ETI
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FEBRUARY 1990 £1.50

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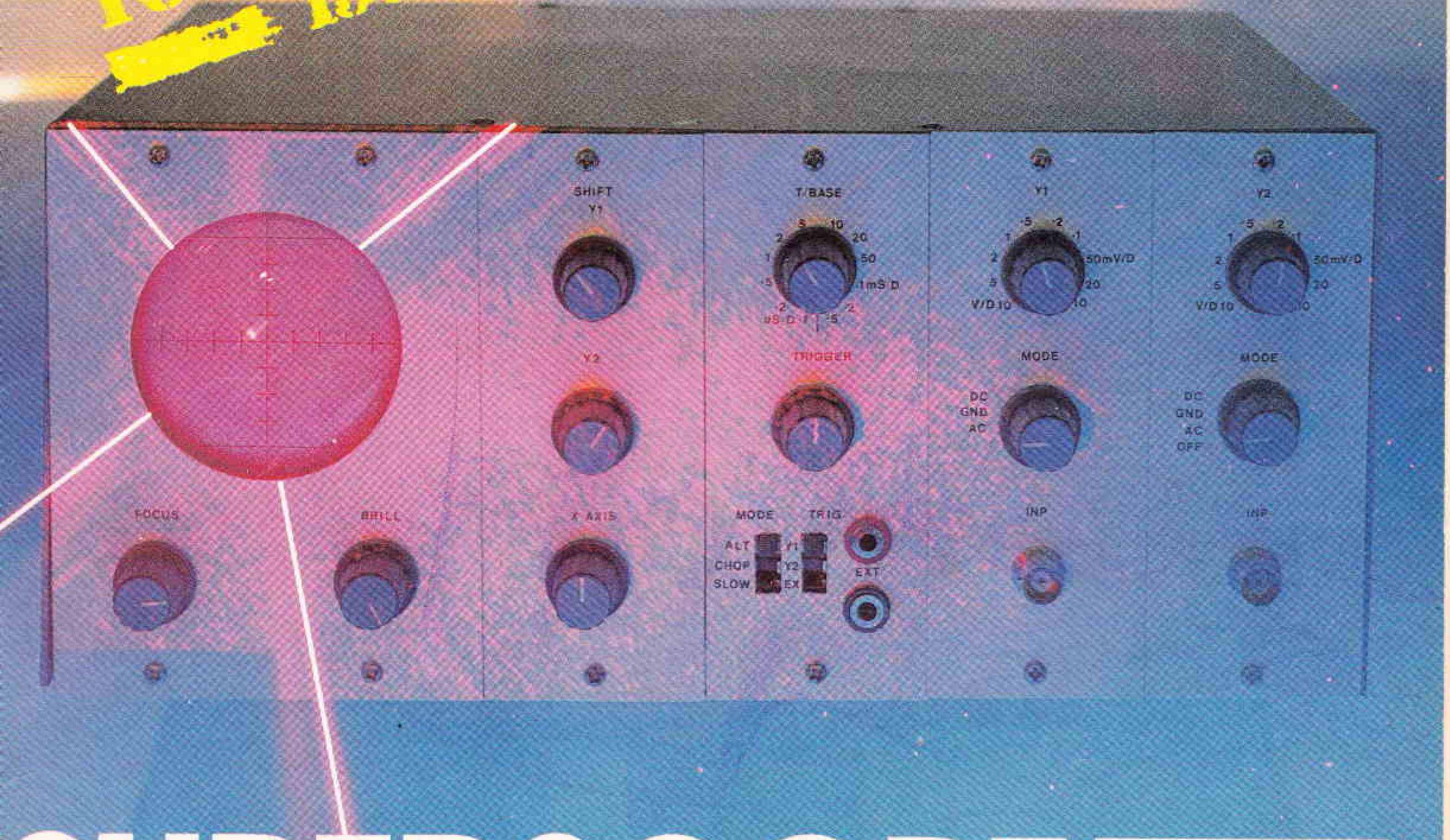

SUPERSCOPE

ISSN 0142-7229

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THE RTC MONITOR II

100 WATT SPEAKER KIT £60.00 +£3.50 P&P (pair)

RESPONSE: 55Hz–20kHz

BASS POLYMER CONE D: 22cm

DOME TWEETER: 14mm

OVERALL SIZE (HWD): 382,252,204mm

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The performance standard achieved in this compact design is distinctively superior to anything else available at the price. The drive units used are of sophisticated design and have been carefully integrated with a Complex Crossover.
Stereo performance is exceptionally good with a well focussed sound stage and sharp resolution of detail. Distortion throughout the frequency range is low even at quite high power input and this gives a great sense of dynamic range and openness especially when used in bi-wired mode.
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CROSSOVER KIT. To build 2 sets of crossovers **£11+£1.75** post. (Featured in *Everyday Electronics*–May 1989 issue). Reprint Free with Kits

AMPHONIC 125+125 POWER AMPLIFIER

125 watt per channel stereo power amplifier with independent volume controls, professional 19" rack mount and silent running cooling fan for extra reliability.

Output power .... 125W RMS max. per channel
Output impedance .... 4 to 16 ohms
(max. power into 4 ohms)
Sensitivity .... 450V at 22K ohms
Protection .... Electronic short-circuit and fuses
Power .... 220-240V a.c. 50Hz
Chassis dim .... 435×125×280mm

£124.99+**£7.00 p&p**

GOODMANS 60W CAR GRAPHIC

As new condition but have been returned by customers or shops, so they may need some attention. Hence the price of only £8.00 each. Order six of these units and you get the seventh one free. Postage £2.90

LCD DIGITAL MULTI TEST METER AC DC Volts resistance and DC Amps. Most of these units are new but have been returned or rejected by the store and sold with all faults at **£11.00** each. Postage £1.00. (Made by Ross Electronics).

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BP012	2	6½" Speaker 4Ω 10 watt
BP013	3	8"×5" Speaker 4Ω 6 watt *made by E.M.I.*
BP015B	1	30 watt, dome tweeter. Size 90×66mil *JAPAN made*
BP016	6	2200µf can type Electrolytic 25V d.c computer grade *made in UK by PHILIPS*
BP017	3	33000µf 16V d.c. electrolytic high quality computer grade *UK made*
BP018	3	2000µf 50V d.c. electrolytic high quality computer grade *made in USA*
BP019	20	20 ceramic trimmers
BP020	4	Tuning capacitors, 2 gang dielectric a.m. type
BP021	10	3 position, 8 tag slide switch 3 amp rated 125V a.c. *made in USA*
BP022	5	Push-button switches, push on push off, 2 pole change over. PC mount *JAPAN made*
BP023	6	2 pole 2 way rotary switch
BP024	2	Right angle, PCB mounting rotary switch, 4 pole, 3 way rotary switch *UK made by LORLIN*
BP025	4	3 pole, 3 way miniature rotary switch with one extra position off (open frame YAXLEY type)
BP026	4	4 pole, 2 way rotary switch *UK made by LORLIN*
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BP030	2	100k wire wound double precision potentiometers *UK made*
BP031	6	Single 100k multitune pots, ideal for varicap tuners *UK made by PHILIPS*
BP032	4	UHF varicap tuner heads, unboxed and untested *UK made by PHILIPS*
BP033	2	FM stereo decoder modules with diagram *UK made by PHILIPS*
BP033A	4	6"x⅜" High grade Ferrite rod. U.K. made.
BP034	3	AM IF modules with diagram UK made by PHILIPS
BP034A	2	AM-FM tuner head modules. *UK made by MULLARD*
BP034B	1	Hi-Fi stereo pre-amp module inputs for CD, tuner tape, magnetic cartridge with diagram. *UK made by MULLARD*
BP035	6	All metal co-axial aerial plugs
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BP037	6	In line fuse holders 20mm type *UK made by BULGIN*
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BP039	6	Double phono sockets, Paxolin mounted
BP041	3	2.8m lengths of 3 core 5 amp mains flex
BP042	2	Large VU meters *JAPAN made*
BP043	30	4V miniature bulbs, wire ended, new untested
BP044	2	Sonotone stereo crystal cartridge with 78 and LP styli *JAPAN made*
BP045A	2	Mono Cassette Record and play heads. (Japan Made)
BP046	4	6-0-6 4VA mains transformers, P.C. mount *UK made*
BP047	1	24V 750mA mains power supply. Brand new boxed *UK made by MULLARD*
BP049	10	OC44 transistors. Remove paint from top and it becomes a photo-electric cell (or P12) *UK made by MULLARD*
BP050	30	Low signal transistors n.p.n., p.n.p. types
BP051	6	14 watt output transistors. 3 complimentary pairs in T066 case *(Ideal replacement for AD161 and 162s)*
BP052A	1	Tape deck pre-amp IC with record/replay switching No LM1818 with diagram
BP053	5	5 watt audio ICs. No TBA800 *(ATEZ)*
BP054	10	Motor speed control ICs, as used with most cassette and record player motors
BP055	1	Digital DVM meter I.C. *made by PLESSEY* as used by *THANDAR* with diagram
BP056	4	7 segment 0.3 LED display (R.E.D.)
BP057	8	Bridge rectifiers, 1 amp, 24V
BP058	200	Assorted carbon resistors
BP059	1	Power supply PCB with 30V 4V/A transformer. MC7818CT IC & bridge rectifier: Size 4"×2¾"
BP060	1	Transcription record player motor 1500rpm 240V a.c.
BP061	5	6.35mm Mono jack plugs
BP063	5	6.35mm stereo switched jack sockets
BP064	12	Coax chassis mount sockets
BP065	1	3mtr Euro-mains lead with a matching chassis socket

