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electronics today

INTERNATIONAL

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MAIL ORDER

Making it work for you

FIRST REVIEWS • FIRST REVIEWS

Hewlett Packard HP-11C Calculator and the Casio Hand-held Printer!

- Digital Capacitance Meter Project
- Infinite Improbability Detector to Build!
- Robot Controller- Get Things Moving!

..AUDIO....COMPUTING....MUSIC...RADIO....ROBOTICS..

Unwanted glitches can often be seen at the DAC output (Fig. 7). These are caused by the data that drives the DAC being skewed in time and also by race conditions inside the DAC. Glitches tend to be largest for major code changes. Much of the energy spectrum of these glitches lies within the system bandwidth and so they cannot be removed by low-pass filtering. However, they can be snipped out with electronic switches or smoothed over with fast-acting sample and hold units.

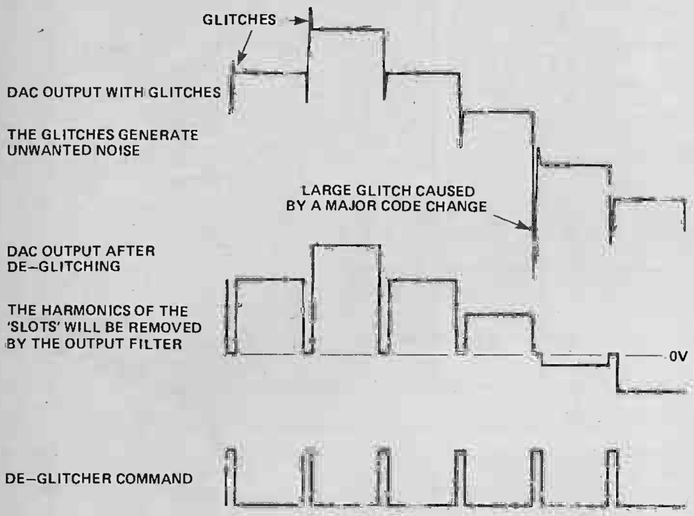


Fig. 7 Deglitcher operation.

In order for the ADC to produce a conversion without errors, the input signal should be stationary. A sample and hold unit is used to freeze the input signal, with a droop of less than 1 LSB, while the ADC produces a conversion (Fig. 8). Figure 9 shows the system timing diagram for Fig. 5 assuming that an eight bit ADC is used.

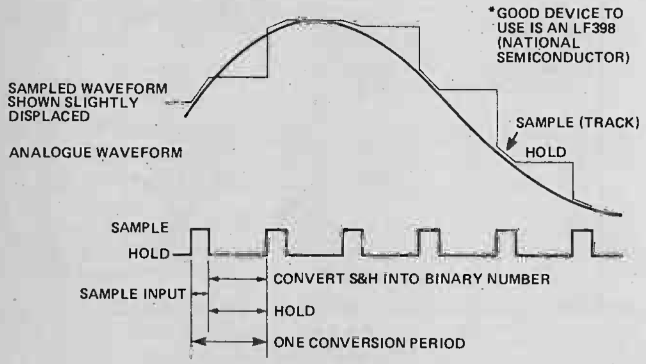


Fig. 8 Sample and hold operation.

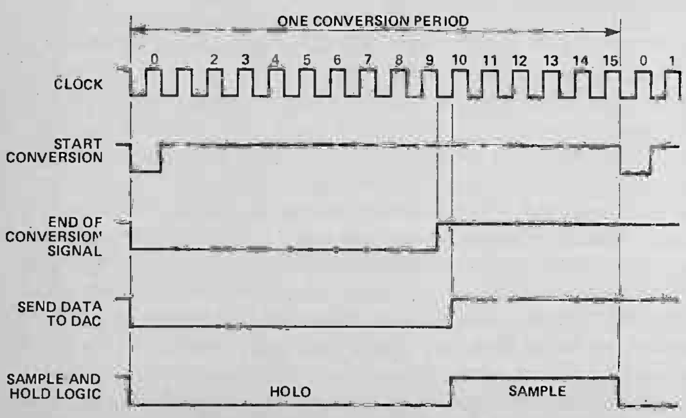


Fig. 9 The timing diagram for the circuit in Fig. 5.

Circuits

DACs can be purchased as whole units or they can be assembled out of assorted electronic parts, as shown in Fig. 10.

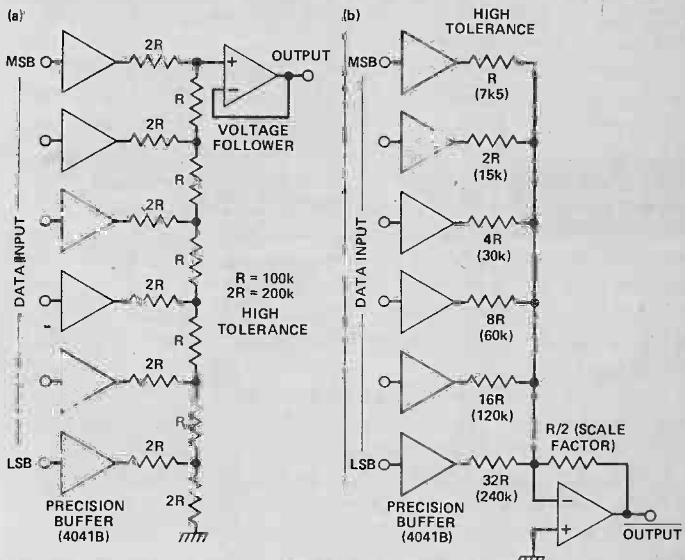


Fig. 10 Two DACs using discrete components. (a) R/2R DAC (b) (b) binary power resistance DAC.

The R/2R network is often used because you only need two values of precision resistors. You can obtain high accuracy using this circuit if 100k and 200k resistors are used, but the speed tends to be a bit slow. The binary power network requires a large range in resistor values and so is often limited to small bit size DACs. Both of these circuits can be used as DIY DAC implementations. Monolithic DACs use various resistor networks and current steering designs. I once opened up a 16 bit DAC to discover that the top eight bits were made from laser-trimmed precision resistors, while the bottom eight bits used a standard cheapo eight bit DAC.

ADCs can also be purchased whole or they can be constructed out of separate circuit elements. Generally an ADC contains a DAC plus some sort of test logic. The counting ADC shown in Fig. 11 demonstrates this. The clock signal causes the binary counter to count up, which in turn causes the DAC to generate a rising staircase waveform. When this is equal to V_{IN} the clock is disabled, and the output word is the digital equivalant of the analogue input. Another type of counting ADC uses an integrator instead of the DAC to form a device known as a dual slope ADC. These devices are capable of very high accuracy (up to 14 bits), they are relatively low cost, but they are rather slow; some devices only produce a few conversions per second. Counting ADCs are often used as the basis for digital voltmeter chips (DVM). Figure 12 shows such a device. The input voltage is directly converted into the data to drive a 3½ digit LED or LCD display.

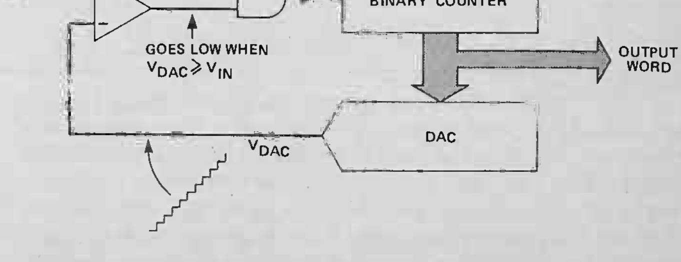


Fig. 11 A simple counting DAC.

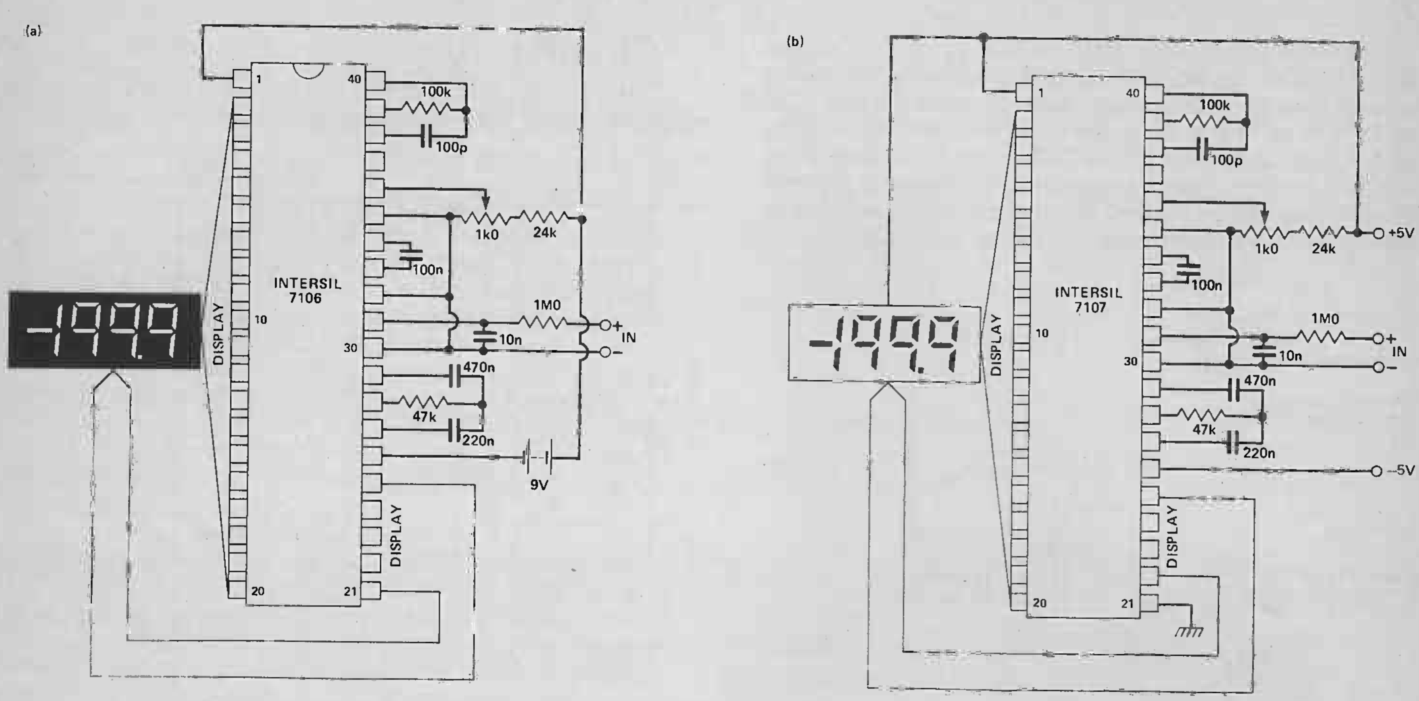
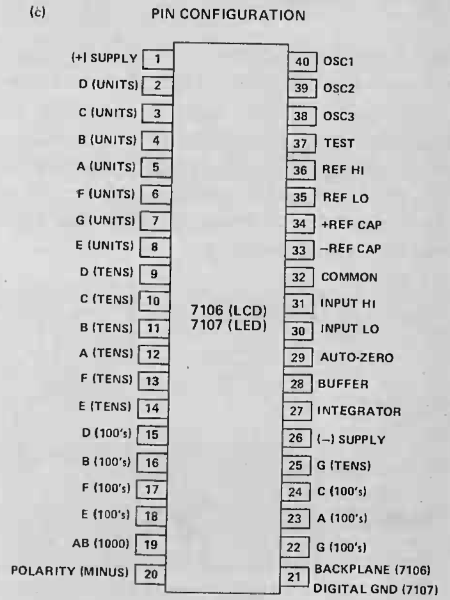


Fig. 12 DVM chips and application circuits.



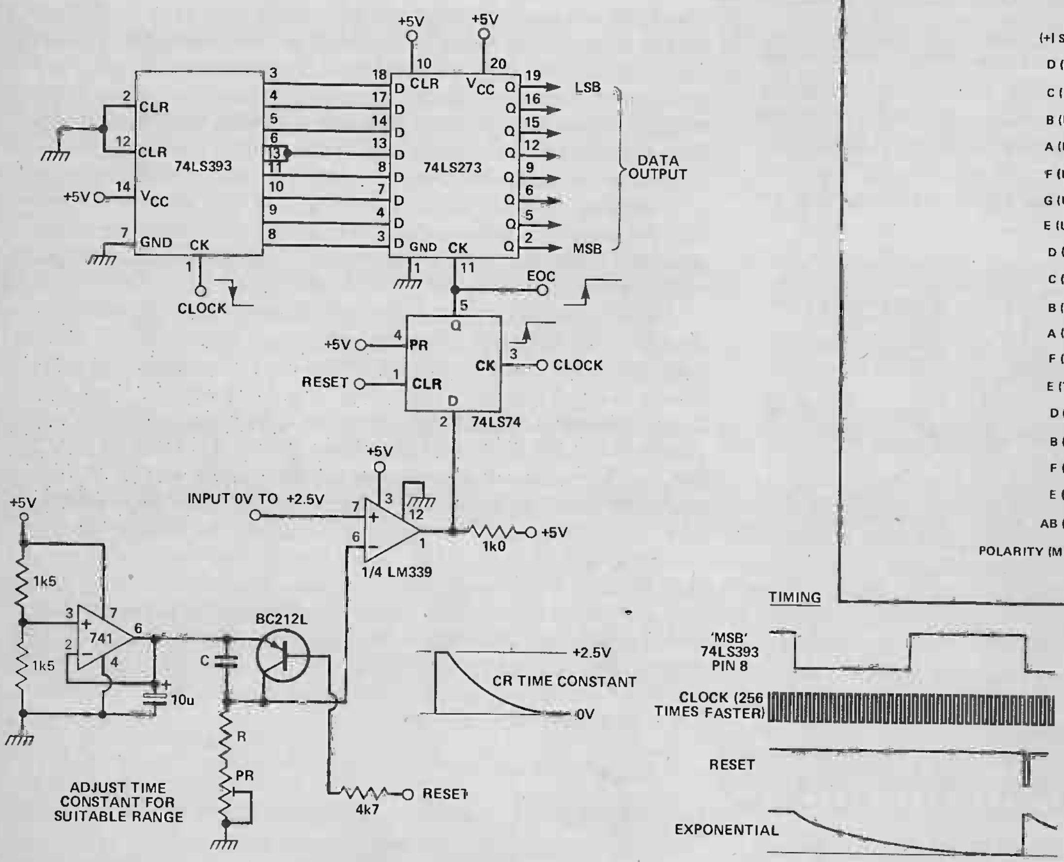


Fig. 13 A logarithmic ADC can be constructed quite easily.

ADCs which use linear integrators have a linear transfer function. If the linear integrator is replaced with an exponential waveform then the ADC will then have a logarithmic transfer function (Fig. 13). This circuit is useful for converting a unipolar input into a logarithmic quantity, such as voltage into decibels.

Fast ADC conversions need a more speedy method than a counter; for example, a counting eight bit ADC may need to count up to 256, making a test on each count. This is slow. However, by using a successive approximation register (SAR) a result can be obtained in a mere eight tests, which makes the whole process 32 times faster for an eight bit conversion. The ZN427 is an ADC which employs this method (Fig. 14). A digital number that represents the value of the input voltage is generated by performing a series of tests. A start conversion signal (SC) initiates the process. The SAR sets the MSB to a logic 1 and all the other bits are set low. The DAC produces half the full scale voltage and compares it to the input signal. If the DAC voltage is greater than the input voltage the MSB is set low;

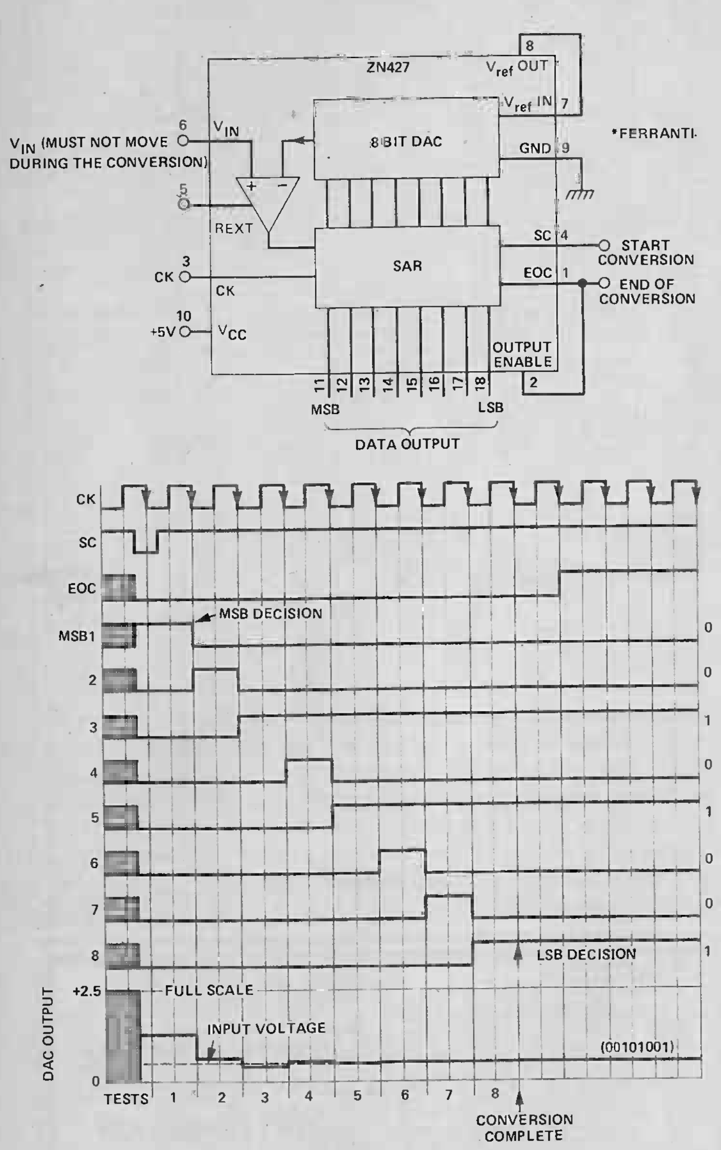


Fig. 14 ADC conversion using a successive approximation register. device (the ZN427). The conversion time for this device is eight clock cycles; the timing diagram shows how this is accomplished.

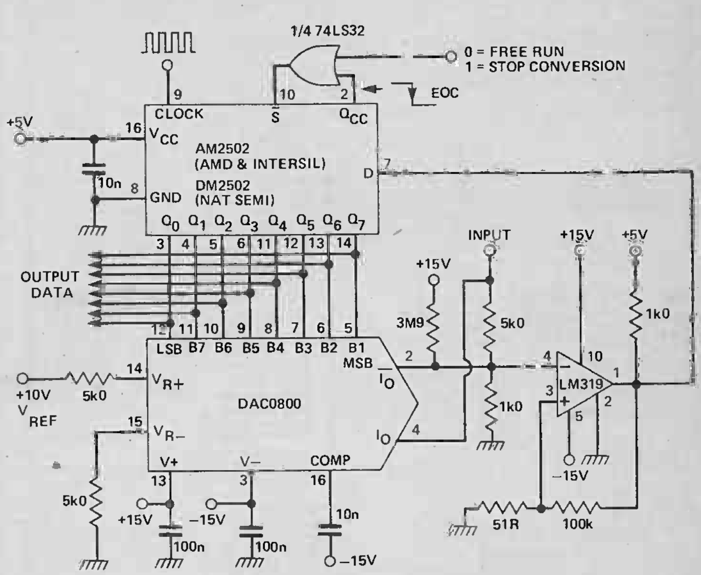


Fig. 15 An eight bit linear DAC using the DAC0800 plus an SAR unit.

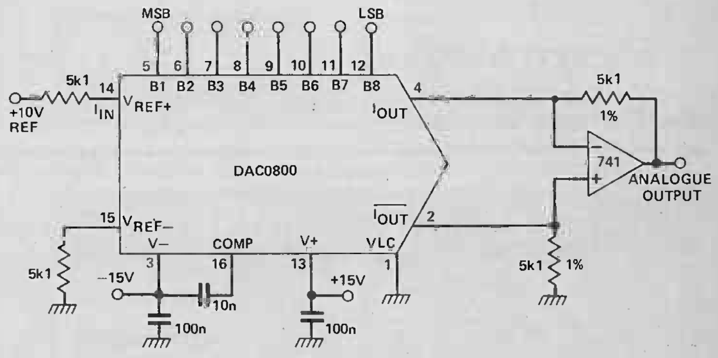


Fig. 16 An eight bit linear DAC.

otherwise it stays high. On the next clock pulse the SAR tests the second bit and then sets it to the appropriate state. The SAR continues to test all the other bits in sequence. When it is finished it generates an end-of-conversion (EOC) signal. The digital code then driving the DAC precisely represents the input signal.

SAR units are available as separate ICs, as shown in Fig. 15. In this circuit an eight bit SAR is used in conjunction with an eight bit DAC and computer to build an eight bit ADC. Different size SARs are available for larger converters. Figure 16 shows the same DAC used on its own. The DAC0800 is a linear eight bit multiplying current output DAC — the input reference current is multiplied by the input binary code. With this particular device a 40 to 1 reference current range is possible. Linear converters can be used for audio applications, but an eight bit converter only has a 48 dB dynamic range. This makes audio signals sound very crunchy at low levels. One way to overcome this problem is to use external audio compressors and expanders to effectively increase the dynamic range (a Signetics NE570 for example). Another solution is to use a companding ADC/DAC, as in Figs. 17 and 18. This device has a bipolar piece-wise-segment logarithmic transfer function; small signals are defined with far more resolution than large ones. The result is that the dynamic range is increased to 72 dB, but at the expense of increased quantization noise. This quantization noise is not

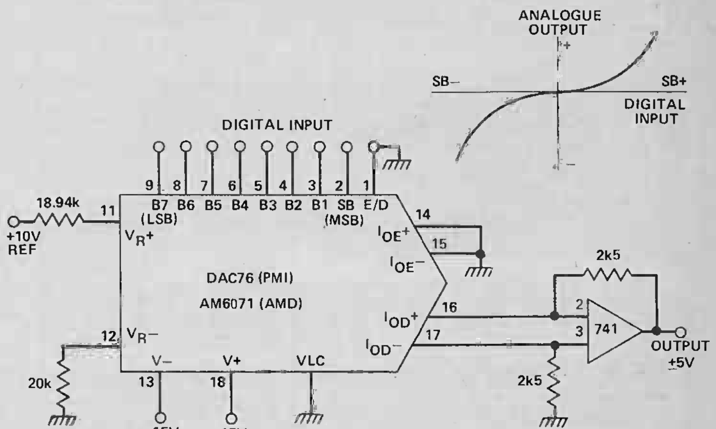
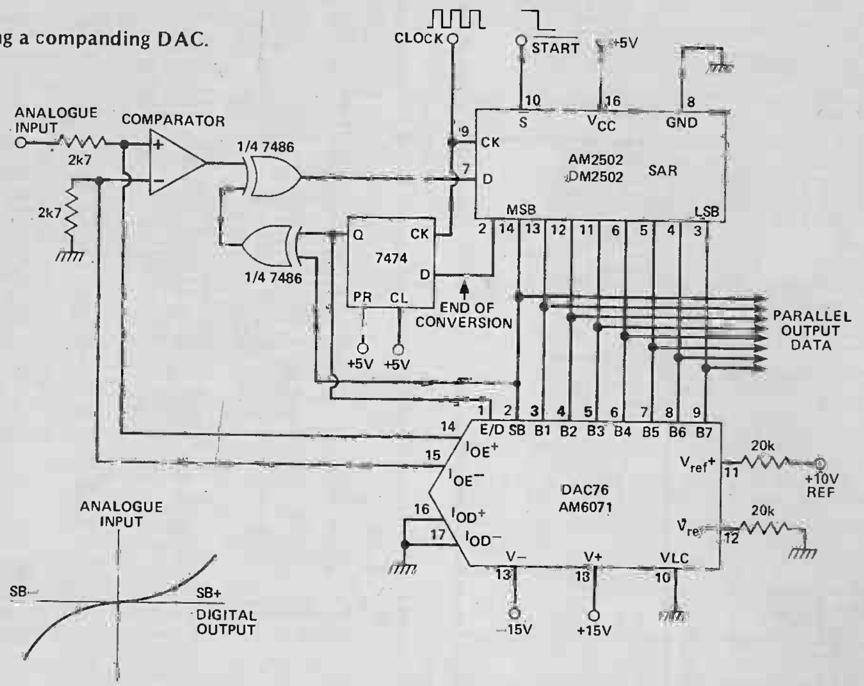


Fig. 17 An eight bit companding DAC.

Fig. 18 An eight bit ADC using a companding DAC.



noticeable on speech waveforms, but it can be heard when low frequency tones are converted.

Design Method

When designing a converter system the following decisions should be made. Select the bit size of the system on the basis of dynamic range, resolution, noise performance, and decide between a linear system or a companding one. Select a system bandwidth and from this determine the clock frequency and the break frequencies of the filters (if you are going to have filters). Draw out the system timing diagram, then the circuit diagram. There is now a very wide range of parts to choose from, so a look through as many current data books as you can manage is advisable. **ETI**

AUDIOPHILE

From the country that brought you the Alps, a new peak in hi-fi receivers. This month Ron Harris listens to the Revox B780; there's good news for seekers after dbx discs, too.

No will power at all, some people. Just can't resist doing something for no other reason than that they want to. Weak as British Rail tea. . . I've wanted to try out the Revox B780 receiver ever since it came on the market and so it took little self-persuasion to begin submitting to my urges again.

Take a look at the photo and perhaps you'll understand the interest. Much as I abhor unnecessary circuitry in audio equipment, such a front panel still exerts the siren call of technology pretty loudly, does it not? What's more, there doesn't seem to be much there that is not needful unto mine ears. Intriguing.

Ostensibly the B780 is an FM-only receiver, specified at 70 W per channel into 8R, which has 18 preset stations and synthesised tuning. The amplifier section will also allow, by use of electronic swtiching, one input to be recorded while another is replayed. There is facility too for fitting Dolby circuits onto the tuner section — should Dolby broadcasts ever lurch from their grave and threaten our bureaucracy with better sound quality.

The digital displays on the panel show tuned frequency, tuning 'mode' or station and input/output selected. That chrome strip along the top edge hinges down to reveal yet more controls, such as threshold for stereo and mute, speaker select, tuning meter and record on/off.

Panel Tuning

The presets are accessed by use of nine buttons, each of which stores two stations. A tenth selects the 'mode' for the switch at the time of use. The display indicates which part of the memory you are addressing.

No wonder they need an MPU to control this lot, it's just a *little* complicated! The central tuning strength meter unusually displays in microvolts, giving a direct reading of station strength.

Battery back-up is provided to ensure that the 18 stations you spent hours entering into the B780 (assuming you can *find* 18 stations) are not lost when you switch off for the evening.

Tuning between locations on the band is done digitally in steps of 25 kHz, although precise station frequencies can be set, using the station selector as a 0-9 keyboard!

Ample Tones

The amplifier section boasts a mid-range tone control — 'presence' if you must. This acts at around 3 kHz and could be useful in particularly heavily furnished rooms, for example, or to correct dull-sounding loudspeakers. I suspect, however, that if you can afford a B780 you are more liable to have trouble can afford a B780 you are more liable to have trouble with the Chesterfield and Chippendale than cheap speakers so the former is the more likely reason!

Filtering is fairly gentle at 12 dB/octave below 50 Hz and above 8 kHz when selected. Pretty innocuous really and at this price I think something better should have been provided. As the treble control has the same turnover frequency as the filter, one of them is redundant by definition.

Heatsinking for the power amp is more than adequate, occupying most of the back panel of this massive unit. (The B780 weighs 37 lbs and measures 18" x 6½ x 17½. You won't move it around very often). This also constitutes the major complaint against the Revox, in that it is practically impossible to get at the sockets on the back panel. The heatsinks overhang them by around four inches, thus rendering any hope of making connections from above a forlorn one. Ridiculous.

Testing Again

Test bench results for the tuner simply got to show how far the electronics side of hi-fi has progressed. My test equipment had its limits exceeded on just about everything. The tuner is technically well-nigh perfect given the limitations of the signal it has to receive.

The amplifier is a first-class design also, while not being the pargon of virtue it would need to be, to match up to the FM circuits. The power output is well above spec, delivering over 90 W across the whole audio band. Burst power at 1 kHz exceeded 160 W, showing good headroom. Burst power into 4R was not so well maintained as it might have been, and this *could* mean that the B780 could encounter difficulty with awkward loads. Throughout my tests no problems occurred with any of the units we tried, so don't let this deter you if you're B780 bound.

Noise figures are exemplary, as are distortion factors. Power bandwidth is a little wide at 130 kHz, especially as the disc input is wide open for most of this. Overload on this input was high at around 30 dB.

In Listening Use

One undeniable consequence of such massive precision engineering is to inspire confidence in the user. Switch the Revox on and it is inconceivable that it will not work, effortlessly, first time and forever. Which it did. (Once I'd spent two hours trying to connect up to those dumb sockets.)

The tuner is totally beyond reproach. It produces an FM reproduction which left anything I compared it to for dead. If you want to hear how good FM really can be, listen to this! As the unit is available separately as a stand-alone unit then *that* gets my wholehearted instant recommendation! Eighteen presets I can't use and the two function buttons are 'fussy' in use.

up and a Mayware T-24 II step-up. In addition the new Shure MV30H was tried. Loudspeakers? Mainly KEF 105 II.

The amp proved to have a distinct character, being rather 'warm' in nature. The dynamics were good and the bass well maintained. Mid-range was well portrayed but not as open as some of the best specialist units. A top-class performance then, and one which would satisfy most listeners, but is a fraction short of the super-league. The tuner on the other hand *is* in the highest possible class.

It is difficult to criticise the Revox — what do you say about a receiver that has everything? It is beautifully made, will continue to work for ever and gives a first-rate audio performance. At around £1000 it is a splendid example of audio technology that would grace any system by its presence.

