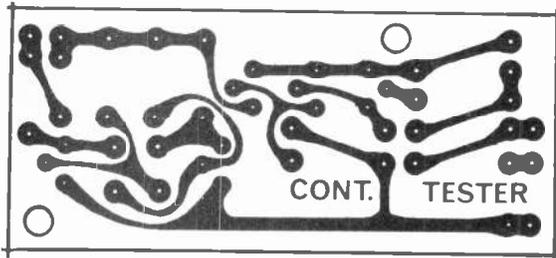


Fig 2 The pcb pattern shown full size (73mm x 33mm)

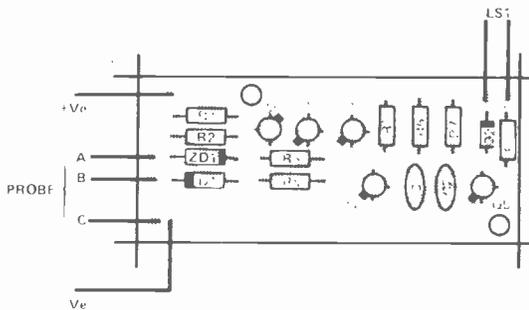
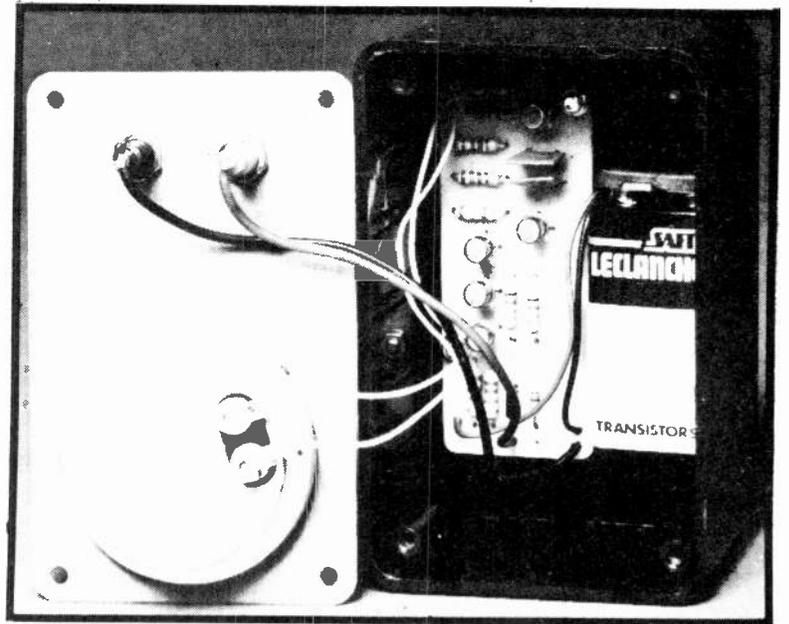


Fig 3 The component overlay on the pcb and other wiring



Inside view of our unit built into a small plastic box with metal top

An experiment worth doing is to select the value of either C1 or C2 to produce a frequency of oscillation that coincides with the mechanical resonant frequency of the particular earpiece transducer in use. Having chosen the correct value, which probably lies in the range 10n-100n, the tone will be louder and more piercing. A "freewheel" diode D2 is connected across the transducer since the fast switching action of the oscillator circuit can produce a surprisingly high back e.m.f. across the coil and these high voltages might

otherwise lead to transistor damage or breakdown.

Zener diodes do *not* provide an absolutely constant volt-drop regardless of current; at the 0.8mA design current an 8.2V diode will quite possibly give only about 8.0V drop since test current for zener selection and marking is typically 5mA or more. A further possible source of error is the battery; the one suggested *nominally* provides 9V but a brand-new specimen may perhaps provide some 9.5 to 9.8V until slightly run-down and this "surplus" voltage, combined with

take R2 from the slider of a control replacing R1. It was not thought worthwhile, however, to spoil the simplicity of the apparatus with anything external other than just the two probes.

There is no easy way to proof the unit against connection to the mains supply. Be careful if checking mains wiring and *switch off first*. In a similar way, if checking electronic apparatus for unwanted bridging between Veroboard tracks, for instance or a suspected crack in a printed circuit track *switch off first*.

# Short Circuits

# STEREO SIMULATOR

Make more of mono with this ETI project team design



IF YOU ARE a member of that illustrious band — the hi-fi enthusiast — read no further. The suggestions contained below are not for your eyes.

If, however, you are a normal human being who wants to get as much fun out of life as possible, read on.

The stereo simulator is designed to take a mono signal, from a mono cassette recorder or, via an isolator please, your TV set, and turn it into a pseudo stereo signal.

It does this by splitting the input into two signal paths and then filtering each signal. The high frequencies are fed to the left input of your stereo amplifier and the low frequencies to the right hand channel.

While this may not sound too exciting, we here at ETI were amazed at the extra *something* this circuit added to many different types of music.

Now they say that one picture is worth a thousand words (hence all the lovely pictures in ETI) and we are sure that somewhere, someone, sometime has said the same sort of thing about sound (no not a picture, silly), so if you want to appreciate the effect of our stereo simulator, please build it and try it. We think you will be amazed too.

## Picking Up The Pieces

The circuit should be assembled according to our component overlay.

Make sure the quad op-amp is correctly positioned before soldering. The input lead from SK1 was earthed at both ends but the leads to SK2 and SK3 should only be earthed at the socket end (to prevent earth loops). Current consumption should be about 2.5mA per battery. The power supply switch, SW1, was a double pole switch to switch both supply batteries, the common of the batteries being 0V.

## HOW IT WORKS

The circuit is based on two second order filters built around IC1(b) and IC1(d).

IC1(b) is a low pass filter with component values chosen to give a break point of about 2kHz. IC1(d) is a high pass filter with, again, a break point of 2kHz.

Thus the output at SK2 will consist of the low frequency portion of the input (bass) and SK3's output will consist of the high (treble) portion of the input signal.

The mono input from SK1 is fed via unity gain input buffers to each filter element. This is to avoid loading the filters which might degrade their performance.

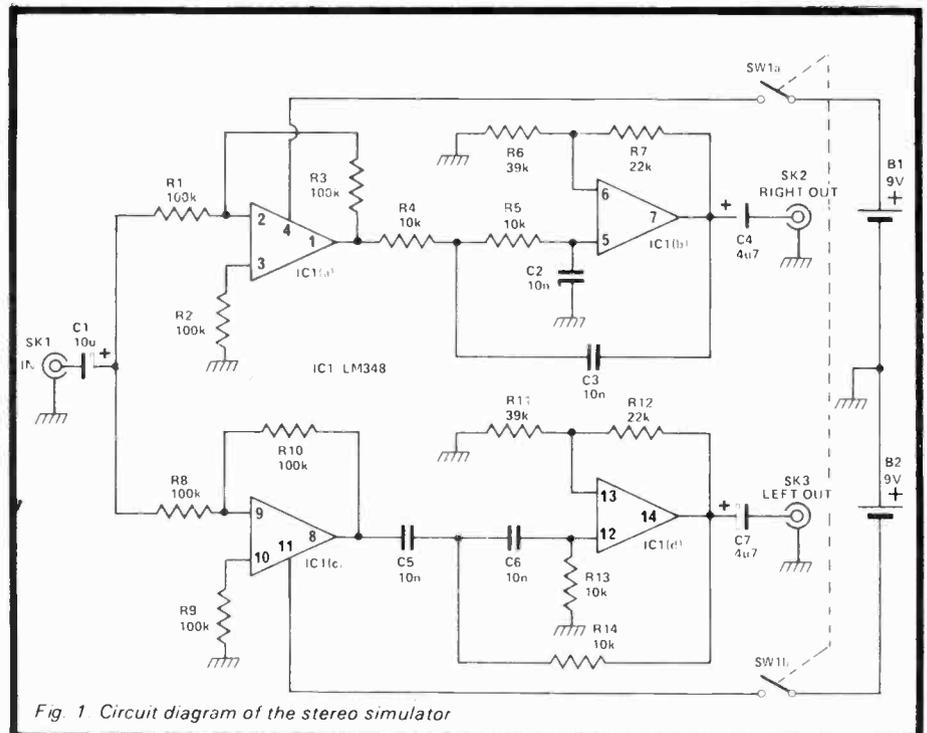
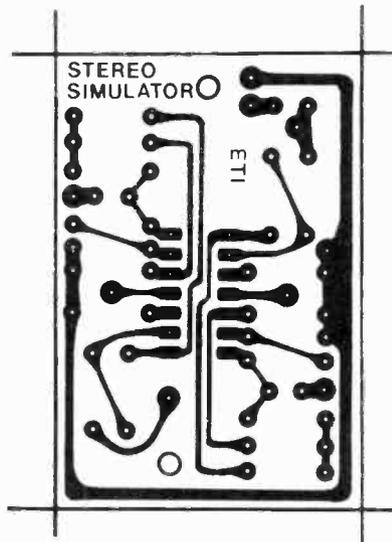
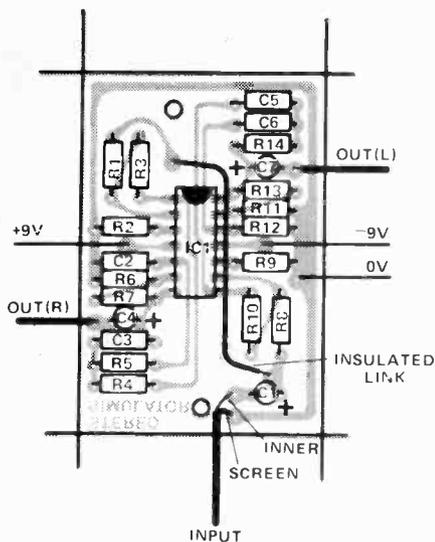


Fig. 1. Circuit diagram of the stereo simulator



Shown full size (60x40mm) above is the foil pattern for the stereo simulator. To the left is the component overlay.

## PARTS LIST

### RESISTORS (all 1/4 W 5%)

R1,2,3,8,9,10	100k
R4,5,13,14	10k
R6,11	39k
R7,12	22k

### SEMICONDUCTOR

IC1	LM348 quad 741 op amp
-----	-----------------------

### CAPACITORS

C1	10u 16V electrolytic
C2,3,5,6	10n polyester
C4,7	4u7 2V electrolytic

### SOCKETS

SK1,2,3	Panel mounting phono sockets
---------	------------------------------

### SWITCH

SW1	Double pole on-off, slide or toggle
-----	-------------------------------------

### MISCELLANEOUS

P.C. Board as pattern, nuts bolts, spacers etc. single screened wire, Two 9V batteries and clips

## Playing The Part

Connect up the stereo simulator to your stereo amp and to a mono signal source. The effect of the

circuit can be modified by use of the amplifiers tone controls (giving a sort of width control) and the balance control. Have fun.

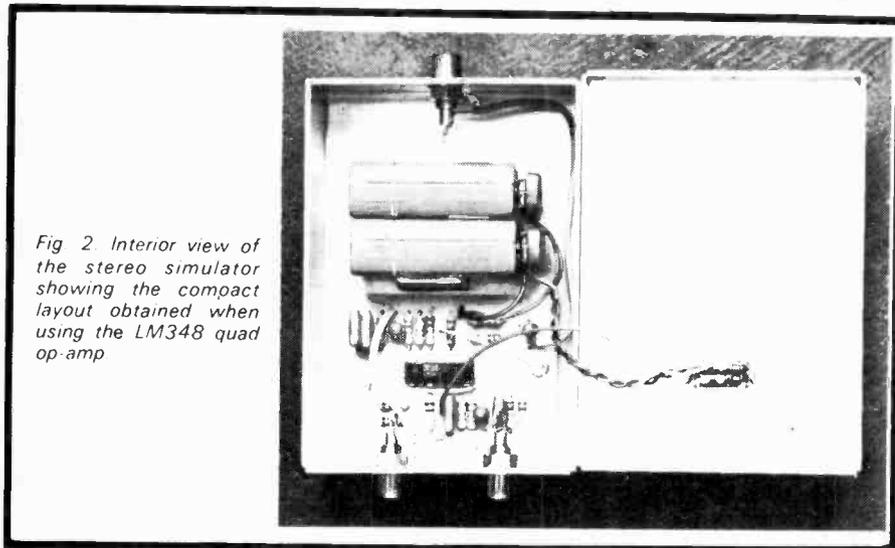


Fig 2 Interior view of the stereo simulator showing the compact layout obtained when using the LM348 quad op-amp

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# ACTIVE FILTERS

Concluding our detailed examination of this particular building block Tim Orr takes a good look at band pass and band reject circuits.