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- Separate treble and bass
- Headphone jack

Size (H.W.D.) 75×400×195mm
Kit enclosed: case, P.C.B., all components, scale and knobs **£36.80.** post £3.50
(Featured project in *Everyday Electronics* April 1989 issue). Reprint Free with kit.

TV SOUND TUNER

In the cut-throat world of consumer electronics, one of the questions designers apparently ponder over is "Will anyone notice if we save money by chopping this out?" In the domestic TV set, one of the first casualties seems to be the sound quality. Small speakers and no tone controls are quite common and that really is quite sad, as the TV companies do their best to transmit the highest quality sound. Given this background a compact independent TV tuner that connects direct to your Hi-Fi is a must for quality reproduction. The unit is mains operated. This TV SOUND TUNER offers full UHF coverage with 5 preselected tuning controls. It can also be used in conjunction with your video recorder.
£29.50 +£2,50 p&p

As above but with built-in stereo headphone amplifier for the hard of hearing
You can tune into the TV channel you want while still receiving the picture on your TV set. In fact it is rather like a second television, but without the screen. So that the ordinary TV can be placed for everyone to see, and the volume on it can be comfortable for others, while the sound tuner can be placed where you can control it. You will need to plug in one of your own listening aids such as headphones or an induction loop to hear the sound. The tuner is mains operated, has 5 pre-selected tuning controls and can be used in conjunction with a video recorder.
Size: 270×192×65mm. **£35.90** +£2.50 p&p

TV SOUND TUNER KIT £11.50+£1.30 P&P
All parts including Varicap tuner, mains transformer, PCB with IC's capacitors and coils etc., to build the unit illustrated above; without case and scale.

SHURE HIFI STEREO MAGNETIC CARTRIDGE Fitted with an elliptical diamond stylus supplied with fitting kit and instructions. A good quality unit made to sell for well over twenty pounds due to scoop purchase, we are able to offer these at a fraction of the manufacturers price. All units are brand new and boxed. **£7.20 each.** If you order in multiples of five you get one free. Postage £1.30 (Made in U.S.A.)

KOSS MINI SPEAKERS Use instead of headphones on your personal stereo, just plug in instead of headphones. Koss sound cells can be mounted on top of your personal stereo with the holder supplied or simply detach for shelf mounting. This quality unit was made to sell for over seventeen pounds by the KOSS professional headphone company of the U.S.A. Due to a massive scoop purchase we can offer these units for **£4.30** each or buy in multiples of ten and you get one free. Postage £1.50.

KOSS STEREO HEADPHONES High quality light weight stereo headphones fitted 3.5mm jack with adaptor to 6.4mm jack. Ideal use Hifi or personal stereos made to sell for nine pounds. Our price for this unit **£4.25**. Postage 60p.

Hi-Fi stereo cassette deck transport mechanism, complete with 3 digit rev counter and tape heads, 12V d.c. operation. Unused manufacturers surplus *JAPAN made*
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February 1990

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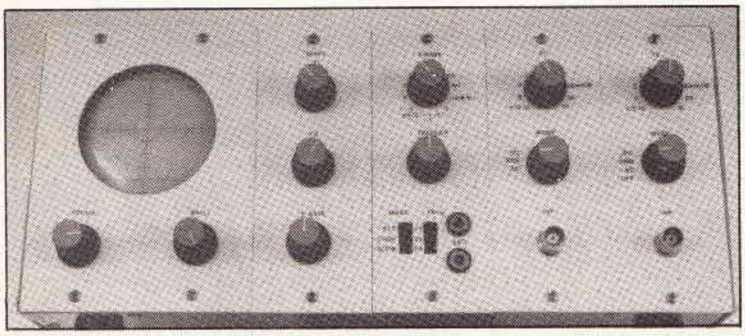

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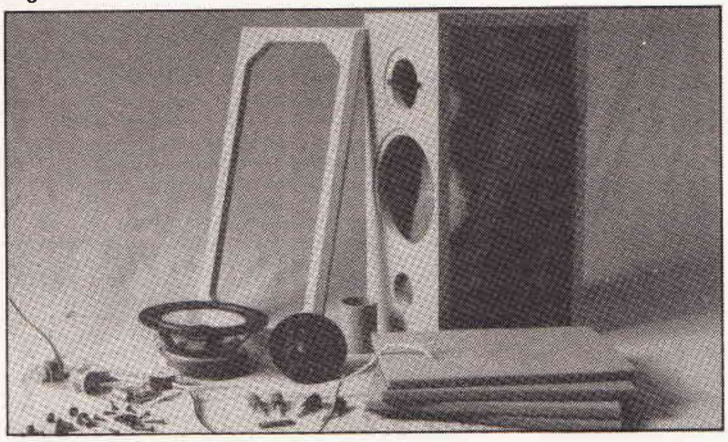

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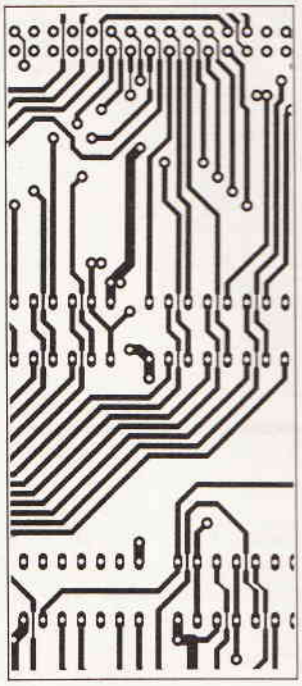

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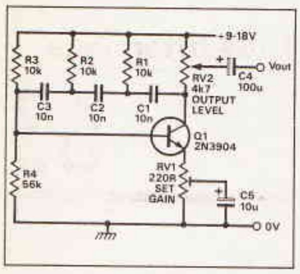
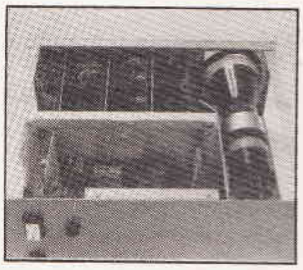
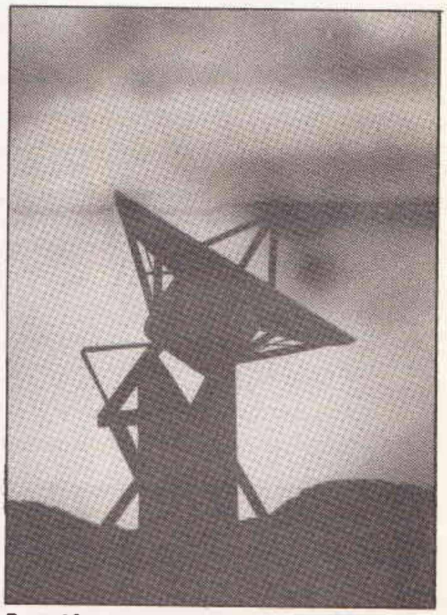
FEATURES/PROJECTS