Tuner Section

Image Rejection	100 dB
IF Rejection	100 dB
Capture Ratio	1.5 dB
Selectivity (alternate)	75 dB
AM Rejection (75 kHz deviation)	70 dB
Freq Response (+ 1 dB)	25 Hz–15 kHz
THD (1 kHz)	0.1%
Sensitivity	1.9 uV
S/N Ratio	–68 dB (ref 1 mV input)

Amplifier

Power Output (into 8 R) : 95 W RMS (from 20 Hz – 20 kHz)
104 W (1 kHz)
160 W (Burst Power)
Power Bandwidth: 150 kHz
IM Distortion : 0.03%
THD : 0.05%
Freq Response : 20 Hz – 20 kHz + 1 dB
Damping Factor : 75
S/N Ratio : power amp : 90 dB
phono : 75 dB
aux etc : 80 dB

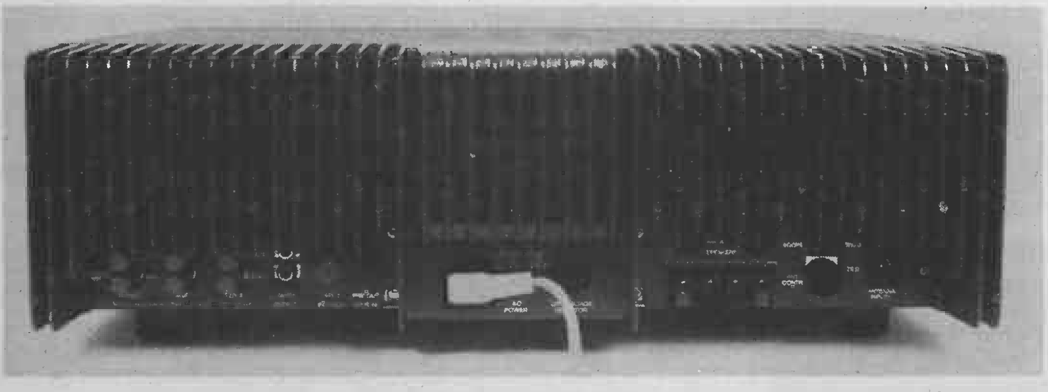
Above: test reults for the Revox B780 receiver. Tuner results would place the unit in the "Super-fi" class and are unimpeachable. The amplifier section, whilest being very good in themselves, do not come up to the same standard—quite. Overall, despite the very high price tag of around £1000 the Revox offers a good return for the money in terms of sheer engineering.

dbx Discs

Following our report on dbx encoding techniques some months back, we received some communications from readers wanting to know if any of the discs were actually available, and if so — where from?

Diligent research has turned up a company called "Harper Music", of Maidstone in Kent. Turns out, once turned up, that they have a catalogue of some 58 recordings at present and this is constantly expanding.

They also supply decoders, the most economical for disc use being the Model 21 which they kindly loaned us to have a listen to dbx ourselves, in somewhat domestic surroundings. A number of LPs were also gratefully received so, boxes in hand, I adjourned home to wire it all up!



Left: the Revox rear. Massive heatsinks are an idea to be encouraged, EXCEPT in this case. Revox have managed to hide the I/O sockets underneath the metalwork in such a way as to guarantee a blown temper to anyone trying to wire up the unit.

Also note the DIN speaker connections. Tsk. Tsk. On a unit of this class? I think not...

Above: the Revox with its hair down, revealing the little used and hence well-disguised controls for tuner threshold determination, speaker output selection and record output on/off.

The blank panel in the centre pulls out to reveal the hidden back-up battery power. This is to preserve the settings on that amazing array of tuner controls.

Set Up

The 21 decoder fits into a system at the tape I/P and has the facility for replaying encoded tapes, should they become available in the UK. Monitoring of tape is possible and a bypass switch is fitted for conventional play. No mains on/off though, which is a pity.

To recap briefly on the principles of dbx, it is a compression/expansion noise reduction system in which the signal is linearly compressed before recording, then expanded by the decoder upon replay. The expansion will drop any noise into inaudibility at the same time, and a possible dynamic range of 90 dB is claimed. (Normal records do well if they manage 50 dB.)

As the photos show, the 21 is well constructed and arrives pre-aligned, except for output level. Internal presets determine the expansion ratio and these are *not* to be tampered with!

Disc Or Not Disc?

The most immediately noticeable effect of dbx is to remove the background noise of the LP. Until the music begins there is total silence! An unnerving effect, I can tell you. The urge is to wind up the volume until you hear something. . . at which 'Police' burst into song at 100 W and you do a back-flip over the coffe table, ear drums shattered and eyes bulging. . .

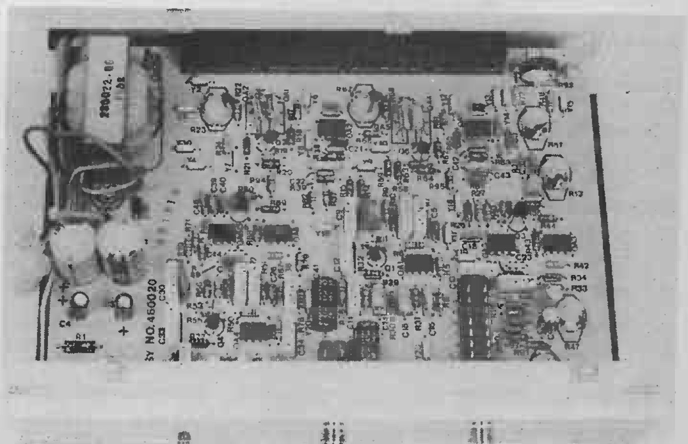
In short, dbx works! The added noise reduction over Dolby has to be heard to be believed. Record noise ceases to be audible and dynamics take on new life. During initial trials with the 21, an aging amplifier blew its fuses when asked to cope with the 'William Tell Overture', dbx style!

My only doubt concerns the fidelity level of the decoder itself. I have 'normal' recordings of a couple of the LPs supplied as dbx and the comparisons showed up some definite colourations. In addition, digital classical recordings with dbx on, simply sound dull and lifeless with no noise, as opposed to dull and lifeless with surface noise!

This is no criticism of dbx, however, it's just that I have yet to hear a digital recording that sounds believably live — all that sense of ambience gets lost amid the bytes. dbx is a system that works well, and I feel that the decoder is probably not letting the best of the method be heard to its fullest advantage. The Model 21 costs only £64.90 from Harper and I feel a 'up-market' version is called for (although for all but the purists the 21 will probably suffice admirably).

Below: the dBx 21 decoder, in both dressed and denuded form. Controls have been kept to such a minimum that there is no mains switch. A bit silly that, if you ask me.

The internal shot shows the very neat layout and high standard of construction. Note the chips with the index numbers filed off!



Cats and Lists

Below is a list of the recordings currently available for those who ask; Harper Music can be found at PO Box 40, Maidstone, Kent. A catalogue can be yours for the asking, and it includes many other 'Supercut' discs. Prices for the dbx LPs run at around £10-£13.

INSTRUMENTAL

THE ART OF RICHARD STOLZMAN: Saint-Saens; Honeggar; Poulenc; Debussy; Valecillo; piano
THE ART OF JULIUS BAKER: Poulenc; Dutilleux; Reinecke; Vallecillo, piano
SCRIABIN: 24 Preludes Op. 11; 5 Preludes Op. 74 Poem Op. 32 Nos 1; Ruth Laredo piano
RICHARD STRAUSS: Piano Quartet in C minor
Los Angeles String Trio
THE VIRTUOSO HARP: GLINKA: Variations of a Theme by Mozart; LISZT/RENIE, etc. Susan McDonald—harp
SONIC FIREWORKS VOLUMN 1: Music for Organ, Brass & Perc. J.S. Bach, Copland, Brahms, Bliss, Gigout
Vierne, Richard Morris; organ; Atlanta Brass Ensemble
SONIC FIREWORKS VOLUMN II: Music for Organ, Brass & Perc. Strauss, Widor, Dupre, Stanley, Mouret, Louis Couperin, Bach; Atlanta Brass Ensemble.
BAROQUE BRASS: Selections by J.S. Bach, Handel, Gabrieli etc.; The Empire Brass Quintet.
THE ART OF LAURINDO ALMEIDA: Galilei, Sor, de Visee, Grandos, Almeida

LIGHT CLASSICAL

A STRAUSS FAMILY GALA: John Georgiadis conducting the Johann Strauss Orchestra.
THE GLORY OF CHRISTMAS—POPULAR CAROLS: arr by Richard Hayman & others—Royal Phil. Orch. & Ambrosian Chorus
OFFENBACH OVERTURES: Orpheus in the Underworld; la Vie Parisienne, etc., Kunzel;-Cincinnati Pops Orch.
POMP AND CIRCUMSTANCE: Various Marches: Elgar; Verdi; Tchaikovsky; Beethoven; Berlioz; Meyerbeer; Fucik; Delibes; Johann Strauss, Jr. & Sr. & Herbert
Cincinnati Pops Orch. & May Festival Chorus
AMERICAN FANTASIA: Richard Rodgers—Carousel Waltz; Slaughter on 10th Ave. Jerome Kern; Herbert; Hayman; Sousa; Kunzel—Cincinnati Pops Orch.
A PORTRAIT OF GEORGE GERSHWIN ON BROADWAY AND IN HOLLYWOOD: Cincinnati Pops Orch.

JAZZ

CAL TJADER: La Onda Va Bien
LIVE AT MONTREUX—SUMMER 1979: The LA^4 Laurindo Almeida, Brown; Hamilton & Shank
LAURINDO ALMEIDA—New Directions
OSCAR PETERSON: Action
JOE PASS: Intercontinental
DAVE BRUBECK QUARTET: Tritonis
JOE SAMPLE, RAY BROWN, SHELLEY MANNE: The Three
THE DRUM SESSION: Paul Humphrey, Shelley Manne, Willi Bobo, Louis Bellson
GEORGE SHEARING & BRIAN TORIFF: On a Clear Day

FILM MUSIC

DIGITAL SPACE—SPECTACULAR MUSIC FOR FILMS: Themes from Star Wars; Airport; The Big Country, etc. Moulton Gould; LSO
JOHN WILLIAMS: The Empire Strikes Back
MIKLOS ROZSA: Suites from the Epic Films: Ben Hur; King of Kings; and El Cid. - Muller-Lampertz, Hamburg Concert Orch.

CLASSICAL — ORCHESTRAL

TCHAIKOVSKY: Romeo & Juliet—Nutcracker Suite
Philharmonia Hungarica
DUKAS: The Sorcerer's Apprentice: CHABRIER—Espana
DEBUSSEY: Fetes, etc. Philharmonia Hungarica
BIZET: Carmen Prelude; BERLIOZ: Rakoczi March
RIMSKY—KORSAKOV—Procession of the Nobles
Philharmonia Hungarica
ROSSINI: The Thieving Magpie Overture, etc. BERLIOZ: Rakoczi March—Philharmonia Hungarica
LISZT: Les Preludes—DVORAK—Slavonic Dance—SMETNA: The Moldau Philharmonia Hungarica
HANDEL: Water Music Suite, Aria from Concerto Grosso
J. S. BACH: Air of a G String; Philharmonia Hungarica
MORTON GOULD: Latin American Symphonnette; Cotillion Philharmonic Waltzes—LSO
RIMSKY KORSAKOV: Scheherazade LSO
PACHELBEL: Canon; ALBINONI: Concerto in F for trumpet & strings; Cambridge Chamber Orch. & Empire Brass Qrt.
RAVEL: Bolero; SHOSTAKOVICH: Festive Overture; GINASTERA: Estancia Ballet Suite; LSO
TCHAIKOVSKY: Capriccio Italian; RIMSKY-KORSAKOV: Serenade in E, etc. RPO
HOLST: The Planets
St. Louis Symphony Orch.
RICHARD STRAUSS: Till Eulen Spiegel's Merry Dance, etc. Cincinnati Symphony Orch.
STRAVINSKY: Petrouchke; PROKOFIEV: Love for Three Oranges Suite — Minnesota Orchestra
COPLAND: Rodeo; Billy the Kid; Fanfare for the Common Man—Dallas Symphony Orch.
A SLAVONIC FESTIVAL: Smetans; Dvorak; Mussorgsky; Borodin; Khachaturian—St. Louis Symphony Orch.
RACHMANINOFF: Symphonic Dances
Dallas Symphony Orchestra
MUSSORGSKY: Pictures at an Exhibition; Night on Bald Mountain; St. Louis Symphony Orch.
RAVEL: Dephnis et Chloe Suites Nos 1 & 2 Minnesota Orch.

CONCERTOS

GERSHWIN: Rhapsody in Blue; An American In Paris; Concerto in F; Cuban Overture; "I Got Rhythm" vars.
Promendade; Second Rhapsody; Lullaby; Catfish Row; St. Louis Symp. Orch. (3 records)
RACHMANINOFF: Piano Concertos Nos 1-4 & Rhapsody on a Theme of Paganini; St. Louis Symp. Orch. (3 records)
VIVALDI: The Four Seasons
Cambridge Chamber Orch.
RACHMANINOFF: Suites Nos 1 & 2 for two Pianos LSO
ALMEIDA: First Concerto for Guitar and Orchestra
Los Angeles Orchestra de Camera
GRIEG: Piano Concerto; Norwegian Dances; Wedding Day at Troldhaugen; Utah Symphony Orchestra.

POPULAR /FOLK

POLICE: Zenyatta Mondata
LOGGINS & MESSINA: Full Sail
BLOOD, SWEAT, & TEARS: Blood, Sweat, & Tears
NEIL DIAMOND: His Twelve Greatest Hits
THE WHO: Who Are You
HERB ALPERT: Rise
THE CARPENTERS: Close to You
PEGGY LEE: Close Enough for Love

ETI

INFINITE IMPROBABILITY DETECTOR

For galactic Hitch-hikers everywhere, the ideal travelling companion for your Electronic Thumb and Guide to the Universe. Designed and developed by Rory Holmes.

Nowadays there are many scientists of the paranormal who will assure us that a person is able to influence and control matter by the direct action of his mind alone. They call this effect psychokinesis; it's akin to the claims of the familiar ardent gambler who is convinced he can influence the throw of a dice, or the spin of a roulette wheel, to come up with his lucky number.

ETI, with an open mind, decided to design a machine which would give a clear indication of any such psychokinetic action directed on it. We thought that a 16 ton weight linked to a movement detector might perhaps give the sceptics an unfair advantage and so decided that the slightly smaller and rather more capricious nature of the electron might be more amenable to the delicate influences from the psyche. In fact, the electron itself does not have to be influenced, but rather those forces involved in producing the random movement of thermally and electrically excited electrons. These forces are completely unknown and unpredictable; that's why they're called random! It's this nature of randomness and its ultimate source which has fascinated people for years; hence the favourite pastimes of staring into the coal fire or watching the ocean waves.

In our machine, the random motions mentioned above are linked electronically to control the movement of a dot of light round a circle of LEDs. This dot of light obviously shouldn't rotate too far in any one direction, but should dither around — both clockwise and anti-clockwise — keeping the same position on average. The light moves at regular clock intervals and at every movement it has, theoretically, a 50-50 chance of going in either direction.

We called it the Infinite Improbability Detector for two reasons. First, in the absence of any assumed psychokinetic intervention from a lively mind, it is incredibly unlikely that it will rotate consistently in one direction. Second, we're Douglas Adams fans. The probability against continuous rotation is, in fact, two to the power of 16 to the power of the number of revolutions. Therefore, if this occurs, *don't panic* — we have proof of an external and paranormal force.

It is hoped that if psychokinetic ability *does* exist, then it should certainly be able to bias our machine to rotate in one direction or another.

In use the operation is simple — if a little indefinable. There is a rate control for setting the overall speed of movement of the light and an on-off switch. After switching on and setting the desired speed, the rest is really up to you. The idea is to concentrate on the moving dot of light in order to make it consistently rotate in one direction.

ETI would be delighted to hear from any readers who can demonstrate impressive results.

Construction

It isn't difficult to obtain a neat and smart appearance with this project (see the photos of our prototype). There are only two front panel controls, making interwiring and assembly completely straightforward. The only point to watch during construction is the mounting of the LEDs; these should be left until the rest of the PCB is assembled.

Solder in all the other components, following the overlay guide. It's easier to start with the links and sockets first, then the passive components. Lead out wires to the pot (RV1) and battery supply can also be connected at this stage.

After assembly the LEDs (LED1 to 16) can be mounted with their anodes towards the centre of the circle, but do not solder them at this stage — the LEDs must be fitted into their front panel holes to provide the right uniform height above the PCB before they are soldered. Take a piece of tracing paper and mark the exact hole positions from the copper track pattern. This can then be transferred to the inside of the case front panel and the positions centre-punched before drilling the holes to a width exactly the same as the LEDs. The sloping front Vero box we used has a detachable aluminium front panel which makes this an easy process. The LEDs are then fitted into the holes and the correct board clearance height can be found before they are soldered up.

We found that after soldering, the good fit of the LEDs was quite enough to hold the PCB in place. Two PP3 9 V batteries were fixed inside the case with adhesive pads and battery clips were used to connect them up to the switch and the PCB. The potentiometer and switch are mounted through two holes on the front panel, after wiring on the front panel, and after wiring them up from the overlay diagram the device can be tested.

Switch on and set the speed control to its lowest rate; if all is well the illuminated LED should move backwards and forwards round the circle in a random manner with no preferred direction. If it does rotate in only one direction, then there is either a construction blunder or the portion of the Universe occupied by the detector has passed through a region of Infinite Improbability.

HOW IT WORKS

IC2 is a four bit up/down counter, set to count in binary mode and thus having 16 count states provided on its four output lines. These binary output lines are decoded by IC3 and Q2 to give a one-of-16 output for driving LED1 through LED16.

IC3 is a CMOS one-of-eight analogue decoder, whose outputs are connected to the anodes of two sets of eight LEDs. The select lines on pins 9, 10 and 11 will take one pair of anodes to positive via R10 for each address. When the D output of IC2 is logic low the cathodes of LEDs 1 to 8 are held low, thus illuminating one of them and Q2 will be switched off. When D goes logic high the reverse takes place, with Q2 now turned on to provide a ground for the cathodes of LEDs 9 to 16. Thus each count state will correspond to one LED being illuminated.

Assume for the moment that the up/down control on pin 10 of IC2 is kept high (the 'up' mode); then, for each clock pulse applied to pin 15, IC2 will move to its next count state from 0 through to 15. Each LED in the circle will in turn illuminate to indicate that particular count, so producing the effect of a rotating dot of light.

However, the up/down control is made to continuously change in a random fashion and at a much faster rate than the clock period. The timing diagram of Fig. 2 shows the clock as a square wave. The CMOS counter IC2 only changes state as the clock moves from low to high and the direction of its counting can only be changed when the clock is high. Thus the state of the up/down control when the clock goes low will determine the count direction when it next goes high again. The dot of light will move randomly either clockwise or anti clockwise on each clock period. If, say, the light moves three places clockwise in succession, this is equivalent to getting three heads in a row from a coin toss.

The random logic level generator is based on Q1, a transistor selected to provide a good noise output when connected in its base-emitter breakdown mode. This produces genuine random noise due to the completely unknown and unpredictable movements of excited electrons in the semiconductor material. The noise voltage so generated is amplified by IC1c and d. These are unbuffered CMOS inverter gates which are biased into their linear amplifying mode by R5 and R7; the gain is determined by the ratio of R4 to R5 and R6 to R7. C2 and C3 provide AC signal coupling.

IC1e and f are configured as a Schmitt trigger, with R9 providing positive feedback for a sharp switching action. Those noise spikes which pass the switching threshold will produce clean logic level pulses at the output. These random pulses are applied to the clock input of IC4, a flip-flop wired as a divide-by-two circuit whose Q output is taken to the up/down control of IC2. Although the number of random pulses in each IC2 clock period will be pretty much the same, the state of the Q output is arbitrary and will be truly random with an equal chance of a 0 or 1 (or rather, not truly random if one allows that the mind can bias this in some way).

The clock used to drive IC2 is the usual CMOS astable using IC1a and b timing components RV1, C1 and R2. Potentiometer RV1 is a front panel control which sets the frequency of the clock and makes available a large range of rotation speeds.

It was found necessary to limit the supply current with R11, since IC1 (the 4069B) is used in the linear mode as a noise signal amplifier and with too high a supply voltage it can start dissipating enough current to destroy itself!

Fig. 1 Circuit diagram of the Infinite Improbability Detector.

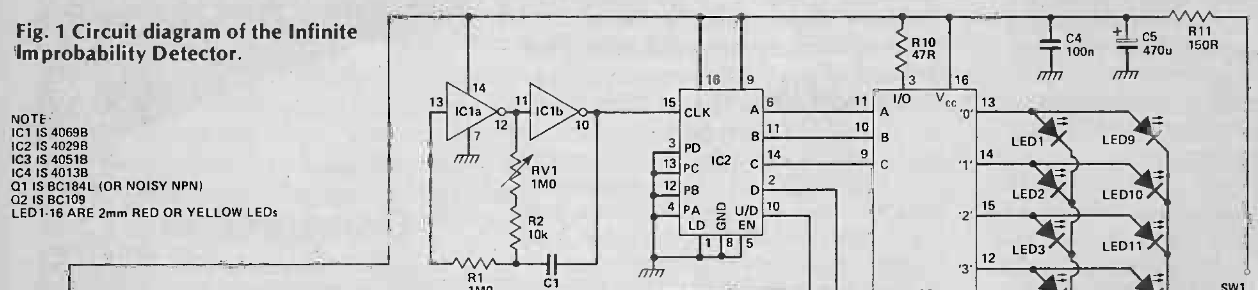
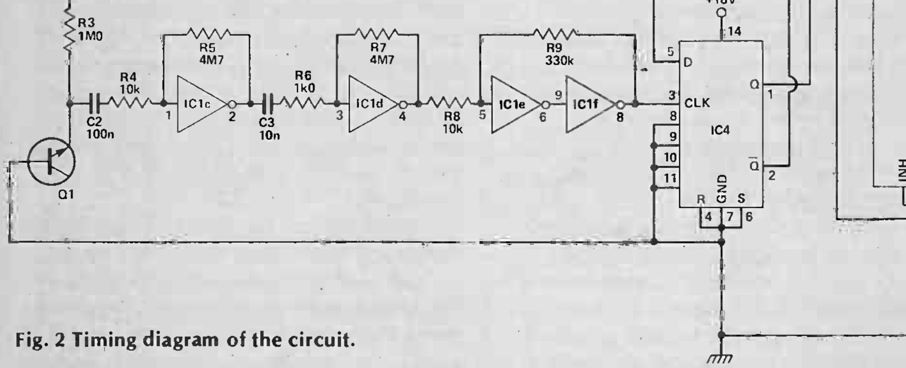


Fig. 2 Timing diagram of the circuit.

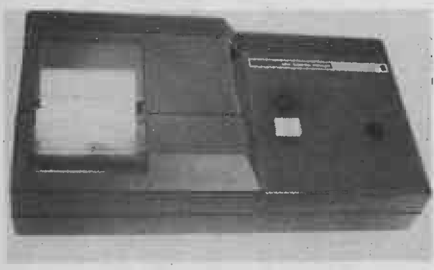


BUYLINES

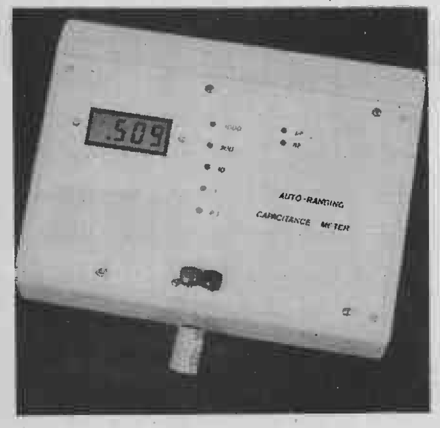
Nothing used in this project should cause the hobbyist any supply problems. All of the components are standard types and the PCB can be obtained from us as usual. The PCB Service ad is on page 71.

Getting hold of your components p.66

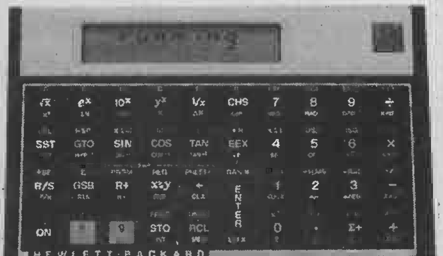
The ultimate receiver? p.28



Battery-operated printer p.40



Made to measure p.48



A clever calculator p.79

electronics today INTERNATIONAL

MARCH 1982 VOL 11 NO 3

FEATURES

PROJECTS

We regret that we are unable to publish the latest computer expansion card this month.

INFORMATION

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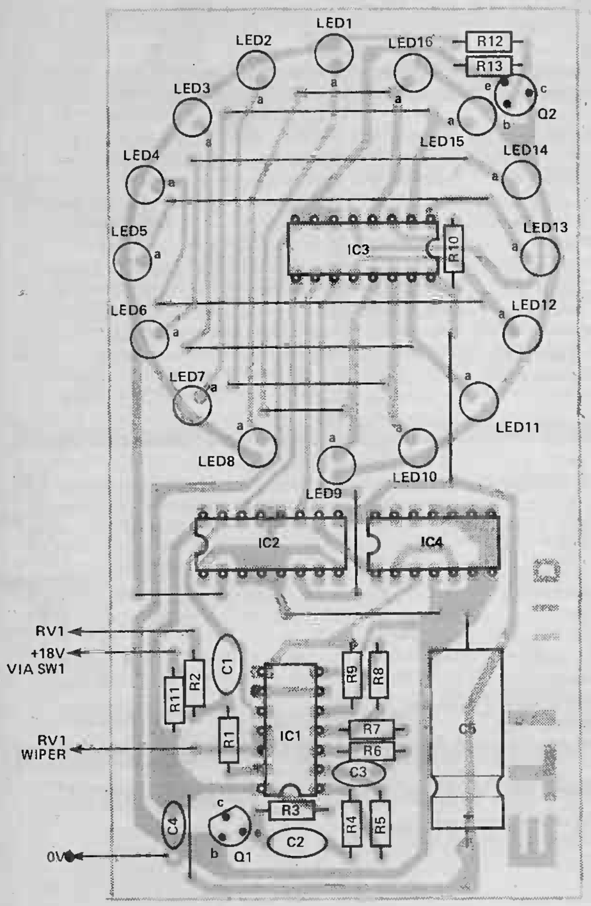


PARTS LIST

Resistors (all ¼ W, 5%)

R1,3	1M0
R2,4,8	10k
R5,7	4M7
R6	1k0
R9	330k
R10	47R
R11	150R
R12	47k
R13	3k3

Potentiometers

RV1	1M0 logarithmic pot

Capacitors

C1	330n polycarbonate
C2,4	100n ceramic
C3	10n ceramic
C5	470u 16 V axial electrolytic

Semiconductors

IC1	4069B
IC2	4029B
IC3	4051B
IC4	4013B
Q1	BC184L (or other noisy NPN transistor)
Q2	BC109
LED1-16	2 mm red or yellow LEDs

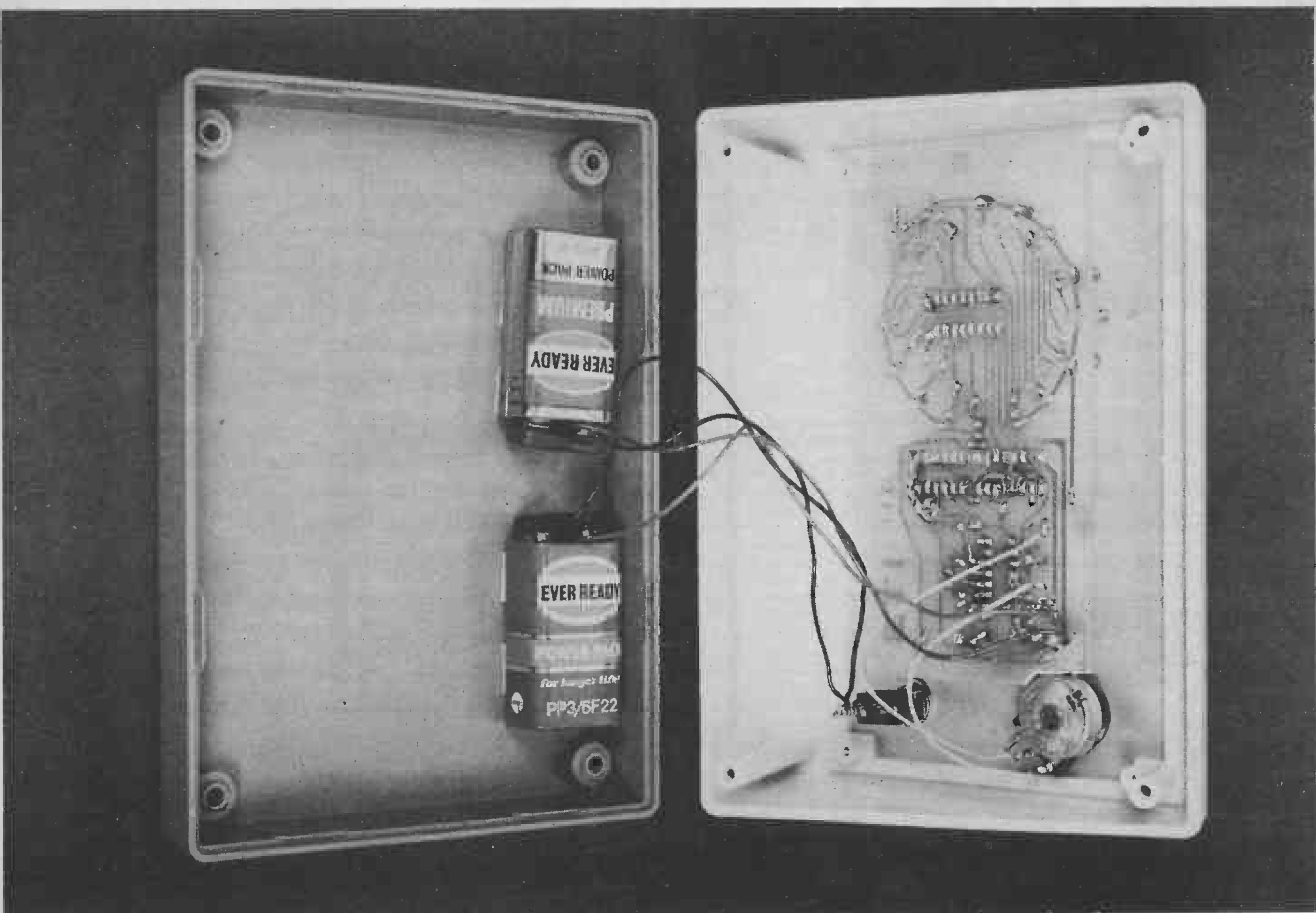
Miscellaneous

SW1	miniature toggle switch

PCB (see Buylines); two off PP3 9 V batteries plus clips; sloping front Verocase (order no. 75-1798K).