## Band reject (notch) filters

SO FAR NOTCH FILTERS have been realised in this article by two methods; by mixing a bandpass signal with the original or by mixing the low and high pass outputs. There are of course, many other methods of obtaining a notch.

Firstly, the Twin T circuit, Fig. 1.

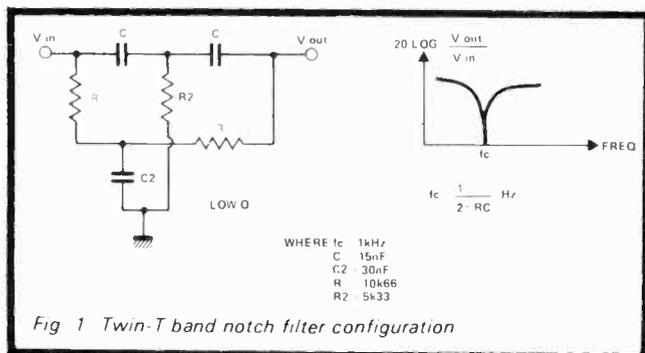


Fig 1 Twin-T band notch filter configuration

This is interesting, in as much as by using only resistors and capacitors, a notch response can be obtained! However, as this filter is passive, only a low Q is possible. This circuit is not used very much, because it has six components that determine its notch frequency. However, it is of interest to note that, when the Twin T is placed in the feedback loop of a high gain inverting amplifier, a bandpass response is obtained. Also if R is made variable it is possible to move the centre frequency, although in doing so, the Q varies. This has been the basis of many Wah Wah effects pedals, Fig 2.

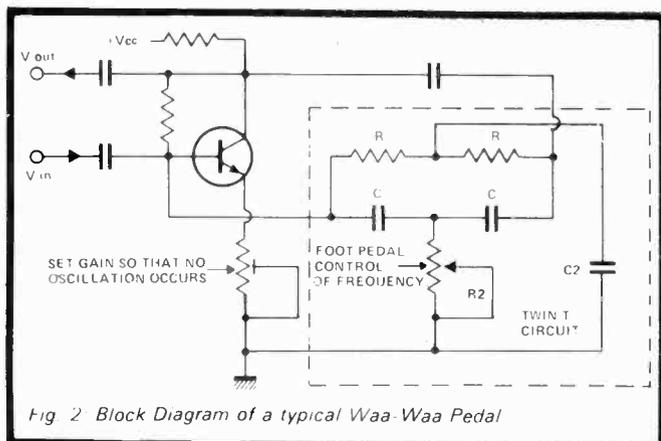


Fig 2 Block Diagram of a typical Waa-Waa Pedal

Another method of obtaining a notch is to use the 'Allpass' filter, Fig 3. The frequency response shows that its output is flat! Not much of a filter I hear you saying. However, it suffers a phase shift which goes from 180°, through 90° at  $f_c$ , to 0°. By cascading two of these filters, the phase shift is doubled.

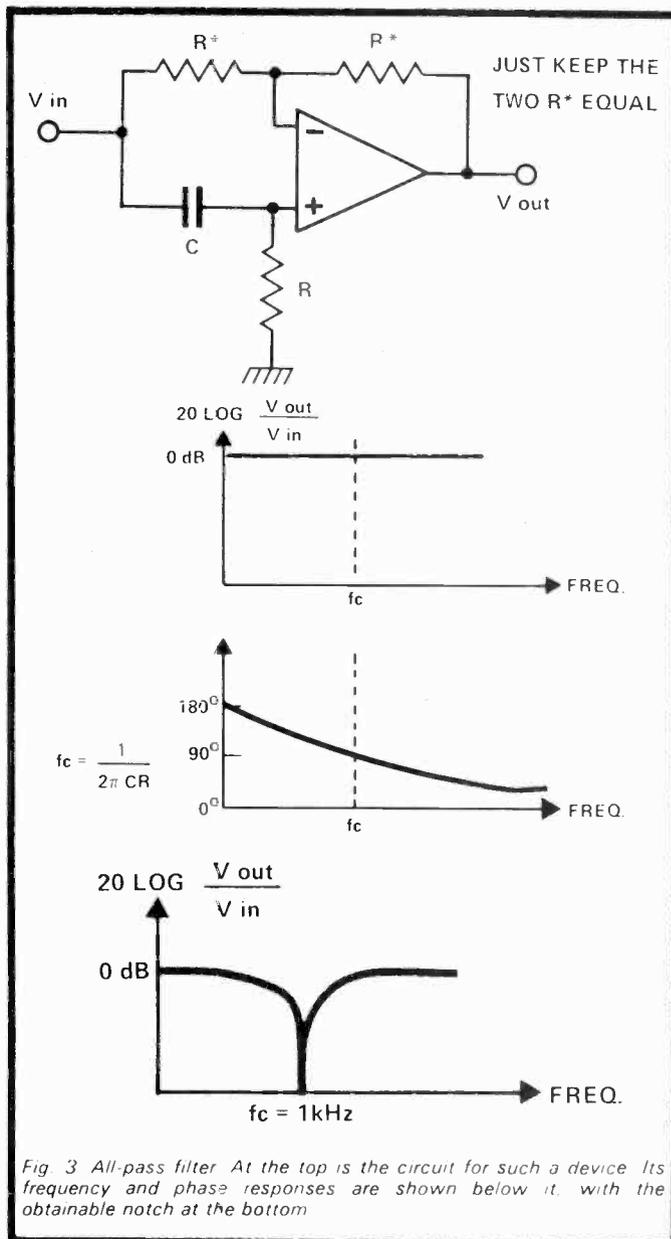


Fig 3 All-pass filter At the top is the circuit for such a device. Its frequency and phase responses are shown below it, with the obtainable notch at the bottom.

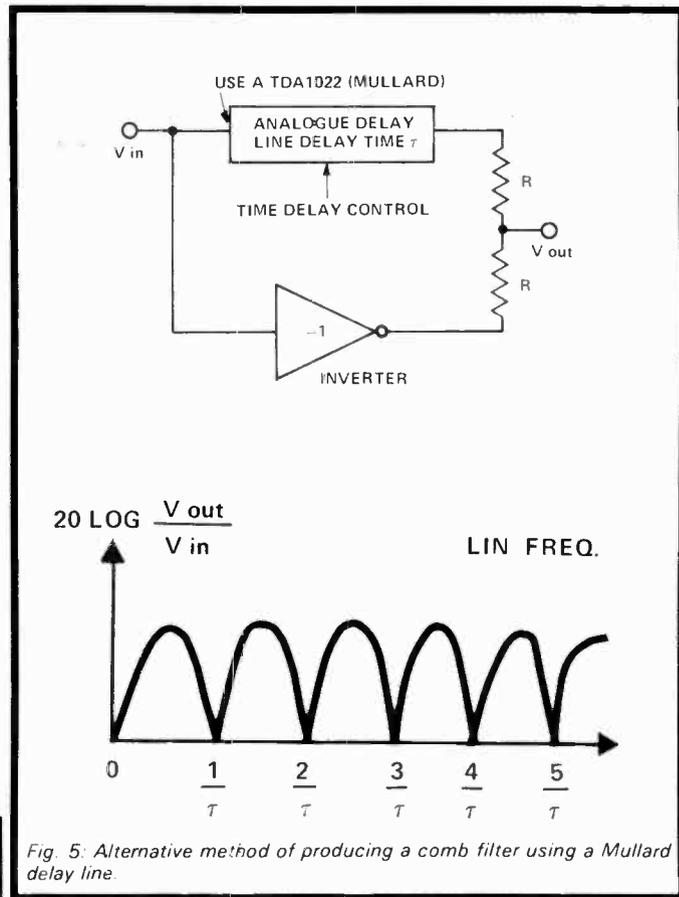
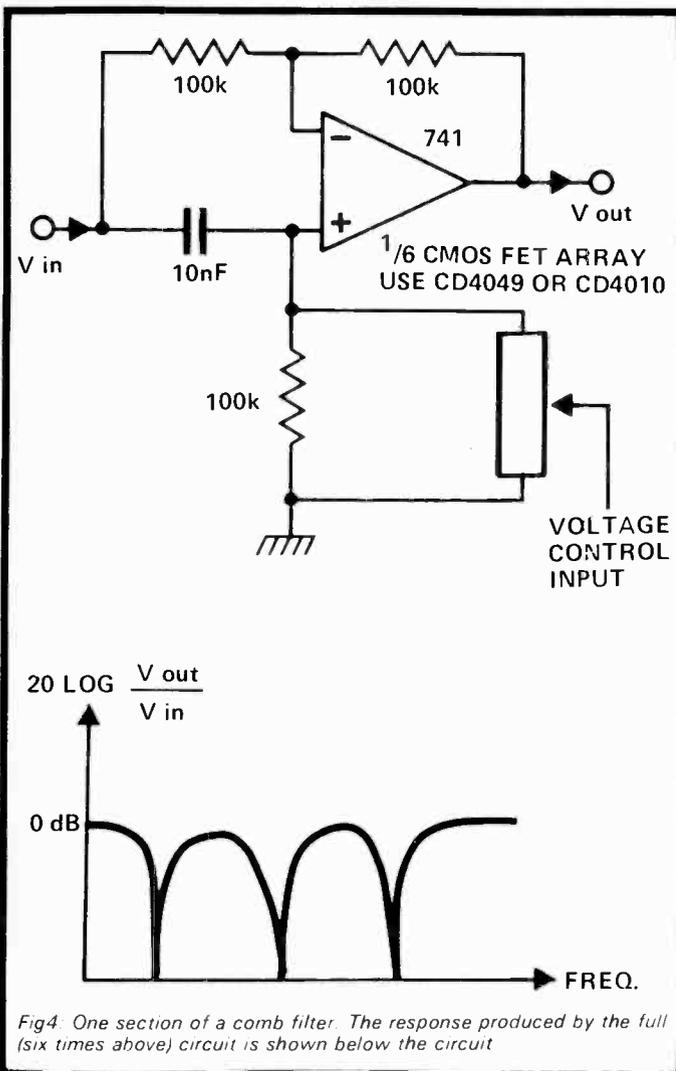
If we then mix the phase delayed signal with the original, a notch response is obtained. This is because at  $f_c$  the two signals have the same magnitude, but the opposite phase and so they cancel each other out.

If the notch is to be made tuneable, then the RC time constants must be varied. For a small tuning range just one R can be varied, for a large tuning range then the R's must be realised with a 'stereo' pot.

## All change

If lots of Allpass filters are cascaded then several notches can be produced. This type of filter is known as a comb filter. Note that it takes two Allpass filters to produce a usable  $180^\circ$  phase shift, and therefore every notch in the comb requires two Allpass sections. By making the R's variable then the notches can be made to move up and down in frequency. This filter forms the well known 'phasing' effect unit, widely used in the music industry to produce colouration!

Fig. 4 shows a small section of just such a unit. A CMOS chip is used to provide a MATCHED set of six MOS FETS. A common voltage is used to control the MOS FETS channel resistance. Thus as the control voltage varies then so do the six MOSFET resistors, and the three notches move in unison along the frequency axis.



Another form of comb filter is shown in Fig. 5.