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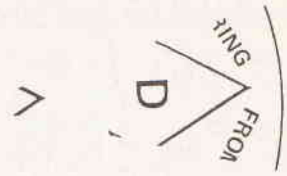
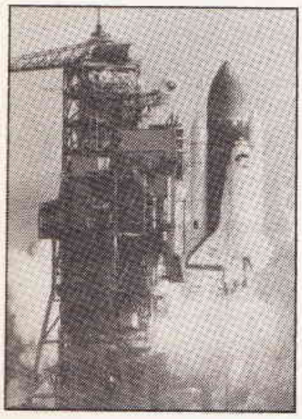
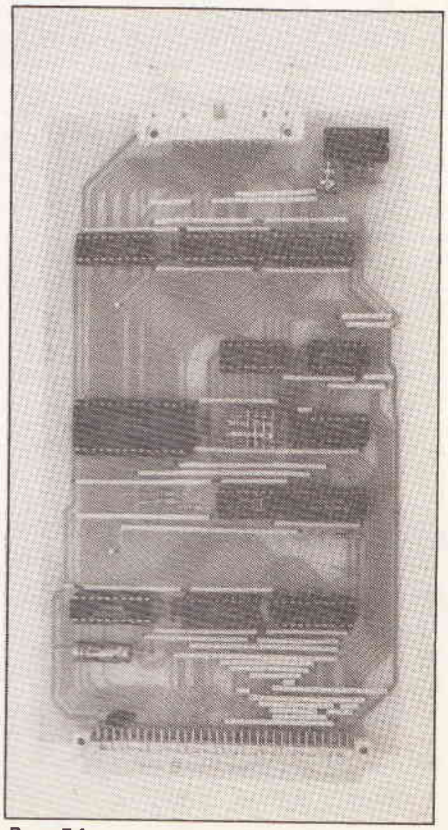




For legal reasons we are not publishing the Supermos II Amplifier Review.



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NEWS

TECH FOR ALL

Technology, design computing and business studies will be taught to all pupils from the age of five to sixteen according to the National Curriculum Council, a body overseeing the implementation of the governments intentions.

Technology, a subject covering such broad interests from electronics to home economics, will be taught in order to correct the nations bias against the subject.

The council is apparently confident the nations schools have the staff to teach the subject but recommended that a large in-service training programme be implemented to safeguard their actions. According to the report, pupils will be expected to appreciate such things as traffic light control by computer, use of spread sheets to estimate costs and make an advertising leaflet using a word processor.

YANKS 1 BRITS 0

The British are more scientifically illiterate compared to our American counterparts.

That's the result of a recent survey regarding the nations scientific wisdom.

37% of Britons do not know the earth revolves around the sun and an even greater 69% do not realise that electrons are smaller than atoms. American knowledge was consistently better when answering the same questions, 47 per cent knew about the planetary route.

The survey showed Americans are concerned over the positive aspects of science in relation to their society and will readily make changes, whereas the British reaction reveals apathy and a fear of scientific advance.

Even more disturbing are results from a general knowledge quiz. When it comes to scoring full marks, Americans are over eight times better than the Brits. The British beat the Americans eleven times over at achieving the minimum score.

These figures must surely be of great concern to government circles and only adds weight to the argument that a greater emphasis should be placed on science and technology in our schools.

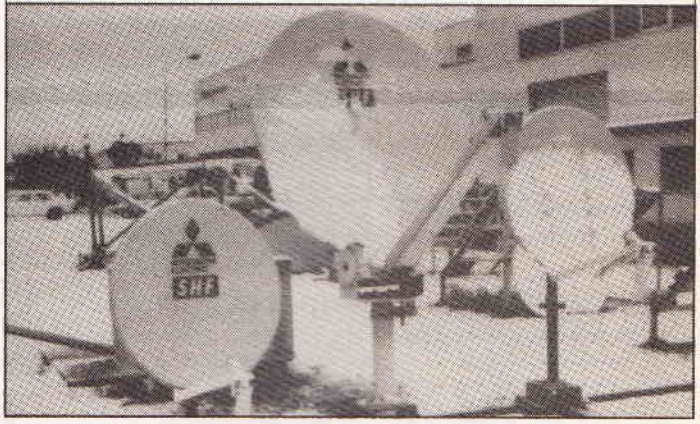
NONSTICK DISHES

The few satellite dishes perched on walls and roofs are about to stand the test of a British winter. A heavy snowfall could result in a loss of picture quality, not from atmospheric attenuation but from the mass of snow changing the geometry of the dish. This could bring a storm of complaints from subscribers that do not realise what has happened.

If the word spreads as to the cause, will we see a new generation of subscribers with extended brooms at the ready to dust down the snow from their latest piece of high tech? Not if Mandoval Coatings Ltd get their way. They have launched a hydrophobic paint onto the market to ban those precipitous dish deposits.

Once on the dish, the coating will deter any water from remaining on the 'almost frictionless surface'. Snow gets the same shifty treatment, as shown in the photograph.

Further information from Mandoval Coatings Ltd, Tel: (0909) 730059.



NEW DEVELOPMENTS IN LCD TECH

Researchers at a Northern Ireland university have succeeded in developing the first ever process for producing high resolution flat screen displays incorporating tin oxide conductors.

Using the new process, staff at the Bioengineering Centre of the University of Ulster have produced pixel electrodes which offer a ten-fold increas in resolution over conventionally produced units.

Common to all flat screen displays are clear conductor films made from either tin oxide or indium oxide. Indium is currently favoured by manufacturers, because until now, it was easier to etch, but it is more difficult and more expensive to deposit than tin oxide.

The key to the University of Ulster's breakthrough is a new method of etching tin oxide films. Conventional wet chemical etching processes are difficult to control, and cannot be patterned to high resolutions.

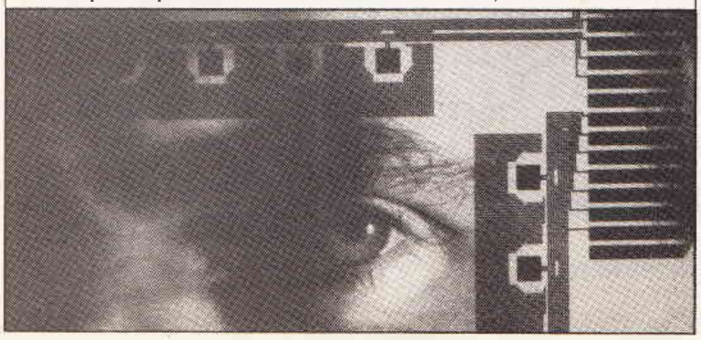
The new technique is based on a vacuum plasma process which uses a reactant gas — a mixture of chlorine and argon. With this method, University of Ulster staff have produced layers of tin oxide patterned with lines as fine as four thousandths of a millimetre, without loss of integrity. This allows the fill ratio — the ratio of active to inactive areas of the pixel — to be maximised, even at high resolution.

University staff say the process achieves fill ratios of better than 99 per cent which compares with a previous typical industry standard of around 56 per cent.

Tin oxide films can be easily fabricated in controlled conditions in-house — another major attraction for flat screen manufacturers, whereas Indium oxide films, are normally fabricated by specialist suppliers.

The University of Ulster reports strong interest from electronics companies in Japan, Europe, and America who believe the development has considerable commercial potential.

Further information contact:
David Brotzen, Tel: 01-831 6262



NICAM STEREO VCR

Ferguson is launching a new NICAM hi-fi video cassette recorder, into the mid-priced sector of the market. The Videostar FV37H is a slimline, three-head machine with a Fastext-capable LCD handset.

The major benefit of the FV37H is its ability to decode and record NICAM digital stereo transmissions, and in audio long play mode, record up to eight hours of hi-fi stereo sound.

Plugging an optional teletext adaptor into the socket at the back of the machine allows it to receive and display teletext pages on screen. The provision of a teletext facility means that the VCR can be programmed with any of the days programmes. Button selection on the remote control handset moves a cursor around the teletext programme pages. The programme information is then stored in the machine's memory, giving probably the simplest method of programming a VCR to date! Users will also be able to record subtitles with this system offering a valuable benefit to the hard of hearing. In addition, the four most frequently used text pages can be allocated to a numeric coding for recall.

The VCR has an advanced indexing facility that allows fast access to indexed points on any given tape — the index marks effectively, allowing the user to 'bookmark' the tape. The marks are automatically inserted on the tape when a recording is made or can be manually added or removed by remote control. The markers also enable an 'intro-search' feature to replay the first few seconds of a recording before fast-winding on to the next, until the desired programme is found.

The Videostar FV37H will retail at around £500.00 and the teletext adaptor at £100.00.

HDTV IS HERE

Thomson, the French state owned electronics and defence company look like being the first outside Japan to manufacture High Definition Televisions this year. Philips is likely to follow hot on their heels with their own version.