Fig. 3 (left) Component overlay for the PCB. The LEDs are arranged in a circle with the anodes to the inside.

Below: the inside of the case showing the uncluttered construction. No nuts, bolts or sticky pads are required to mount the PCB; the LEDs should be able to support it when they're jammed into their holes in the front panel.



CASIO FP~10 PRINTER

If you've been tempted by our recent articles on the Casio range of programmable calculators, Peter Freebrey brings news of a useful accessory.

These days it seems that we see a new calculator, digital watch or electronic musical instrument being advertised each week. The whole situation almost appears to have got out of hand and I really wonder where the profit can lie — because a piece of equipment may easily be superceded before the retailers have received delivery of last week's latest and best!

Having seen the recent introduction of Casio's programmable calculators, the FX-601P, FX-602P and the top-of-the-range (for the moment) FX-702P, we now have a dedicated printer for these machines: the FP-10 Mini Electro Printer. Although it is a little too large to fit in the pocket (6.25" x 3.25" x 1.75"), it is light enough (13.1 oz) to carry comfortably in the briefcase (or handbag?). RRP is £49.95.

The FP-10 may be powered by four AA size batteries, a special rechargeable battery pack or from the mains via a special Casio AC adaptor. Printing is achieved by the now familiar discharge system, whereby the metallised coating of the paper is vapourised, revealing the black paper beneath the aluminium surface layer. The 'paper' is 35 mm wide and allows up to 20 characters to be printed per line. Replacement rolls of this metallised paper come in packs of five, each roll being 3.6 m long and the pack costing £2.50. Each line of print occupies about 3.5 mm, so approximately 1000 lines of print may be produced on each roll. The printing speed is a nominal two lines per second and the characters are made up on a 5 x 7 dot matrix.

On opening the box, first impressions of the FP-10 are quite favourable. It is, of course, constructed in that ubiquitous black plastic but nevertheless looks well-built, with clean mouldings and a quality switch and push-button which have a nice feel to them. The instructions provided with the FP-10 are clear and concise with less of the translation ambiguities which occasionally accompany Casio's programmable calculators. Line drawings show the general layout of the printer, how to replace the batteries and print rolls, and how to connect the FP-10 to the FX-601/2P or the FX-702P with or without the FA-2 adaptor (for cassette record/playback). They are all very clear and easily understood.

The printer has only two controls, a FEED button to advance the paper and an ON/OFF switch; so familiarising yourself with the controls should not prove to be an insurmountable problem! Having reached this stage, the instructions split into two sections, one covering the use of the FP-10 with the FX-601/2P and the other dealing with the necessary commands for use with the FX-702P.

FX-601P, FX-602P

The instruction manual lists nine uses of the printer with the FX-601/2P. Although these nine different uses appear in a fairly logical manner they really reduce down to the following:

- to print the result currently displayed
- to print the current contents of all memories
- to print current program listings from any or all programs
- to print required results from instructions within a RUNning program

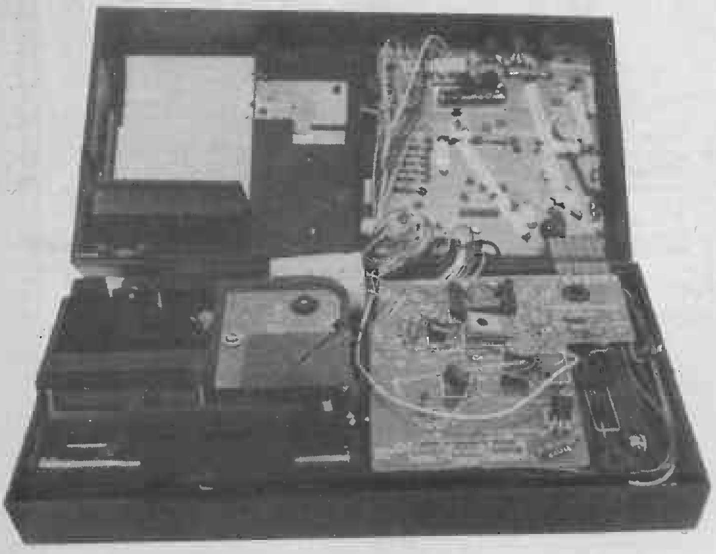
Other options allow the combination of two of the above, ie you may print both specified program listings and the contents of the memories. You may also print the music memory list with or without the music program listing.

Operational control of the FP-10 Printer is quite straightforward but can sometimes involve as many as 10 keystrokes plus your 'filename' and 'password' if used. Hints on reducing these are given, as well as a couple of warnings concerning the use of certain symbols or commands which might either have the effect of the 'ALL CLEAR' key or possibly cause misprinting to occur.

FX-702P

Again the four major options are as listed above for the FX-602/1P, but in the case of the FX-702P calling the FP-10 Printer into operation is very much simplified. Only two keys need to be pressed (MODE and 7) to have the printer print everything shown on the display. This literally means *everything*. . . READY, RUN and READY P0:_123456789 all come up clearly on the printer if MODE 7 has been actioned. Obviously this is wasteful of printing paper and a more sensible method when printing 'manually' is to 'call up' the printer immediately *prior to* when the required result is to be printed. So if you wish to print the result of (23 x 32 x 5.6) x .75, key in (230*32*5.6) .75 and before you press EXE (execute), key in MODE followed by 7. This results in the printer first printing the expression (up to 62 characters long on the FX-702P) followed by the result. MODE 8 cancels the print command.

Should you wish to print out the current values of the variables (A-Z, A1 etc), LIST V MODE 7 will result in *all* variables being printed. Should you wish for selected variables (assuming only a limited number have been assigned) then the manual method above would be chosen ie MODE 7 A= EXE B= EXE



Here we have the innards of this compact little gadget.

. . . . MODE 8. To print a program listing is simplicity itself: LIST Pn MODE 7 EXE (Pn = the program area to be printed). Should you wish to print a complete record of what is currently stored in your FX-702P then LIST ALL MODE 7 EXE will give you a complete list of all program areas followed by the current variable list. Whenever a program list is printed, the number of steps utilised by that program is also recorded.

Results obtained during the RUNning of a program may be printed in two ways: either by keying MODE 7 prior to EXEcuting the RUNning of the program, in which case the result of every PRT (print) command will be printed; alternatively the operation of the printer may be written into the program. For example:

```
10 INP "HOW MANY SHARES",A
20 INP "UNIT COST:POUNDS",B
30 MODE 7
40 PRT A;" SHARES COST "
50 PRT A*B;" POUNDS"
60 MODE 8
```

Line 30 — MODE 7 — has to be keyed in full as the 'MODE' key does not display MODE but is simply for fast manual operation.

The Casio FP-10 Printer performed faultlessly throughout the time we have had it for review. The printout is always clear and readable but, with only 20 characters per line, this means programs intended to be printed out need a little more thought to ensure that important words are not split and printed on two lines. The specifications state that approximately 6000 lines can be printed with one set of standard AA batteries. At present the review model has reached over 3000 lines with no sign of print degradation. If you feel the need for a printer to broaden the scope of your FX-601/2P or FX-702P then the FP-10 can be relied upon to make your copy 'hard' for a reasonable outlay. **ETI**

READ/WRITE

Welcome to our new feature. We often get requests for a readers' letters page, so here it is — a soapbox for both you and us to air our viewpoints. If you've got something interesting to say, write to the Editor, ETI, 145 Charing Cross Road, London WC2H 0EE.

Dear Sir,
FM mains remote control.

The letter from D.V. Ford, Head of Distribution, The Electricity Council, comes oddly from a body which itself employs the power distribution system for remote control and signalling purposes and thereby, in some areas, completely blots out the BBC's signals on 200 kHz, Radio 4.

Here, anywhere in the region of certain power distribution lines, the listener to Radio 4 is assailed by a hideous cacophony emanating from these lines at a frequency which has been cleverly chosen to be spot on 200 kHz.

Before writing silly letters about the highly improbable possibility of interference resulting from your FM mains control unit I think the Electricity Council should get its own house in order.

Yours sincerely,
Geoffrey H. Hillier, T.D.
Nottingham.

Dear Sir,
Feature: Pickup-Amplifier Design; Jan 82 issue, pp 19-25

You do pick 'em, don't you?. . . especially in audio-amplifier design. Take the section, "Noisy Thermals", p 25.

Certainly there is thermal (or Johnson) noise in the base spreading resistance, r_{bb}'; but the main causes of noise in a transistor when properly used are the shot-noise currents in the base current and in the collector current. The first adds noise to the signal by flowing through the source impedance (here the pickup), r_{bb}' and, of course, through any other impedance that may be in series with these (eg a resistance added for RF filtering). The second is already present in the collector current; and — as is well known — is usually divided by the transconductance, g_m ($= 1/r_e$ approx.), to yield an equivalent noise potential in series with the source (or in series with the base, if one prefers to think of it so). Your author fails to make this clear and, moreover, utterly confuses three separate resistances: r_{bb}', $r_{b'}$, and r_e. It is r_e that is equal to $25/I_e$ (in mA) approx: $r_b = 25/I_b$ (in mA) approx.

Nor are the errors and confusions confined to this section. The calculations at the top of p. 24 are inconsistent within themselves. The author says; "At sufficiently low frequencies. . . ", and the context shows that this means below 5 Hz: he then substitutes $\Delta f = 20{,}000$.

Some of the phraseology is poor also: ie "electrolytic or tantalum" for "aluminium or tantalum electrolytic". And the proof reading has not been well done; ie "recommended equivalent input noise voltage" for "typical" or possibly "guaranteed". . .

As I think I have said in an earlier letter, you really do need to supplement your own expert knowledge with that of a panel of readers or referees.

Yours truly,
E.F. Good,
Darlington.

Dear Sir,

For many years I have been a hi-fi enthusiast and have owned systems ranging from Amstrad to Bang and Olufsen, but have never owned anything high powered. I have been using Kef speakers, Thorens turntable, Audio Technica arm and Ortofon VMS 20E cartridge for some time now, and have longed to build an amplifier similar to the Meridian.

I buy ETI on a regular order, and when the July issue arrived, my dreams had come true, or so I thought. The preamp appeared to be everything I had wanted, so I immediately made a PCB (without the error) and one for the PSU and started building them.

Then the August issue arrived and I nearly died when I saw the power amps! I had anticipated that all the modules would be the same size (as are Meridian) and had built seven identical cabinets (12" x 6" x 2"!) in readiness for the "matching parametric equaliser unit and two other blocks 'still under development' — which I quote.

That was in August and everything has since shared the same corner of the shed as the spiders and rats!

Today I was cleaning out that same shed when I had a sudden idea, which brings me to the point of this letter and a possible reprieve for Mr. Stan Curtis and myself. Please ask him the following questions:
1) could the standard preamp be used with the power amp advertised by J.W. Rimmer, model no PFA 80, page 101 of the December issue?
2) if not, could the preamp be altered to be used with the PFA 80? And if so, please help with details.
3) what ever happened to the parametric equaliser you promised?
4) if the PFA 80 is unsuitable, can you advise an alternative power amp of about the same size and price which could be used with your standard preamp?

If you can help I will be extremely grateful and will continue to read ETI in the hope of finding more modules.

Yours faithfully,
F.S. Curry,
Blackpool.

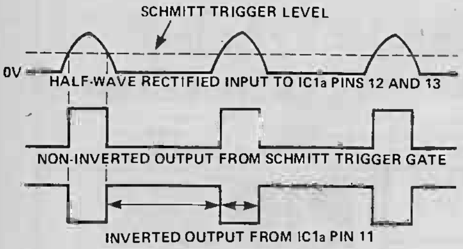
1) Yes.
2) Not necessary.
3) We're working on it.
4) The Crimson reviewed in Audiophile last month will also be fine.

Dear Sir,
Ref: Digital Clock — ETI May '81.

What follows is probably 'old hat' to you by now — but I've had to make the following modifications to your design in order to obtain a reliable time keeper from the kit obtained from 'Magenta'.

Having completed the clock and set it going, I found that two errors were occurring. (a) Random clocking of two minutes forward instead of one. (b) Gaining about 30 seconds per day.

I located the cause of this latter error with the aid of my scope. It is *caused by the following sequence:-*



The output of IC1a is a square pulse train of about 15 mS pulses followed by 5 mS intervals (sorry — drawing is not accurate representation). The reset pulse at IC1b is about 50 uS duration and thus IC2 is being reset so fast it is counting the 3000th pulse at the end of one minute and at the beginning of the next, thereby adding 1440 pulses to a 24 hour period. This I have overcome by adding an extra 4093B on a small board behind the main board and by using one gate, re-inverting the pulse train to obtain pulses of about 5 mS with intervals of about 15 mS. I have also lengthened the reset pulse by adding a 10nF ceramic capacitor in parallel with C3, tacking it on to the back of the board. The clock then kept perfect time with the mains clock on my stereo timer apparatus. The extra gate was inserted by cutting the track from IC1a pin 11 to IC2 pin 10 and running link wires from the back of the main board to the additional board.

The reset pulse bouncing at IC4a pin 10 appears to have been cured by reducing R6 from 10k to 6k8. The clock has now been running for five days and keeping perfect mains frequency time.

In early trials of the clock, ZD1 (12 V 400mW) appears to have overloaded and short circuited so I also had to increase the capacity of this diode.

The following comments on the kit are probably not of interest but:-
The kit supplied by Magenta is supplied with LEDs round in shape and they are too large to fit on the board without paring, even though your article states that round LEDs of 6 mm size are too big for the board design.
The track from IC2 pin 5 to IC3 pin 11 is missing from the board supplied by Magenta. (I've had two boards and it was missing from both.)
Many of the tracks on the component side of the board are too close to the LED leads and will come into contact with the LEDs unless, as I had to, you file away the LED lead shoulders and make the tracks even thinner.

However, having finished it and made it work correctly I'm quite pleased with the result — it certainly is visible and legible from a distance.

Yours sincerely,
J.C. Davison,
Whitstable.

P.S. From 'Electronics Digest' Vol.2. No.2:-
FM Mains Distributor — page 18 — Transmitter board — IC1 (78L12) drawn in the wrong way round in component overlay diagram.
Ambush — page 26 — I could not get this to work unless I took 12 V to pin 12 (carry out) of IC12. Having done that the game works perfectly well. Take away the 12 V and the 'zero' goes high and stays that way, slightly oscillating with the clock pulses.

What more can we say — except thank you!

AUTORANGING CAPACITANCE METER

Look — no hands! The only control on this piece of test-gear is the on/off switch; the only connection is to the test terminals. Design and development by Phil Walker.

This project is designed to measure capacitance in the range of 100pF to 1000uF with no help (or hindrance) from the operator once the component is connected. Apart from the power switch, there are no external switches or knobs to adjust and only one internal adjustment. Once the instrument is working, setting up and using it is very simple.

The measurement capability of the circuit covers eight decades of capacitance and all but the lowest range should give true readings. The limitation on the 100pF range is due to the stray capacitance at the measurement terminals and the very high impedances necessary to give any sensible result.

The accuracy of the whole instrument depends on the quality of the five range resistors and the adjustment of PR1. The range resistors should preferably be 1% tolerance and of good quality. The threshold setting resistors in the comparator stage (R24, R27, PR1) should also be close tolerance devices if possible, although 5% components would be adequate in most cases.

There is a mixture of technologies used in the project; bipolar and TTL devices have been used where speed of operation, high current or low leakage were of greatest importance, while CMOS logic devices have been used to keep power requirements low wherever possible. The range switching logic and measurement sequencer are fairly complex but this was found to be necessary to avoid using very high frequencies, excessively high or low resistances, or waiting too long for a reading. The maximum response time for this device is about one second to get a reading on the 1000uF range. The lower ranges respond in milliseconds — faster than the display can follow.

Theory

If a voltage is applied via a resistor to a discharged capacitor, the voltage across the capacitor rises exponentially towards that of the supply (Fig. 1). From basic principles:

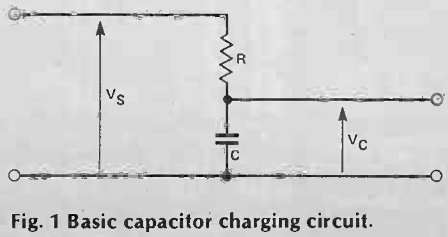


Fig. 1 Basic capacitor charging circuit.

$$V_C = V_S(1 - e^{-t/RC})$$

$$\frac{V_S - V_C}{V_S} = e^{-t/RC}$$

$$\log_e \frac{V_S - V_C}{V_S} = -t/RC$$

$$t = -RC\log_e \frac{V_S - V_C}{V_S}$$

$$t = RC\log_e \frac{V_S}{V_S - V_C} \quad \ldots\ldots(1)$$

This equation shows that the time to charge to a fixed proportion of the supply voltage is independent of the actual supply voltage and only proportional to the RC product (or "time constant"). This also means that the time to charge between any two fixed proportions of the supply voltage will similarly be independent of the supply voltage.

There are two main operations to be performed by the circuitry; the first is to determine what range of measurement to use for any particular component; the second is to use that range and give a measure of the component's capacitance. To do this the relationship found in equation (1) above is used twice, but in slightly different ways.

For any measurement 1600 clock cycles are allocated out of each 2000. These may be at 100 kHz or 100 Hz depending on the current range. At the start of the 1600 clock cycles, the unknown capacitor is in a discharged state and will charge via one of the range resistors at a rate depending on its capacitance. If the range is correct, its voltage will reach an upper threshold between 100 and 1600 clock cycles later. If the range is too low, the rate of charge will be too slow and the upper threshold will not be reached in time. The range will be changed for a higher one and the process repeated until it is correct or the maximum range is reached.

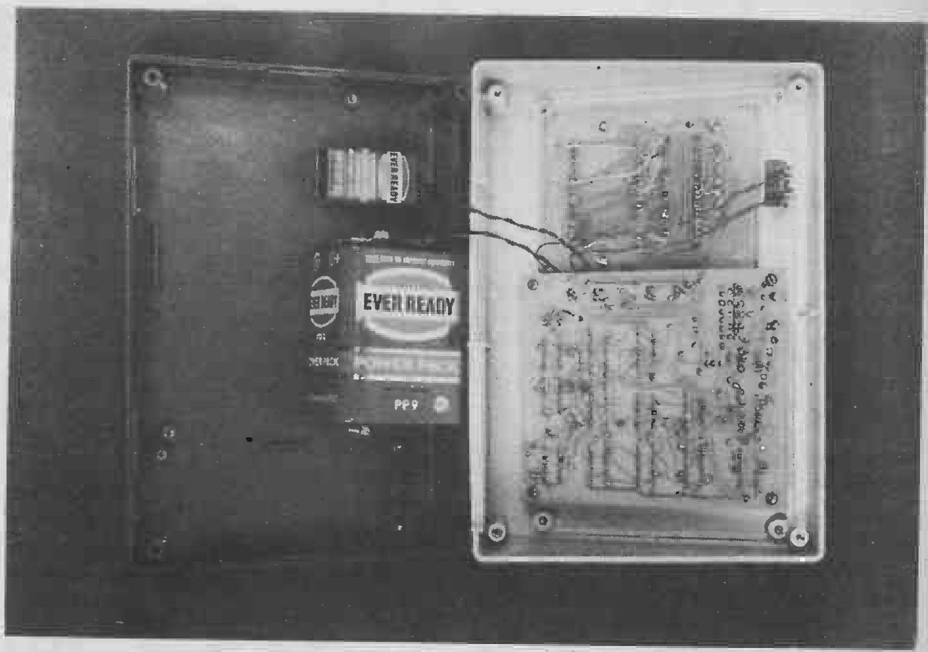
If the range is too large, the rate of charge will be very fast and the upper threshold will be reached before 100 clock cycles have elapsed. This time the range will be changed for a lower one and the process repeated until it is correct or the minimum range is reached.

In order to determine what the upper threshold will be, we choose — not entirely arbitrarily — that the range change point will be at 120% of the nominal for that range. This means that, with a capacitor 1.2 times the nominal, it will just reach the upper threshold in 1600 clock cycles. The resistors we use are in powers of 10 and the clock is also in powers of 10, so we can assume that the CR product will also be 1.2 times some power of 10. For convenience we can assume 1200 clock cycles. This also avoids thresholds ridiculously close to the supply rails. From (1) and the above we have:

$$1600 = 1200\log_e \frac{V_S}{V_S - V_C}$$

$$\frac{V_S}{V_S - V_C} = e^{1600/1200} = e^{4/3}$$

$$\frac{V_S - V_C}{V_S} = e^{-4/3}$$



The inside of the meter. Full constructional details will appear next month.

$$1 - \frac{V_C}{V_S} = e^{-4/3}$$

$$\frac{V_C}{V_S} = 1 - e^{-4/3} = 0.736 \text{ (upper threshold)}$$

This shows that the upper threshold should be at 73.6% of the supply for autoranging up at 120% of nominal.

To find the lower limit of the range we know that if the capacitor voltage reaches the threshold voltage just calculated within 100 clock cycles, the range will change down. From (1) we have:

$$100 = 1000C\log_e \frac{V_S}{V_S - V_C}$$

$$C = \frac{100}{1000\log_e \frac{1}{1 - V_C/V_S}}$$

$$C = \frac{1}{10\log_e (1/0.264)}$$

C = 0.075 or 7.5% of nominal for the range.

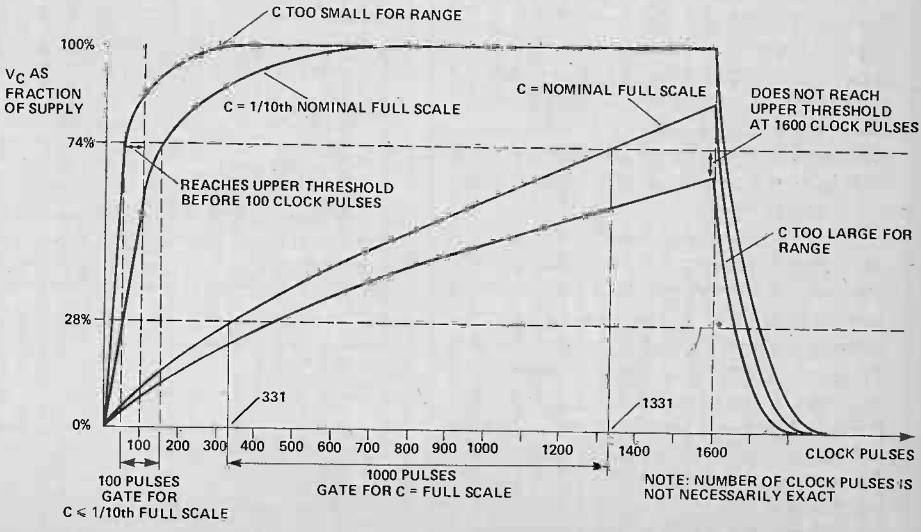


Fig. 2 The various modes of operation of the meter.

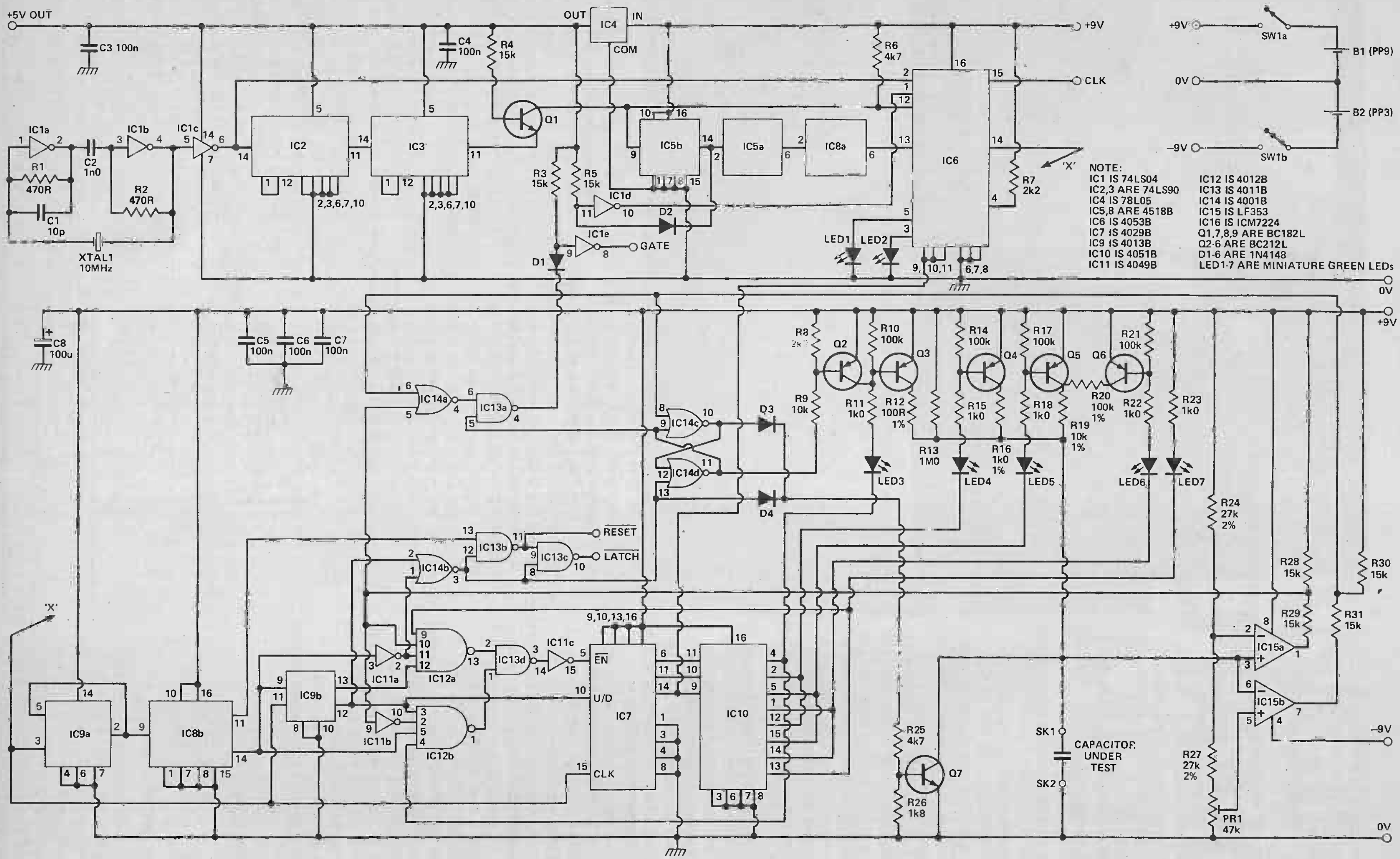


Fig. 3 Circuit diagram for the main board of the Autoranging Capacitance Meter

HOW IT WORKS

The master clock for the whole instrument is provided by a 10 MHz crystal-controlled oscillator made from three sections of IC1. This is divided by 10 in IC2 and IC3 (74LS90). TTL devices have been used here because operation of CMOS devices is not certain at these frequencies with a 9 V supply. Further division is provided by IC5 and IC8a which are CMOS devices. From these divider stages, frequencies of 10 MHz, 100 kHz, 10 kHz and 100 Hz are passed to IC6, which selects the output and sequencer clock frequencies of 10 MHz/100 kHz or 10 kHz/100 Hz as required. IC6 also drives two LEDs to show which set of ranges is in use.

The measurement sequencer is probably the most complex part of the circuit and consists of IC9, IC8b and parts of IC11, IC13 and IC14. These provide the signals which discharge the capacitor between counts 8 and 9 of IC8b while also controlling the counter-display chip via outputs from IC13. IC14c, d are connected as a set/reset latch and control Q7 via D3 and D4 to ensure that the test capacitor is discharged to below the lower threshold before each measurement begins. IC9, IC12 and parts of IC11 and IC13 form the gating logic which determines whether the range. The other part of IC12 (IC12b) is enabled for one clock period immediately after period immediately after IC8b counts from 9 to 0 and the range counter IC7 will be enabled if the upper voltage level comparator output goes high before the next clock pulse arrives. Under these conditions IC7 will count down a range. The other part of IC12 (IC12b) is enabled for one clock period immediately after IC8b counts from 7 to 8 and the range counter will be enabled if the output from the upper voltage level comparator is still low when the next clock pulse arrives. In this case the range counter will be incremented to the next higher range.

If the range counter IC7 is already on its maximum or minimum range, further counting in that direction would result in completely the wrong range being selected, so the extreme range outputs from IC10, which is the range resistor switch selector, are taken back to the relevant sections of IC12 to prevent further counting in the wrong direction.

Before going on it may be worth saying that IC9a and IC8b form a divide-by-20 circuit which, together with the fact that the output clock runs 100 times faster than the input to this circuit, means that there are 2000 clock pulses to each measurement. IC9b is a one bit shift register which delays the Q_4 output bit from IC8b for one clock cycle and with the logic of IC11, IC12, IC13 and IC14 does all the timing described above.

The next section is the part which actually provides the measuring function. IC10 is a one-of-eight analogue switch which is used here to drive the four resistor-switching transistors and also the LED range indicators. Six of the outputs of IC10 are connected in pairs to cope with the range overlap mentioned elsewhere. The lowest range does not have a transistor switch and its resistor (R13) is permanently in circuit. The effect of this on the next range is offset by connecting the next range resistor to the switch end of the one above it (R20 to R19). This enables decades of resistors to be used without needing any odd values.

Q2 in the resistor switch section serves to switch off Q3 which controls the smallest value resistor while the test capacitor is being discharged. This is necessary because, on the highest capacitance range, there is only a relatively short time in which to complete the discharge and Q7 does not have enough base drive or enough current capability to do its job if it has to sink the current which would flow through R12 as well. With this in mind it would be wise to ensure that Q7 has a high gain.