Instead of a phase delay line, a time delay line is used. This produces a large number of notches which are linearly spread along the frequency axis. Their spacing being determined by the delay time.

A bucket brigade delay line can be used to implement the time delay and this can be made variable. This type of filter is known as a Flanger, which is a superior type of phasing unit, and is used to generate high quality phasing effects. An even more impressive sound can be produced by adding some feedback around the delay line. A multi peak, high Q filter is formed which makes very interesting musical sounds when swept.

## Variable Tuning

Very often a variable centre or cut off frequency is wanted. This causes problems in filters of order greater than two, simply because getting ganged potentiometers with more than two sections is difficult. One well known manufacturer uses four presets mounted on a common spindle to produce a fourth order Rumble and scratch filter. For manually controlled filters, the resistors are made variable by using ganged potentiometers or switched resistor networks.

The switches can be mechanically operated or electronically controlled, Fig. 6. An alternative method of switching control is to use mark/space modulation, Fig. 7. This has the advantage of being a continuously variable control with a useable sweep range of 100 to 1. Also, lots of sections can be used, and they will all track. Therefore, if two CD4016 packs were used then an eighth order (4 transmission gates per pack), variable frequency filter could be constructed. There are of course, problems;

# ACTIVE FILTERS

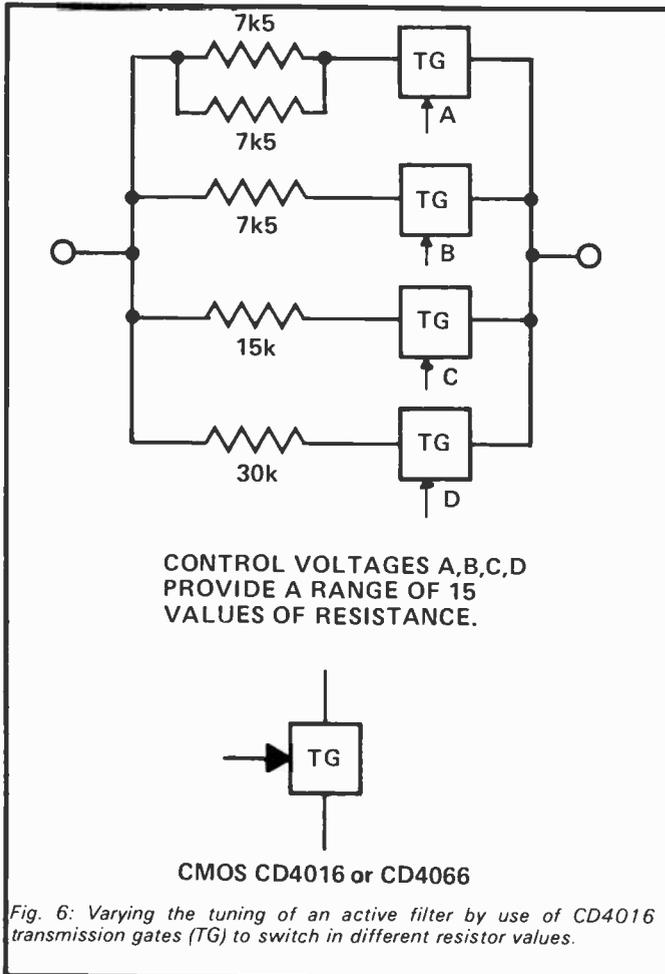


Fig. 6: Varying the tuning of an active filter by use of CD4016 transmission gates (TG) to switch in different resistor values.

1. The switching waveform must be several times higher in frequency than the highest frequency to be filtered.
2. More circuitry, to generate the switching waveform is required.
3. Switching noise is generated.

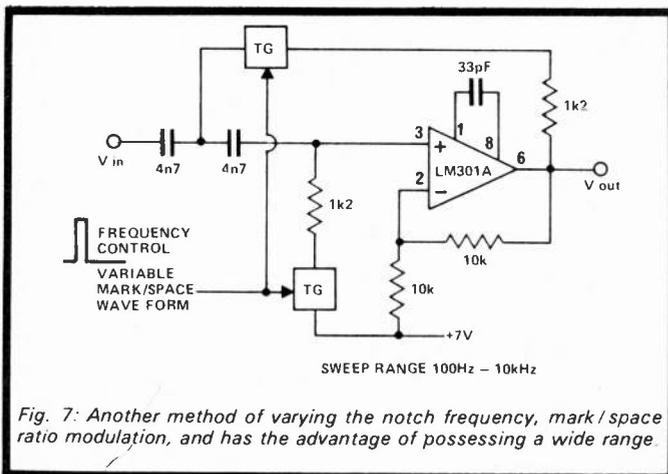


Fig. 7: Another method of varying the notch frequency, mark/space ratio modulation, and has the advantage of possessing a wide range.

## Multiplying FETS

Voltage controlled resistors can be used. These take the form of junction or MOS FETS, where the gate voltage controls the channel resistance,  $R_{ds}$ . The problems with this method are that the characteristics from FET to FET vary considerably and also the  $R_{ds}$  does not have a predictable relationship to the gate voltage. Also, to avoid distortion, low signal levels must be used. Nevertheless, FETS are used in many variable filters such as phasing units.

A set of six MOS FETS having matched characteristics can be obtained from a CD4049 or a CD4010 pack. Alternatively LED photo conductor arrays can be used. The LED produces light which controls the photo conductor's resistance, the two devices being housed in a lightproof box. Large signals can be handled with very low distortion and low noise generation.

Again there are drawbacks. The units are quite expensive, the relationship between LED current and photo conductor resistance is rather unpredictable and the photo conductor's characteristics drift. Another method of varying a filter frequency is to use electronic multipliers. A two quadrant multiplier function can be used to vary the gain of a stage and so produce frequency scaling.

## Some Audio Circuits

Active filters have found great use in equalising audio signals, from tone controls on a domestic Hi-Fi to Parametric equalisers in recording studio. Fig. 8 shows a common tone control with just bass and treble functions. Again cut and lift ranges are 20dBs. If

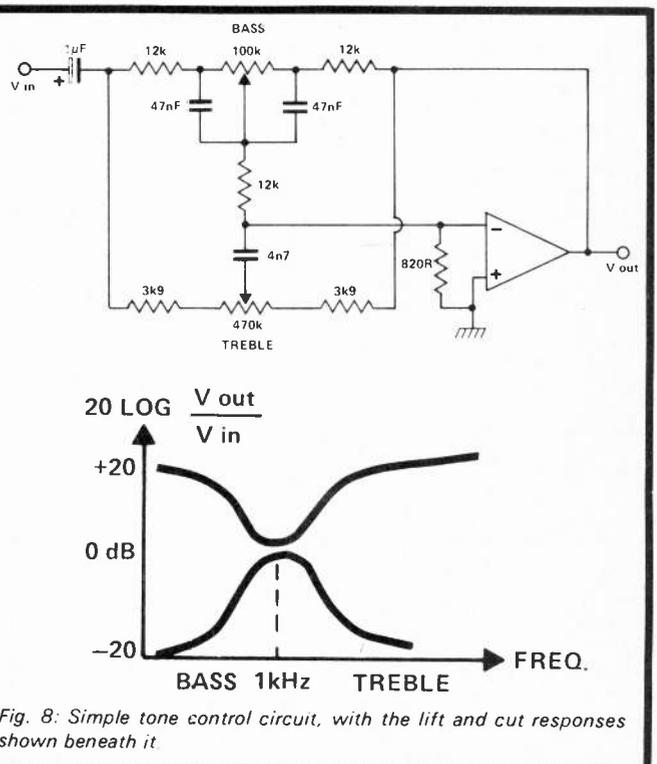
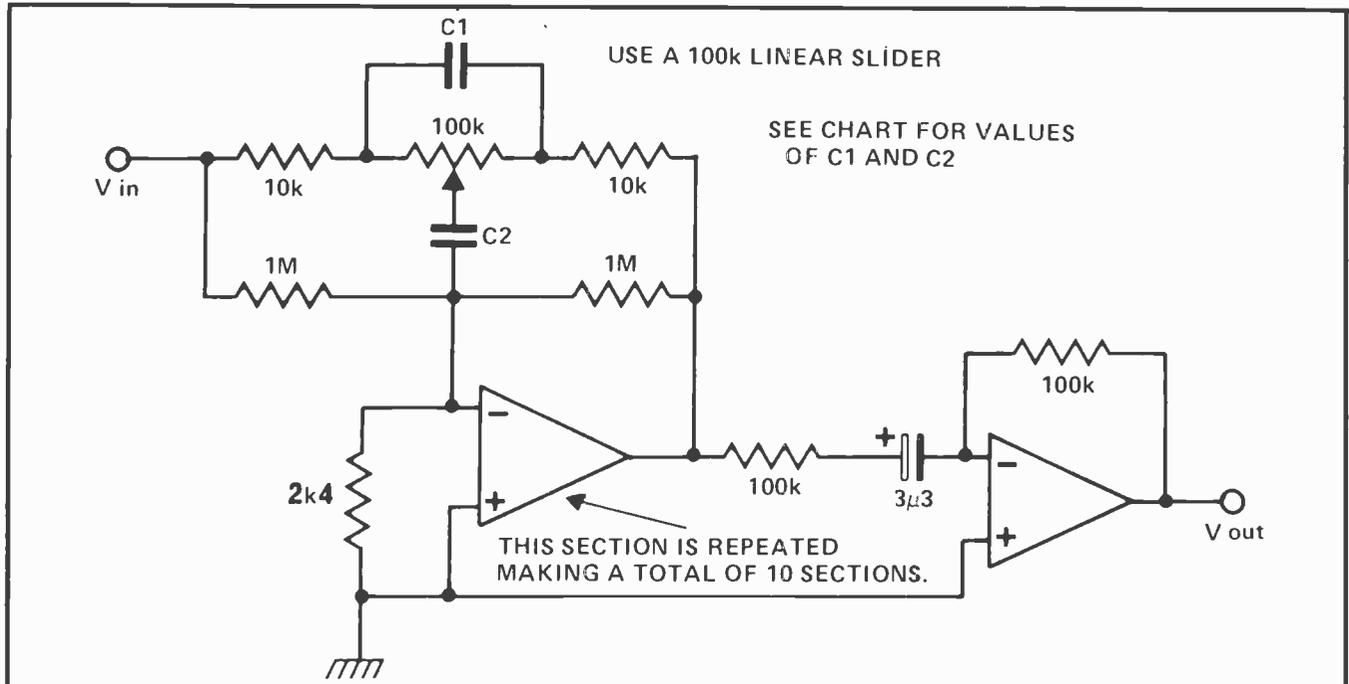


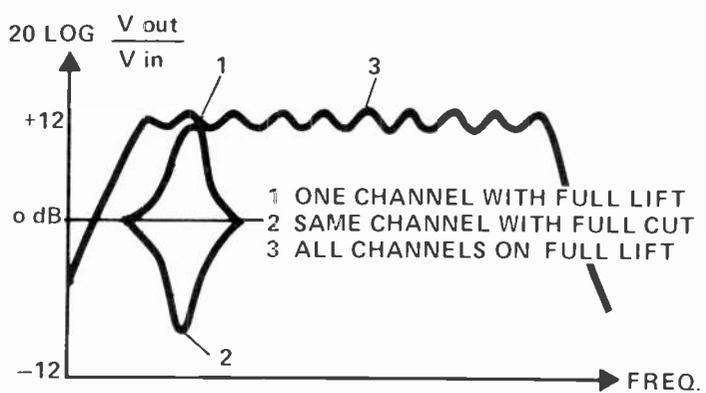
Fig. 8: Simple tone control circuit, with the lift and cut responses shown beneath it.