Thomson, the biggest TV manufacturer in the world unveiled at an audio-visual fair in Berlin, a TV that meets the technology half way at an estimated initial selling price of £3000. The cost increase is partly due to ten times the number of components being used over conventional sets.

The set uses the existing European scanning frequency of 50Hz as compared to the Philips set of 100Hz, but the picture quality is much improved. This comes about from the number of lines appearing on the screen. Thomson has doubled the existing number to 1250. The extra 625 lines are generated internally and are interlaced with the existing transmitted picture information to give higher definition. It does this by making a good guess as to what the information should be.

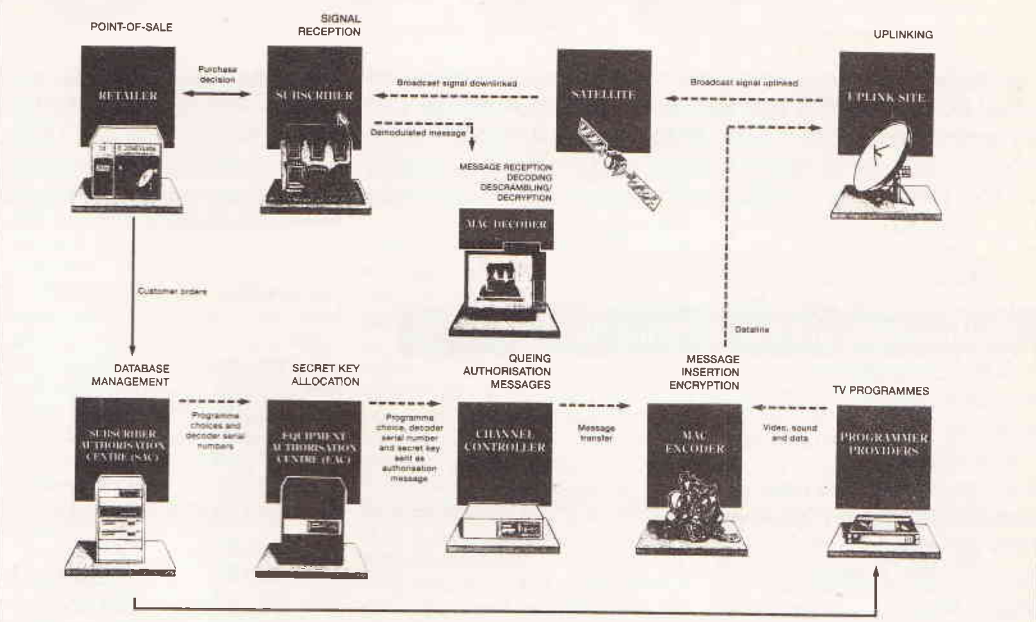
The aspect ratio comes in a more pleasing 16:9, a ratio similar to the cinema screen and the viewer has the option of splitting the screen into a 4:3 picture on the left leaving other channels to be received and viewed on the right.

Meanwhile the battle for a possible HDTV world standard goes on. The three cornered fight between Europe, Japan and America seems to have resigned itself to going their respective ways for the moment.

The only major concession is that the European camp has persuaded the Americans to think again about their choice. Should it be the Japanese or European system?

BT MANAGE TO SCRAMBLE TV SIGNALS

THE SUBSCRIBER MANAGEMENT SYSTEM FROM BT VISION



British Telecom has launched a satellite management system which allows broadcasters to keep track of their customers. It also combats piracy of satellite entertainment channels.

The system uses the D2MAC transmission standard (a standard adopted by the forthcoming BSB channels) to provide encrypted information that only authorised subscribers can receive with the use of a smart card or an authorisation code.

The system also allows the programme provider, the technology to control the transmission of possible offensive material.

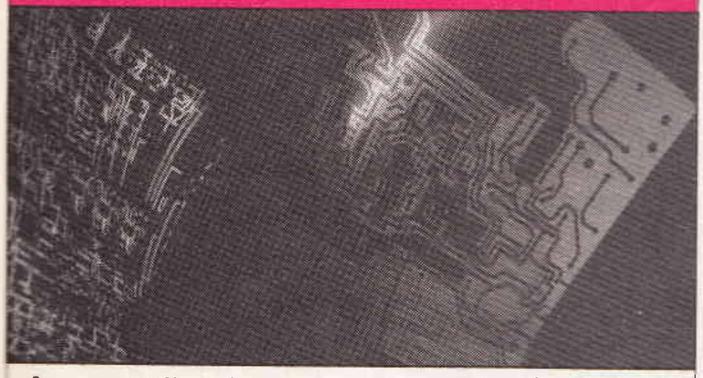
If a common standard of transmission and encryption can be agreed between British Telecom and France Telecom, it will allow consumers to receive many channels using only one decoder.

Programmes will be scrambled using a complex algorithm before it is uplinked to the satellite. An authorisation code is also transmitted with the television picture telling a set-top decoder to accept the programme signal, provided the viewer has paid the all important fee. Any change to the viewers circumstances can be amended quickly at the control room.

Another feature is the ability to black-out pictures in specific locations. This may apply to countries where distribution rights have not been agreed or programme content may be unacceptable.

Further general information on the subject of scrambling a signal, can be found in this issue of ETI.

CHEAP LASER PLOTTERS



A new range of laser photoplotters which cost almost half the price of similar systems on the market are now available in the UK from Photax (UK). Prices start from as low as £65,000.

The laser plotters, manufactured in France by Secmai, offer many state-of-the-art features including high resolution and high accuracy without breaking the bank. Photax currently is offering five different laser plotting systems covering plot areas from 24 x 22in up to A0 with resolutions varying from 1000 to 4000dpi and the ability to plot a 24 x 22in area in as little as seven minutes.

The plotters handle a number of standard inputs such as Gerber, DPF, Quest, Secrol and HPGL.

For further information contact Malcolm Maxwell, Photax (UK) Limited, Tel: (0753) 27484.

A FISHY BUSINESS

Eight rainbow trout equipped with a Vodafone and Racal-Vodata cellular data transmission equipment are playing a central role in a study on the impact on rivers of impurities and pollutants washed from the land.

The technique of monitoring water quality by observing the breathing patterns of fish was developed by the Water Research Centre at Medmenham in Buckinghamshire.

The monitored water is diverted through a tank containing a rainbow trout. Silver oxide electrodes immersed in the tank detect minute electrical impulses generated by the muscles in the gills as the trout breaths. Changes in breathing patterns as the trout reacts to a build-up of impurities in the water are detected by the electrodes and recorded by a computer. If breathing patterns deviate from preset limits for more than a few minutes, an alarm is generated.

Eight tanks contain trout so that any individual fish is not continually 'on duty'.

The research centre has supplied fourteen systems to regional water authorities as permanent installations for assessing the quantity of water at the intakes to treatment works. One has been housed in a caravan to study the effects of rain from urban areas.

The remote location makes it impractical to install a fixed telephone in the caravan so the research centre has bought a Vodafone and modem to retrieve data from the monitoring station. The hardware, is currently under evaluation at the centre.

Information from sensors measuring the physical characteristics of the water such as the oxygen content, temperature, acidity, conductivity and turbidity is also collected via the cellular link.

Since the trout prefer subdued lighting, the remote access offered by the auto-answer Vodata CDLC modem minimises the number of occasions when the fish are disturbed by field staff switching on the lights as they enter the caravan.

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OPEN CHANNEL

Paytelco is a company, recently formed jointly by Associated Leisure, Boots, GEC Plessey Telecommunications (GPT), Shell, and Trust House Forte, which intends to launch a brand new telephone callbox network of around 9000 payphones by the end of the year. Cost of the network is said to be over £60 million.

The network is to be based around GPT's own-designed intelligent payphone, which allows users to pay for calls with cash, credit cards, or standard phonecards. Telephone lines will be supplied via Mercury's national telephone network, so the system represents a first, in that it will be the only significant national payphone installation not run by British Telecom. Mercury's own attempt to set up such a network itself has run into difficulties, with only a handful of callboxes being installed. Incidentally, to give some idea of the size of the proposed Paytelco installation, BT's payphone installation base currently has over 80000 callboxes.

GPT has a problem when using its intelligent payphone, in that they are also sold to BT. To prevent potential clashes Paytelco has been set up.

Choice of member companies in the organisation is interesting, and gives an inkling of where the callboxes will be located: hotels, high-street chemists, petrol station forecourt and so on.

Next Left, Right?