The last part of the circuit is the window comparator formed by IC15 and IC14a. These are the components which detect when the voltage on the test capacitor is between the upper and lower voltage limits. If this is the case and the capacitor is not being discharged, the display counter is enabled and the number of clock cycles counted is the measure of the capacitance. Outputs from the upper voltage level comparator feed back into the autoranging circuit and from the lower level comparator into the discharge latch. It was unfortunately found necessary to supply the comparator (a dual JFET op-amp) with a negative supply in order to get it to work at the voltage levels required, but this disadvantage was offset by its high input impedance and fast slew rate.

THE DISPLAY

IC16 consists of a 4½ digit counter, latches, display decoder and LCD driver. The logic signals from the main circuit control its sequence of operation but in some cases need to be conditioned to match the logic levels of the device. There are also two transistors on the display board; one drives the decimal point segment while the other drives the half digit segment.

The display itself is a 3½ digit LCD device. The three full digits are driven directly from the display driver least significant outputs while the half digit is driven via an inverter from segment 'a' of the fourth digit. This is necessary to get the half digit to respond at the correct time.

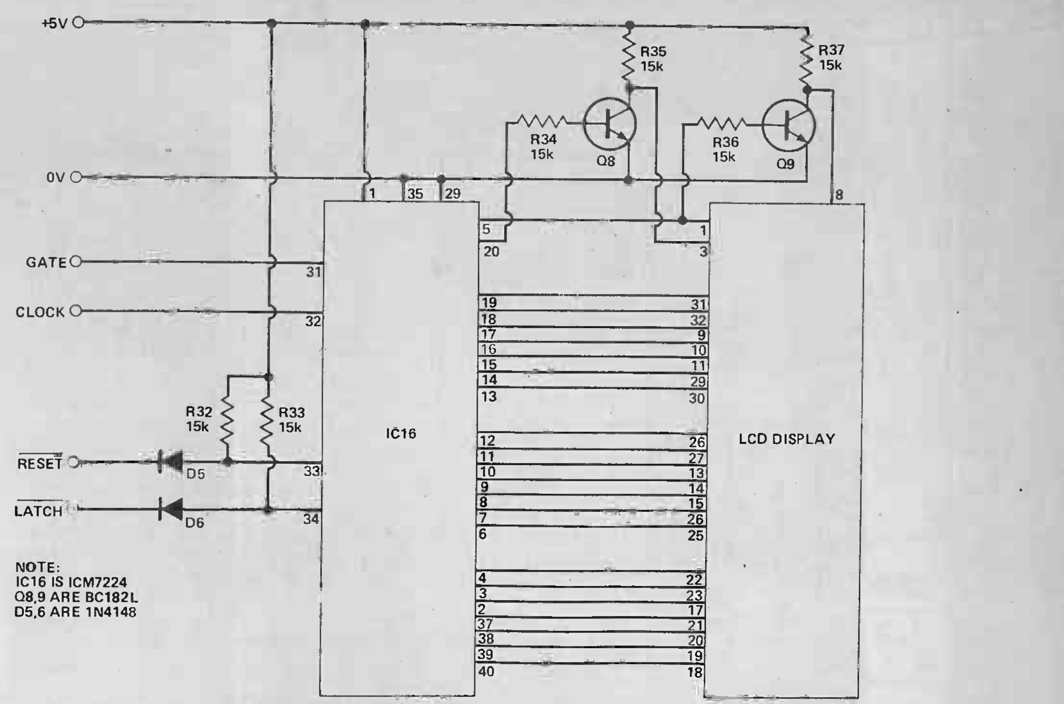


Fig. 4 Circuit diagram of the display board.

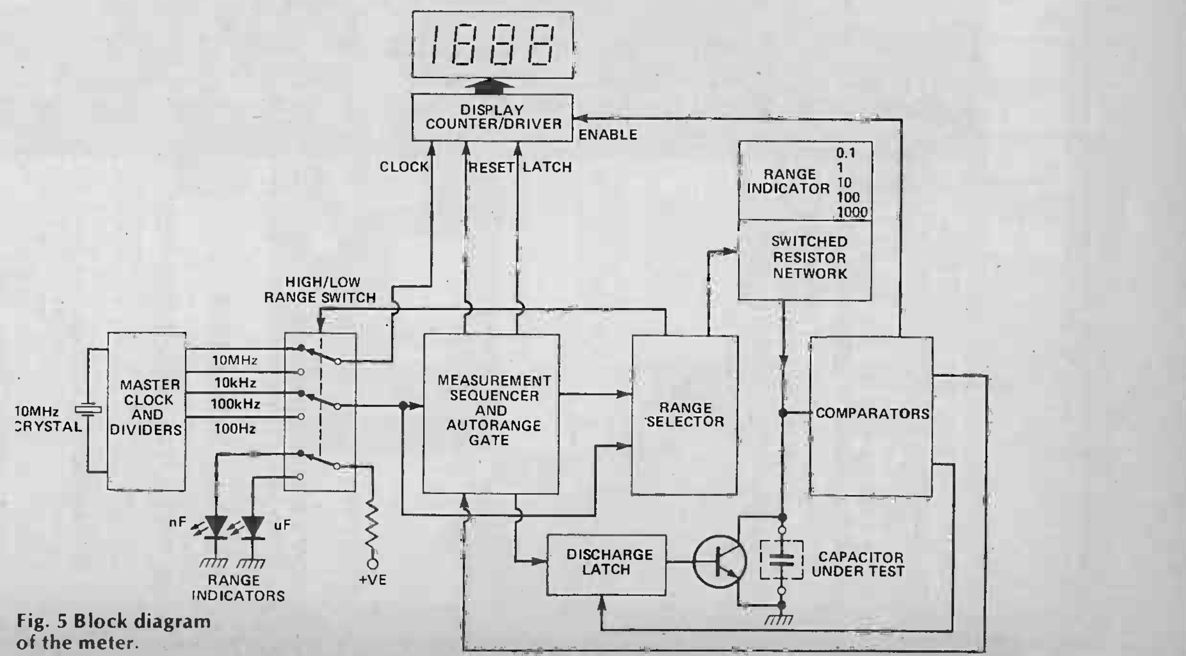


Fig. 5 Block diagram of the meter.

Having decided on the upper threshold using the requirements for autoranging, we must now consider what the lower threshold will be. With a nominal maximum capacitance for the range connected there must be 1000 clock cycles between the capacitor voltage crossing the lower threshold and it crossing the upper threshold. The time to reach the upper threshold is:

$$t = RC\log_e \frac{V_s}{V_s - V_c}$$

$$= 1000\log_e \frac{1}{1 - V_c/V_s}$$

$$= 1000\log_e \frac{1}{1 - 0.736}$$

$$= 1333.3 \text{ clock cycles.}$$

Therefore the number of clock cycles to reach the lower threshold is:

$$1333.3 - 1000 = 333.3$$

and the threshold voltage will be found from:

$$333.3 = 1000\log e \frac{1}{1 - V_c/V_s}$$

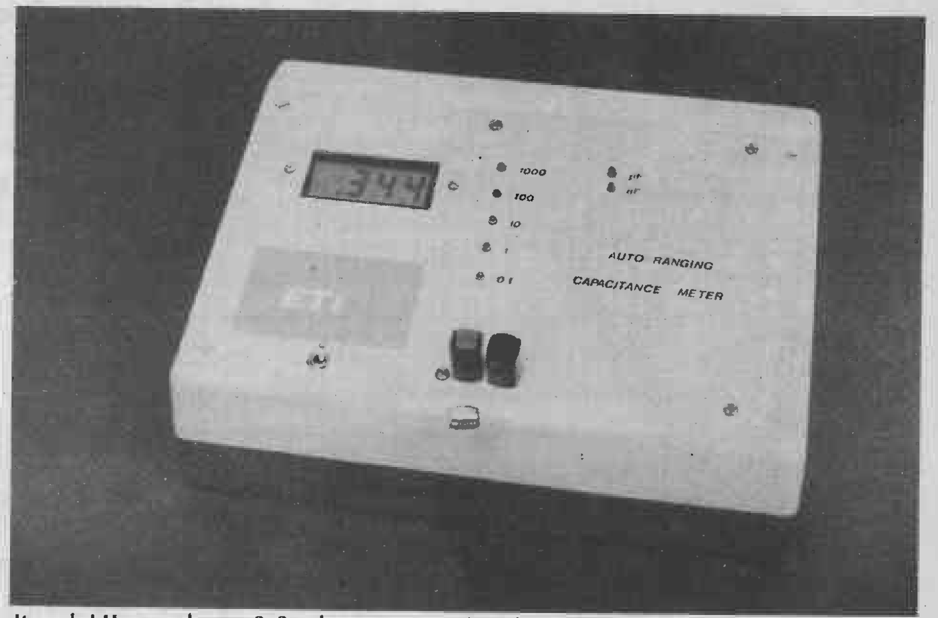
$$\frac{V_c}{V_s} = 1 - 1/e^{0.33} = 0.283$$

This shows that the lower threshold will be at 28.3% of the supply voltage.

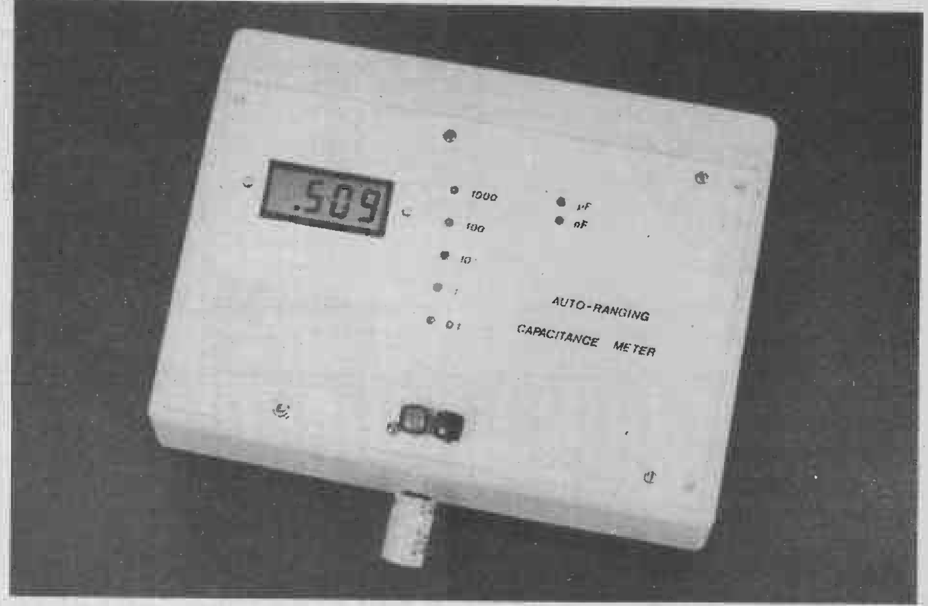
Once we have set the upper and lower thresholds, the relationship between the measurement range and the autoranging function is defined. In this case the nominal range is 0.1 to 1 with an underrange down to 0.075 and an overrange up to 1.2 times the nominal. The relationship between ranges is defined by the range resistors and the digital division ratio. The various modes of operation are shown in Fig. 2.

In this instrument we use only five range resistors to give a coverage of eight ranges. This is desirable to avoid the use of very large resistors with small capacitors, or the use of very small resistors with very large capacitors and consequent battery drain. It is made possible by sharing three of the range resistors between six ranges and reducing the clock speed by a factor of 1000 on the high capacitance ranges to compensate.

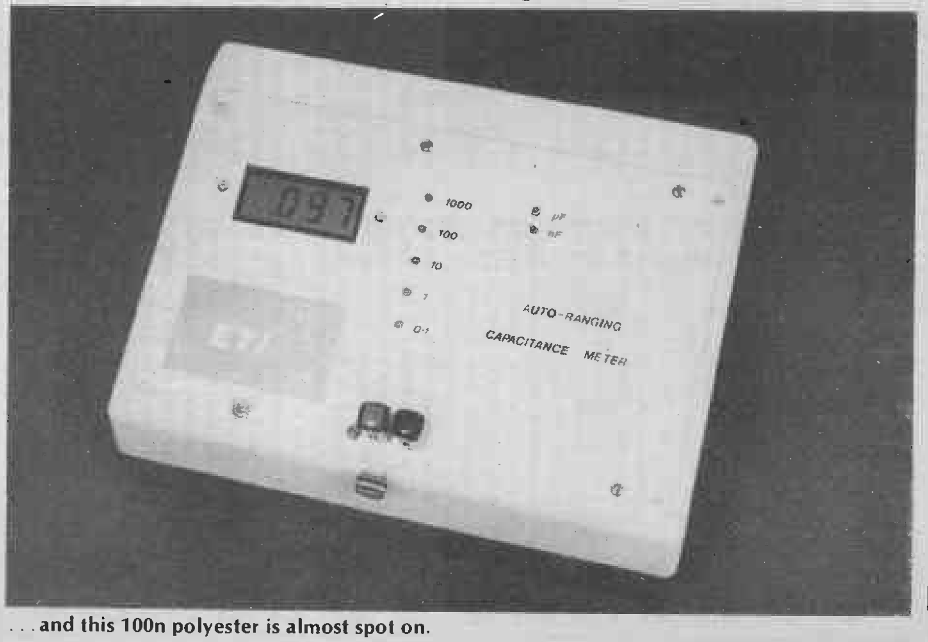
Next month we conclude this project with the Parts List, constructional details and overlays.



It works! Here we have a 3n3 polystyrene capacitor, fairly accurate . . .



. . . whereas this 470uF electrolytic is about 8% too big . . .



. . . and this 100n polyester is almost spot on.

ETI

DIGEST

Tuner Kit

The new BI-KITS S.453 Stereo FM Tuner comprises push-button varicap tuning and a phase-locked loop decoder for the reception of mono or stereo broadcasts. The unit is fitted with a four-position switch which provides for the selection of four pre-tuned frequencies. The selected frequencies are tuned by four multi-turn potentiometers. Careful circuit design has resulted in an extremely stable unit that may be used in a wide range of equipment. Provision exists for the addition of an LED stereo indicator, a centre zero tuning meter and a mono/stereo switch. The ready-built module is supplied complete with installation instructions. Specifications include a tuning range of 88-108 MHz; a sensitivity of 4 uV for 30 dB S/N; an audio output of 200 mV for ± 75 kHz deviation; a stereo separation of 30 dB; and an operating supply voltage of 18-25 V at a supply current of 43 mA (for Vs = 22 V). The unit costs £19.00 plus £2.85 VAT and 50p p&p and is available from: Bi-Pak Semiconductors, PO Box 6, Ware, Herts, SG1 9AG.

Alien Attack

One of the more popular small projects we had on show at Breadboard was the Alien Attack game and one person came up to ask about the secret identities of Q5 and Q6, which preferred to remain anonymous in the original article. He left his name and address, but small pieces of paper have a habit of disappearing at large exhibitions and we can't write as promised. So for you, sir, and anyone else who was wondering, Q5 is a BC108 and Q6 is a 2N2219.

Interface Your Micro

With the ever increasing use of microcomputers in laboratories, Cytel have been prompted to produce a range of microcomputer interface boards. These boards provide a cost-effective means of making full use of microcomputers in areas such as data recording, data acquisition, motor speed control and stepper motor control. Each board is designed to operate on the Cytel 40-way Cybus, whereby two 40-way DIL sockets provide a ready means of daisy-chaining the range of boards. There are currently three boards in the range. The F011 combination analogue-digital output boards feature two analogue channels, one reed relay channel and three TTL digital channels. The F012 eight channel microcomputer data acquisition board provides eight multiplexed analogue-to-digital channels; channels 0 and 1 are fully buffered differential analogue inputs with zero offset null control, variable gain control and may be switched to accept unipolar or bipolar inputs. Channels two to seven accept unipolar signals of 2V55 maximum.

Finally the F015 combination digital input output board will give you eight inputs connected to eight switches, four handshake lines and eight output lines with LED display, including seven buffered to 50 V 500 mA, and a reed relay (240 V AC 0A5). The F0 range, together with the appropriate adaptor, may currently be used with the PET, Apple, Motorola D5 and AIM 65. For more details contact Cytel Instruments Ltd, 61 Woodburn Road, Carrickfergus, N. Ireland.

Oops

A minor gremlin crept into the Guitar Tuner project in the January ETI. On the circuit diagram, page 43, R12 and C10 should be connected to pin 6 of IC3c, not pin 5 as drawn. Also the supply pin numbers (4 and 11) on IC3 were seapped over. The PCB and overlay are correct. Sorry!

Asimov For Tandy

Tandy Corporation (UK) have just announced the signing of science writer Isaac Asimov for extensive advertising and product promotion. Mr. Asimov, world-renowned author of over 200 science fiction novels and related articles, has been contracted to promote the state-of-the-art high technology products of Radio Shack, a subsidiary of Tandy Corporation. Among Asimov's most popular works are two volumes of 'The Intelligent Man's Guide to Science', 'Robot', 'The Caves of Steel' and 'The Naked Sun'.

Free And Easy

London Information have started a new free consultancy service to help engineers identify and acquire the specs and standards or other documentation they may need for their latest projects. Enquiries are already running at hundreds of telephone calls a week. In the present climate of fierce competition for every tender, the prompt acquisition of correct documents is a matter of vital importance.

Three examples illustrate that the range of enquiries is enormous. Recently a batch of Australian wallabies gave their importers a problem. It seemed that the Australians had changed the quarantine regulations but had failed to supply the necessary documentation. Desperate importers contacted Canberra to be told that they must wait at least six weeks for the documents — totally impractical since the crated wallabies were already waiting in several ports in Europe. A telephone call to London Information saved the situation. Within five days London Information had the essential regulations from Australia and the wallabies were safely despatched to their respective zoos.

A sports stadium complex was put out for tender by a middle eastern state. Specs and standards were required for all the component parts — from carpets, paint, tiles, partitioning, plumbing, olympic tennis courts and swimming pools up to the structural steel and concrete. London Information was able to pin-point the documents called for in the tender by return telex. Four companies tendering, including one from France, used London Information's service and one was awarded the contract.

One of the largest British electronics companies was invited to tender for a major US government contract but were unable to acquire the relevant US Mil specs in time. On being recommended by the US Embassy in Britain to try the London Information service, they made a quick telephone call and London Information was able to supply all the specs required within a few days, thus enabling them not only to submit their tender on time but to win another contract for Britain.

London Information can now get any available document from any source anywhere in the world. If they are unable to supply the information themselves, they will put firms in contact with a source that can. Further details from London Information (Rowse Muir) Ltd, Index House, Ascot, Berkshire SL5 7EU. Telphone: 0990 23377. Telex: 849426.

X-Cellent!

There's more good news for those of you who are tired of buying batteries! Appearing soon in your local emporium is the X-cell, a revolutionary type of rechargeable battery. It is suitable for routine domestic and outdoor applications and will replace traditional lantern-type batteries. The remarkable feature of this unit is its built-in charging unit, which means you need no other adaptor or recharging device — you simply plug into the nearest power supply with the leads provided and the battery recharges itself. Tests have proved that the X-Cell will give at least 300 (in certain conditions up to 3,000) charge-discharge cycles — at a cost of less than 1/10 of a penny a time! The unit will recharge from cars, lorries, boats, aircraft, etc. The unit is leak-proof, shock-proof, vibration-proof, resistant to extremes of heat and cold, water resistant — in fact virtually indestructible. This innovative unit was developed by Ni-Tech Ltd, so if you want further information contact them at: 4 Castle Street, Hastings, East Sussex TN34 3DY.

TECH TIPS

Car Lights Warning Device

A.W. Jones, Cardiff

The Car Lights Warning device published in the October '81 Tech Tips is an excellent example of the over-application of technology. We have seen 'alternative technology' and 'appropriate technology' in the press recently — perhaps a new category of 'good-enough technology' should be formed to provide an out-of-bounds region for the over-enthusiastic designer in the area of perfectly adequate development.

Here are two circuits of 'good-enough technology' applied to the sidelights reminder. Both are so simple that they require no explanation and the first (Fig. 1) performs exactly the same function as last October's, ie it triggers the buzzer if the ignition is turned off with the lights still on — operation being cancelled if the lights are switched off then back on again. It performs this operation with only one active component. Figure 2 is another, even simpler system which is activated by the interior light, thus reminding the driver if he tries to leave the car while the sidelights are on.

Both these designs can be built for under £1 and are very simple to install. Component values are not critical and may be found in any electronic junk box. The cheap 12 V solid-state buzzers, which are widely available, form an excellent warning device.

Fig. 1

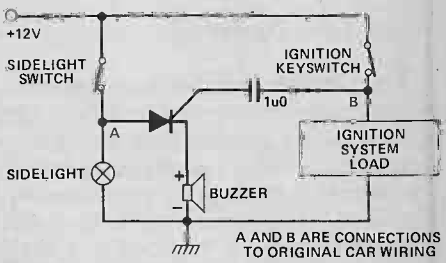
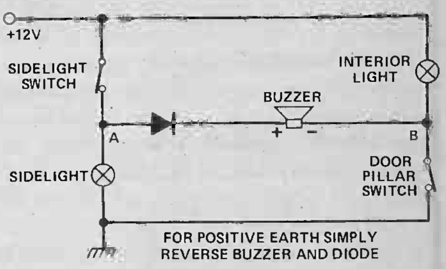
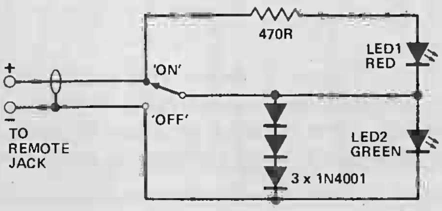


Fig. 2



Indicating Remote Switch For Cassette Recorder

P.F. Taylor, Nottingham

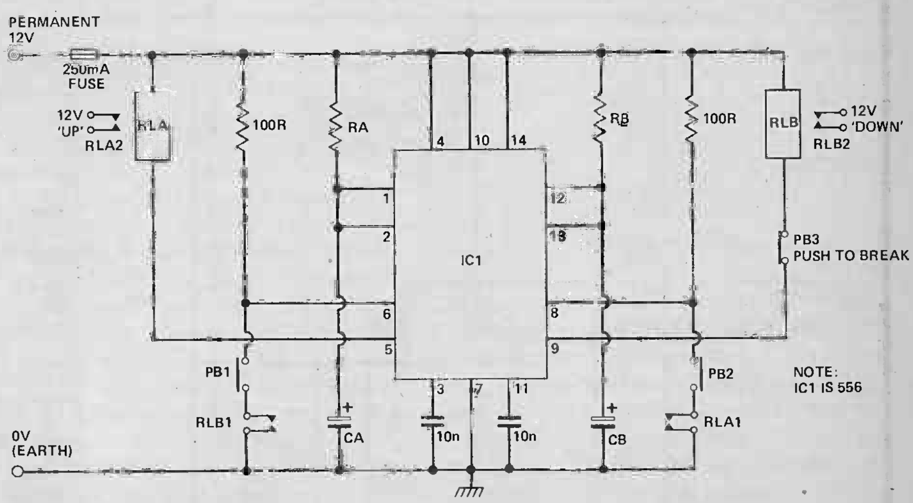


This circuit adds visual indication to a remote on/off switch for cassette recorders. When switched to 'off' the cassette motor will not turn, but provided the 'play' button on the recorder is depressed, a path exists for sufficient current to light the red LED1. If the LED will not light then warning is given that the recorder is not ready; if it lights, then the recorder is ready. When switched to 'on', motor current passes through the three 1N4001s, dropping sufficient volts to power LED2 (green), indicating that the cassette motor is turning. When the tape reaches the end and automatically shuts off, the green LED goes out.

The price paid for this indication is a reduction of about 1V5 in the effective cassette power supply, but on mains supply or with relatively new batteries this should cause no problems. The components can, with care, be fitted into the spare room in the sort of remote cassette switch box available widely in the shops.

Aerial Lift For Car Radio/cassettes

M.D. Peake, Wellingborough



Many car radios have 'automatic' circuits to lift an electric aerial when switching on; however, where radio/cassette players are concerned this can be a definite disadvantage, especially at high speeds on a long motorway trip. This unit enables the aerial to be raised or lowered at the touch of a button, also making it useful with semi-automatic aerials.

Operation of the 556 dual timer is triggered by pressing either PB1 or PB2; RLA and RLB control the respective power circuits, as well as protecting the motor by disabling Timer B when Timer A is on, and vice versa. Values of RA (= RB) and CA (= CB) are given by t = 1.1 x R x C, ie for a delay of about four seconds, use a 390k resistor and a 10uF capacitor. The push-to-break switch PB3 is included for connection and reconnection purposes; since the 556 triggers both outputs on connection, it is necessary to starve RLB of power to prevent motor burnout.

Differential Mixer Overcomes Earthing Problems

Andy Fiore, Deal

The problem with single-ended virtual earth mixers is that what is earth (or God) to the mixing amplifier may not be to the preamps or other circuits being fed into it. Although this may be minimised by a generous single-point earthing system, the earth wire (or missionary) is not as pure as we'd like to think and consists of a chain of very small resistances and reactances (or devils) waiting to cause trouble. It is therefore possible to develop a potential difference of a few millivolts, including power supply noise, across this wire which will be seen as part of the preamp signal to the mixer input. Admittedly, circuits using a split rail power supply will be much less prone to this than single rail types which use the earth as a power line, but as many low-noise preamp ICs are single rail devices we may not always have the choice.

However, the use of a differential mixer can overcome this problem. By applying the preamp output signal to an inverting input of the mixer and the earthing point at the preamp to a non-inverting input, we can effectively cancel out any earth wire noise as it will be applied equally to both inputs.

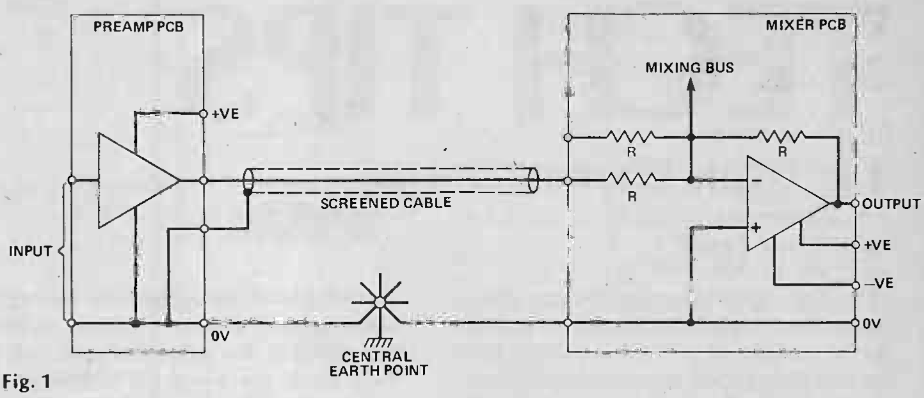


Fig. 1

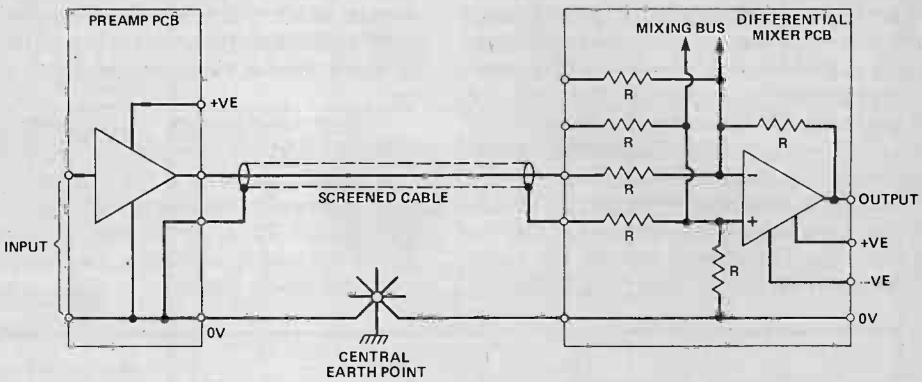


Fig. 2

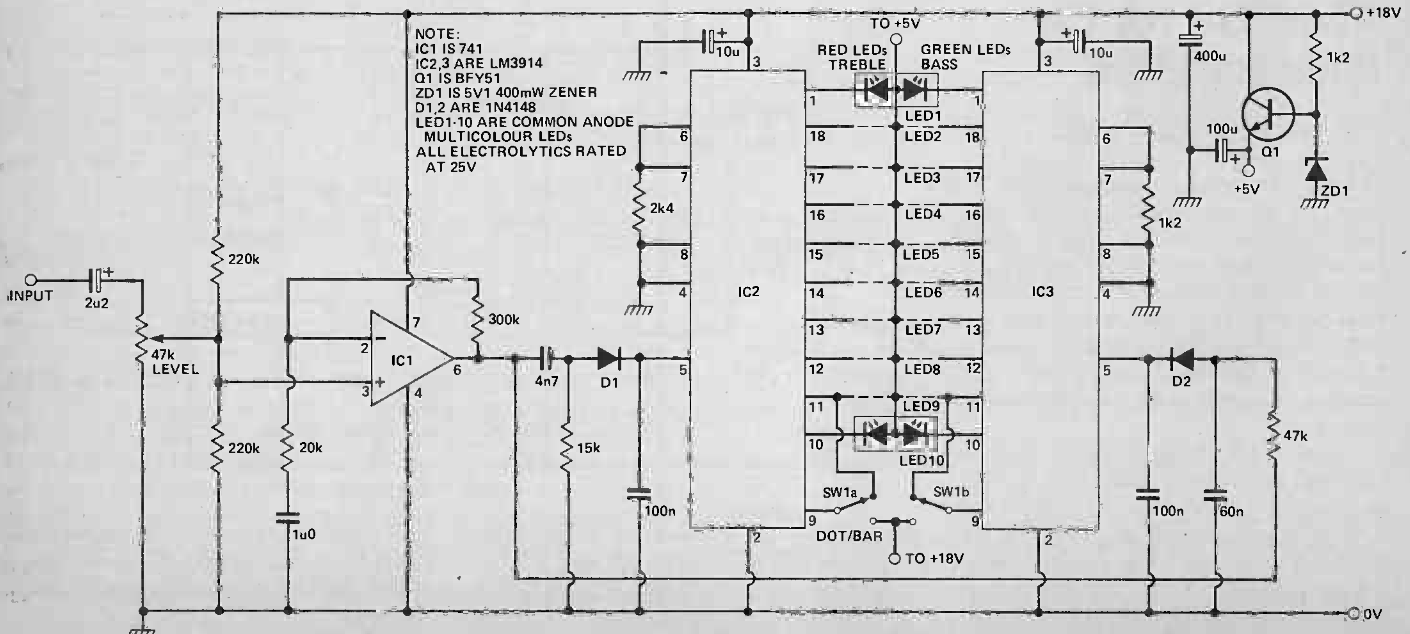
Figure 1 shows the usual single-ended virtual earth mixing method; and Fig. 2 the addition of a few resistors to convert it to the differential equivalent.