SEE CHART FOR VALUES OF C1 AND C2

CHANNEL CENTRE FREQ. IN Hz	C1	C2
32	180n	18n
64	100n	10n
125	47n	4n7
250	22n	2n2
500	12n	1n2
1000	5n6	560p
2000	2n7	270p
4000	1n5	150p
8000	680p	68p
16000	360p	36p

Fig. 9 A design for a graphic equaliser, using active filters. The above circuit is repeated however many times you wish. Use the table on the left to calculate values



a more flexible control of the spectrum is needed then a ten band graphic equaliser (Fig. 9) could come in handy.

### Testing Designs

Once the process of designing active filters has been

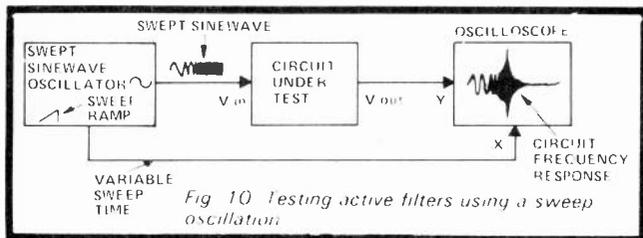


Fig 10 Testing active filters using a sweep oscillation.

reduced to a simple procedure, testing them should also be made as easy as possible. The most basic is to use a swept sinewave oscillator (Fig. 10).

An XY oscilloscope is used to display frequency-log against amplitude-linear. The ideal display would be log amplitude, but this is not so easy to obtain. The beauty of this method of testing is that the display is real time and so any changes made to the filter, like varying one of the capacitors, appear instantly on the oscilloscope. If high Q's or rapid roll offs at low frequencies are involved, then the sweep time will have to be reduced, otherwise the effects of Ringing, will 'Time smear' the display. The harmonic distortion of the sinewave can be quite large, 0.5 to 2.0% without causing too much of a display problem for most filter designs.

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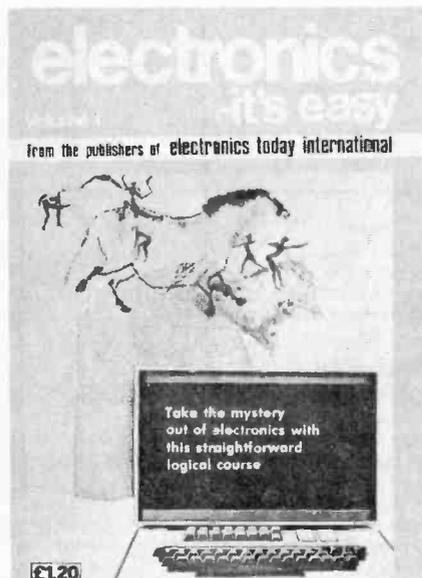
A brand new concept from the house of ETI more than 100 pages packed with a wide range of experimenters circuits. Based on the 'Tech Tips' section carried in the overseas editions of ETI, Circuits 1 is the first of a series of specials - produced for the enthusiasts who know what they want, but not where to get it! Circuits 1 will also act as a catalyst for further development of ideas, ideal for the experimenter. The collection of more than 200 circuits is complemented by a comprehensive index, making searches for a particular circuit quick and simple. Also, similar circuits can be compared easily, due to the logical layout and grouping used throughout. Last and by no means least, Circuits 1 has no distracting advertisements in the main section!

## TOP PROJECTS No. 4:

A collection of 28 constructional projects reprinted from ETI. This is the fourth in a series published by the British edition (Nos. 1 and 2 are not available). Projects are complete and include: Sweet Sixteen Stereo Amp, Waa-Waa, Audio Level Meter, Expander/Compressor, Car Anti-Theft Alarm, Headlight Reminder, Dual-Tracking Power Supply, Audio Millivoltmeter, Thermocouple Meter, Intruder Alarm, Touch Switch, Push-Button Dimmer, Exposure Meter, Photo Timer, Electronic Dice, High Power Beacon, Temperature Controller, Electronic One-Arm Bandit plus many more.

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# ETI DATA SHEET

## LM 3911 TEMPERATURE CONTROLLER

NATIONAL

The LM3911 is a highly accurate temperature measurement and/or control system for use over a  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range. Fabricated on a single monolithic chip, it includes a temperature sensor, a stable voltage reference and an operational amplifier.

The output voltage of the LM3911 is directly proportional to temperature in degrees Kelvin at  $10\text{ mV}/^{\circ}\text{K}$ . Using the internal op amp with external resistors any temperature scale factor is easily obtained. By connecting the op amp as a comparator, the output will switch as the temperature transverse the set-point making the device useful as an on-off temperature controller.

An active shunt regulator is connected across the power leads of the device to provide a stable 6V8 voltage reference for the sensing system. This allows the use of any power supply voltage with suitable external resistors.

The input bias current is low and relatively constant with temperature, ensuring high accuracy when high source impedance is used. Further, the output collector can be returned to a voltage higher than 6V8 allowing the circuit to drive lamps and relays up to a 35V supply.

The LM3911 uses the difference in emitter-base voltage of transistors operating at different current densities as the basic temperature sensitive element. Since this output depends only on transistor matching the same reliability and stability as present op amps can be expected.

The device is available in three package styles — a metal can 4-lead TO-5, a metal can TO-46 and an 8-lead epoxy mini-DIP. In the epoxy package all electrical connections are made on one side of the device allowing the other 4 leads to be used for attaching the device to the temperature source. The LM3911 is rated for operation over a  $-25^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range.

### Applications

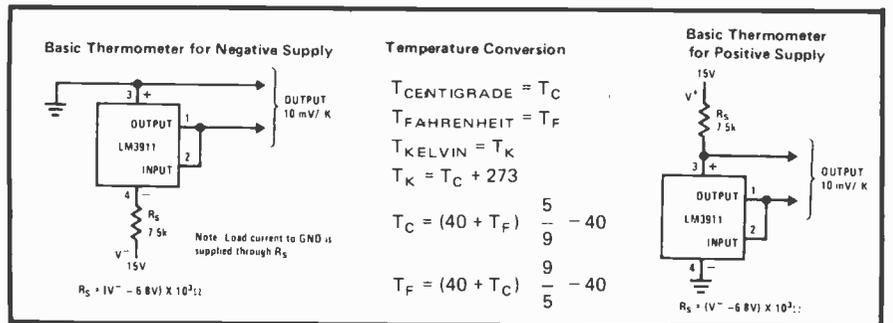
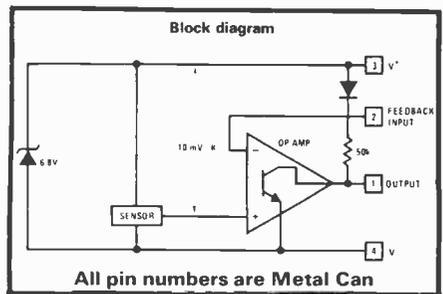
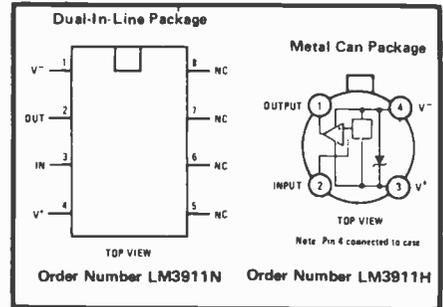
- Thermometer
- Over/Under temperature alarm
- Fish tank controller
- Photographic development systems
- Greenhouse controller
- Weather station transducer
- Fire alarms

### Absolute Maximum Ratings

Supply Current (Externally Set)	10mA
Output Collector Voltage	36V
Feedback Input Voltage	OV to +7VQ
Output Short Circuit Duration	Indefinite

### Features

- Uncalibrated-accuracy  $\pm 10^{\circ}\text{C}$
- Internal op amp with compensation
- Linear output of  $10\text{mV}/^{\circ}\text{K}$  ( $10\text{mV}/^{\circ}\text{C}$ )
- Can be calibrated in degrees Kelvin, Celsius or Fahrenheit
- Output can drive loads up to 35V
- Internal stable voltage reference
- Low cost



### Temperature Conversion

$$T_{\text{CENTIGRADE}} = T_{\text{C}}$$

$$T_{\text{FAHRENHEIT}} = T_{\text{F}}$$

$$T_{\text{KELVIN}} = T_{\text{K}}$$

$$T_{\text{K}} = T_{\text{C}} + 273$$

$$T_{\text{C}} = (40 + T_{\text{F}}) \frac{5}{9} - 40$$

$$T_{\text{F}} = (40 + T_{\text{C}}) \frac{9}{5} - 40$$

### Application Hints

As with any temperature sensor, internal power dissipation will raise the sensor's temperature above ambient. Nominal suggested operating current for the shunt regulator is 1 mA and causes 7 mW of

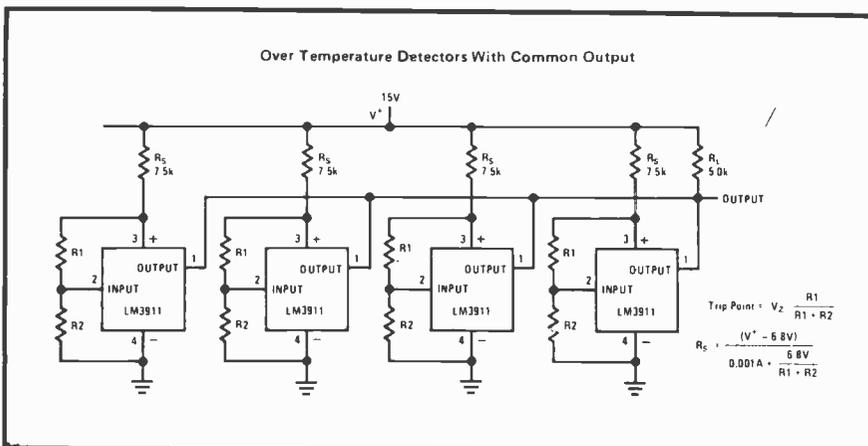
power dissipation. In free, still air this raises the package temperature by about 1.2 K. Although the regulator will operate at higher reverse currents and the output will drive loads up to 5 mA, these higher currents will raise the sensor temperature to about

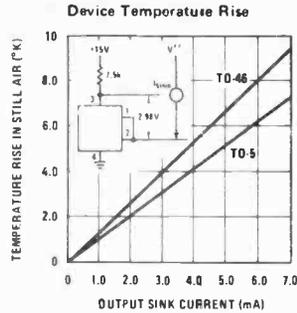
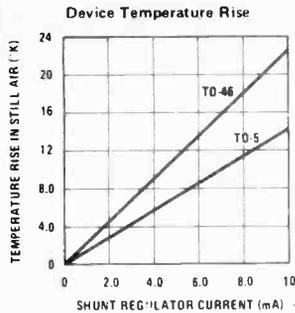
19° K above ambient — degrading accuracy. Therefore, the sensor should be operated at the lowest possible power level.

### Heat Sinks

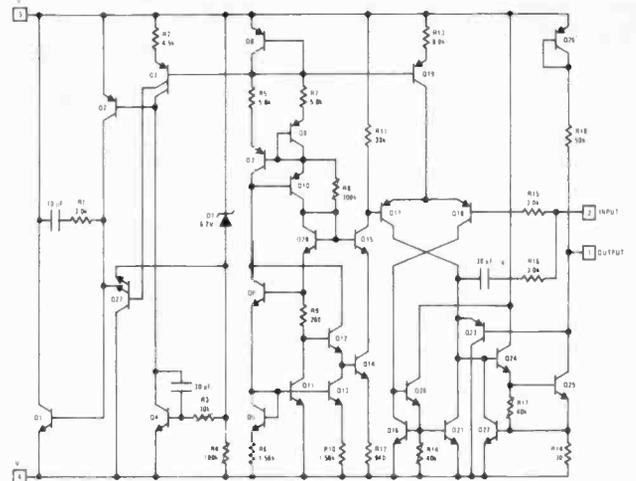
With moving air, liquid or surface temperature sensing, self-heating is not as great a problem since the measured media will conduct the heat from the sensor. Also, there are many small heat sinks designed for transistors which will improve heat transfer to the sensor from the surrounding medium. A small finned clip-on heat sink is quite effective in free-air. It should be mentioned that the LM3911 die is on the base of the package and therefore coupling to the base is preferable.