Well, it finally looks as though it's going to happen. After the many years of talk, London is to get an electronic in-car guidance system. Autoguide is the system, to be set up by GEC as soon as possible to help to cope with the capital's traffic problems by indicating to motorists which is the quickest and best route to a desired destination. I'll be giving more details about the system in the coming months.

Ready, EDI?

So far, the UK hosts some 65% of all electronic data interchange (EDI) sites in Europe. This amounts to some 2,200 UK sites out of around 3,200 in the whole of Europe. Government sources say this is due at least partially to our early liberalisation of telecommunications.

This may look promising, but its still not a patch on the US situation. There, with some 10,000 or so EDI sites, US companies are already enjoying the faster and more efficient trading which EDI affords. US companies have it easier too, in that they have a more-or-less common system, common language, and common legal framework.

European companies on the other hand, are severely restricted by Europe's conventional attitude to new things — each country designs its own system, totally incompatible with another country's. There are other specifically European problems, too. For example, national legal restrictions tend to prevent straightforward expedition of goods, particularly through customs.

Nevertheless, the nearing of the open European market next year should move matters along rapidly, but we still have far to go to catch up with the Americans. Figures for the number of EDI sited worldwide by the turn of the century have been estimated at around 400,000 — an increase of some 2,800%. We (us Europeans, that is) had better get a move on.

ISDN

Another area where our traditional European attitudes have delayed progress is that of the future integrated services digital network (ISDN) telephone network. ISDN is, put simply, the complete digitalisation of the telephone network, so that all signals on all lines are digital. Implications of this are that all telephones must convert analogue voice signals into digital before transmission, and from digital to analogue after transmission. Differing demands from network providers in each country have delayed ISDN introduction — the concept was first dreamed up some ten years ago, but at last it seems we're about to get what we deserve.

Initial trials of ISDN services are currently underway in the UK as well as France and Germany, following what is known as a basic rate interface. This is effectively, a single user telephone line, which comprises two B channels (each of which allows data transfer at 64 Kbit/s) and a D channel (at 16 Kbit/s). Main problems up to now with these trial services (yes, you've guessed it) is that they are incompatible. 1992 is the magic date for compatibility — believe it when you see it.

A higher level of service, the primary rate interface is also planned for the ISDN, comprising a 2 Mbit/s line between a network exchange and the user's. Primary rate interfaces will be used, typically by larger organisations with private branch exchanges.

Already, many parts of the network are digital. Most trunk exchanges within the UK network for example, are digital. Local exchanges, most of which are presently analogue, are in the process of being replaced by digital counterparts. Final part of the changeover to ISDN will the come when user's handsets are replaced with digital handsets. But this is likely to be a while, for the average user at least.

Marcopolo is Go

British Satellite Broadcasting's satellite Marcopolo I is up in orbit and running rings around the competition apparently. After a successful launch the Hughes HS376 satellite has been fully tested and is now ready for use. This, hopefully disproves Sky's recent attempts to downgrade BSB's potential by stating the service's finances are 'floundering'.

Only a month or so after this issue of ETI hits the streets, BSB should be broadcasting satellite television on a day-to-day basis. Further, BSB's plans to broadcast DataVision, a system of data broadcasting by satellite for commercial users, which will give BSB a source of revenue right from day one. DataVision is therefore going to be piggy-backed on top of ordinary direct broadcast satellite television pictures, giving a distinct financial head-start in the satellite television race — even though they enter the race late.

What About The Kids?

In the Ballyhoo and hype of future television trends such as cable, satellite and broadcast, little has been voiced regarding programme content. Basically, as I've said often enough in this column, we get what we deserve. Following on from this, if we don't like what we get, it's our own fault. We can take an analogy with the printed medium of newspapers — complaints about the quality of the content of some of the papers (the 'gutter' press) is common, yet the fact is, those same papers appeal to a wider public than the 'quality' counterparts. Simply, 'you get wot you pays for'.

But this shouldn't be true of one particular type of televised programme. I'm talking about children's television programmes, where children themselves aren't able to decide properly for themselves what to watch. You see, the viewing needs of childen are significantly different to the viewing needs of the rest of us.

It's not that children's programmes should be censored. No; nothing as sinister as that. It's just that the content of children's programmes should be carefully guided to allow television itself to become a support tool for parents to use as they bring up their children.

One of the main difficulties as you may imagine, is the need for a television producing organisation to make profit. Following this precept, children's programmes can become second-rate programmes; produced as extremely low budget items to fill-in the hole in the day known when I was a lad, as 'children's hour'.

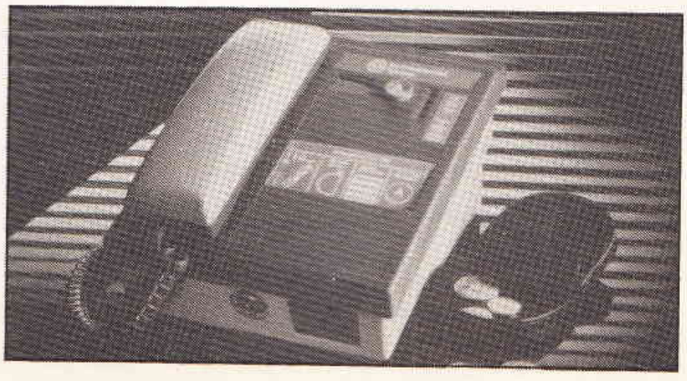
Another difficulty, is nothing to do with the programme producers. It is a parental concern. All too often parents use television as a tool to keep the kids quiet and out of the way. Sit the kids in front of the box and get on with the housework — heard it before? Ideally, television should be a tool to use with the children; discussing with them programme content and quality.

Yet another difficulty is to get the broadcasting standards and governmental agencies involved to even accept that children do watch television. Even the recent White Paper, which sets out how the Government proposes television of all broadcast forms to proceed, fails to give an idea how the laws of supply and demand can be used to control the content and quality of children's programmes.

British Action for Children's Television (BAC TV) is a recently set-up appliance of television users seeking to guide the range of children's television programmes. It attempts to meet these difficulties (and others) head on, through a variety of means: conferences, publication, research projects, symposia, workshops, and its own awards. Any interested individual or group are invited to participate.

More about BAC TV another time. Meanwhile information may be obtained from: British Action for Children's Television, 21 Stephen Street, London W1P 1PL. Telephone: 01-255 1444.

Keith Brindley



BLUEPRINT

Blueprint is a column intended to provide suggested answers to readers' electronics design problems. Designs are only carried out for items to be published, and will not be prototyped by the columnist. Circuits published in Blueprint are believed to work, but may need minor alteration by the reader after prototyping. Individual correspondence will not be entered into, save as necessary to prepare items for publication.

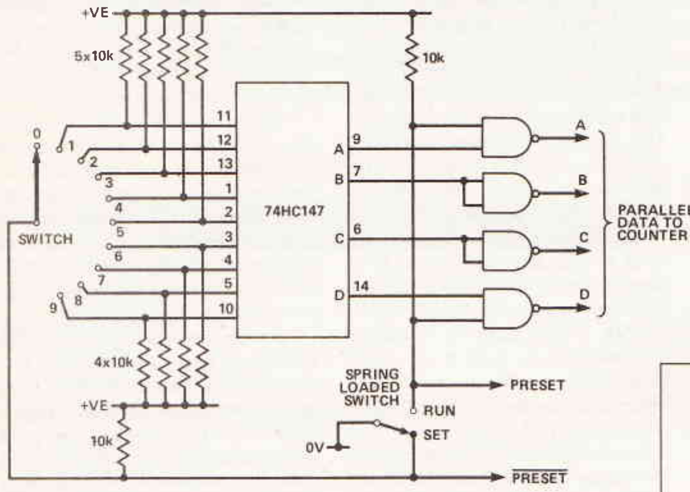


Fig. 1

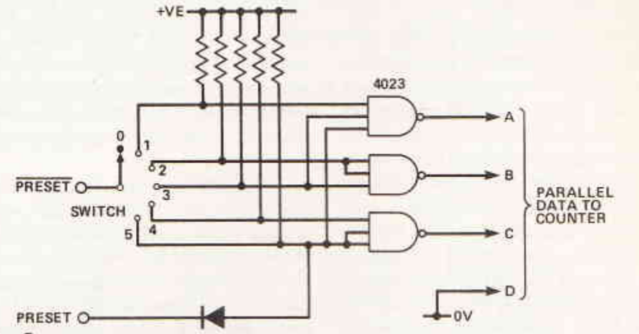


Fig. 2

This month we continue the design of the timing device for use by a blind person. The plot so far: A student is designing a timer to permit a blind person to record his/her favourite radio program while away from the house. To provide a means of setting which the blind person can check easily, while avoiding excessive circuit complexity, it has been decided to use rotary switches to set the delay time before switch on, and the on time duration.