As it is a technique rather than a circuit; I have left out component values and preamp details to simplify the diagrams.

Visual Simple Sound Analyser

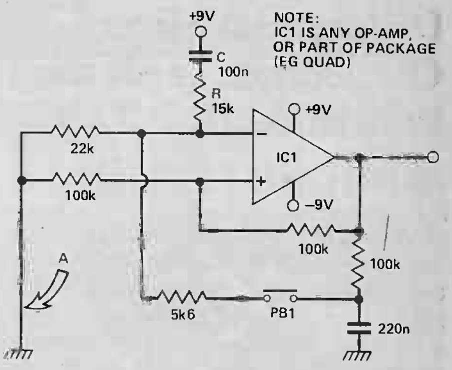
J.R. Walker, Norwich

This circuit is a simplified (and cheaper) version of the ETI VCSA, displaying bass and treble levels simultaneously on one bank of 10 multicolour LEDs. In dot mode, this provides an interesting effect, but in bar mode the effect is really weird. The circuit works in a similar way to its big brother, except for the LED arrangement — these are run at a lower voltage to avoid overloading the LM3914. Be sure to wire the 10uF electrolytics close to the chip, and use a well regulated supply at 12 V (maximum), 250 mA (minimum).



Single Push-button Op-amp Flip-flop

T.J. Hill, Watford



This circuit will be of use to constructors who find that while designing a circuit with quad op-amps, they have only one spare op-amp in their packages.

Upon switch-on, the CR combination at the inverting input takes the output to −9 V. The non-inverting input causing the output to switch to 9 V.

Even if the push-button is kept depressed, the circuit will not oscillate because the non-inverting input will now become 4V5, and the inverting input (22k/127k6) x 9 = 1V55. When the push-button is released the 220n capacitor can then charge fully to the op-amp output of 9 V and the non-inverting input falls to 0 V.

The circuit will maintain this new state until the push-button is pressed once again, when the reverse will occur taking the op-amp output back to −9 V.

There are two further points; the CR combination may be taken to the −9 V terminal to allow the op-amp output to become 9 V upon circuit switch-on. This circuit may also be powered from a single rail power supply if point A is connected to a voltage divider comprising two resistors of 4k7 between the battery positive and ground, giving approximately positive and ground alternating states.

Fig. 1

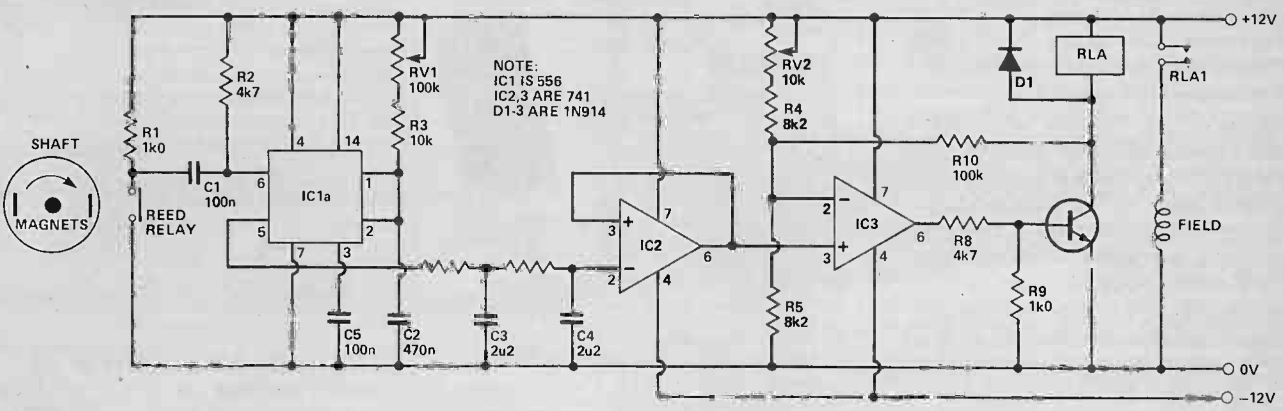
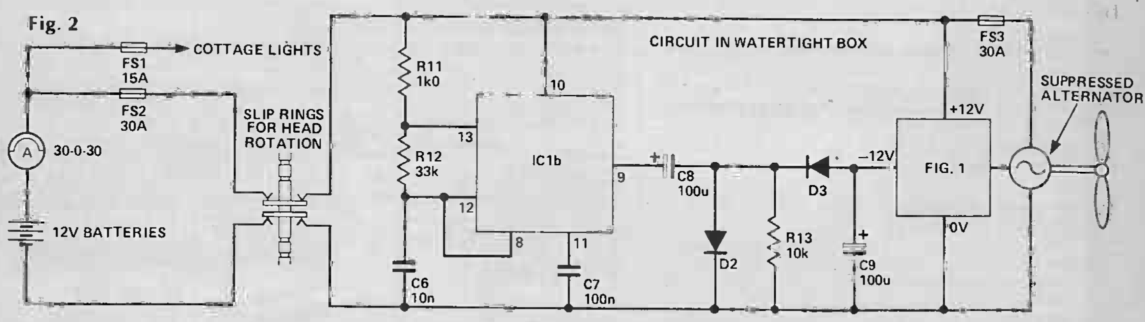


Fig. 2



Control Wind-power Circuit

E.A. Parr, Carluke

This circuit was designed to control a windmill at a remote holiday cottage. The cottage's electrical supply is derived from 12 V batteries which are recharged by an alternator driven by the windmill. The field on an alternator draws about 1 A when the battery is not being charged, and the circuit was designed to cut out the field when the windmill speed is too low to permit charging.

The windmill speed is measured by two magnets on the shaft which pulse a reed relay. This in turn fires the 556 monostable IC1 as shown in Fig. 1. The output from IC1 is thus a constant width pulse train whose frequency is determined by the windmill's rotational speed. This is smoothed by the two stage filter R6-C3-R7-C4 and buffered by IC2 to give a DC voltage at pin 6 of IC2 which is directly proportional to the windmill speed. This is compared with a preset voltage by IC3 and used to switch the field relay via Q1. R10 provides hysteresis, necessary because the windmill speed drops slightly as the alternator comes on load.

For IC2 and IC3 to work properly, a negative supply is needed. To provide this from the single 12 V battery supply, the simple DC-to-DC inverter shown in Fig. 2 was necessary. This utilises the other half of the 556 and gives a low current −12 V supply.

The voltage at pin 6 of IC2 is proportional to speed until the period of the monostable is equal to the rate at which the reed relay is pulsed. At frequencies above this, the voltage falls due to cycle skipping, giving the output voltage versus frequency graph of Fig. 3. As a windmill operates over a wide frequency range, it was expected that cycle skipping would occur at high speed. This is,

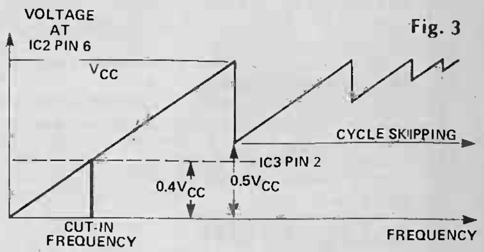


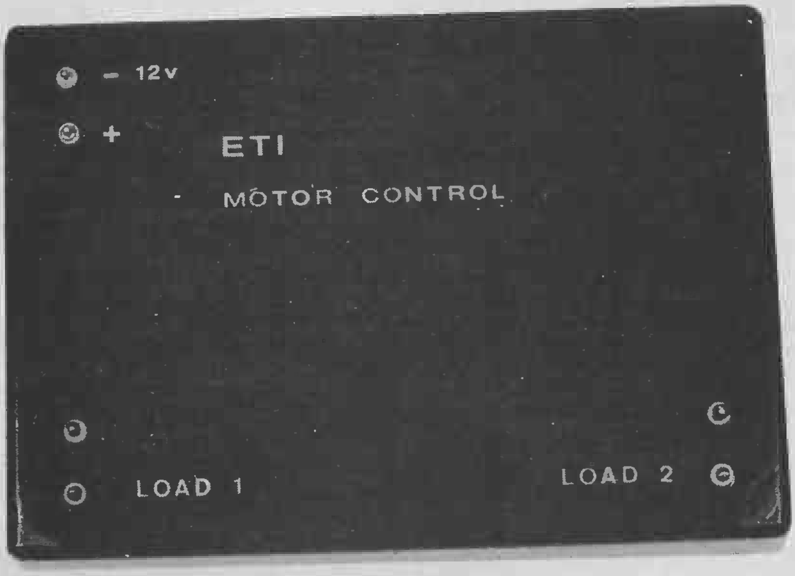
Fig. 3

however, of no importance if the trigger voltage is set at 40% of V_{cc} giving a single unambiguous cut-in point.

The coarse cut-in point is set by RV1, and the fine by RV2 (subject to the comments in the preceding paragraph). The circuit was designed for a cut-in speed of about 400 RPM which suited the windmill/alternator combination. The circuit draws minimal current from the battery therefore allowing the windmill to be left to its own devices while the cottage is unattended.

ROBOT MOTOR CONTROLLER

This heavy-duty piece of hardware is the first part of a series which will lead up to an intelligent programmable mobile. Design and development by Rory Holmes.



In this article we are offering a design for a high powered DC motor controller based on a switching amplifier capable of independently driving two motors at currents of up to 10 A.

The first part describes the design and construction of the power switching circuitry; in the following part next month we shall be offering both digital and analogue versions of pulse width controllers for driving the power stage.

Motor speed control amplifiers are very useful devices, finding many applications in such things as motorised wheelchairs, mobile computer peripherals, robots and many industrial process control functions. We are using ours as the main traction control in a small vehicle intended as the basis for a mobile computerised robot.

The ETI motor control is a four quadrant servo type; it can provide motor speed and torque in negative and positive directions and is designed to use 20 kHz constant frequency pulse width modulation. It features two CMOS logic inputs for forward/reverse control and duty cycle control and will suit a variety of motors up to 12 V — or even more if reduced speed is acceptable.

With suitably designed positional feedback it may also be used as the power amplifier in a positional servo system. Each control channel can handle 10 A of motor current and, due to a symmetrically designed PCB, it can easily be built as a single motor speed controller if desired.

DC motors are unruly beasts as far as electronic control is concerned and there is more to the design of suitable amplifiers than meets the eye.

Speed control can be achieved using a linear amplifier where a regulated voltage applied to the motor is varied; however, the torque available falls off at low speeds and the power dissipation in the output transistors becomes excessive at large currents due to the voltage dropped.

This power dissipated also represents a waste of valuable battery power. Hence the decision to use a 'pulse width modulated' system, where the amplifier switches the supply voltage on and off at a fixed frequency with variable mark-space periods so that an adjustable average current through the inductive motor load is produced.

The first problem encountered is in selecting the switching frequency. Most motors produce a disturbing noise if this lies in the audio band, but on the other hand power transistors don't switch off very quickly, which ruins high frequency performance. Fortunately this problem can be minimised using higher frequency transistors and low values of transistor "base turn-off" resistors.

Another problem encountered is when the transistors switch off; the motor current doesn't, due to motor inductance. This disaster can be averted by using 'flywheel' diodes to provide an alternative current path in a closed circuit round the motor. These diodes also protect the output transistors from switching transients caused by the back EMF of the motor. A single supply rail suitable for a 12 V car battery was chosen, and since a reversing function was desired, an 'H' type bridge output stage must be used. This can provide reversal of the motor voltage polarity within a few microseconds and is thus suitable for positional servos.

Construction

We have arranged the PCB and the general construction to make it easy for those who only require one motor control, rather than the dual version we are presenting. The PCB is symmetrical and can simply be sawn in half and wired up in a smaller box in the same manner described for the double system. We strongly recommend using the diecast box we have specified, since this provides RFI screening and also acts as a firm heatsink for bolting the power transistors to.

Our aim was to bolt all the transistors on to the metal case with their leads directly soldered to the PCB and to get all the components on the inside of the box! Hence the unusual method of soldering the transistors from the copper track side of the board (see the internal photos). Bridge rectifiers come in all shapes and sizes and at the specified current rating usually have a hole for heatsink mounting and large connecting tags. For this reason we decided to mount the bridge off the PCB, using stiff wire links for connecting to the board.

Solder the components to the PCB as normal, checking component polarity and remembering to solder the Veropins at the input points marked on the overlay; do not connect the power transistors yet. These power transistors, Q1-4, should now have their leads bent as shown in Fig. 3. They are fitted in to their appropriate holes from the underneath of the board and soldered in place — allowing a gap of 1 cm between the component side of the PCB and the metal bottom of the transistor.

Lengths of thick tinned copper wire (about 3") can now be wired to the PCB at the points marked for connection to the bridge rectifiers. They should be left protruding from the top of the board. Testing of the assembled board can be done at this stage, providing a resistive load is used as described below, and it's probably worth doing before everything is tightly bolted up. After testing, the holes for transistor mounting must be drilled in the bottom of the diecast box.

The board is bolted by the transistors, component side up, in the bottom of the box and the bridge rectifiers are bolted on either side. Remember, it is essential to use insulated mounting kits for the transistors. The leads to the motor and battery supply can be let out of the box through small holes drilled near the bridge rectifiers. We actually used leadthrough insulating terminals mounted on the case and took the supply and motor leads from the bridge rectifier tags.

Testing

The unit can be tested using a resistive load of about 100R, under these conditions it need not be connected to the bridge rectifier or the heatsink.

Connect a 12 V, 1 A power supply at the points shown on the overlay to one channel and a 100R resistor across the leadout wires where the motor

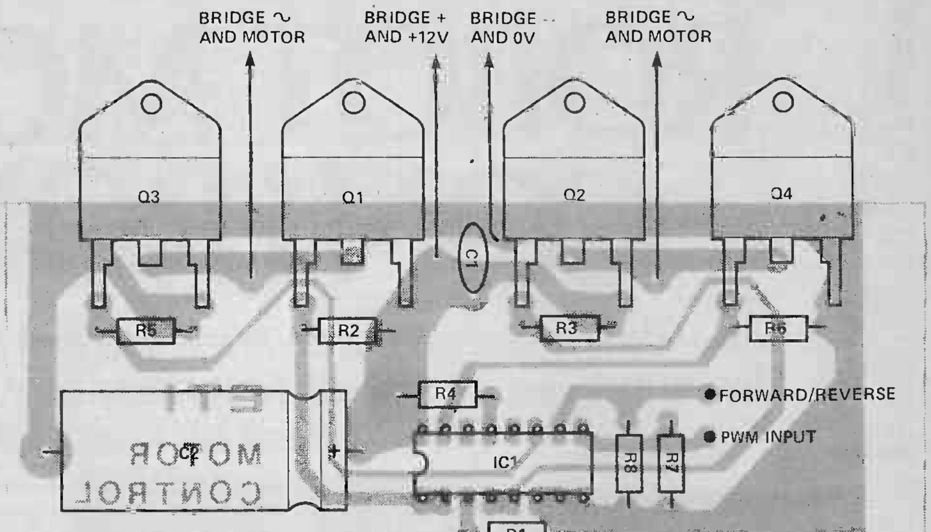
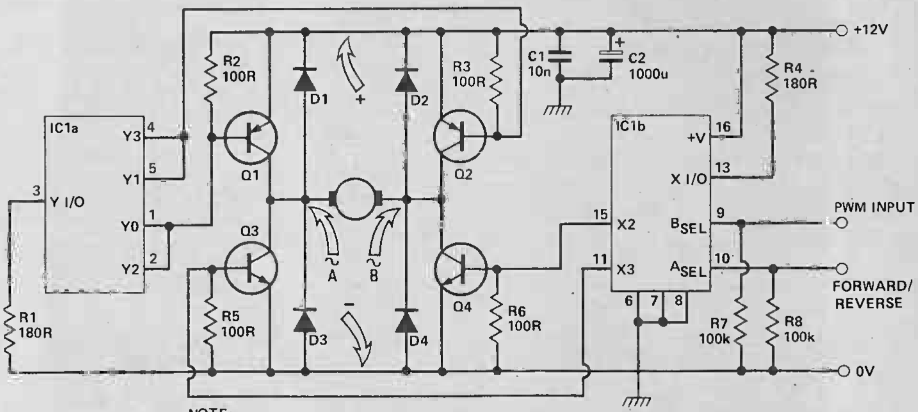


Fig. 1 Component overlay for one half of the PCB. The other side is symmetrical.



NOTE:
IC1 IS 4052B
Q1,2 ARE TIP146 OR TIP147
Q3,4 ARE TIP141
D1-4 IS 10A, 100V BRIDGE RECTIFIER

Fig. 2 Circuit diagram for one channel of the controller. Components for the other channel are designated R101, R102 etc.

PARTS LIST

Power Switching Section
(for dual controller)

Resistors (all ¼ W, 5%)

R2,3,5,6,102,-103,105,106	100R
R1,4,101,104	180R
R7,8,107,108	100k

Capacitors

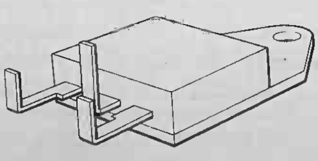
C1,107	10n ceramic
C2,102	1000u 25 V axial electrolytic

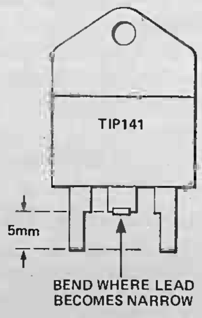
Semiconductors

IC1,101	4052B
Q1,2,101,102	TIP147 or 146
Q3,4,103,104	TIP141
D1,2,3,4,101,102,103,104	Bridge rectifier (10 A, 100 V; heatsink mounting type)

Miscellaneous
Transistor mounting kits; diecast box (172 x 120 x 55 mm); PCB (see Buylines); robot chassis and DC motors; 12 V battery.

Fig. 3 Bending details for the power transistor leads.





BUYLINES

The semiconductors used in this project are somewhat exotic; however, the Darlington power transistors (a gain of 1000 at 10 A) are available from Rapid Electronics and Technomatic, while the bridge rectifiers should also be available from these firms and other semiconductor suppliers. The robot chassis that we used is available from Remcon Electronics, 1 Church Road, Bexleyheath, Kent DA7 4DD, at a price to be announced.

should be. With the two logic inputs unconnected, points A and B on the circuit diagram should both be at nearly 12 V. When a 20 kHz square wave of 12 V peak is now applied to the modulation input, the switching waveforms should now be obtained. If a variable pulse-width square wave is available it should be possible to control the average current through the resistor by altering the pulse width.

Once the unit is fully assembled and bolted up, the above procedure can be repeated using a DC motor as the load. Speed control should now be achieved by varying the duty cycle of a logic square wave applied to the modulation input.

Fast rise time power switching circuits are notorious generators of RFI, hence our screened diecast enclosure and decoupling capacitors C1 and C101. Ceramic bypass capacitors of 1nF should also be wired directly across the motor terminals (although many motors already have such suppression fitted). For the truly ambitious interference suppressor, very high permeability ferrite beads can be included round the supply and motor leads to absorb stray RFI.

HOW IT WORKS

Transistors Q1-4 form an 'H' type bridge output stage. This has the advantage of being able to apply the full supply voltage across the motor in either polarity direction using only a single supply rail, enabling 'solid state reversing' without the use of clumsy relay switching. The transistors used are high power Darlingtons which have a gain of 1000 at 10 A collector current (quite impressive!) and thus require a base drive of about 10 mA for the full rated output. This is a switching amplifier and so the transistors are switched either hard on or fully off; this not only reduces the transistor dissipation for a given power regulation but also the current consumption, so valuable in battery portable applications.

The bridge works in the following manner; when Q1 and Q4 are on, Q2 and Q3 are arranged to be off. Point A is now close to + 12 V and point B will be near ground, applying nearly 12 V across the motor in one direction. Q4 is now switched on and off by a 'duty cycle' or 'pulse width' modulated square wave. The supply voltage is thus switched on and off across the motor in bursts of varying size; with the help of the motor inductance this produces a controlled average current in the motor.

Applying the full supply voltage in short bursts across the motor provides a much higher motor torque than would a constant but lower voltage, which assists greatly in the regulation of low speeds.

To reverse the motor, Q1 and Q4 are switched off and Q2 and Q3 now turn on, operating in exactly the same way as described above. The switching frequency we shall be using is around 20 kHz, since anything less produces an infuriating whine from the entire motor assembly.

The transistors switch off sharply, removing the source of current from the motor, but the motor current can't change suddenly due to the motor inductance. Thus the circuit wouldn't work if it wasn't for D1 and D2, which act as 'flywheel' diodes. When Q4 switches off, the motor current that was flowing through Q4 to ground now flows in a circle through D2, Q1 and the motor. This is the reason for keeping either Q1 or Q2 continously switched on while Q3 or Q4 provide the switching modulation.

The bridge rectifier (D1 to D4) also protects the output transistors from the back EMF switching transients caused by the inductive load. They would be destroyed without this protection.

The base resistors R2, R3, R5 and R6 enable the Darlingtons to switch off faster. The base drive and logic selection of the transistors is all provided by the unconventional use of IC1, a dual one-of-four analogue switch (the CMOS 4052B). These switches connect the bases of the appropriate transistors via resistors R1 and R4 to the corresponding supply polarity. If the 'A' and 'B' select lines of IC1 are both low, pin 3 will be connected by the internal 120R resistance to pin 1, effectively taking the base of Q1 to ground through a 300R resistor and turning it hard on. If the 'B' select is now taken high, pin 3 will switch to pin 2 keeping Q1 turned on, and pin 15 will connect to pin 13, taking the base of Q4 to + 12 V. Q4 now switches on applying the voltage across the load.

ETI

BUYING MAIL ORDER

Without mail order suppliers of components, most of the projects you build (not to mention this magazine) couldn't exist. Kathryn McFarland and Ron Harris take a look at both sides of the fence.

If there is one common factor uniting the adherents to the hobby of electronics, it is the dependence upon mail order companies. Magazine projects invariably seek to employ new devices which may not have filtered down to the corner component shop at the time of publication. Prices from a mail order house will generally be lower, as they tend to buy in vast quantities and thus attract trade discounts.

Laying aside for the moment the whims of the GPO, it is remarkable how well the system runs, given the volume. Just about every enthusiast in the country orders *something* each month and will almost certainly receive excellent service. Naturally some people get a raw deal — things go astray, orders are not fulfilled, or incorrect goods are supplied. Normally such mistakes can — and will be — rectified immediately by the company and all will be well!

When things continue to go wrong, however, there is the 'Mail Order Protection Scheme' to ensure that the consumer is fairly treated. (More on that later). As a magazine with a large number of mail order advertisers, ETI sits fairly and squarely in the centre of the mail-order world. We produce the projects, we carry the adverts for the components. . . and we get the complaints when something goes wrong!

Breadboard

At the recent Breadboard '81 exhibition, we took the chance to gather both sides of the mail order story. Most people using the service will not have heard the history, nor know exactly to whom it is they are sending off their hard-earned cash. From talking to some of the companies involved, it was also apparent that there were obvious ways in which people ordering goods could make life easier on themselves and ensure a good service.

Thus the purpose of this article is to give both sides of the business a much needed airing, to fill in the details for the man at home and pass on the hints from the suppliers. We went around the show and interviewed some of the people behind the companies and talked to many of the visitors to our stand at Breadboard, from both the trade and the public.

What follows is a round-up of their comments and suggestions for improving relations and service. Not all the companies interviewed have been quoted — there is only so much space in an article, but we thank them all for their time and trouble! (We can assure you that your words were not wasted and nonetheless went into the shaping of this article.)

Days Of Mail Order Past

The oldest service of this variety in England began some 20 years ago, although many of the better-established firms insist *they* were the first, despite being founded well after this. The pioneers came from all walks of life; most, however, had at least a spark of enthusiasm for electronics (besides an interest in the potential pound notes!). Several were electronics designers, or keen hobbyists, while others were already established in related fields. A few companies, such as Global Electronics, began as UK offshoots of American companies.

Of this early business most was only a sideline conducted from kitchen tables, basements, and bedrooms, with friends and family employed as slave labour more often than not. What started as a scheme to earn a few extra quid a week took off almost immediately, to the delighted surprise of the founders. Orders poured in and business boomed. The market lay open with profit gleaming like a pearl on its surface. Success spurred the new businessmen to quit their office and sales jobs, leaving them free to go full-time in the expanding field of electronic component mail order.

Mail order served then — as now — as the main source for designers and amateurs to obtain transistors, components, electronic instruments and semiconductors; with products like electronic keyboard kits available strictly through a particular company. "Back then, electronics wasn't as advanced", says Mr. Nazir Jessa, co-founder of Watford Electronics (who have been in business for nine years).

Modern Mailings

Today, mail order takes many forms. Companies often function as manufacturers and distributors, supplying both the domestic and trade markets in the UK and abroad. In addition, several firms run a shop or two in various locations.

While single component sales and special kits comprise the bulk of the domestic market, industrial orders continue to bring in the big money. The average hobbyist's order ranges from six to 15 pounds, including the standard 50p to 75p postage and packaging charge. Industrial orders run from £20 to upwards of £350. Enthusiasts are often discouraged from ordering small, low-cost items because of the static 'P and P' charge, but it is not necessarily the intention of the companies to deter these buyers. Apparently, it costs the company the

same amount of money to process each order, regardless of size, hence the fixed fee.

Despite added costs, amateurs often get the best deal through mail order. While some companies maintain a policy of applying a 50% mark-up on their goods, others tailor prices in accordance with the competition which is, at present, fairly steep. "The amateur often gets goods at trade prices", says Mr. Longland of Electrovalue Electronics.

Lone Rangers?

In addition to the well-known firms, there exists fly-by-night 'hit and run' companies which buy in surplus, and charge less than the established traders are able to — but only for a short time before moving on. These 'cowboys', as they're referred to in the business, ride the market for a time, aiding the amateur in his quest for inexpensive components, while simultaneously reeking havoc throughout the mail order world.

Many companies will admit they are a bit put off by the cowboys' temporary influence on the market situation. "This business is plagued by them", says Mr. Shipton of A. Marshalls Ltd.

"An awful lot of companies come and go. Fly-by-nights can be expected in his business. Other companies are around year after year and you will see them in Breadboard. These are the names you can rely on", says Global Electronic's Tina Knight. Mr. Longland (Electrovalue) has resigned himself to the problem, taking a philosophical view: "We've always had cowboys and we always will".

In the long run, companies rely on their good reputation, the quality of their products and (excellent) service to see them through hassles of this sort. In most cases, satisfied customers re-order regularly as they establish trust and confidence in a particular mail order company.

Many customers, however, go straight to the company offering the lowest prices — a basic human reflex nowadays — which can only be combatted by compromise. "We're affected initially by cowboys because people tend to go by price", says Tina Knight (Global), "but you get what you pay for in the long run".

Competition Time

With the current economic climate as chilly as it is, competition has acted as a catalyst, forcing companies to become more dynamic. "Business is holding", says Global, "but we've had to work harder to maintain it". Mr. W. P. Baines, of Bi-Pak Semiconductors, says his company is "feeling (its) way around the recession". Although Bi-Pak is maintaining turnover, they plan to open more shops and get more sales representatives on the road to increase sales. A few companies aren't as affected by competition, such as Vero Electronics, which manufacture *and* distribute goods and have only(!) the recession to worry about.

Businesses like Clef Products Electronics, suppliers of kits and made-to-order electronic instruments, say they "aren't participating in the recession", which must mean business is excellent. The majority in the field, however, have had to become more efficient to survive. That and price-cutting makes competition the consumers' ally.

Mail order efficiency means knowing the market — what products to stock, on which components to hold prices, which to cut — and understanding the customer.

It also involves making your advertisements more attractive, according to Electrovalue, as well as keeping a mailing list of known good customers. "If you know the market, you can hold your own", says Longland. "We keep a log of our customers (when they tell us who they are) and what they're interested in".

Satisfying Customers

Keeping customers happy is another concern of an efficient mail order firm. Many will now guarantee the prices printed in their catalogues, while others distribute updated price lists regularly free of charge.

Several companies offer unconditional guarantees and 24-hour delivery to attract and maintain business. According to Mike Humphrey at Vero Electronics, customers develop a 'relationship' with their suppliers. "It's very emotional," says Humphrey, "they'll never buy again from a company that upsets them". Companies therefore try to maintain prices (within reason) as customers often become dismayed if another bill accompanies their order. Not all prices printed in catalogues remain the same, unfortunately, and a company can't realistically afford the time and expense of publishing more than one catalogue per year. Therefore it's best to check monthly magazine advertisements for a supplier's latest prices, or to call the company *before* placing an order. If they issue regular lists, make sure you use the current one.

One of the biggest complaints mail order suppliers receive is that the goods aren't delivered quickly enough. Several factors interfere with the smooth processing of orders including customer errors, discontinued or out of stock items, and the postal service. It's easy to blame a faceless institution such as the GPO, but apparently orders disappear or are delayed in the post from both ends of the process. "We occasionally get stick from our customers due to the postal service", says Mr. Shipton (A. Marshalls). Although Clef Electronics promises immediate dispatch of orders received (unless a product is made to order), they cannot guarantee actual delivery will be that rapid. Bi-Pak, for instance, sees to it that 97% of orders they receive in the morning go out that afternoon, the remainder may be held up in re-ordering if an item is out of stock. It usually takes 10 days (less if you're lucky, more if you aren't) for products to show up on your doorstep.