The internal reference regulator provides a temperature stable voltage for offsetting the output or setting a comparison point in temperature controllers. However, since this reference is at the same temperature as the sensor temperature changes will also cause reference drift. For application where maximum accuracy is needed an external reference should be used. Of course, for fixed temperature controllers the internal reference is adequate.





The LM3911 is available from National stockists. Radio Shack shops also stock it under the name RS3911 (part number 276-1706).



## MC 14433 3 1/2 DIGIT A/D CONVERTOR

MOTOROLA

A high performance, low power, 3 1/2 digit A/D converter combining both linear CMOS and digital CMOS circuits on a single monolithic IC, the MC14433 is designed to minimize use of external components. With two external resistors and two external capacitors, the system forms a dual slope A/D converter with automatic zero correction and automatic polarity.

The MC14433 is ratiometric and may be used over a full-scale range from 1.999 volts to 199.9 millivolts. Systems may operate over a wide range of power supply voltages for ease of use with batteries, or with standard 5 volt supplies. The output drive conforms with standard B-Series CMOS specifications and can drive a low-power Schottky TTL load.

### Absolute Maximum Ratings

Supply voltage 18V  
Pin current 10mA  
 $V_{EE} \leq (V_{in} \text{ or } V_{out}) \leq V_{DD}$

### Circuit Operation

During each conversion, the offset voltages of the internal amplifiers and comparators are compensated for by the system's autozero operation. Also each conversion "ratiometrically" measures the unknown input voltage. In other words, the output reading is the ratio of the unknown voltage to the reference voltage with a ratio of 1 equal to the maximum count 1999. The entire conversion cycle requires slightly more than 16000 clock periods and may be divided into six different segments. The waveforms showing the conversion cycle with a positive input and a negative input are shown in Figure 2. The six segments of these waveforms are described below.

Segment 1 — The offset capacitor ( $C_o$ ), which compensates for the input offset voltages of the buffer and integrator amplifiers, is charged during this period. This segment requires 4000 clock periods.

Segment 2 — The integrator output decreases to the comparator threshold voltage. At this time a number of counts equivalent to the input offset voltage of the comparator is stored in the offset latches for later use in the autozero process. The time for this segment is variable, and less than 800 clock periods.

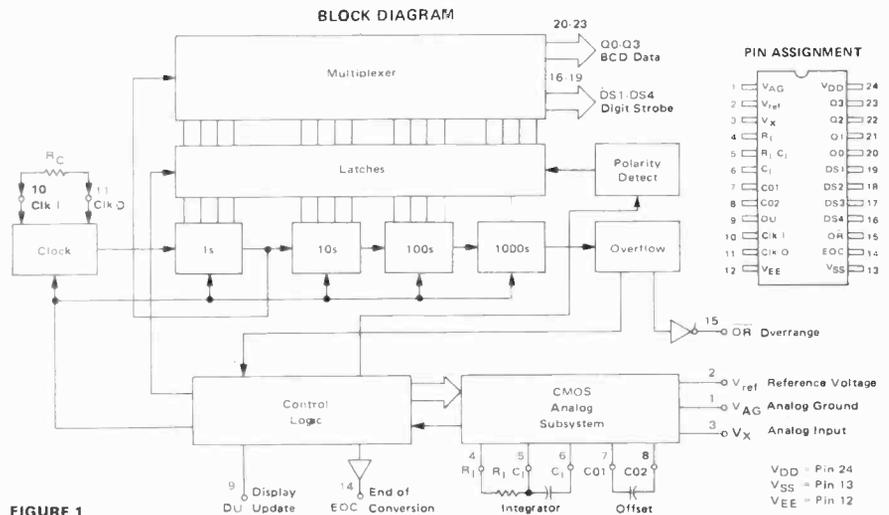


FIGURE 1

### Applications

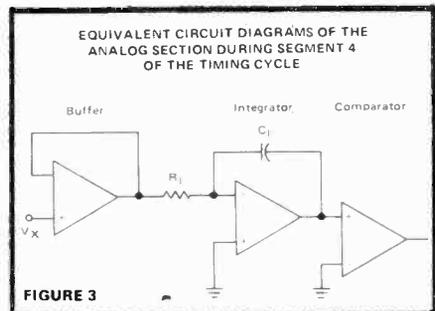
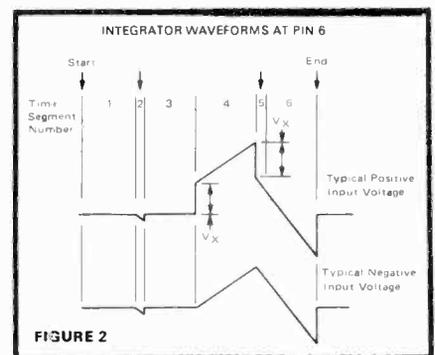
- DVM/DPM
- Digital scales
- Digital thermometers
- Remote A/D and D/A systems
- MPU based interface
- Current and resistance meters

Segment 3 — This segment of the conversion cycle is the same as Segment 1.

Segment 4 — Segment 4 is an up-going ramp cycle with the unknown input voltage ( $V_x$ ) as the input to the integrator. Figure 3 shows the equivalent configuration of the analog section of the MC14433. The actual configuration of the analog section is dependent upon the polarity of the input voltage during the previous conversion cycle.

Segment 5 — This segment is a down-going ramp period with the reference voltage as the input to the integrator. Segment 5 of the conversion cycle has a time equal to the number of counts stored in the offset storage latches during Segment 2. As a result, the system zeros automatically.

Segment 6 — This is an extension of Segment 5. The time period for this portion is 4000 clock periods. The results of the A/D conversion cycle are determined in this portion of the conversion cycle.



**Pin Functions**

**ANALOG GROUND (V<sub>AG</sub>, Pin 1)**

Analog ground at this pin is the input reference level for the unknown input voltage (V<sub>x</sub>) and reference voltage (V<sub>ref</sub>). This pin is a high impedance input.

**REFERENCE VOLTAGE (V<sub>ref</sub>, Pin 2)**

**UNKNOWN INPUT VOLTAGE (V<sub>x</sub>, Pin 3)**

This A/D system performs a ratiometric A/D conversion; that is, the unknown input voltage, V<sub>x</sub>, is measured as a ratio of the reference voltage, V<sub>ref</sub>. The full-scale voltage is equal to that voltage applied to V<sub>ref</sub>. Therefore, a full-scale voltage of 1.999 V requires a reference voltage of 2.000 V while full-scale voltage of 199.9 mV requires a reference voltage of 200 mV. Both V<sub>x</sub> and V<sub>ref</sub> are high impedance inputs. In addition to being a reference input, pin 2 functions as a reset for the A/D converter. When pin 2 is switched to V<sub>EE</sub>, the system is reset to the beginning of a conversion cycle.

**EXTERNAL COMPONENTS**

**(R<sub>x</sub>, R<sub>1</sub>/C<sub>1</sub>, C<sub>2</sub>; Pins 4, 5, 6)**

These pins are for external components for the integration used in the dual ramp A/D conversion. A typical value for the capacitor is 0.1 μF (mylar) while the resistor should be 470 kΩ for 2.0 V full scale operation and 27 kΩ for 200 mV full scale operation. These values are for a 66 kHz clock frequency which will produce a conversion time of approximately 250 ms.

**OFFSET CAPACITOR**

**(CO1, CO2; Pins 7, 8)**

These pins are used for connecting the offset correction capacitor. The recommended value is 0.1 μF.

**DISPLAY UPDATE INPUT (DU, Pin 9)**

If a positive edge is received on this input prior to the ramp-down cycle, new data will be strobed into the output latches during that conversion cycle. When this pin is wired

**Features**

- Accuracy: ±0.05% of Reading ± 1 Count
- Voltage Ranges: 1.999 V and 199.9 mV
- Up to 25 Conversions per second.
- Z<sub>in</sub> > 1000 M ohm
- Auto-Polarity and Auto-Zero
- Single Positive Voltage Reference
- Standard B-Series CMOS Outputs
- Uses On-Chip Clock, or External Clock
- Low Power: 8.0 mW typical @ ± 5.0 V.
- Supply Range: ± 4.5 V to ± 8.0 V.
- Overrange and Underrange Signals

directly to the EOC output (pin 14), every conversion will be displayed. When this pin is driven from an external source, the voltage should be referenced to V<sub>SS</sub>.

**CLOCK (Clk I, Clk O, Pins 10, 11)**

The MC14433 device contains its own oscillator system clock. A single resistor connected between pins 10 and 11 sets the clock frequency. If increased stability is desired, these pins will support a crystal or LC circuit. The clock input, pin 10, may also be driven from an external clock source which need have only standard CMOS output drive. For external clock inputs this pin is referenced to V<sub>EE</sub>. A 300 kΩ resistor results in clock frequency of about 66 kHz.

**NEGATIVE POWER SUPPLY**

**(V<sub>EE</sub>, Pin 12)**

This is the connection for the most negative power supply voltage. The typical current is 0.8 mA. Note the current for the output drive circuit is not returned through this pin, but through pin 13.

**NEGATIVE POWER SUPPLY FOR OUTPUT CIRCUITRY (V<sub>SS</sub>, Pin 13)**

This is the low voltage level for the output pins of the MC14433 (BCD, Digit Selects, EOC, OR). When this pin is connected to

analog ground, the output voltage is from analog ground to V<sub>DD</sub>. When connected to V<sub>EE</sub>, the output swing is from V<sub>EE</sub> to V<sub>DD</sub>. The allowable operating range for V<sub>SS</sub> is between V<sub>DD</sub> - 3.0 volts and V<sub>EE</sub>.

**END OF CONVERSION (EOC, Pin 14)**

The EOC output produces a pulse at the end of each conversion cycle. This pulse width is equivalent to one half the period of the system clock (pin 11).

**OVERRANGE (OR, Pin 15)**

The OR pin is low when V<sub>x</sub> exceeds V<sub>ref</sub>. Normally it is high.

**DIGIT SELECT (DS4, DS3, DS2, DS1; Pins 16, 17, 18, 19)**

The digit select output is high when the respective digit is selected. The most significant digit (½ digit) turns on immediately after an EOC pulse followed by the remaining digits, sequencing from MSD to LSD. An inter-digit blanking time of two clock periods is included to ensure that the BCD data has settled. The multiplex rate is equal to the clock frequency divided by 80. Thus, with a system clock rate of 66 kHz, the multiplex rate would be 0.8 kHz.

**BCD DATA OUTPUTS (Q3, Q2, Q1, Q0; Pins 20, 21, 22, 23)**

Multiplexed BCD outputs contain 3 full digits of information during DS2, 3, 4, while during DS1, the ½ digit, overrange, underrange and polarity are available.

**POSITIVE POWER SUPPLY (V<sub>DD</sub>, Pin 24)**

The most positive supply voltage pin.

**Simple DVM**

The 3½ digit voltmeter of Figure 4 is an example of the use of the MC14433 in a system with a minimum of components.

In this circuit the MC14511B provides the segment drive for the 3½ digits. The MC75492 or MC1413 provides sink for digit current. (The MC75492 or MC1413 are devices with 6 or 7 darlington transistors respectively with common emitters.) The worst case digit current is 7 times the segment current at ¼ duty cycle. The peak segment current is limited by the value of R. The current for the display flows from V<sub>DD</sub> (± 5 V) to ground and does not flow through the V<sub>EE</sub> (negative) supply. The minus sign is controlled by one section of the MC 75491 or MC1413 and is turned off by shunting the current through R<sub>M</sub> to ground, bypassing the minus sign LED. The minus sign is derived from the Q2 output. The decimal point brightness is controlled by resistor R<sub>DP</sub>. Since the brightness and the type and size of LED display are the choice of the designer, the values of resistors R, R<sub>M</sub>, R<sub>DP</sub>, and R<sub>R</sub> that govern brightness are not given.