The mains is used as the time standard, and mains derived pulses are counted by presettable down counters. When the delay counter reaches zero it is held stopped and the duration counter commences. While this counter is active, the load remains switched on. The basic count structure was described last month. The next part of the design is the programming logic.

Counter Reset

The down counter chains consist of cascaded 4-bit binary counters, with surrounding circuitry designed to reload them with parallel data when each counter reaches its end count. Only when all have counted down is the clock stopped. For example, suppose that the duration timer is set for 0 hours 30 minutes. At the start of the count, 0 will have been loaded into the minutes counter, and 3 into the tens of minutes counter. At the first clock pulse, 9 should be loaded into the minutes counter, while the tens counter counts down to 2.

This illustrates a crucial aspect of the counter programming logic. The counters must load to their maximum count number while counting down even though they may load to a different number on initial programming. Thus the minutes counter must be set to 9 on the clock pulse after it reaches zero, while the tens of minutes counter must reset to 5 after reaching zero, though of course it must wait for the minutes counter to go round once so that the carry input is at logic low.

There are many ways to address this logic problem, and no method is clearly the only correct one. Three main categories of solution are diode matrices, random logic, and msi chips intended for part or all of the required function. The method shown in Fig. 1, intended for the stages which count to 9, uses a priority encoder to translate the one of ten switch positions to BCD. The only priority encoders listed in my CMOS book are 74HCxxx types. As with much 74 series logic, BCD output is negative logic, while positive logic is required to program the down counters. A quad NAND gate pack is used to invert the signals and to set the outputs to 1001 (decimal 9) when the unit is in run mode.

For the counters which only count to 5, the expense of a priority encoder is not justified. The triple 3 input NAND gate pack does the necessary encoding for a count of 0 to 5. This is illustrated by Table 1, which shows that output A is at logic 1 for three switch positions, but outputs B and C are only at 1 for two positions. The gate inputs are connected to these switch positions, functioning as OR gates in negative logic. The diode connected to the preset line holds the outputs to 0101 (decimal 5) except while the counters are initially loaded from the switch information.

These circuit modules are used in each suitable programming position for the two counters. The logic for the 0-1-2 count is too trivial to draw.

Control Logic

One important characteristic of the control logic is that it must unambiguously switch on when the delay time is completed, and must switch off again when the duration time is finished. It must be guaranteed not to switch on again until the circuit is reset. This function is accomplished, as shown in Fig. 3, by two set/reset latches, which can only be reset by the reset switch. When both latches are reset, the output from the upper latch holds off the OR gate. When the terminal count signal from the delay timer sets that latch, the output of the OR gate switches to logic 1, switching on the load.

The load remains switched on until the terminal count signal from the duration timer sets the lower latch. When this latch is set, it inhibits the output, and it can only be reset by the reset switch.

In this circuit, the load itself is switched by a triac, triggered via an opto triac. This provides adequate isolation for safety reasons, so long as the board layout is adequate. a snubber network is included across the triac, for protection purposes, and to absorb small amounts of high frequency energy generated by the switch on. The capacitor should be class X rated for safety. This is a rating for capacitors to be connected to the mains supply in situations where a short circuit will not result in hazard of electric shock. Capacitors so rated show a specified resistance to breakdown under voltage spikes, and a specific level of resistance to combustion. It is easy to overlook this type of safety consideration in electronic designs, because the incidence of catastrophic failure even of components not specifically rated for safety is very low. However, a failure to avoid the potential one disaster out of many tens of thousands of possible failures is not worth the risk.

The triac chosen to switch the load, the TIC206D, is chosen because it has a reasonable maximum current rating (4A if properly heatsunk) is

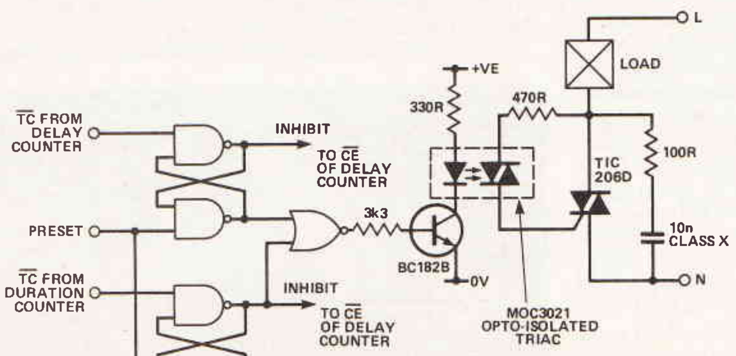


Fig. 3

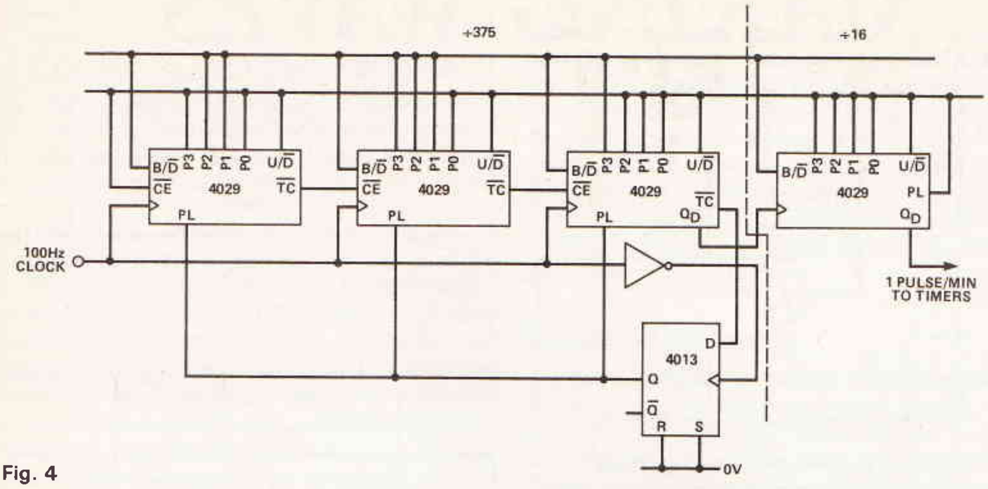


Fig. 4

sturdy and does not easily break down under voltage spikes, and triggers reliably at a low gate current.

Frequency Divider

The basic timing frequency is derived from rectified mains, and is thus 100Hz. The timer circuits have been designed to work with an input frequency of one pulse per minute, and to provide this frequency the 100Hz must be divided by 6000. At first sight, it is not clear how best to do this. One good technique is to find out the largest binary number by which it can be divided to produce an integer. Dividing 6000 by 16 gives the answer 375, so the divider may be made from two stages, one dividing by 375 and the other by 16. A circuit to do this is illustrated in Fig. 4.

Several types of counters would be suitable for this job, but 4029s have been chosen to be consistent with the rest of the circuitry. The divide by 16 part of the circuit is very straightforward — the 4029 is simply clocked and allowed to count round, and the output is taken from the most significant bit. Having this part of the circuit last ensures an even mark:space ratio, which may make testing easier.

The divide by 375 circuit employs the same principles as the individual timer stages shown last month. The sequences of operation is as follows; the counters are set to count down in binary mode, and every time the terminal count output of a less significant counter switches, the more significant counter is allowed to clock once. In this way, the counters count down from whatever binary number is programmed into all the counters considered as a unit. In the circuit as shown, the most significant bit is on the right, and in order to divide by 375, it is necessary to program 374 into the counters as the state following the zero. In this way, there are 375 possible counter states, including zero. The binary representation of 374 is 101110110, and the connections to the program inputs of the counters represent this number.

The design of this divider showed a minor error in the design of the counters last month. In order to avoid the counters remaining in state zero for two clock pulses, it is necessary to clock the D-type flipflop from a signal out of phase with that clocking the counters. This gives rise to the waveform diagram shown in Fig. 5.