That's An Order

Simple errors in orders add to delay by confusing staff and result in wasted time. "We'd save five minutes on every order if people checked the prices on items", advises Mr. Jessa (Watford Electronics). Many people forget to enclose payment or, would you believe, neglect to include their return address when ordering. Tina Knight (Global) thinks remembering to put *both* name and address on orders is the best advice she can offer to help customers get the most out of mail order, or, for that matter, to get anything at all!

Writing clearly and enclosing an SAE with queries is also advisable. There are several ways to place an order, the most common being that of a letter, with remittance enclosed, whether in the form of a Giro, cash, or cheque. Ordering by phone, or with an Access or Barclaycard are other alternatives. Telex is usually employed in overseas orders.

Despite the obstacles, electronic component mail order continues to gain popularity in this country. One reason might be that people are finding it increasingly difficult to afford to purchase ready-built goods. More consumers are getting into DIY projects, including electronics. "Every year, more and more hobbyists go into electronics," says Mike Humphrey (Vero) "some are having a dabble. They're getting a soldering iron and becoming consumers of components."

Mail order will undoubtedly survive the recession and continue growing. "The market is big and constantly changing", says Mr. Humphrey, "many companies have realized a recession means a major understanding. They've *had* to become more efficient."

"You have to be good to survive. Components bought today can be worth half as much tomorrow because of the increasing technology. But a high technology product can set manufacturers off to the moon. They can annihilate the market!"

Foreign Practices

Retail trade in England is quite different from that in France, Belgium, or Germany. Components are sold in shops resembling supermarkets throughout these countries and mail order takes a back seat. In Germany, there are only four or five large mail order houses for the entire country. Most cities have shops that sell everything you need to complete almost any project. Of course, there are cowboys over there as well.

Mail Order Watchdog

You're not out there entirely on your own when mail ordering, you've got a friend — the mail order protection scheme. Essentially, you may be eligible for compensation if you order goods from an advertiser in participating magazines, pay in advance by post, and don't receive your order should the company be **officially declared insolvent or go bankrupt**.

The scheme is observed by every responsible publisher, and is explained entirely in the back of ETI. Provided the goods haven't been sent by the supplier, you should write to the magazine's publisher explaining the problem and giving proof of payment (between 28 days and 2 months from the day you sent the order); customer claims will be honoured if they satisfy the requirements.

This guarantee covers those who sent advance payment in *direct* response to an advertisement run in the magazine and not for payments made to advertisers' catalogues.

NAME	ADDRESS & TELEPHONE	Kits	Hardware	Transformers	Passive Components	Semiconductors	LSI	TTL	CMOS	Casings	Breadboard	Tools	Surplus Supplies	Modules	PCBs	Books	P&P Charges (Min)
A.J.H. Electronics	20 Barby Lane, Hillmorton, Rugby, Warwickshire CU22 5QT Tel: 76973 eve. 71066		●		●	●	●										
A. Marshall Ltd	Kingsgate House, Kingsgate Place, London NW6 4TA Tel: 01-624 8582		●	●	●	●	●	●	●	●	●	●		●		●	60p
Ambit International	200 North Service Rd, Brentwood, Essex CM14 4SG Tel: (STD 0277) 230909	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Audio Electronics	301 Edgware Rd, London W2 18N Tel: 01-724 3564		●		●	●				●	●	●		●		●	65p
Audio Video Service	19 Galsworthy Ave, Romford RM6 4PX Tel: 01-599 6680		●			●	●	●	●		●				●		35p
B. Bamber	5 Station Rd, Little Port, Cambs CB6 1QE Tel: Ely (0353) 860185		●	●	●	●							●	●	●	●	75p
Bi-Pak	P O Box 6, Ware, Herts Tel: Ware 3182	●	●	●	●	●	●	●		●	●	●	●	●	●	●	50p
B K Electronics	37 Whitehouse Meadows, Eastwood, Leigh-on-Sea, Essex SS9 5TY Tel: 0702 527572	●		●										●			
Chordgate Ltd	75 Faringdon Rd, Swindon, Wilts. Tel: Swindon (0793) 33877		●	●	●	●	●	●	●	●	●	●	●		●		15p
Clef Products (Electronics) Ltd	44A Bramhall Lane South, Bramhall, Stockport, Cheshire 5K7 1AH Tel: 061-439 3297	●	●	●	●	●	●	●	●				●	●	●		Incl.
Crimson Components Ltd	101 St Leonards Rd, Windsor, Berks SL4 3BZ Tel: 07535 57340	●	●	●	●	●		●	●	●		●			●	●	20p
C.T. Electronics (Acton) Ltd	267/270 Acton Lane, London W4 5DG Tel: 01-747 1555/994 6275		●	●	●	●	●	●	●	●	●	●	●	●	●		
Electrovalue Ltd	28 St. Judes Rd, Englefield Green, Egham, Surrey TW20 0HB Tel: Egham 33603 (STD 0784; London 87)	●	●	●	●	●	●	●	●	●	●	●			●	●	40p
Global Specialties Corp. (UK) Ltd	Unit 1, Shire Hill Ind. Est., Saffron Walden, Essex CB11 3AQ Tel: (0799) 21682	●	●					●	●	●	●						
Greenbank Electronics	Chester Rd, New Ferry, Wirral, Merseyside L62 5AG Tel: 051-695 3391	●	●	●	●	●	●	●	●	●					●	●	40p
Greenweld	443A Millbrook Rd, Southampton SO1 0HX		●	●	●	●							●	●			40p

Readers answering classifieds are on their own as classified advertising is excluded from this scheme. Perhaps the expression *caveat emptor* is a sufficient word to the wise.

Check It Out

In our quest to make mail order a comprehensive subject, we've included a sampling of companies and a checklist of their components and services.

Perhaps it would be valuable for regular mail order customers to do a little research on their own and compile a complete chart (including price) as quick reference. For our guide, we scanned advertising pages of seven monthlies, concentrating on those firms which dealt mainly with components.

MAIL ORDER MADE EASY

- Compare company prices, postage and packing charges and policies, to find the one suitable for you.
- Make sure you know the correct price of an item before you send in an order. Check recent adverts and catalogues, or better yet, call the company directly and ask them to quote current prices.
- Enclose the proper remittance (including P&P charges) in the form of a postal order, cheque, Access or Barclaycard number, or cash. Company policies will dictate which to use. Sending cash should be avoided as it is risky. And *don't* send your credit card!
- Print your NAME and ADDRESS clearly on the order!
- Enclose a self-addressed stamped envelope with all enquires to ensure a reply.

NAME	ADDRESS & TELEPHONE	Kits	Hardware	Transformers	Passive Components	Semiconductors	LSI	TTL	CMOS	Casings	Breadboard	Tools	Surplus Supplies	Modules	PCBs	Books	P&P Charges (Min)
Henry's	404 Edgware Rd, London W2 1ED Tel: 01-723 1008/9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	50p
Langrex Supplies Ltd	Climax House, Fallsbrook Rd, Streatham, London SW16 6ED Tel: 01-677 2424					•											
L.B. Electronics	11 Hercies Rd, Hillingdon, Middlesex UB10 9LS Tel: Uxbridge 55399		•	•	•	•		•	•		•		•		•		40p
Magenta Electronics Ltd	135 Hunter St., Burton-on-Trent, Staffs DE14 2ST Tel: 0283 65435	•	•	•	•	•	•	•	•	•	•	•		•	•	•	40p
Maplin Electronic Supplies Ltd	P O Box 3, Rayleigh, Essex SS6 8LR Tel: Southend (0702) 554155	•	•	•	•	•	•	•	•	•	•	•		•	•	•	25p
Micro Times	19 Mill St, Bideford, North Devon EX39 2JR Tel: Bideford (02372) 79798	•				•	•	•	•		•	•					50p
Modular Electronics	95 High St, Selsey, Nr Chichester, Sussex. Tel: Selsey (024361) 2916				•	•						•		•			50p
Namal Associates	No 1 Claygate Rd, Cambridge CB1 4JZ Tel: 0223 248257					•	•	•	•		•						100p
Parndon Electronics Ltd	Dept No 23, 44 Paddock Mead, Harlow, Essex CM18 7RR Tel: 0279 32700				•												
Rapid Electronics	Hillcroft House, Station Rd, Eynsford, Kent DA4 0EJ Tel: 0322 863494	•	•	•	•	•	•	•	•	•	•	•	•	•	•		50p
Technomatic Ltd	17 Burnley Rd, London NW10 1ED Tel: 01-452 1500/450 6597			•		•	•	•	•		•	•	•		•	•	40p
T.K. Electronics	11 Boston Rd, London W7 3SJ Tel: 01-579 9794/2842	•		•	•	•	•	•	•	•	•				•	•	50p
T. Powell	Advance Works, 44 Wallace Rd, London N1 Tel: 01-226 1489	•	•	•	•	•		•	•	•	•	•	•		•		40p
Vero Electronics	School Close, Industrial Estate, Chandlers Ford, Hants SO5 3ZR	•	•								•	•		•	•	•	50p
Watford Electronics	33/35 Cardiff Rd, Watford, Herts Tel: Watford (0923) 40588	•	•	•	•	•	•	•	•	•	•	•		•	•	•	50p

This table is comprised of those component suppliers who could be directly contacted, and excludes specialist kit companies. Data was obtained through recent magazine adverts when companies could not furnish complete information over the phone. (Conditions subject to change.)

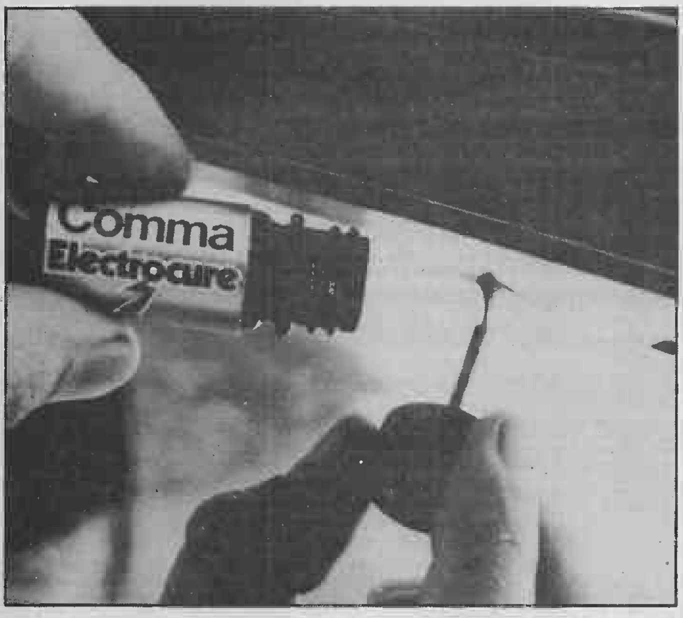
ETI

Brush Up On Repairs

Electrocure 7, a revolutionary new conductive paint-on preparation for the repair of rear window demisters is the latest addition to the Comma range of car care products. This silver-based, specially formulated, paint enables motorists to overcome the irritating problem of broken heating elements quickly and simply, eliminating need for replacement of expensive rear windows. Comma Electrocure 7, which retails for a recommended price of less than £5.00, can provide the motorist with substantial savings.

Demister elements can be damaged easily by scratches from sharp objects, abrasive cleaners and stickers. With hatchback cars this is a common problem, but it can be overcome easily by using Electrocure 7. Because of its outstanding conductivity, it is also ideal for curing problems in a multitude of other low voltage electrical applications. These include repair of radio antennae incorporated onto front windscreens and making good broken connections in printed circuit boards, instruments, connectors and other items.

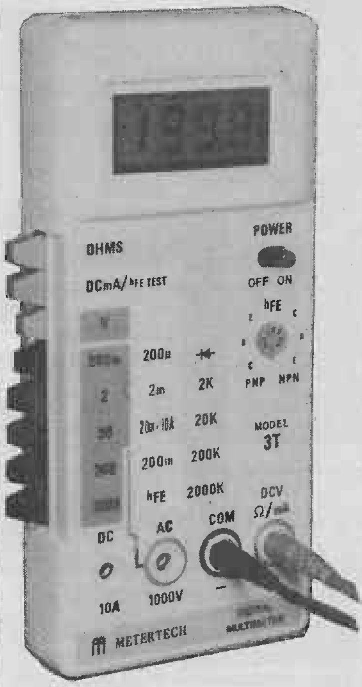
Electrocure 7 allows a permanent repair which is highly-resistant to abrasion. It is also resistant to alkalis and hydrochloric acid and will not discolour when subjected to temperatures of up to 300°C. It has been developed for use on non-solderable surfaces, including glass, plastics, acrylics and ceramics. The product is available in blister-packed glass bottles incorporating applicator brushes; applications and directions for use are on the blister-pack header cards. Electrocure 7 is now available from garages, motor accessory shops and other appropriate outlets.



Sinclair Scheme

To help meet the need for more ZX81 educational software, Sinclair Research is sponsoring a special award scheme offering six ZX Printers as prizes for the best programs accepted into the MUSE software library by the end of March 1982. With over 100,000 ZX81s now sold and with sales to more than 2300 secondary schools under the company's recent subsidised purchase scheme, Sinclair is keen to support the development of educational software. "We have a very strong commitment to expanding computer applications in schools", commented Clive Sinclair, Chairman of Sinclair Research. MUSE, the teachers' organisation for computer users in schools and the Educational ZX80/81 Users Group (EZUG), are to administer the scheme and, in consultation with Sinclair, judge submissions in the following categories: primary maths and science; other primary; secondary maths, science and computing; other secondary and special education. Entries and inquiries should be sent to Eric Deeson, EZUG organiser, Highgate School, Birmingham B12 9DS. Closing date is February 27th, 1982.

Hand-held MM



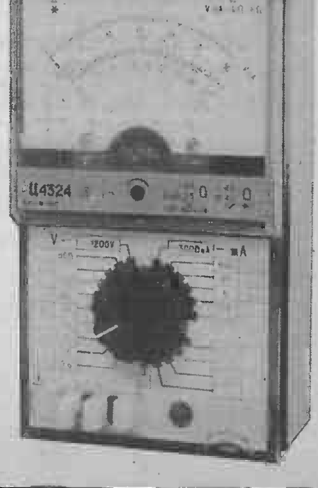
The Model 3T from Centemp is a battery operated 3½ digit hand-held digital multimeter with a 0.5" liquid crystal display. The meter provides six functions in 16 ranges permitting measurement of DC voltages, AC voltages, DC current, resistance, Diode/continuous check and an HFE measurement facility. Push-button controls allow fast and easy operation while small size, robust construction and long battery life make the 3T a portable unit. Supplied complete with battery, test leads and instruction manual for £49.95 including VAT. However, due to the mistake in printing the picture of this meter in last month's ETI, we have arranged a discount for our readers, so you can get this meter for £42.50 including VAT and p&p. All you have to do is cut out this news item and send it with your order. But if desecrating the mag brings tears to your eyes, just mention ETI! Orders to Centemp, 62 Curtis Road, Whitton, Hounslow, Middlesex TW4 5PT.

Ultrasonic Module

The Autona US4012 Ultrasonic Module is a low cost stable module which is designed as the basis for an effective intruder alarm. The unit is designed to reduce false alarms to a minimum but still provide detection at distances over 20 ft. It is flexible enough, however, to be used in counters and automatic door opening equipment, etc. Using CMOS circuitry, the unit has a low quiescent consumption thus ensuring extended operation using battery back-up systems in the event of power failure. The unit will switch currents up to 100 mA and is small enough to be fitted into discreet enclosures, such as simulated books, wall decorations and the like. The unit is supplied with a comprehensive data sheet and is available at a cost of £12.59 (one off) including VAT, but add 50p for P&P. Order from: Riscomp Ltd, 21 Duke Street, Princes Risborough, Bucks HP17 0AT.

Blunder

In last month's News Digest you may have noticed that the item entitled 'Miser's Meter' had the wrong picture with it! The meter in the pic was a digital one from Centemp and the item which should have gone with it appears in this issue. The real Miser's Meter is shown here and is available from Marco Trading, The Old School, Edstaston, Wem, Shropshire SY4 5RJ for 10.50 plus £1.50 p&p.



LIGHT WAND

A portable, battery-operated light has a thousand and one uses. Torches are fine, but their narrow beam limits their application. This project describes a highly practical, battery-operated fluorescent light which is highly efficient. Design by Jonathan Scott and Eric Mills. Development by Phil Walker.

Fluorescent torches, fluorescent lights on buses and trains, and battery backed-up fluorescent emergency lights have been with us for some time now. The original motivation for designing this particular circuit, however, was to produce the most light for the least weight. The design had to be compact, reliable, able to take a wide range of input voltages, but above all — be reliable.

Our basic model — the 8 W one — uses parts which are readily obtained. We built a 4 W version similar to the 8 W one simply by using the smaller tube directly. This is physically nicer, but inherently less efficient.

Neatness and care is important in this project, though construction is not difficult.

Construction

The first step is the most important and the most time consuming; winding T1. Ensure that you have adequate 26 swg, 32 swg and 40 swg wire; about 2 m of the first and 10 m each of the second and third will be required. Have a sharp blade, some ordinary clear sticky tape and about 90 minutes on hand.

Start with the secondary winding. Leaving about 3 cm of wire projecting, close wind the 32 swg wire on to the former; 150 turns is almost exactly 4 layers. When the first layer is complete, cut a strip of sticky tape the correct width and, without letting the turns unravel, insulate the layer with the tape. Repeat this procedure, layer by layer, until you have wound four layers.

Terminate the winding to the pins shown in Fig. 1. Next wind on the secondary and the feedback windings. The 30 turn primary is about 1½ layers and the feedback winding will go in the remaining ½ layer. Again terminate to the pins as shown in Fig. 1. Put a layer of tape over the windings.

Now wind on the starter winding — 150 turns of 40 swg. This is very fine and must be handled with care. The winding must be as even as possible to avoid flashover. If more than one layer is needed, insulate with tape between them. Also put a layer of tape over the top. Terminate this winding to the proper pins.

Finally wind on the heater winding; 10 turns of 32 swg. Insulate and terminate.

The specified core is a gapped one. It is rather fragile and should be handled with care and reverence. Fit the cores into the former and secure with the clips provided. Under no circumstances should they be held tightly by the centre.

Circuit Notes

This converter circuit is actually much more complex in its operation than the circuit diagram appears! Hence the long How It Works section.

D1 is a protection diode. It can be used in either of the two positions indicated and will protect the circuit from damage in the event of reversed polarity being applied. In position, it blocks any flow of current in the reversed polarity condition but drops about 0V8 from the supply in normal operation. Where a car battery or rechargeable battery pack is used and efficiency is not at a premium, this is satisfactory. If, however, dry batteries are used or efficiency is at a premium, the supply can be connected to point A, but no polarity protection then operates.

Capacitor C1 is the supply bypass capacitor. Due to the high speed switching transients present, this capacitor needs to be a tantalum type.

Actual power consumption and apparent light output can vary from unit to unit. The amount of power delivered to the tube – and hence the power consumption overall – can be varied by adjusting R1 and R2. The values of 820 ohms and 22 ohms are given only as a guide. In order to have a current consumption of about 250 mA, which seems to be the best compromise, as little as 560 ohms or as much as 1k2 might be required for R1 and down to 2R2 for R2. Generally, if the supply current exceeds 400 mA, R1 should be increased and if starting is unreliable it should be decreased.

One final note; Q1 appears to be very overrated, being a 40 W device which can carry many amps – much more than necessary. However, we have found that transistor dissipation goes up (and efficiency down) if a transistor of smaller rating is used. This seems to be because the beta falls if the knee current is exceeded and the transistor dissipates power during switching as a direct result. Thus, we recommend the use of a TIP31 rather than, say a BD139 or Philips BDY50.

The next step is to assemble the PCB. The transformer should be inserted such that the secondary tags are nearest D2.

Initially it would be wise to connect the transformer to the board using short lengths of insulated wire until operation is verified.

Connect the tube to the board as shown in the overlay.

With some method of limiting current, such as a supply limiting at about 200-500 mA or a 22 ohm resistor in series with a 12 V supply, apply power. Now, one of three conditions will exist:

1. No oscillation. If there is AC on the secondary, the device is oscillating. If you wish to check this without a multimeter, bridge the 1N4007 momentarily. Any flicker indicates oscillation. If there is none, reverse the phase of the feedback winding by swapping its wires. This should get you to condition (2) or (3).
2. Oscillation; but tube glows dimly or only with the 1N4007 bridged out. This means that the secondary sense is wrong. Swap both the primary and feedback wire pairs. This should get you to condition (3).
3. It works.

If necessary re-terminate the transformer windings and solder it into the PCB. Check the power consumption next. If it is more than 400 mA, or the

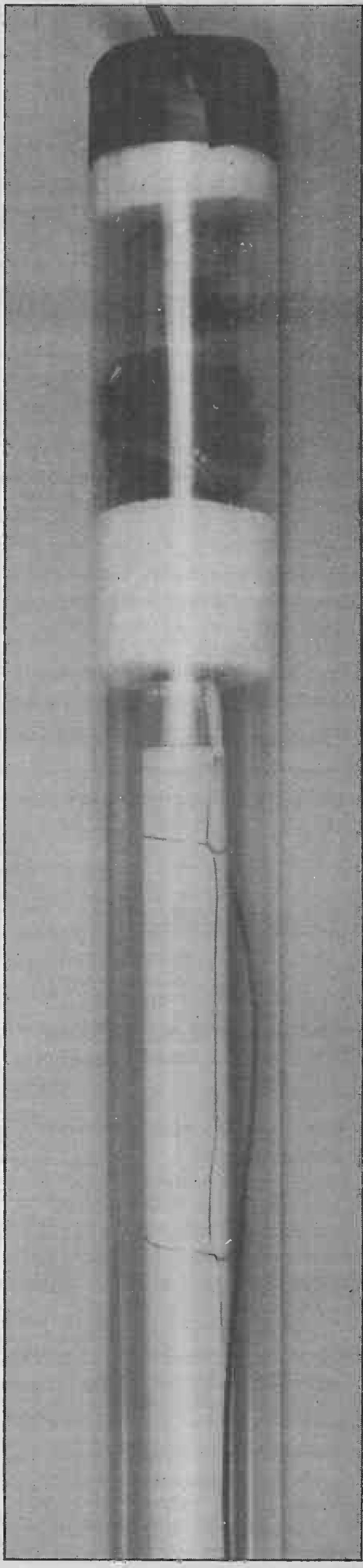
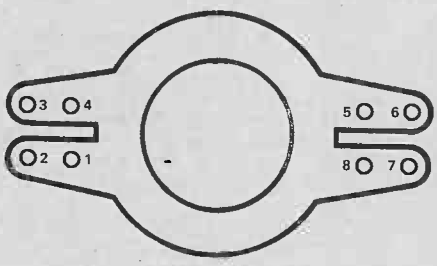


Fig. 2 T1 winding details.

START	FINISH		
1	2	PRIMARY	30 TURNS 26 SWG
4	3	FEEDBACK	5 TURNS 32 SWG
8	5	SECONDARY	150 TURNS 32 SWG
5	6	HEATER	10 TURNS 32 SWG
6	7	STARTER	150 TURNS 40 SWG



FORMER – PIN VIEW

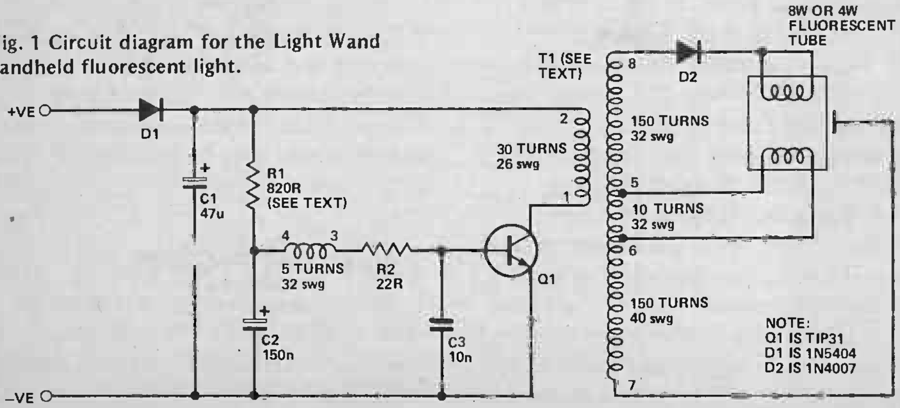


Fig. 1 Circuit diagram for the Light Wand handheld fluorescent light.

PARTS LIST

Resistors (All ¼ W, 5%)
R1 820R
R2 22R

Capacitors
C1 47u 16 V tantalum
C2 150n 35 V tantalum
C3 10n polyester
D1 1N5404
D2 1N4007 or similar 1kV PIV diode

T1 Neosid RM10 with 0.3 mm gap.
F1 Fluorescent tube; TL8W (8 W)
Wire, 32 swg (0.2 mm) and 26 swg (0.4 mm) enamelled wire; Perspex tube, 32 mm I.D., length to suit; Alligator clips.

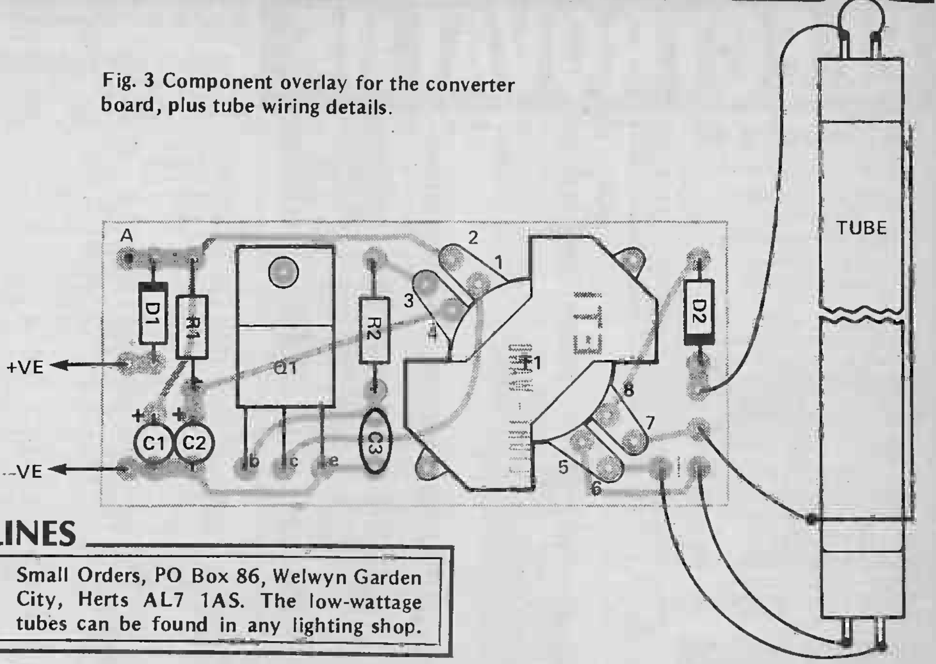
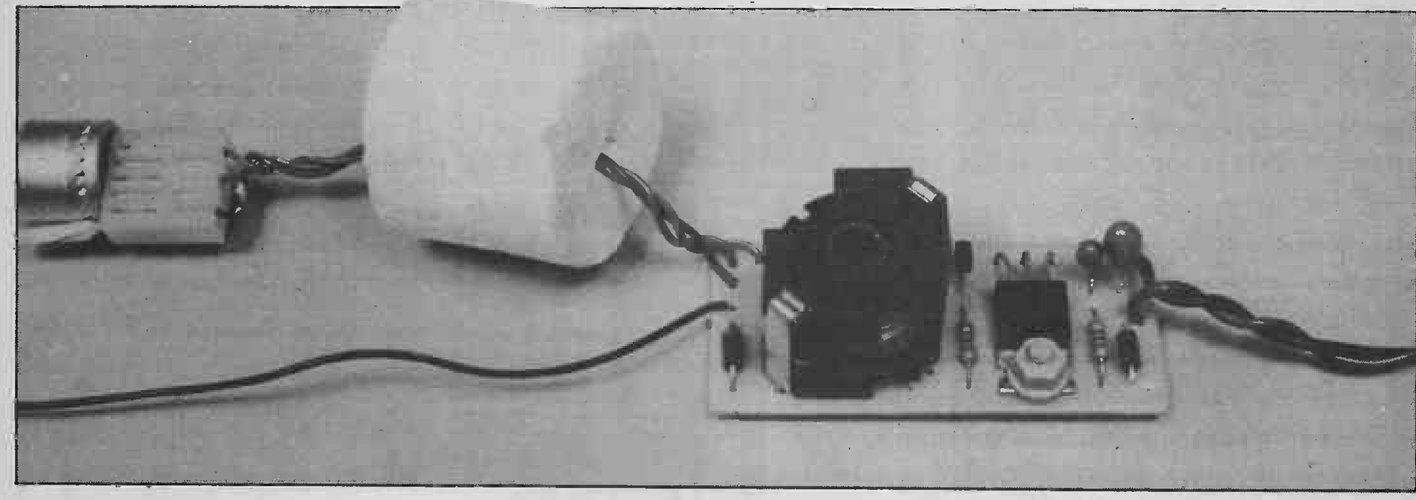


Fig. 3 Component overlay for the converter board, plus tube wiring details.

BUYLINES

The only out-of-the-ordinary component in this project is the Neosid pot core RM10. This can be obtained from Neosid Small Orders, PO Box 86, Welwyn Garden City, Herts AL7 1AS. The low-wattage tubes can be found in any lighting shop.



transistor gets too hot to touch, increase R1 to 1k0 or 1k2. If the whole draws less than 200 mA or is dim, increase it to 680 or 560 ohms.

If the lamp is still too dim, decrease R2 until it is satisfactory, while still not drawing excessive current or overheating.

The remaining construction is up to you, depending on how you have chosen to house the assembly. The following description pertains to our prototype. You will require a 400 mm length of acrylic tube; 32 mm I/D. It is available from any large perspex dealer (see Buylines). The end pieces and spacer inside the tube were made from polystyrene which is very easy to cut and provides support for the light tube. The ends are held in place and made waterproof with plastic tape. You may then fit a suitable connector on to the power cable – we built our device with alligator clips. A reflector may be formed by sliding some white paper behind the tube.

HOW IT WORKS

R1, R2, C2, C3, Q1 and T1 comprise a self-oscillating DC-DC converter.