During an overrange condition the 3½ digit display is blanked at the BI pin on the MC14511B. The decimal point and minus sign will remain on during a negative overrange condition. In addition, an alternate overrange circuit with separate LED is shown. There are leftover sections in either the MC75492 or MC1413.

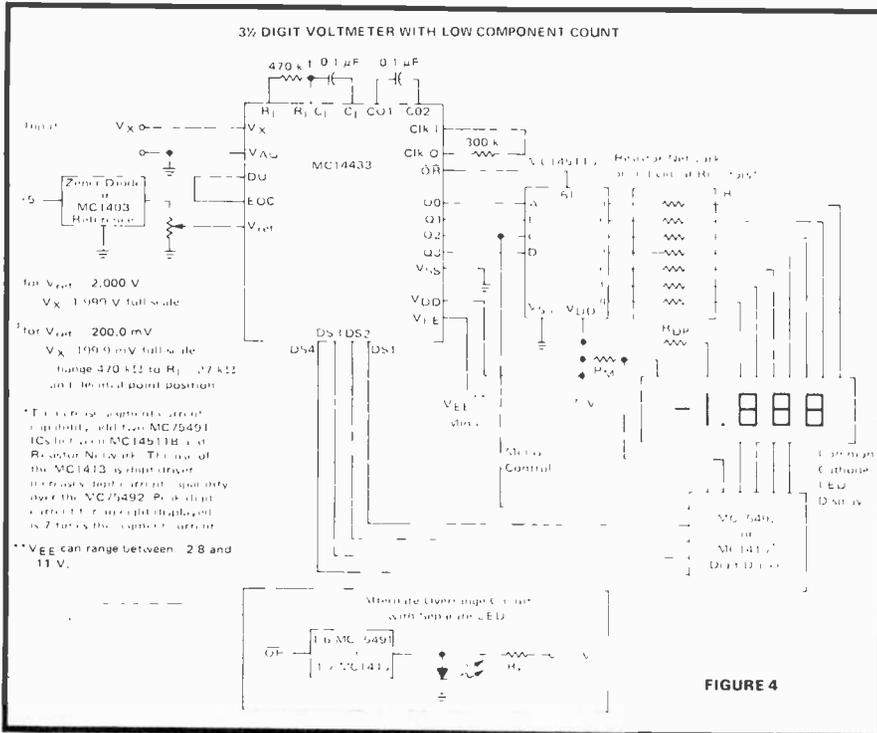


FIGURE 4

# MURPHY'S LAW

IT HAS LONG BEEN the consideration of the author that the contributions of Edsel Murphy, specifically his general and special laws delineating the behaviour of inanimate objects, have not been fully appreciated. It is deemed that this is, in large part, due to the inherent simplicity of the law itself.

It is the intent of the author to show, by references drawn from the literature, that the law of Murphy has produced numerous corollaries. It is hoped that by noting these examples, the reader may obtain a greater appreciation of Edsel Murphy, his law, and its ramifications in engineering and science.

As is well known to those versed in the state-of-the-art, Murphy's Law states that "If anything can go wrong, it will". Or, to state it in more exact mathematical form:

$$1 + 1 \rightarrow 2$$

where  $\rightarrow$  is the mathematical symbol for hardly ever.

Some authorities have held that Murphy's Law was first expounded by H. Cohen when he stated that "If anything can go wrong, it will during the demonstration". However, Cohen has made it clear that the broader scope of Murphy's general law obviously takes precedence.

To show the all-pervasive nature of Murphy's work, the author offers a small sample of the application of the law in electronics engineering.

## Engineering

- I.1 The more innocuous a design change appears, the further its influence will extend.
- I.2 Firmness of delivery dates is inversely proportional to the tightness of the schedule.
- I.3 Dimensions will always be expressed in the least usable term. Velocity for example, will be expressed in furlongs per fortnight.
- I.4 An important Instruction Manual or Operating Manual will have been discarded by the Receiving Department.

## Mathematics

- II.1 Any error that can creep in, will. It will be in the direction that will do the most damage to the calculation.
- II.2 All constants are variables.
- II.3 In any given computation, the figure that is most obviously correct will be the source of error.
- II.4 A decimal will always be misplaced.

## Prototyping

- III.1 Any wire cut to length will be too short.
- III.2 Tolerances will accumulate unidirectionally toward maximum difficulty of assembly.
- III.3 Identical units tested under identical conditions will not be identical in the field.
- III.4 The availability of a component is inversely proportional to the need for that component.
- III.5 If a project requires  $n$  components, there will be  $n-1$  units in stock.

III.6 If a particular resistance is needed, that value will not be available. Further, it cannot be developed with any available series of parallel combination.

III.7 A dropped tool will land where it can do the most damage. (Also known as the law of selective gravitation.)

III.8 A device selected at random from a group having 99% reliability, will be a member of the 1% group.

III.9 When one connects a 3-phase line, the phase sequence will be wrong.

III.10 A motor will rotate in the wrong direction.

III.11 The probability of a dimension being omitted from a plan or drawing is directly proportional to its importance.

III.12 Interchangeable parts won't.

III.13 Probability of failure of a component, assembly, sub-system or system is inversely proportional to ease of repair or replacement.

III.14 If a prototype functions perfectly, subsequent production units will malfunction.

III.15 Components that must not and cannot be assembled improperly will be.

III.16 A dc meter will be used on an overly sensitive range and will be wired in backwards.

## General

IV.1 After the last of 16 mounting screws has been removed from an access cover, it will be discovered that the wrong access cover has been removed.

IV.2 After an access cover has been secured by 16 hold-down screws, it will be discovered that the gasket has been omitted.

IV.3 After an instrument has been fully assembled, extra components will be found on the bench.

IV.4 In an instrument or device characterized by a number of plus-or-minus errors, the total error will be the sum of all errors adding in the same direction.

IV.5 In any given price estimate, cost of equipment will exceed estimate by a factor of 3.

IV.6 In specifications, Murphy's Law supercedes Ohm's.

*Murphy's Law had an effect on page 62 in last month's issue!*

The man who developed one of the most profound concepts of the twentieth century is practically unknown to most engineers. He is a victim of his own law. Destined to a secure place in the engineering hall of fame, something went wrong.

His real contribution lay not merely in the discovery of the law but more in its universality and in its impact. The law itself, though inherently simple, has formed a foundation on which future generations will build.

In fact, the law first came to him in all its simplicity when his bride-to-be informed him that his boss had beaten him to the altar.

This hitherto unpublished photograph of Edsel Murphy was taken just after he had heard his ex-fiancée's news.

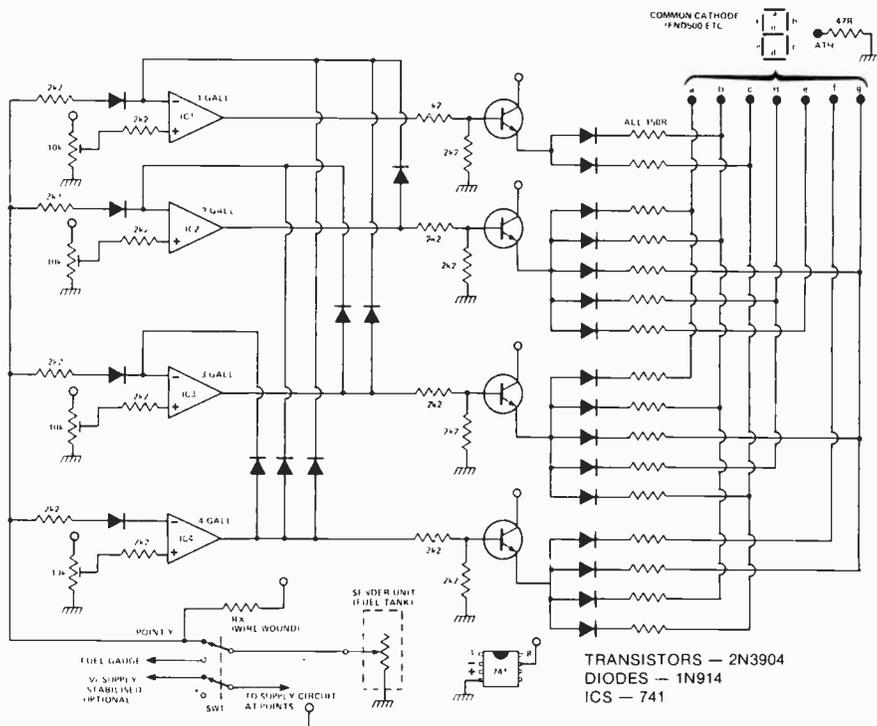


## Digital Fuel Gauge

P. Walsh

This circuit will give a digital readout of tank capacity in gallons, up to the 4 gallon mark. As the sender is of a log. nature, and knowing you have at least 4 gallons in the tank I did not find it necessary to provide a greater figure display.

The switch is a means of switching to fuel gauge. The voltage across the sender unit *must not exceed five volts*, thus, the resistance of RX must be  $2.5 \times$  resistance of sender, when the tank is empty, presuming that the resistance is high on an empty tank. Disconnecting the output of a sender unit on a car fuel tank, and wiring it in series with a resistor RX we create a positive potential at point Y, relative to earth, which varies in relationship to the fuel level. Connecting point Y to the inverting input of a 741 op. amp., and using a trimmer at the non-inverting input, a condition is created whereby the output of the IC is either + or -, depending on the fuel level. A corresponding voltage, which represents X gallons, can be set at pin 3, and a drop in fuel will give an increase in potential at pin 2, which will result in a negative output, at pin 6. In the circuit above, voltage drop may cause one particular IC to go negative, but still be at a level to give another IC a positive output.



In the case of IC4 (representing 4 gallons), the voltage at point Y may be of a level to give IC4 a + output, but also be lower at pin 3 on ICs 3, 2 and 1. This would mean that the non-inverting inputs would, in each case, also be positively biased, giving a positive output from each IC. To overcome this positive feedback from pin 6, of any IC

which has a positive output, is fed to inverting inputs to preceding ICs causing those particular ICs to 'turn off'.

The outputs from pin 6 of each IC may then be used to drive individual indicators, or the discrete decoder which drives a seven segment display as shown in the circuit.

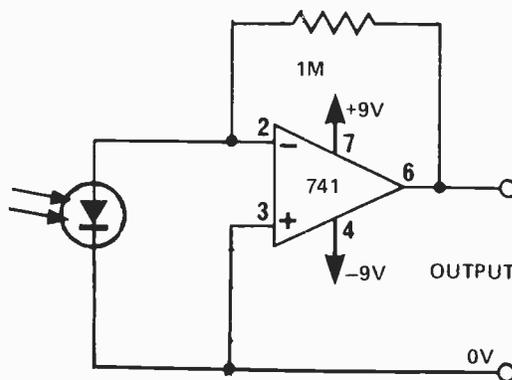
## What's A Nice LED Doing In A Place Like That?

Mary Volpe

Has ETI's staff finally gone off the deep end? Was our artist asleep at the pen?

Nope, but we too were a bit surprised to see this tip. The contributor has been doing some experimenting using LED's as light sensors and reports that they work quite well.

Not too much data is available on this mode of operation so try this basic amplifier circuit as a start. An output of .25V to .5V is achievable. You will note that there is no input resistor as might normally be expected in such a circuit. This is apparently not needed, probably because the LED internal resistance is quite high.