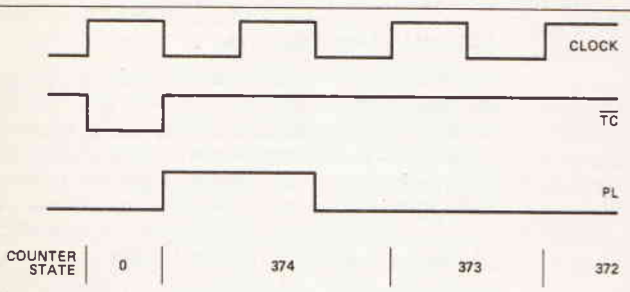


Fig. 5

Power Supply

The power supply for this circuit is straightforward. Because 74HCxxx logic is used in the circuit, a 5V power supply is necessary. The current consumption is low, so the power supply design itself is conventional, and the voltage regulator probably doesn't need a heat sink. An extra diode is added to the circuit in order to provide an unsmoothed, rectified signal from which a clock can be derived. One part of a 4093 quad Schmitt NAND gate is used to convert the half sinewave pulses into a clean clock signal. Resistors are used to limit the input signal to the 4093, and a small capacitor is used to reject mains interference.

This is the last of the modules forming this timer project. The interconnection of these modules should be more or less obvious, and is left to the reader. It is hoped that the principles shown in these simple sequential digital designs will assist readers in their own designs.

Alternatives

This is clearly not the only way in which this project could have been designed. I suspect that if it had been a design for substantial production, a microprocessor would have been used, possibly something like a Z80, or perhaps even a single chip device. The gadget would probably have worked on real-time instead of duration, and would have included a battery backed real time clock. It would, in fact, have been nearer in function to the timers which one can buy nowadays for this sort of job. However, the work of writing a program for a one-off design exercise is completely out of proportion.

Equally, there are several different ways in which the hardware could have been designed, and because of the modular form in which it has been presented, the reader may choose to use one part as designed while totally redesigning another part. To cite an obvious example, the divide by 6000 circuitry could equally have been implemented using a 4526 binary down counter, or even a prom and a latch!

In any event, if a hardware design had been required for production it is likely that several designs would have been carried out on paper and costed. It is not often clear at the start of a design which way will cost less. For example, will one expensive chip save more than its cost of cheaper ones? Will it be cheaper to use a slightly cheaper ic for one part of the circuit, or to stick to a more expensive one used elsewhere to get quantity discounts, and to cut stores costs? These questions are rarely considered in amateur project design, but for a student of design it is important at least to know that the questions exist.

Throughout the design, it has been assumed that two rows of switches would be used to set delay and duration. With a little alteration to the circuitry, but without a serious redesign, it would be possible to use only one row of switches, but to have two programming buttons, one to program delay, and the other to program duration.

As the circuit stands, it has very little resistance to the effect of power cuts. This situation could be improved by several methods: first of all, one could simply include a much larger power supply storage electrolytic to maintain the power supply during power cuts of up to, perhaps, five seconds. If this were inadequate, a battery could be included to provide a much longer period of operation, and if it were necessary to maintian approximate timing during a power cut of several minutes, a phase locked loop with a very limited locking range could be included between the 4093 clock pulse generator and the frequency divider. In this way, timing would be maintained, perhaps to an accuracy of 5% of the period of the power cut.

These are just a few ideas as to how the modules shown in this design could be modified and employed. Because, in common with most blueprint designs, this circuit has not been prototyped, it is entirely possible that it will contain other errors of a similar level to that of the missing inversion of the clock pulse to the D-type flipflop. It falls to the reader to correct such minor design problems once the principles have been laid out. Also, of course, it would surely spoil the fun if the student who made the original enquiry had no further work to do to produce the final project.

Andrew Armstrong

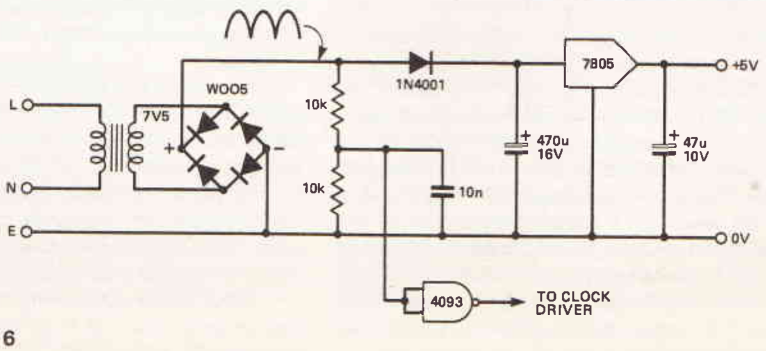


Fig. 6

MAKING WAVES

Ray Marston presents the second half of his mini-series showing a bumper bundle of sinewave circuits

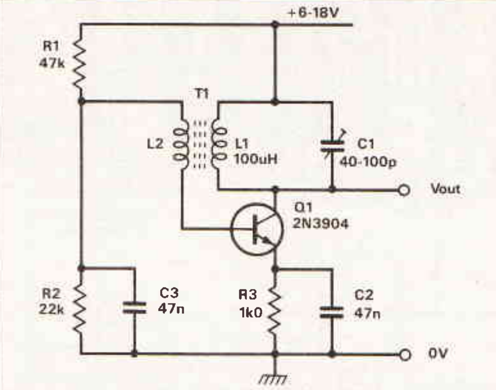


Fig. 1 Tuned-collector feedback L-C oscillator

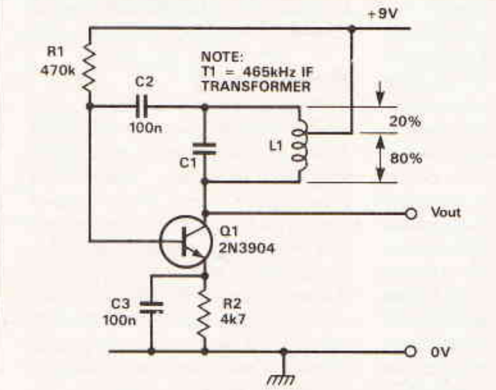


Fig. 2 Basic Hartley L-C oscillator

In December's episode we looked at a variety of practical C-R based sine-wave oscillator circuits. This month we conclude by investigating the L-C oscillator and sine-wave synthesiser designs.

L-C Oscillator Circuits

The C-R sine-wave oscillator circuits that we looked at previously are useful for generating signals ranging from a few Hz up to a maximum of tens or hundreds of kHz only. L-C oscillators, on the other hand, are useful for generating signals ranging from a few tens of kHz to hundreds of MHz.

A transistor L-C oscillator consists, in essence, of a simple transistor amplifier stage plus a frequency-selective L-C network that gives appropriate positive feedback between its output and input. L-C networks have inherently high 'Q' or frequency-selectivity, so such oscillators consequently tend to produce reasonably pure sine-wave outputs, even when the oscillator's loop gain is far greater than unity.

Many different versions of the transistor L-C oscillator are in common use. The simplest is the *tuned collector feedback* oscillator, an example of which is shown in Fig.1. Here Q1 is wired as a common emitter amplifier with base bias provided via R1, R2 and with emitter resistor R3 decoupled to high-frequency signals via C2. L1,C1 forms the tuned collector circuit, and collector-to-base feedback is provided via L2, a small winding inductively coupled to L1. This provides a transformer action — by selecting the phase of this feedback signal, the circuit can be made to give zero loop phase shift at the tuned frequency so that if the loop gain (determined by T1's turns ratio) is greater than unity, the circuit will oscillate.

A feature of any L-C tuned circuit is that the phase relationship between its energising current and induced voltage varies over the range −90° to +90° and equals zero at a centre frequency given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Figure 1 gives zero overall phase shift and thus oscillates at this centre frequency. With the component values shown, the frequency can be varied from 1MHz to 2MHz via C1, but in practice the basic circuit can easily be designed to operate at frequencies ranging from tens of Hz (by using a laminated iron-core transformer) up to tens or hundreds of MHz.