Initially, Q1 is turned off. At switch-on, current flows through R1, charging C2. Subsequently C3 charges up via the five-turn feedback winding and R2. When C3 reaches about 0.55 volts, Q1 begins to conduct. The feedback winding then forces more current into C3 via R2 because of the phase of its connection. Q1 is then turned hard on. During this positive feedback cycle C2 is actually forced to discharge. R2 limits the maximum base current, and C3 removes fast spikes from the base circuit. These together serve to protect Q1's base.

Eventually, the magnetic field induced by the collector current of Q1 in the primary ceases to increase and the positive feedback ceases. Q1 then begins to turn off and the magnetic field in the core begins to collapse. This produces a negative voltage across the feedback winding which biases Q1 hard off. Then the cycle repeats, R1 and C2 defining the frequency and the power delivered to the tube, since a constant amount of energy (equal to I^2 max times L) is transferred to the load each cycle.

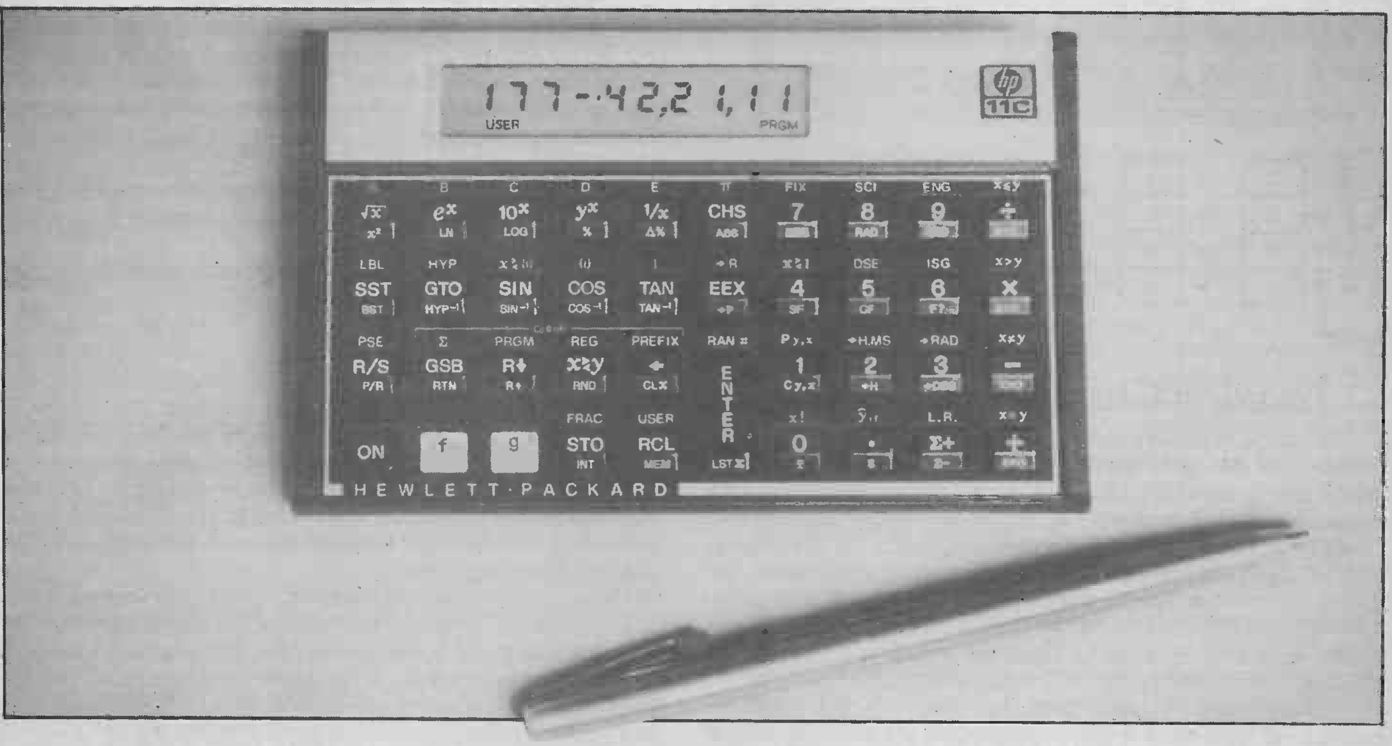
The magnetic field collapsing in the core induces a very narrow high voltage spike in the secondary. When the unit is first turned on, the fluorescent tube will appear as an open circuit and a high positive potential will be present across it as a result of the secondary turn winding. Also, the negative (cathode) end of the tube is pulled negative by the starter winding. As these voltages add a very high potential exists from the anode to the external starter contact. This is enough to force some gas to ionize and the tube breaks down or 'strikes'; This occurs for a few cycles until the 10½ turn winding heats the cathode filament and the tube conducts completely.

Once started, the increased temperature and traces of unrecombined gas permit it to conduct quickly each cycle and the tube no longer relies on the earth electrode for breakdown. Once this condition is reached the secondary voltage is held low by the tube conducting, the inductance of the core and secondary limiting the current, as in a conventional 240 V ballast. Diode D2 prevents any conduction in the reverse phase which would upset the magnetic field buildup. If a high voltage is applied to the circuit and D2 is absent AC can flow in the tube and efficiency falls markedly. Hence the circuit in its correct mode acts in a magnetic pumping fashion rather than a pure transformer action. While the cathode is heated, tube life is reduced by the fact that the DC flow of current eventually strips the cathode. Theoretically, when the cathode is stripped to the point of failure the tube should be able to be physically reversed, since the anode end filament will not have been used at all. The tube does however have quite a long life.

ETI

THE HP~11C

The lovelorn Peter Green meets up with the calculator of his dreams this month. Hewlett-Packard rule OK.



My relationship with Hewlett-Packard calculators has always been one of unrequited love; after all they're the Rolls-Royces of the calculator world. They first stole my heart back in late 1974, when I was at Glasgow University and began reading Scientific American regularly. Every month HP would take a two-page advert and I'd sit drooling over the magazine as yet another model appeared, each more advanced than the last. Back in London during the vacation, I wandered down Oxford Street and stared pititfully for hours through the window of a shop which had rows of Hewlett-Packards hiding behind massive price-tags. The harsh realities of economics and the student grant drove me into a nearby chain-store chemist where I coughed up for a Sinclair Scientific, a good workhorse but nothing like an HP thouroughbred. (Three weeks later Uncle Clive knocked £10 off the price and I've never forgiven him). Now I could at least solve problems, but still I dreamed . . .

HP Source

Some time later, my astronomy course took me to the University Observatory for lectures and practicals, where I made the ecstatic discovery that the department had bought an HP programmable desktop model as a research tool. This 'calculator' was about the size and shape of a portable electric typewriter, and was just *loaded* with scientific functions. It may not have belonged to me, but at least I had finally got my hands on a calculator worthy of the name. Nevertheless I turned green with envy the day our lecturer mentioned that the Hewlett-Packard sales rep had shown him a pocket calculator with all the functions of the desk model. Was I forever doomed to seek companionship above my station?

Eventually the university got wise to the fact that academic life wasn't my strong point; so a full-time job in the real world offered the possibility of finally owning my own HP. But with no need to solve complex scientific problems any more, the harsh realities of economics dictated that I couldn't buy what would amount to an expensive plaything. That's how things have remained ever since. When the editor of Hobby Electronics said he didn't have time to review the HP-11C and would I like it for ETI? . . . I cleared my desk in a single bound.

Two Of A Kind

The calculator in question is the scientific half of the latest double-act from Hewlett-Packard, the other being the HP-12C financial and business version. What does the latest object of my desires have to offer? To start with, the HP-11C features Hewlett-Packard's usual superb styling. Although many readers of this magazine may only be aware of HP through their calculators, these form only one branch of the companies' products. Hewlett-Packard are one of the largest data acquisition, processing and instrumentation manufacturers in the USA and their experience shows. The case is moulded in black crinkle-finish plastic with brushed chrome trim and four small rubber feet grip even the most polished table-top. The keyboard follows the HP tradition of being, quite simply, the best in the world.

These two new calculators break away from HP's previous keyboard format; instead of being tall and slender, they are short and wide. Although it would probably upset you if this happened to your girlfriend, it works very well here and leads to an elegant layout. The shape of the keys has also been changed — for the better — and the legends will never wear off because they're moulded all the way through. There is a positive click on each key so you feel the connection, and the degree of stiffness is just right — this keyboard is a pleasure to use.

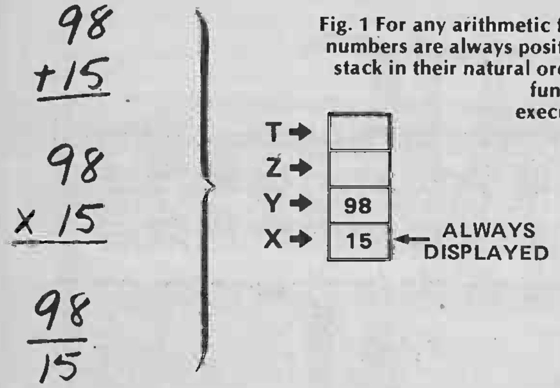
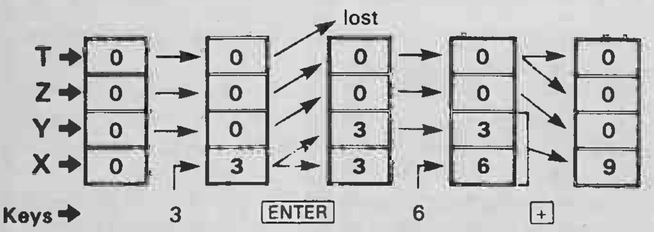


Fig. 1 For any arithmetic function, the numbers are always positioned in the stack in their natural order first. The function is then executed and the stack drops.



Looking Good

It's a joy to look at, too; each key has three functions coded white, blue and gold (actually a sort of pale tan). Against the black background the labelling stands out clearly and unambiguously as well as presenting an attractive appearance. Two 'shift' keys, f and g, select the alternative functions. The display is a 10 digit LCD type — not centrally placed and looking the better for it — and contains several smaller annunciators which provide user information. When the calculator is running a program, segments light up to flash the word "running" in the display; "Error" will appear if a mistake is made.

In the past I haven't been too keen on LCD displays because of their slow response times; I've played with several cheap calculators which could give wrong answers if keys were pressed faster than the display could follow. Some fast fingerwork on the HP-11C showed it to be relatively immune to this kind of thing. Of course an LCD display also means lower power consumption so the whole calculator runs on just three button cells, which should last up to a year.

Enter The Functions

The HP-11C has so comprehensive a range of functions that it might be easier to list what's not available, rather than what is. (The manual is thicker than the calculator). The most obvious omission from the keypad is the "equals" key — instead there is a large button marked ENTER. Yes, the HP-11C uses Reverse Polish Notation in which two numbers are entered and *then* the operator, which acts immediately to give the answer. Hewlett-Packard have always adopted RPN logic in their calculators, as indeed did my Sinclair Scientific. I never really liked RPN on the Sinclair because it used a single accumulator and intermediate results in a long calculation had to be written down or they were lost. HP overcome this problem by using an automatic stack with four registers (X, Y, Z, and T). As you work from left to right through a calculation, intermediate results get pushed up the stack and brought down again automatically as required. Stack manipulations such as roll up, roll down and X exchange Y may be performed without loss of values, but pushing the stack when it is full causes the contents of the T register to be lost. If the four level stack is inadequate (unlikely), you can also store intermediate results in one of the 21 memories and recall it when it is needed.

As well as the four arithmetic keys there's a full range of scientific functions including normal and hyperbolic trigonometrical functions and their inverses, squares and roots, reciprocals, logs (base 10 *and* base e), e^x, 10^x, y^x, percentages, polar-rectangular coordinate conversion and vice versa, a π key, permutations and combinations. One-number functions act on the value in the X register, two-number functions use the X and Y registers. Although people used to algebraic calculators may be a little wary of RPN, in practice it quickly becomes a natural way of working.

Statistically Speaking

A generous helping of statistics functions are also provided. Six of the data memories are automatically used as accumulators for the $\Sigma+$ and $\Sigma-$ functions, which act on the values in the X and Y registers. The following statistics are accumulated: n (number of data points), Σx, Σx^2, Σy, Σy^2 and Σxy. Once all the data has been entered functions such as mean, standard deviation, and linear regression (fitting the best straight line to the data pairs) can be calculated using the accumulated data.

A pseudo-random number generator is provided for use in games programs and the like.

On Display

A bonus of the HP-11C is that the user can choose the display format to suit his purpose; there are three possibilities.

- Fixed decimal, which displays numbers using a fixed decimal with no exponents (eg 123,456). The user may specify how many decimal places the display is rounded to. If a displayed number is too large or too small for fixed decimal, scientific notation is automatically selected.
- Scientific notation represents a number as a mantissa (maximum of six decimal places) followed by a two-digit exponent. The decimal point is always after the first digit (eg 1.2346 05).
- Engineering notation is the same as scientific notation except that all exponents are in multiples of three (with a corresponding shift in the decimal point if necessary, eg 123.46 03).

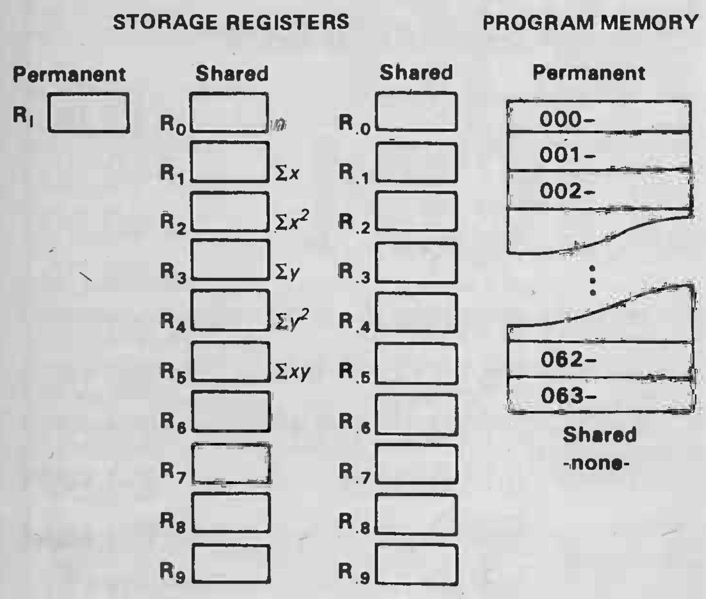
Rounding may occur in the display, but all numbers are held internally to 10 digit accuracy. The user may also choose whether angles are to be entered in degrees, radians or grads, and the form of the radix mark and digit separators (ie commas and decimal points are swapped for our continental friends).

Programmability

Entering a program into the HP-11C means nothing more than causing it to remember a sequence of keystrokes which will solve a particular problem. While this doesn't sound particularly exciting it is a very powerful tool, especially when use is made of the special programming aids incorporated into the device. Since the stack responds to instructions in a running program in exactly the same way as it does to an identical set of instructions from the keyboard, no programming experience at all is required. If you can use the calculator, you can write programs for it.

The simplest type of program will allow you to repeat the same calculation using different starting values with only one keystroke instead of many; to draw a graph for example. However, a great deal more can be accomplished using the programming aids. Fifteen program labels are available, so up to 15 different programs or subroutines can be used simultaneously. Eight conditional test and two flags will allow branching and looping. Subroutines may be nested up to four levels. An index register enables indirect addressing to be used. Run/Stop allows data input during program execution. Who needs BASIC?

The normal allocation of memory is 21 data storage registers and 63 lines of program space; one line will store one instruction, regardless of whether one, two or three keystrokes are required to generate it. If you key in a 64th instruction once the 63 lines are full, the calculator automatically re-allocates



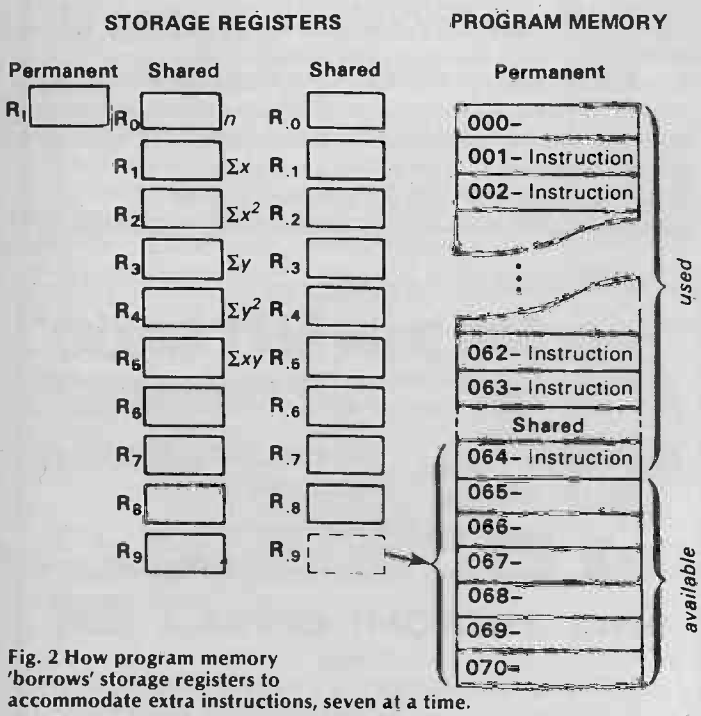


Fig. 2 How program memory 'borrows' storage registers to accommodate extra instructions, seven at a time.

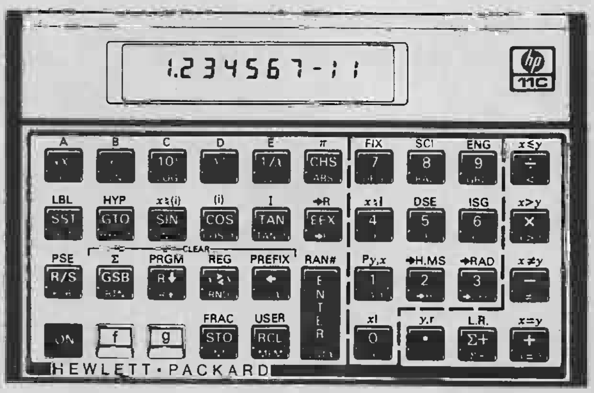


Fig. 3 The numeric keys (inside dotted line) have single digit keystrokes.

the last storage register to seven more program lines. The memory configuration is now 70 lines of program memory and 20 registers. Keying in a 71st instruction reallocates the next storage register and so on, until finally there are 203 program lines and only one data storage register (the index register, which cannot be converted in this way). Registers which have been reallocated as program storage are not available for data storage and when converted back (by deleting a program) any values previously stored in them are lost.

Keycoding Made Easy

When programming, the display will indicate the current line number and the 'keycodes' for the instruction stored there. Each element in a keycode consists of two digits describing the row/column position of the key on the keypad (except for numeric keys, which are represented by a single digit). So 003—43,22,25 indicates that line 3 contains the instruction 'hyptan $^{-1}$' (since g is row 4, column 2, hyp $^{-1}$ is row 2, column 2, and tan is row 2, column 5). With this in mind, and using the GOTO, single step, back step and delete keys, editing is quite easy. Extra program lines may be inserted anywhere, with all the following lines moving up in memory automatically.

To show how easy (and powerful) the HP-11C programming is, the manual gives several complete applications programs including matrix algebra, Newton's method (solution to f(x) = 0), curve fitting, chi-square evaluation and submarine hunt (a game I found quite absorbing while commuting!) A further chapter gives hints on programming techniques.

Good Memory

Since there is no facility for storing programs on cassette, you may wonder what happens to your laboriously-entered program when the calculator is switched off. The astounding answer is — nothing! The HP-11C features 'Continuous Memory' and the following are retained in the calculator when it is switched off: all of the numeric data; all programs stored; display mode and settings; flag settings; position of calculator in program memory; any pending subroutine returns and trig mode. If that isn't impressive enough, Continuous Memory is maintained for a short while even while you're changing the batteries! Gosh, and other expressions of amazement. To top it all, the HP-11C will conduct self-tests of the keyboard and internal circuits without affecting data and programs in memory.

Teaching Tool

Apart from the fact that it's a beautiful piece of engineering and a powerful tool for the scientist, engineer and mathematician, there is another reason why I enthuse. Recall the desktop model in Glasgow University Observatory? It too had keystroke programming, plus the ability to store the 1000-odd steps on magnetic cards, and a printer. However, the department heavy work was done on a time-sharing mainframe in Edinburgh via a teleprinter, modem and a telephone, and I hated it. The language made no sense to me and I couldn't write programs for it; it all seemed incomprehensible and put me off computers for years (I only learned how to write BASIC a year ago).

Yet at the same time I was programming, if only I'd known it, on the Hewlett-Packard. I didn't realise that I was getting groundwork in techniques such as branching, looping, subroutines, I/O control, subroutine nesting and structured programming. And it was all so *easy!* So if you're baffled by BASIC, frightened by FORTRAN, or not yet ready to commit yourself to a computer you don't know how to operate — go and buy an HP-11C. At around £93 including VAT it's cheaper than a microcomputer; it's unnoticeable under your jacket (when did you last try to get a PET in your pocket?); and after a couple of evenings you'll be using it with confidence.

Is my unrequited love affair with Hewlett-Packard finally fulfilled? Not really, because the company want the calculator back. Life can be so cruel . . . **ETI**

DESIGNER'S NOTEBOOK

This month, Don Keighley shows how a well-positioned preamplifier can improve poor system performance. He introduces equivalent circuits and their use in helping us to understand the action of complex electronic devices.

Any electronic system's frequency response can be broadly defined by the use to which the system is to be put. For example, if we refer to a high-fidelity audio system, we immediately know that it must have a frequency response of 20 Hz to 20 kHz; if we talk about a telephone system, a quick check with a good reference book will tell us that it has a frequency response of 300 Hz to 3.4 kHz.

The frequencies quoted as a frequency response tell us the outside limits of signal frequency which the system can pass. In other words, any signal whose frequency lies within the two limits will be passed, but any signal with a frequency outside will not.

Figure 1 shows the frequency response that a high-fidelity audio amplifier might have. It is shown as a graph of amplifier gain against frequency. There are three points to note from it:

- the upper and lower frequency limits are defined as the frequencies at which the gain falls by 3 dB.
- these 3 dB 'corners' occur where the output power has fallen to one half of the mid-band output power.
- the band of frequencies between the two 3 dB corners is known as the bandwidth of the system.

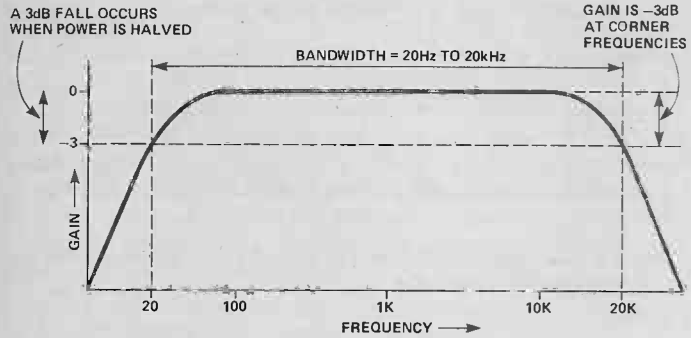


Fig. 1 Frequency response of an audio system, showing bandwidth defined by the 3 dB corner frequencies, ie the frequencies at which gain is 3 dB lower than it is over the mid-band frequencies.

Any reduction of bandwidth means that some audio signals are missing, which in turn means that the overall quality is lowered. It's important that we do all we can to maintain bandwidth.

One way in which the bandwidth of a system can, all too easily, be drastically lowered (if the designer is not careful) occurs at the input to the system. Whenever a signal source is connected to a system's input, bandwidth is at risk. Let's take an example of a microphone (the signal source) connected to an amplifier. Because the signal from the microphone is small (about 1 mV), screened coaxial cable must be used to connect to the amplifier, to reduce the amount of interference which gets onto the signal line. Seems fine so far, doesn't it?

Well, the problem arises because screened cable has a very definite capacitance, characteristically 200pF m^{-1}! The connecting cable of an average microphone might be 10 metres long, so the overall cable capacitance is 2nF!

It helps to look at the system using a type of diagram used a great deal by electronics designers — an equivalent diagram — in which each part of the system is visualised as its simplest electrical equivalent. In this way we can see what's going on inside the systems without having to get involved with all its theoretical technicalities. Figure 2 shows such a diagram of the microphone-cable-amplifier example and it's very easy to understand. The microphone is depicted as a current generator, in parallel with the microphone's internal resistance; the cable is shown as a 2nF capacitor between signal line and earth; the input stage of the amplifier is a resistance.

Now the two 50k resistors, in parallel, can be thought of as a single 25k resistor and so we can simplify the equivalent diagram in Fig. 2 to that in Fig. 3. It is, as some readers will have spotted, a first-order R-C low-pass filter. The 3 dB corner frequency of a low-pass filter is given by the equation:

$$f = \frac{1}{2\pi RC}$$

where R and C are the resistor and capacitor values in the filter. Because it's a low-pass filter, all signal frequencies below this corner frequency will be passed. Substituting the values of Fig. 2 into the equation gives a 3 dB corner frequency of 3.2 kHz. Thus, the band-width of the system is only 20 Hz to 3.2 kHz — and we've lost a huge part of the possible sound spectrum. If such a microphone-cable-amplifier arrangement existed it would give a muffled and 'boomy' sound output.

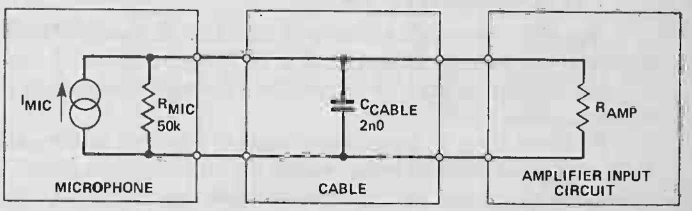


Fig. 2 Equivalent diagram of a microphone-cable-amplifier sound system.

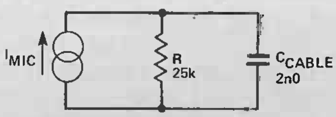


Fig. 3 Simplified equivalent diagram of that shown in Fig. 2.

So how do we prevent bandwidth reduction due to cable capacitance? The equation, $f = 1/2\pi RC$ itself can give us a clue! The corner frequency, f, is inversely proportional to both resistance and capacitance in the filter, so reducing either one will increase the bandwidth. But we can't reduce the capacitance because we need the 10 metre length of cable to get from the microphone to the amplifier — so we have to reduce the effective value of resistance.

The best way of doing this is with a buffer preamplifier situated close to the microphone (it could be fastened to the microphone-stand or even inside the microphone-case). A buffer preamplifier does just that — it buffers the output of the

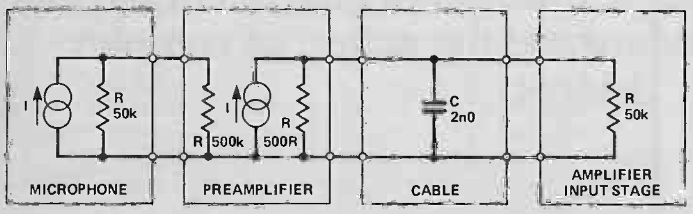


Fig. 4 Adding a preamplifier and the resultant equivalent diagram.

microphone with a high resistance and presents a low resistance to the screened connecting cable. Figure 4 is an equivalent diagram of the circuit. The microphone, cable, and amplifier are shown as in Fig. 2, but in between the microphone and cable is a preamplifier (shown as a high-resistance input stage and a current generator-with-low-parallel-resistance output stage).

You'll notice that no cable capacitance exists between microphone and preamplifier, so no bandwidth is lost. You'll also notice that the output resistance of the preamplifier (the new R in the frequency equation) is only 500R. The upper corner frequency of the system is now:

$$f = \frac{1}{2\pi \times 500 \times 2 \times 10^{-9}} = 160\ \text{kHz}$$

and the overall bandwidth is extended way past any frequencies the microphone and amplifier can deal with.

So the solution to the problem of maintaining bandwidth in an audio system can be as simple as the inclusion of a single transistor and just a couple of resistors; or perhaps a 741 operational amplifier. The preamplifier doesn't even need to have gain (high gain makes no difference to the bandwidth) — it only needs to be a resistance *buffer*.

Noise Annoys

Not all systems have bandwidth problems. Take a 90 MHz stereo VHF tuner, for example, or a TV (200 to 800 MHz). Noise is the most immediate problem here — or more specifically the signal-to-noise ratio.

At these sorts of frequency, noise is inherent in the cable itself and remains constant *whatever the received signal level*. So if we tune to a good, strong signal from the aerial, the signal-to-noise ratio will be high and audio output will be of high quality. However, if the signal is weak, say from a distant or low-power transmitter, the signal-to-noise ratio will be poor (lots of hiss!).

The best signal-to-noise ratio must obviously be obtained at the aerial. Because of this you could be forgiven for thinking that the best reception would always be obtained if you connected the tuner directly to the aerial (ie with *no* cable, as shown in Fig. 5). This is not the case, however, because of the noise which the *tuner* adds. The tuner noise is expressed by what we call the noise factor, F, a typical value for which might be eight.

To illustrate the example let's say the best possible signal-to-noise ratio is 50 dB (a ratio of 100,000 to 1). The overal signal-to-noise ratio of aerial tuner is given by

$$\frac{\text{best possible signal-to-noise}}{F}$$

so in this example, the output signal-to-noise ratio is

$$\frac{100{,}000}{8} = 12{,}500\ (= 41\ \text{dB}).$$

You can see the signal-to-noise ratio has suffered a 9 dB fall.

If we now connect the tuner to the aerial via a length of coaxial cable (from roof-top to living-room), as shown in Fig. 6, the noise which the cable introduces must be taken into account in the *system* noise factor. The system noise factor is calculated from the expression:

$$F_{SYS} = F_1 + \frac{F_2 - 1}{G_1}$$

where F_1 and F_2 are the noise factors of cable and tuner and G_1 is the gain of the cable. Of course, coaxial cable can't have gain (it's not an amplifier) but it's convenient to leave the expression as it stands (you'll see why later!). Cable 'gain' is expressed as a loss, L_1, where

$$L_1 = \frac{1}{G_1}$$

The loss is also numerically equal to the cable's noise factor, F1 (neat, eh?). So the system noise factor with a cable loss of six, say, is

$$6 + (6 \times 7) = 48,$$

giving an overall signal-to-noise ratio of

$$\frac{100{,}000}{48} = 2083\ (= 33\ \text{dB}).$$

Quite a drastic performance loss.