What colour LED to use? The following factors may be of interest. Any photons of energy (i.e. frequency) greater than or equal to that which the LED customarily emits will contribute to the current output. Hence a red LED (low frequency) will get excited by a

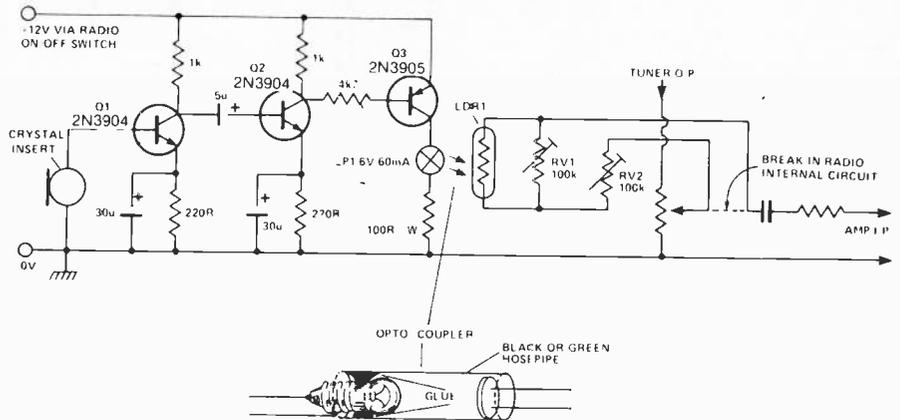
larger range of light. Another factor is the filtering action of the plastic case of the LED. Here, a red LED with clear (uncoloured) body will respond to a wider light input range than a red LED, with red body.

Tech-Tips is an ideas forum and is not aimed at the beginner. ETI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for. Drawings should be as clear as possible and the text should preferably be typed. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, Unit 6, 25 Overlea Blvd., Toronto, Ontario, M4H 1B1.

## Car A.V.C.

R. Johnson

As the noise from the engine increases the lamp IP1 is lit by Q3 which causes the resistance of LDR1 to decrease. This change in resistance controls the volume of the radio. A home-made opto-coupler is used to reduce circuit cost, and the LDR is connected as shown. Adjustment of RV1 and RV2 is necessary so that the increase in engine noise corresponds to an approximately equal increase in radio volume.



## Time Delay Switch

T. Huffinley

IC1a is provided with resistive and capacitive feedback to form an integrator with initial conditions. IC1b is in an "open loop" mode so that its output is either high or low depending on its inputs, and changes state when the output of IC1a goes more negative than the voltage set at ZD2. When the output of IC1b goes positive the transistor Q1 biases hard on switching the SCR on. Diodes D1-D4 are to make the SCR conduct on both halves of the AC wave form.

The delay period is set by the components ZD1, ZD2, C, RV1, and

R. If ZD1 is chosen to be 0V5 and ZD2 at 5V, then the maximum delay period is given by  $T = 10 \cdot C \cdot R$ .

$$RV1 = \frac{ZD2}{ZD1} \times R \leq 10 \cdot R$$

The meter is a voltmeter with a fsd equal to the value of ZD2. The switch then operates when the meter reaches fsd. The meter can therefore be calibrated to show remaining delay with 0V equal to T and fsd equal to zero.

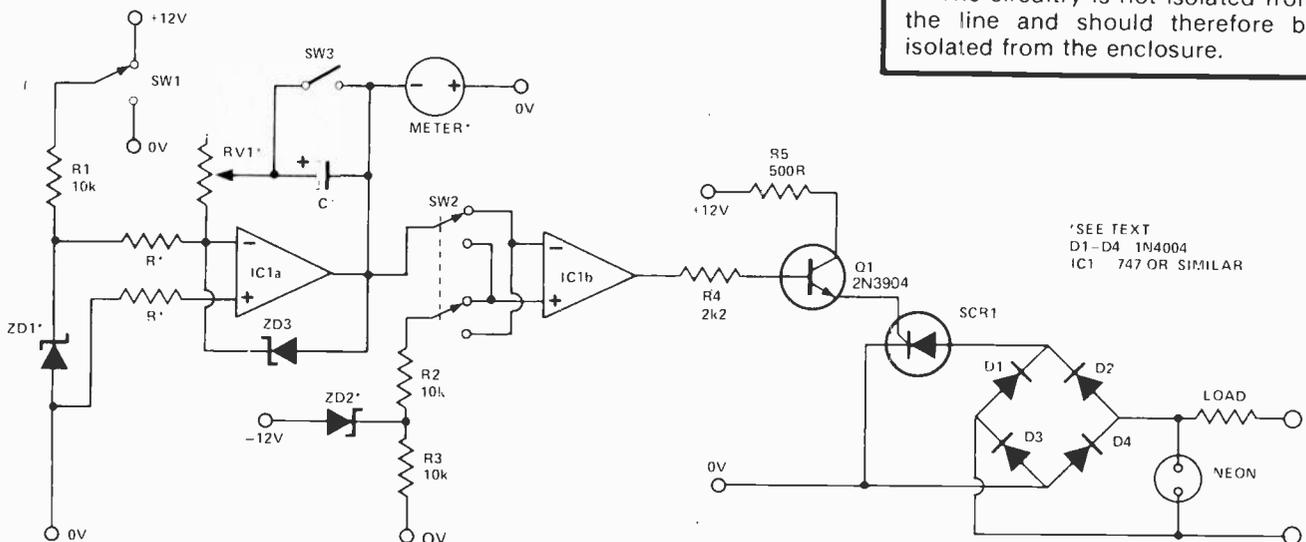
SW2 changes round the inputs of the op-amp so that the output either swings from high to low, or, low to high. SW3 is to reset the time delay which it does by discharging the capacitor. ZD3 should be chosen

to be a value slightly higher than ZD2, this is to stop the capacitor charging beyond a set limit and therefore overloading the meter. SW1 is the run-hold switch. When the switch is at +12 volts the integrator charges the capacitor. When the switch is set to 0V the charging of the capacitor is stopped until the switch is set back to 12 volts.

Q1 is a buffer to avoid loading on the IC and to trigger the SCR. The supply voltage should be 12-0-12 and does not need to be well smoothed as the zener diodes set the timing function.

### Warning

The circuitry is not isolated from the line and should therefore be isolated from the enclosure.



\*SEE TEXT  
D1-D4 1N4004  
IC1 747 OR SIMILAR

# tech-tips

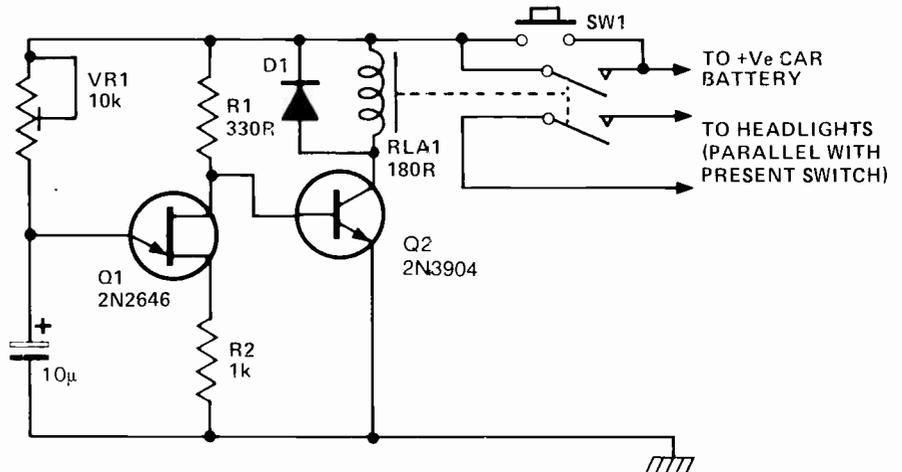
## Headlight Delay Unit

D. Chivers

This circuit will operate a car's headlights for a predetermined time to light up the driveway or path after the driver has left the car, thus enabling him (or her) to open the front door without knocking over the milk bottles.

SW1 is pushed and Q2 is turned on closing the relay and turning on the car's headlights. C1 begins to charge through VR1 until Q1 turns on, turning Q2 off. The relay will then open switching off both the lights and the unit.

The delay is governed by the time taken for the capacitor to charge, which is about one minute.



## Model Railway

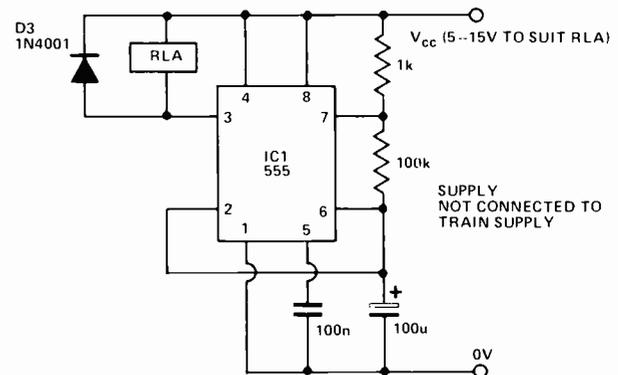
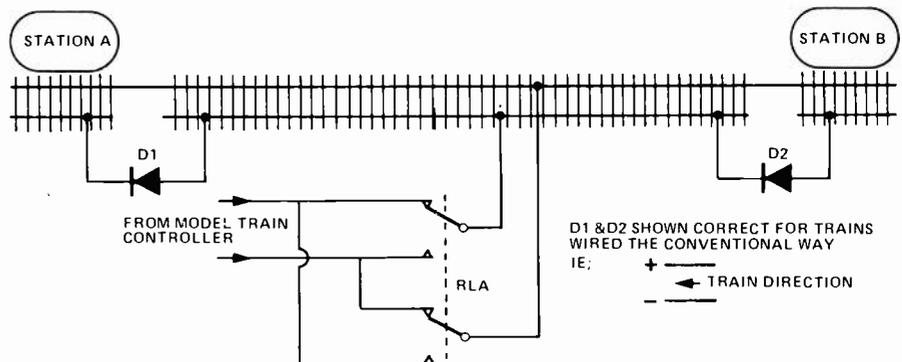
E. A. Parr.

This simple circuit provides an interesting little branch line service for a model railway. A small country railbus starts at a station, stops, then returns to the first station again, the cycle repeating indefinitely.

The track is arranged to have two isolated station sections at each end. The power is fed to the centre long section via a changeover relay, RLA. Diodes D1 and D2 feed the station sections and ensure that a train in station A can only move towards station B and vice versa. The diode connections are correct for conventionally wired trains.

RLA is under control of a 555 timer. This is connected as an oscillator with almost equal mark/space ratio. The period is longer than the time taken for the train to travel from one station to the other. When the train reaches the station, as the diode will be reverse biased, it will stop. When, however the relay changes over the diode will conduct, and the train can return to the first station.

The half period of the oscillator should be made equal to the journey time plus the stop required at the station. The values shown give about 12



seconds which should be sufficient for most layouts.

The stop/start is unramped, but this is

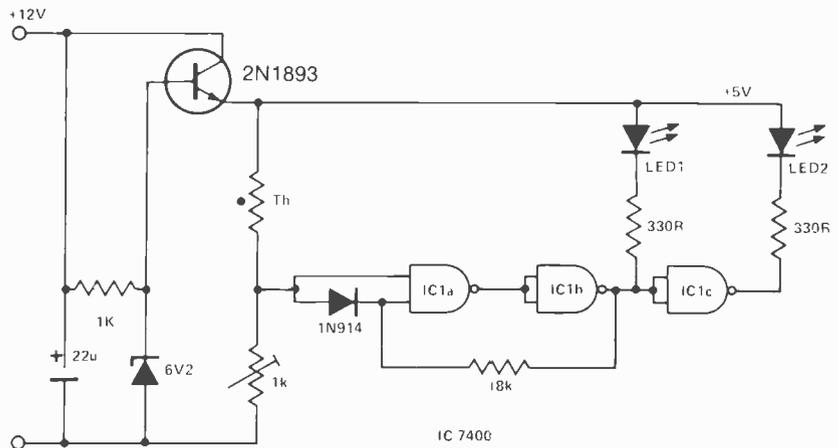
not particularly noticeable at the speed all self respecting branch line trains travel.

## 'Warmth' Indicator

C. J. Cooksey

A simple indicator was required for a gas fridge in a trailer to show when the pilot light had gone out. The sensing element used was a thermistor, attached to the outlet which is 'warm' when the pilot light is on. A rod-type thermistor was used for cheapness, with a resistance of about 3k at 20 C.

Two gates of the 7400 provide a Schmitt trigger with a low hysteresis (determined by the 18k feedback resistor) and the third gate inverts that output. When the pilot light is on, the input of IC1a is high, IC1c output is logic 0 and LED2 (green) is on. If the pilot light fails, the



temperature falls, all gates change state. LED2 goes off and LED1 (red) comes on.

The temperature at which the changeover takes place is set by the 1k preset.

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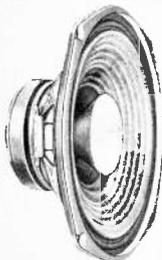
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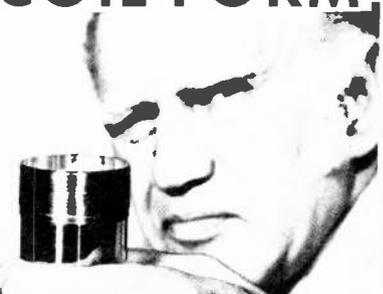
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# INFORMATION

## COMPONENT NOTATIONS AND UNITS

We normally specify components using the recently agreed International Standard. Many readers will be unfamiliar with this but it's simple, less likely to lead to error and will be used by everyone 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 100n, 5600pF is 5n6. Other examples are 5.6pF = 5p6, 0.5pF = 0p5.

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

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We cannot solve the problems faced by individual readers building our projects unless they are concerning interpretation of our articles. When we know of any error we shall print a correction as soon as possible at the end of News Digest. Any useful addenda to a project will be similarly dealt with. We cannot advise readers on modifications to our projects.

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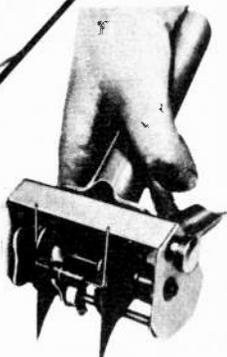
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NOT SINCE THE Second World War has a country been so stripped of an industry so rapidly as Canada and its electronics industry. By the end of this year, our color TV manufacturing industry will have all but disappeared. Whose to blame?

When asking a university co-worker in electronics in the late 60's — an Egyptian — what was his country, he replied: "I'm a citizen of the World!" It didn't have significance then, but it does, now. Not because he was Egyptian, but because electronics being universal, has brought Canadians into competition with the whole world.

briefs later (the last was in 1975-76 — and on a technicality), we lost, a point that is going to be pondered for years to come.

### **COST**

The irony of the situation is evident when, on the one hand, the government asks business to create jobs, while on the other, they refuse to offer even sympathetic support for the industry's dilemma. In fact, they encouraged companies to go into contract electronics (more specialized lines other than color TV). The argument appears to be that Japan — with huge assembly lines only now

### **GRAIN LOBBY**

At this point, one wonders what the powerful Grain Lobby in the West has to do with this. It seems to go like this . . . they, the grain lobby, sell grain (not surprising!); Japan's voracious appetite can never be satiated in wheat and derived products; Japan needs dollars to buy the wheat, which we help them earn by buying their TV's — even if it means Canadian jobs. (In S.W. Ontario alone, over 1000 have gone by the board because of electronic plant shut-downs . . . and the end's not in sight).

In contrast to our neighbours to the south, we don't seem to care. After

# **COLOR TV DEMISE IN CANADA**

By Jim Essex

An electronics plant I subsequently worked in, doing specific lines of electronic work, managed to hold its own. The monitors produced were finding acceptance, not only on the North American continent, but in Britain as well. Not bad for a relatively obscure plant hidden amongst the giants in S. Western Ontario. The plant also made color TV's and they became widely accepted for excellence. Then, the crunch came! Not only had we to compete with the U.S. and Britain, but also with the Japanese.

This became a new dimension in the competitive scheme of things. What had brought it about?

### **IMPORTS**

The growing use of air-freight, the impact of which is yet to be fully felt on our economy was I believe, a principal cause. For example, we even ship cows now by air, where the glimmer of a new industry is just beginning. The breeding and selling of prize cattle has made the sky the limit (if you'll pardon the pun), and if they can ship cattle by air, think what they can do with electronic chassis. It has spelled doom for our electronics industry.

Even our own government makes no apologies for this strange turn of events. Two years ago, some electronic firms pleaded for protective tariffs against the growing land-swell of Japanese TV's entering our country. Even when it was merely a trickle, and we should have done something, we hesitated. By then it was too late. Two

"getting the bit between their teeth", can amortize TV costs over a far greater volume, hence bringing individual TV costs down. Well, that's arguable. We haven't seen any sudden decrease in the cost of color TV's. Nor has the demand slackened appreciably for those who say the lush days of the early 70's are gone. Replacement sets are just beginning to be felt, although black and white set demands long ago tapered off. (According to Statistics Canada for 1976, only 45,744 black and white sets were produced in all Canada, while 393,283 color TV's were made.)

### **LAST HOPE**

What is peculiar to all this is that the last vestige of hope we might have had appears to be gone, even in our own manufacturing element. Mr. David Armour, of the prestigious Electrical and Electronics Manufacturers Association of Canada (EIA for short) said earlier this year, "I am afraid I cannot give you much comfort in regard to the future of the TV industry in Canada", he goes on to point out, "the industry is not just threatened by off-shore production, it is RAPIDLY DISAPPEARING"! And the government apparently doesn't appear to be even interested in our plight. With their TV Duty Remission Program, they are actually telling us to get out — and . . . we'll help you convert to other forms of production!"

seeing the writing on the wall, they're putting quotas on off-shore TV production (coming into their country), while here, all we have done is restrict textile goods to protect the only other vulnerable industry suffering the same fate.

### **BLAME**

Who is to blame for the loss of a once viable industry in electronics in Canada? Some blame labor, and while the statistics are ominous, they are probably not wholly to blame.

According to Statistics Canada, income from all goods and services rose steadily over the years . . . from 62.6 billions in 1973, to 99.76 billions in '76, but productivity did not! Let's look at those figures more closely. Our TV industry, for example, dropped from a high of 509,329 units (both black and white and color) in '75 to 439,027 units a year ago, in 1976. But at the same time, there was a corresponding increase in imported TV's. In other words, the productivity was still there, only the Japanese were making them! And as of now, their chassis are in our cabinets! How can Canadian production of color TV's be other than down!

In 1974, Motorola claimed it had lost 10 millions making TV's. It seems paradoxical that a nation whose technology can put a man on the moon, can't make an inexpensive TV! And the cry is the same from other manufacturers, Philips, Electrohome, RCA — you name them — they all claim losses from color TV.

Are management to blame? Yes, at least in part; the abdication of management in failing to bring about new approaches to utilization of labor — not just labor's built-in escalating cost-of-living "equity of income" thinking — has been one main problem in keeping costs realistic. But in the "lush" days of color TV — the early '70's — everything was fine and labor seemed to have no difficulty producing a workable, reliable color TV at a price Canadians were willing to pay. But we went to sleep.

### VOLKSWAGON TV!

Long ago, we should have been developing what Joe Blaskavitch described as a "Volkswagon TV". A "no-frills" approach to uniquely Canadian production would have assured us a design and usefulness which might have kept us competitive. First, look at engineering, the least productive and the first to become redundant in the mass-production chain of manufacturing.

For some time, we've had a well-thought-out circuit which should have satisfied our needs for years to come. Only stream-lining our production facilities would have done it. Instead, we went on re-designing and re-

designing, even though no actual new changes in the mode of transmission — outside of the introduction of color itself — brought any significant changes to our 525-line system! In short, instead of emphasizing "cosmetics", we threw out the bath water with the baby, when, each year prompted new design changes.

The incontestable fact is that if circuitry remained essentially the same, there wouldn't be the high costs. We pay dearly for engineering "snobbery", adding unnecessary frills "to meet the competition". Better the cost was spent in installing production techniques which would have guaranteed us pre-eminence in the field.

### JOB LOSS

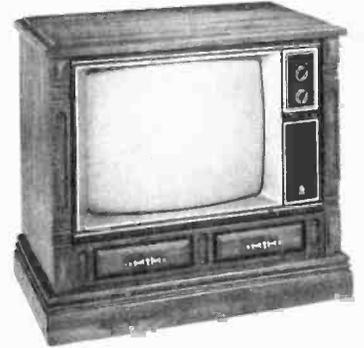
Taking the Canadian manufacturers as a whole, the net loss in jobs from this one industry alone becomes staggering! It means Japan now has a net gain of over 10,000 jobs, at our expense. We could have used those jobs.

### TURN!

Surely, there's more to supporting an industry than the short-term gain of supposedly cheaper labor elsewhere, in Japan? What will happen when

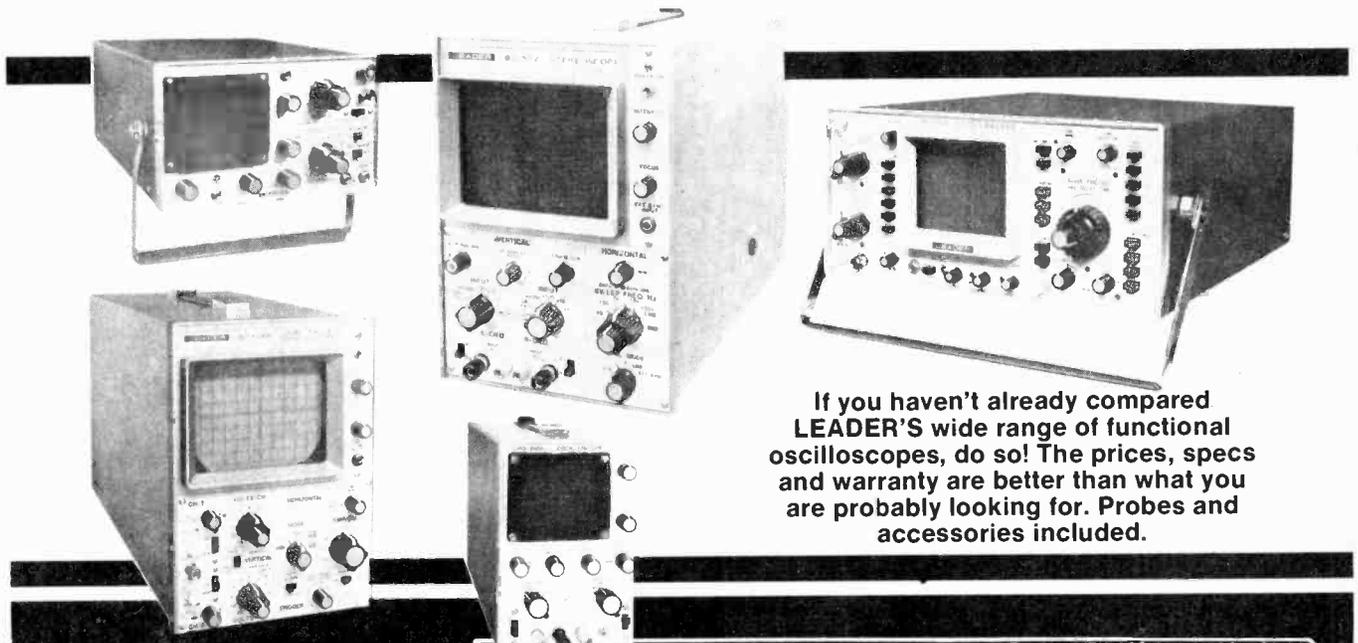
labor rates go up — as surely they will! (Already, sociologists are alarmed at a country which has now 60% of the population (of 112 million), living on only 2% of the land area. With the suicide rate — a measure of a country's stability — rising nearly a third over the already high figure of '75, the present happy labor force may change.

If besides labor rates, air freight goes up the wheel could just turn again and it may not be long before someone realises that we could make the sets cheaper here. But will we be ready willing and able next time?



A 26 inch colour set made by C.G.E. in Canada — one of the few still left.

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