You'll have guessed by now that the way to improve the signal-to-noise ratio is to add a preamplifier. As we shall now

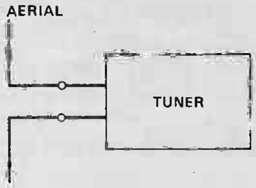


Fig. 5 A tuner directly connected to its aerial does not necessarily give the best signal-to-noise ratio.

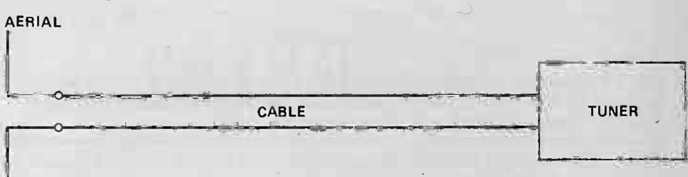


Fig. 6 The long cable between aerial and tuner, found in most radio and TV applications, reduces the signal-to-noise ratio, sometimes with drastic consequencies.

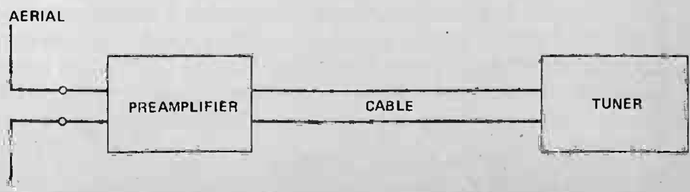


Fig. 7 A mast-head preamplifier can produce the best results of all.

see, the best position for this preamplifier is as close to the aerial as possible (as shown in Fig. 7). In this respect, a radio-frequency preamplifier is similar to the audio preamplifier previously discussed. Unlike the audio preamplifier, however, an RF preamplifier is better to have gain (because the second part of the system noise factor expression is inversely proportional to gain).

The system noise factor expression can be extended to include a third element, to

$$F_{SYS} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

where F_1, F_2, F_3 are the noise factors of preamplifier, cable, and tuner; and G_1, G_2 are the gains of preamplifier and cable.

The overall system noise factor, with a preamplifier noise factor, say, of four (a factor as low as this is easily obtained with modern transistor and IC technology), a gain of, say, 20 with all other factors as before, is

$$4 + \frac{5}{20} + \frac{42}{20} = 6.35$$

and the overall signal-to-noise ratio is

$$\frac{100{,}000}{6.35} = 15{,}750 (= 42\,\text{dB}).$$

You will notice that this signal-to-noise ratio is not only greater than that of the aerial-cable-tuner set-up, but is *also greater than that when the tuner is connected directly to the aerial*. The exact results of this example aren't true of *any* application because different noise figures, gains and losses mean different signal-to-noise ratios. Nevertheless, the concept is correct and a considerable improvement in quality will be obtained by using a so-called mast-head preamplifier.

Practical Matters

If you're looking for a mast-head preamplifier and want to make your own, then you could do far worse than to use the OM335. It's a hybrid single-in-line IC, the internal circuit of which is shown in Fig. 8. Any voltage of about 10 V to 26 V will operate the IC and at a voltage of 24 V, it gives a gain of 22 times (27 dB) and bandwidth of 40-900 MHz: therefore it can be used to preamplify all FM stereo radio and British TV transmissions.

Literally no other components are required to operate the preamplifier, as all coupling and decoupling components are internal, so with a simple PSU (the IC can even be battery-powered) you have a working preamplifier. Its noise factor is 3.5.

Maybe now you'll be able to listen to Radio Outer Mongolia on 96.0 MHz VHF and not have to put up with that hiss you always seem to get on stereo reception!

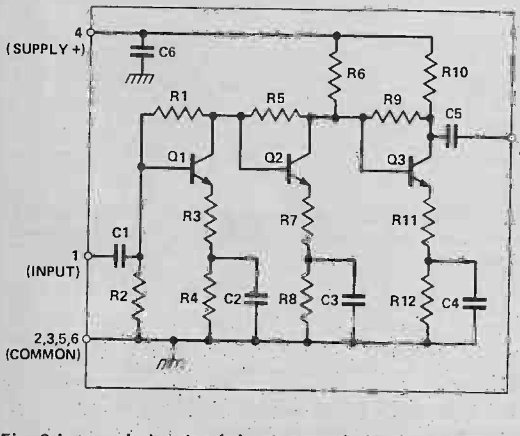


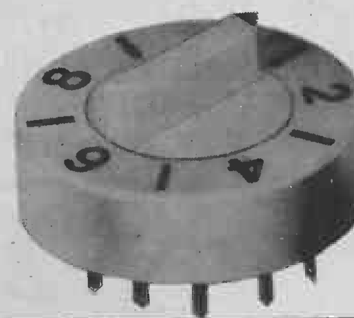
Fig. 8 Internal circuit of the OM335 hybrid preamplifier. All coupling and decoupling capacitors are inside the IC so no extra components are required.

ETI

Components

BCD On PCB

Church House Components announce a range of robust rotary BCD coded switches which are 19 mm in diameter and are known as the 420 series. The indexed positions are clearly marked and the position indicator is the actuating knob. A special feature of this series of switches is that the pin-out is in circular or DIL pattern. This means that they can be soldered directly to the board or plugged into a standard IC socket. The contact system is gold plated, as are the terminals, resulting in a very high mechanical endurance in excess of 10,000 operations. Contact resistance is a maximum of 50 milliohms. For further information contact: Church House Components, 70-74 Barnham Road, Barnham, Bognor Regis, West Sussex PO22 0ES.



Rapid Recall, PROMs And Delivery

Rapid Recall are able to offer a full range of high-speed bipolar PROMs, direct from stock, at competitive prices. Manufactured by Intel, they include the 3628A, the 3636 and the 3632 PROMs which provide 8K, 16K and 32K bits of memory respectively. Rapid Recall, claim that any order received before 3.00 pm will be dispatched the same day. In addition, they are now able to offer a range of bipolar PROMs with industry standard part numbers. The new parts will program exactly the same as the corresponding 36XX family of bipolar PROMs, using Intel's standard algorithm.

All the PROMs employ Schottky charged TTL technology with polysilicon fuses to achieve high fuse reliability and programmability. The three-state outputs of the PROMs are initially high, with logic low levels programmed electrically in selected bit locations. Supplied in 24-pin hermetically sealed DIPs, the PROMs have a number of chip select inputs allowing them to be easily integrated into large memory arrays.

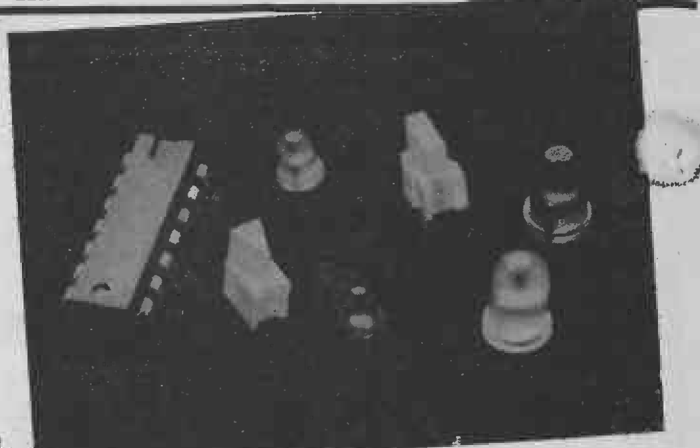
The 3628A is a fully decoded 1K x 8 bit bipolar PROM that has worst case access times of 50, 70 and 90 nS for the −1, −3 and −4 versions respectively. These times are specified over the full temperature range 0 to 75°C and with ± 10% voltage power supply tolerances. Power consumption for the 3628A is typically 0.08 mW/bit.

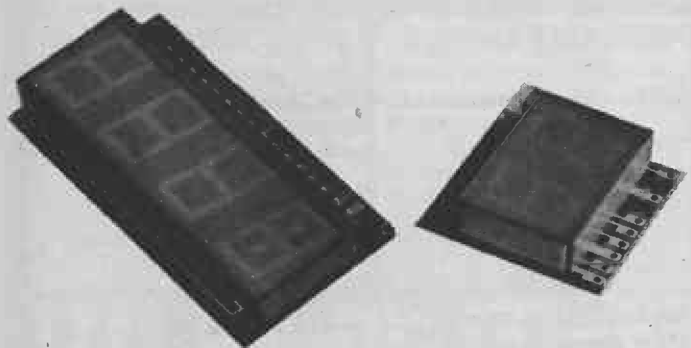
The 3636 and 3636B are 2K x 8 bit PROMs which have access times ranging from 80 nS to 35 nS maximum. Typical power consumption is 0.05 mW/bit.

The highest density bipolar PROM currently available is the 3632, a 4K x 8 bit device which offers access times of 40 and 50 nS. Fully compatible with the other Intel bipolar PROM families, it offers the designer a simple upgrade path to higher density memory arrays without the need for expensive circuit board re-design, or, alternatively, as a way of reducing the overall size of memory boards without losing memory capacity. Rapid Recall are at Rapid House, Denmark Street, High Wycombe, Bucks HP11 2ER.

IC Driven LEDs

IMO Electronics have added to their range of lamps and indicators a full range of newly developed high brightness LEDs which can be direct driven from IC components. The 5000 series of LEDs is available in 3 mm diameter, 5 mm diameter, rectangular and triangular bodies. The high brightness is achieved with only a 10 mA drain at 20 mW allowing the series to be directly connected to IC devices with no interface required. The 5000 series is available in all standard colours plus bi-colour red/green. They are encapsulated in coloured, diffused and non-diffused finish and are available ex-stock from IMO Electronics at the competitive price of less than 10p for both medium and high brightness types. For more information contact: IMO Electronics Ltd, 1000 North Circular Road, London NW2 7JP.





Highly Illuminating

Now available from BA Electronics is a range of multidigit stick displays incorporating high performance 0.5" LED numeric digits prematched for brightness and hue. The new GI MMN50 000 Series offers a very high luminous intensity in orange, yellow and high-efficiency red colours. Both two and four digit versions are available in end-stackable packages, with a wide range of options on drive configurations and lens colours. They are all visible in sunlight under normal operating conditions and packaging is rugged enough for a wide range of consumer, industrial and automotive applications. Both storage and operating temperature ranges are −40°C to +85°C. If you want more information contact: BA Electronics Ltd, Millbrook Road, Yate, Bristol BS17 5NX.

Micropower Micro

Zilog have just introduced a new version of their Z80 eight-bit microprocessor which consumes only 10% of the power of the standard Z80. Known as the Z80L, the new processor is available for operation at clock rates of 1 MHz, 1.5 MHz, or 2.5 MHz identified by the suffix L1, L2 or L3 respectively.

Power consumption for the Z80L family is 75 mW, compared with 500 to 750 mW for the standard part and is therefore ideally suited for use in hand-held or portable battery-powered products. The low power consumption allows battery backup to be implemented easily in systems where the data being processed is of a critical nature or where the application relies on continuous processing.

Another feature of the Z80L is its full pin and software compatibility with the Z80, allowing it to be used in existing circuit boards without the need for circuit re-design. In addition, the device is fully supported by Z80 development systems and in-circuit emulators allowing products based on the Z80L to be developed, tested and debugged quickly.

The Z80L can be used with the range of Z80 eight-bit peripheral devices also offered by Zilog. A new range of low-power peripherals will be announced soon, including a version of the PIO (parallel input/output), SIO (serial input/output), CTC (counter/timer circuit) and DART (dual asynchronous receiver/transmitter). These devices will consume about 10% of the power of currently available products at prices substantially lower than CMOS equivalents.

The Z80L family employ a single +5 V power supply and operates over the temperature range 0 to 70°C. They are available in either ceramic or plastic packages.

Defence Digest

Seeker Tested

A Hughes Aircraft Company technician at the company's flight test facility in Van Nuys, California, checks over the infra-red seeker being developed by Hughes for a new US Navy version of the Maverick air-to-surface missile. The seeker is mounted in the nose of a B-26 aircraft, shown here, for a series of captive flight tests off the California coast to demonstrate its ability to detect and track ship targets.

B-1 Bomber Programme

Full-scale development of the defensive electronics system of the B-1 bomber is under way at the Deer Park, New York, headquarters of Eaton Corporation's AIL Division under an initial £4.7 million contract awarded by the US Air Force. Negotiations are under way for a full-production go-ahead. The system, known as the ALQ-161, will enable the Strategic Air Command's B-1B to detect, identify and classify hostile radar threats and to direct appropriate jamming responses automatically against the most serious, in a descending order of priority.

Eaton's AIL Division entered the competition to supply the defensive electronic countermeasures system in the early 1970s when the US Air Force first began its programme to develop a replacement for the B-52 bomber that had been in service since the Korean War. Although former President Carter cancelled the project in 1977, the US government continued to support research and development and now the Reagan Administration has revived the B-1. The Eaton system has been extensively flight tested since a pre-production system was installed in a prototype aircraft in 1979. Eaton's AIL Division is one of four prime contractors for the B-1 bomber. The others are Boeing (offensive avionics), General Electric (engines) and Rockwell International (aircraft construction). Eaton's AIL Division is also the world's largest supplier of air traffic control processing and display systems, with over 400 installations throughout the world. Other major contracts have included designing the microwave landing system for the Space Shuttle and a vessel traffic control system for the Suez canal.

First Flight

The world's first aircraft to fly solely with an all digital quadruplex fly-by-wire control system took off from British Aerospace Warton Division's aerodrome in Lancashire at 12.14 hours on October 20th 1981. The aircraft was an extremely modified Jaguar GR Mk.1 on contract loan from the Royal Air Force. This Jaguar is the first truly practical digital ACT (Active Control Technology) aircraft to fly with equipment made to production standard. In effect, this fly-by-wire system replaces all the previous mechanical units — the autostabilisers, compensation equipment and cumbersome control rods currently used to move the control surfaces. Their places are taken by four independent electrical channels, which relay instructions in the form of electronic impulses, issued by four main high-speed, mutually self-monitoring computers. These are linked with a further two subsidiary actuator drive and monitor computers, which lead to the duo-triplex 'failure absorption' actuator. These signals are not only issued in direct response to the pilot's demands, but are also initiated automatically to correct uncommanded aircraft motion detected by aircraft sensors. Apart from the considerable weight savings, the main advantage of the ACT is that an unstable aircraft can now be flown. Under conditions like these flight corrections are required many times a second; a task, until now, quite impossible for a pilot using conventional controls. This major technological achievement opens the way to the future design and production of smaller, lighter and more agile fighter aircraft.

Anti-Tank Weapons

The Bristol Division of British Aerospace Dynamics Group, under subcontract from the Stevenage Division, is now manufacturing control and launch equipment for two new anti-tank weapon systems for the British Army. The first is for the MILAN medium-range man-portable system which is designed and produced in the USA by Hughes Aircraft Company. British Aerospace has been granted a licence to equip the British Army Air Corps, under contract from the Ministry of Defence, with a roof-mounted sight for installation on the Lynx helicopter. The roof sight is a British Aerospace adaptation of the chin-mounted sight used in the USA. The sight is a fully stabilised optical platform which tracks the missile during flight, and is associated with various electronic units produced by Ferranti at Manchester for the Bristol Division. The missile launchers are also produced at Bristol for installation on the Lynx helicopter. TOW missiles are obtained by the Ministry of Defence directly from the USA.

Both these projects have brought extra work to Bristol Division's manufacturing facilities and, in particular, utilise existing skills in specialised optic and infra-red techniques. New optical clean areas with ultrasonic cleaning facilities have been provided, and the manufacturing facilities are complemented by extensive automatic test equipment. In addition, new climatic and vibration test facilities have been installed for acceptance testing of the MILAN Firing Post. Deliveries to the British Army for both the above systems commenced in 1980 and the production lines will continue for some years.

Airborne Computation

Ferranti Computer Systems Ltd has received an order valued at £¾ million for 12 FM 1600D airborne computers with spares support from EMI Electronics Ltd. The FM 1600D is being incorporated in the Searchwater radar system to be installed in the Royal Air Force's Nimrod Mk2 maritime reconnaissance aircraft. This order follows an initial contract which covered the production of more than 50 of these computers for the Searchwater radar — which was developed by EMI for the UK Ministry of Defence for the Nimrod Mk2 and for associated crew training and ground support facilities. The airborne version of the FM 1600D is the most powerful of all the Ferranti avionic computers and can be used in all systems where there is a requirement for high processing power and reliability.

Rapier Sales

Orders for the British Aerospace Dynamics Group Rapier low-level air defence system have exceeded £600 million over a twelve month period. Rapier is the only system of its kind declared operational with NATO and is operated in this role by the British Army and Royal Air Force regiment. Rapier has been adopted by ten overseas countries, making it the widest used system of its kind in the world in all climates. These users range from Australia, through Asia, the Middle East, Africa, Europe and Central America. Rapier has gained a reputation for being a reliable, cost effective system which benefits from low manning by average military personnel. It is highly mobile and can be rapidly and effectively deployed. Its modular construction makes maintenance and further improvement practical. Over 4,500 firings have proved the high lethality of the missile. The addition of the Marconi Blindfire Radar gives Rapier a round-the-clock, all weather capability.

FACTS ON DACs AND ADCs

That doyen of the data sheet, Tim Orr, reaches into his cornucopia and brings forth circuits for digital-to-analogue conversion — not to mention the other way round.

The digital world is relatively boring; it's the analogue world that stimulates the senses. The analogue world is full of colours and sounds, visual images and other sensations. Analogue electronics is tremendously good at performing many tasks, but it's not too good at precise mathematical computations, fast decision making, and long term non-volatile storage of information — all of which are the domain of digital electronics. Because of this, it is common practice to convert analogue signals into digital codes and vice versa in order to get the best performance out of a product. The device which converts analogue signals to digital codes is known as an analogue-to-digital converter (ADC) and one that performs the opposite task is called a digital-to-analogue converter (DAC).

Several applications of converters are shown in Fig. 1. The audio delay line is used to process musical signals and to generate several audio effects. These include phasing, flanging, chorus, reverberation and echo. All of these can be produced with analogue electronics, but it is now possible to obtain superior performance with a digital design. The best signal-to-noise ratio that can be obtained from a tape recorder without any signal processing is something like 65 dB and it's a figure that doesn't seem likely to change too much. However, it is possible to obtain a 90 dB signal-to-noise ratio using a digital encoding and decoding system. The digital data can then be recorded by the tape recorder; the system now has the physical characteristics of a normal tape recorder, plus the improved noise performance of the digital system.

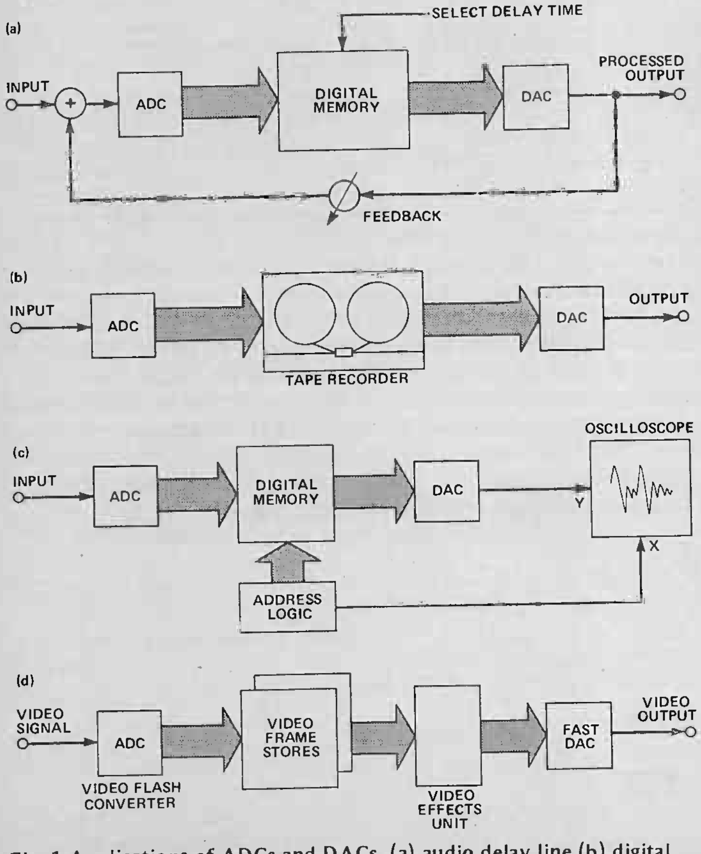


Fig. 1 Applications of ADCs and DACs. (a) audio delay line (b) digital recording (c) transient recorder/oscilloscope memory (d) video effects desk.

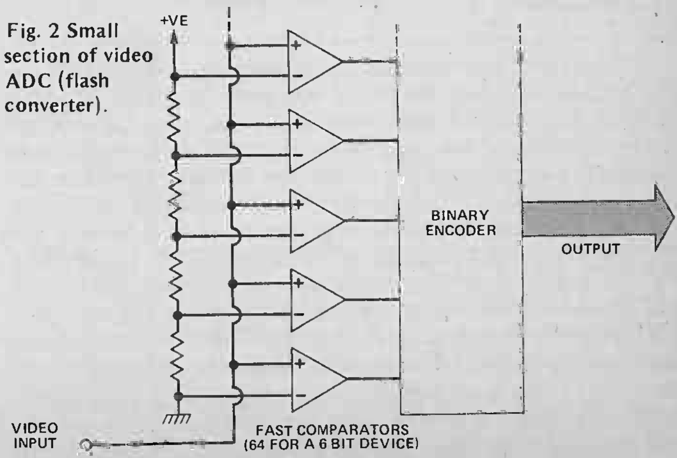
Converters are also used in oscilloscope memory systems as a replacement for storage scopes. Very fast converter techniques are needed if the system is going to have a wide bandwidth. The digitization of video signals is the most demanding of all in terms of the conversion speed. Bytes of data describing the luminance and chrominance information of each point of video are generated at about 18 bytes per microsecond (four times the sub-carrier frequency). This data is then stored in a frame store, where it is manipulated to produce various effects such as shrinking the picture size and keying it into another picture. Video converters (ADC) are unique in their method of operation. If you were to open up a six bit video ADC you would discover 64 comparators in parallel. One input of the comparators goes to a potential divider string, the other inputs are connected to the video signal (Fig. 2) This is the only way you can perform a six or eight bit conversion in 60 nanoseconds!

Other uses for converters include input/output devices for computer analysis and digital filtering of signals, direct digital synthesis from waveform tables, harmonic synthesis, automatic testing of electronic products and sequence and parameter generation for music synthesizers.

Using Converters

An ADC is a measuring device. It has an analogue input which it converts to a binary code. The resolution with which an

Fig. 2 Small section of video ADC (flash converter).



ADC can describe a voltage is determined by the bit size of the unit. The input is quantized into 2^n equal steps, where n is the bit size of the converter. An eight bit ADC, for example, can resolve the input into 2^8 (which is 256) equally sized steps (Fig. 3). The same is true for DACs; in fact most ADCs are constructed out of a DAC plus some test circuitry.

The noise performance of DACs can be specified in two ways. First, as a static device where the input binary code does not change — the output noise level will probably be very low, but it is likely to contain digital noise from surrounding electronics. If care is taken to separate analogue and digital grounds then this source of noise should be minimal. Second there will be noise present when the DAC is generating a dynamic output. This noise is known as quantization noise and is caused by the limitations of the resolution of the converter. The dynamic range of the converter is the ratio between the full scale output and the smallest output step and can be calculated using the following equation;

$$\text{dynamic range} = 6 \times n \text{ dB}.$$

Therefore an eight bit DAC will have a 48 dB dynamic range.

Noise is also a problem in the ADC. If the quiescent noise at the ADC input is greater than 1 LSB (Least Significant Bit) then the ADC will generate a dithering code in an attempt to measure that noise. If the input noise is less than 1 LSB then it is possible to DC-shift the input voltage so that the ADC ignores the noise in the quiescent state. This is a free noise gate! It is a common trick in audio converters to use a small DC shift so that the quiescent noise doesn't cause a major code change with its attendant high noise. Converters suffer from many problems, such as quantization noise, non-linearity and step size irregularities. The latter fault is shown in Fig. 3. At best a DAC should have equally sized quantization steps, but the usual manufacturers specification is for graded parts with tolerances of ± 1 LSB, ± ½ LSB, ± ¼ LSB. When a DAC has an accuracy of worse than ± 1, then it is known as non-monotonic; that is, for an increasing binary input code, there are places where the output actually decreases. A device which does not suffer from this is known as monotonic. Errors of this nature cause harsh harmonic distortions in audio systems.

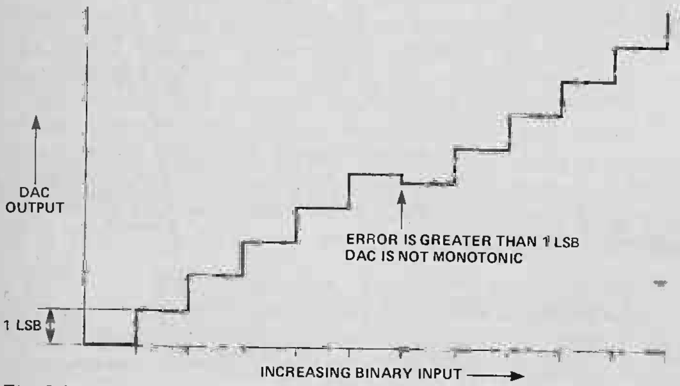


Fig. 3 DAC errors.

Converters can be tested using the system shown in Fig. 4. The transfer function will reveal how well the overall system is working, but the error plot examines in fine detail the inherent errors. The biggest error will probably occur at the major code change in the centre of the range. The dynamic distortion can also be measured using a standard THD measuring technique.

A typical converter system is shown in Fig. 5. Several problems will manifest themselves when the system is operating. ADC conversions will occur at regular intervals and this conversion frequency will determine the bandwidth of the system. If the conversion frequency is F_c, then the theory for sampled data says that the maximum bandwidth the system can handle is less than $\frac{1}{2}F_c$. If the input signal has harmonics which are higher in frequency than this, it is possible that modulation between the input signal and the conversion frequency will generate

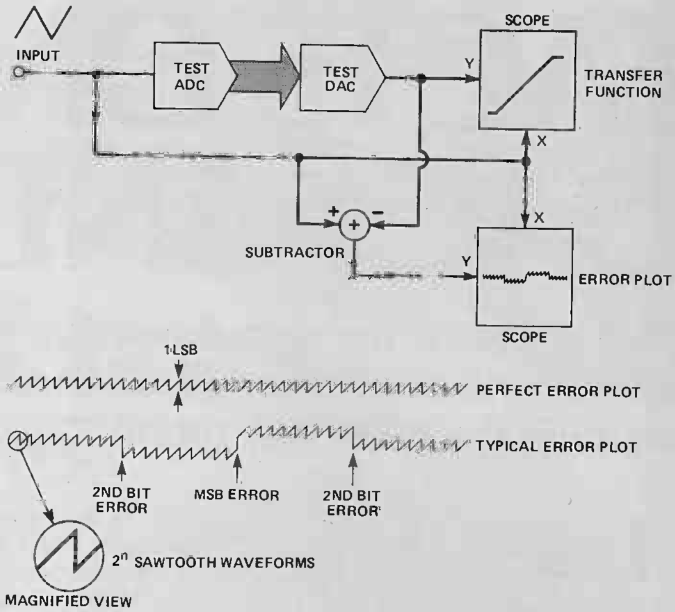


Fig. 4 Testing converter systems.

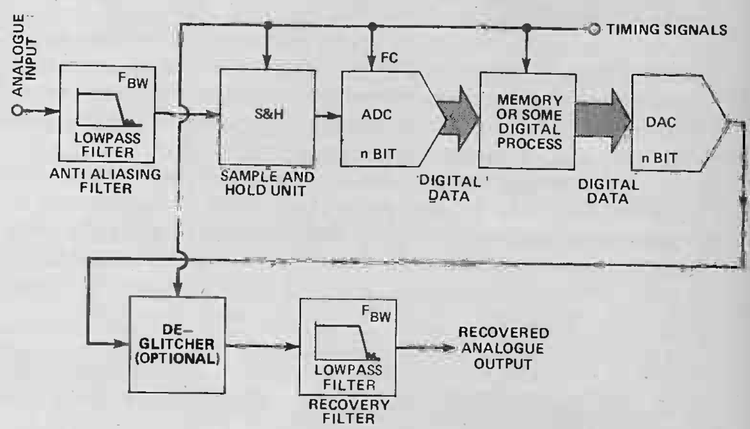


Fig. 5 A typical ADC/DAC system.

spurious sidebands whose frequencies fall within the system bandwidth. This effect is known as aliasing; it sounds like ring modulation, and it is totally unwanted. The way to remove it is to band-limit the input signal with a steep cut-off low-pass filter (known as an anti-aliasing filter). Usually an elliptic filter structure is used as this has a very sharp roll-off slope. Even with a sharp filter response aliasing can occur, so the break frequency of the filter is usually set at 0.4 to 0.3 of the conversion frequency. The DAC output is also similarly filtered to recover the original waveform and to reject the high frequency harmonics caused by the quantization process (Fig. 6).

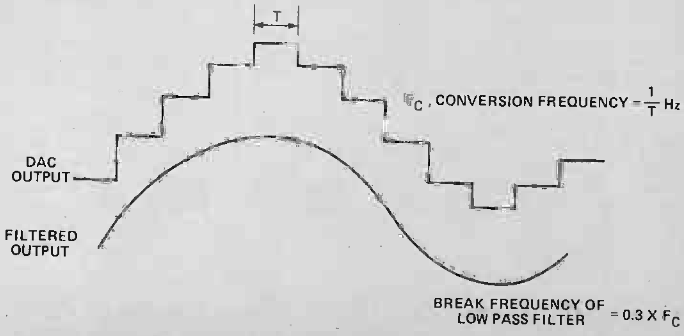


Fig. 6 The use of a recovery filter.