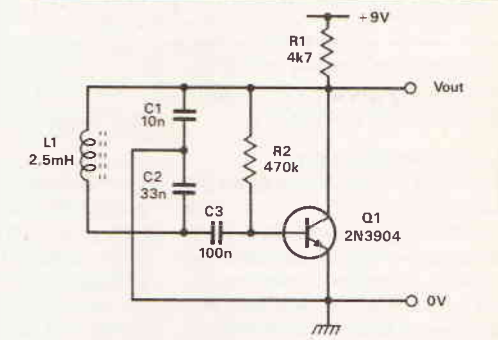


Fig. 3 37kHz Colpitts L-C oscillator

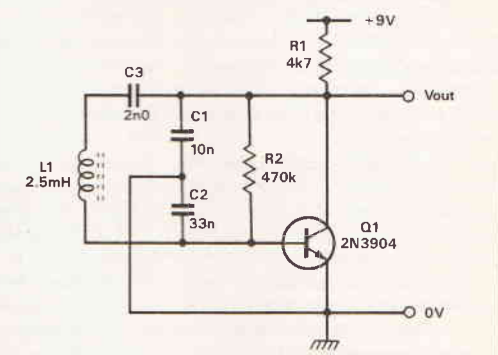


Fig. 4 80kHz Gouriet or Clapp L-C oscillator

Circuit Variations

Figure 2 shows a simple variation of the Fig.1 design, this particular circuit being known as a Hartley oscillator. Here, collector load inductor L1 is tapped 20% down from its top, and the circuit's positive supply rail is connected to this tap point. The inductor thus gives an auto-transformer action in which the signal voltage appearing at the top of L1 is 180° out of phase with that on its low (Q1 collector) end. The signal voltage from the top of the coil (which is 180° out of phase with the collector signal) is coupled to Q1 base via isolating capacitor C2 — the circuit thus oscillates at a centre frequency determined by the L-C values.

Note from the above description that oscillator action depends on a 'common signal' tapping point being made into the tuned circuit, so that a phase-splitting autotransformer action is obtained. This tapping point does not in fact have to be made in the actual tuning coil, the tuning capacitor can be used as in the Colpitts oscillator shown in Fig.3. This particular circuit oscillates at about 37kHz.

Note here that C1, is in parallel with Q1's output capacitance and C2 is in parallel with its input capacitance. Consequently changes in Q1 capacit-

CIRCUITS

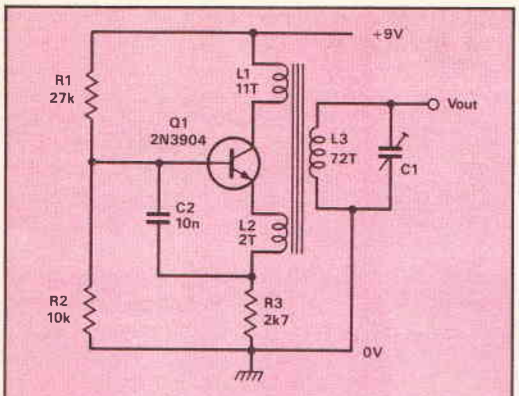


Fig. 5 Basic Reinartz L-C oscillator

ance (due to thermal shifts and so on) cause a change in frequency. This effect can be minimised (and good frequency stability obtained) by making C1 and C2 large relative to the internal capacitance of Q1.

A modification of the Colpitts oscillator, known as the Clapp or Gouriet oscillator, is shown in Fig.4. Here a further capacitor (C3) is wired in series with L1 and has a value that is small relative to C1 and C2. Consequently, the circuit's resonant frequency is determined mainly by the values of L1 and C2 and is almost independent of variations in transistor capacitances. This circuit thus gives excellent frequency stability. With the component values shown, it oscillates at about 80kHz.

Figure 5 shows the so-called Reinartz oscillator. Here the tuning coil has three inductively coupled windings. Positive feedback is obtained by coupling the collector and emitter signals of the transistor via windings L1 and L2. Both of these inductors are coupled to L3 and the circuit oscillates at a frequency determined by L3 and C1. The diagram shows typical coil-turns ratios for a circuit designed to oscillate at a few hundred kHz.

Finally, to complete this look at basic L-C oscillators, Fig.6 shows how the Fig.1 design can be modified so that it acts as a 465kHz beat-frequency oscillator (BFO) that is 'Varicap' tuned via potentiometer RV1. Here, a standard 465kHz transistor IF transformer (T1) is used as the L-C tuned circuit and silicon diode D1 is used as an inexpensive Varicap diode or voltage-variable capacitor.

It is a simple fact that when any silicon diode is reverse biased it exhibits a capacitance that varies with the applied voltage — the capacitance is greatest when the voltage is low, and is least when the voltage is high. Varicap diodes are specially manufactured to exploit the effect, but the ordinary 1N4001 silicon diode can be used for the same purpose, as in Fig.6. Capacitor C2 (which gives DC isolation between Q1 and D1) and 'capacitor' D1 are wired in series. The combination is effectively wired across the T1 tuned circuit (since the circuit's supply rails are shorted together as far as AC signals are concerned). Consequently, the oscillator's centre frequency can be varied by altering the capacitance of D1 via RV1.

Sinewave Synthesisers

All the circuits so far are oscillator types that give direct sinewave generation. Sinewaves can also be produced by synthesising them from other types of waveform, and several manufacturers produce dedicated 'waveform synthesiser' ICs that use this principle. The best known of these ICs are the XR-2206, produced by Exar Integrated Systems Inc. of America, and the 8038, which is available from a number of manufacturers.

Both of these ICs work in the same basic way. They contain a linear triangle waveform generator that has its frequency controlled by a simple external C-R network, and this waveform is then shaped into a sine form via an integral non-linear amplifier. The major advantages are that the frequency is variable via a single external resistor or capacitor, that the frequency can easily be varied from a fraction of a Hz to hundreds of kHz, and that the waveform is free of 'bounce'. Disadvantages are that sinewave outputs have typical distortion factors of 0.5% in the case of the XR-2206, and 2% in the case of the 8038. Also the ICs are fairly expensive.

XR-2206 Circuits

The XR-2206 is a sophisticated 16-pin IC capable of generating high-quality sine, square, triangle, ramp and pulse waveforms at frequencies from a fraction of a Hz to hundreds of kHz, using either resistance or voltage control of frequency, and of generating either FM, AM, or FSK forms of waveform modulation. It can operate from either single-ended or dual power supplies. For our present purpose we are only concerned with using the IC in its most basic modes.

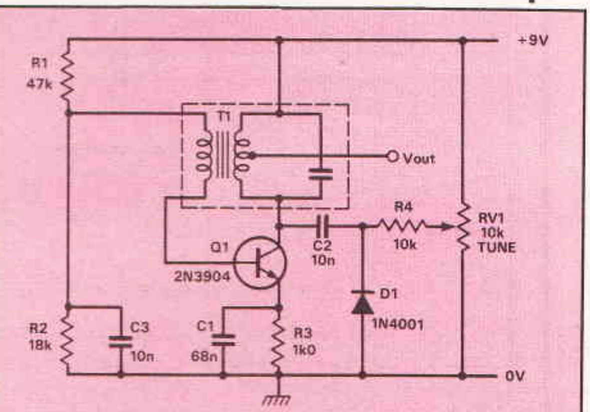


Fig. 6 465kHz BFO with varicap tuning

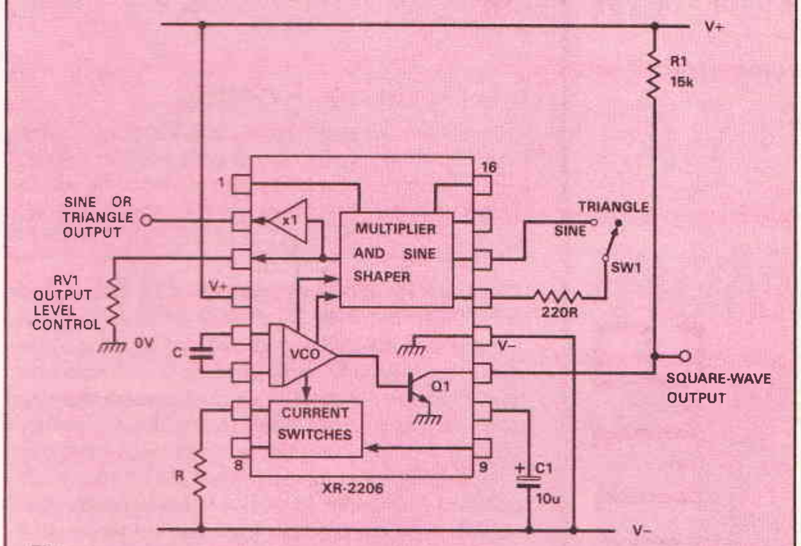


Fig. 7 XR-2206 block diagram and basic 'sine/square/triangle' waveform generator connections

With this in mind Fig.7 shows the IC (complete with internal block diagram) connected as a simple sine/square/triangle generator that is powered from a dual power supply.

The circuit operates as follows. The heart of the XR-2206 is a voltage-controlled oscillator (VCO), which is driven via a pair of current switches. The VCO's main timing capacitor C (1n0 to 100μ) is wired between pins 5 and 6, and its timing resistor R (4k0

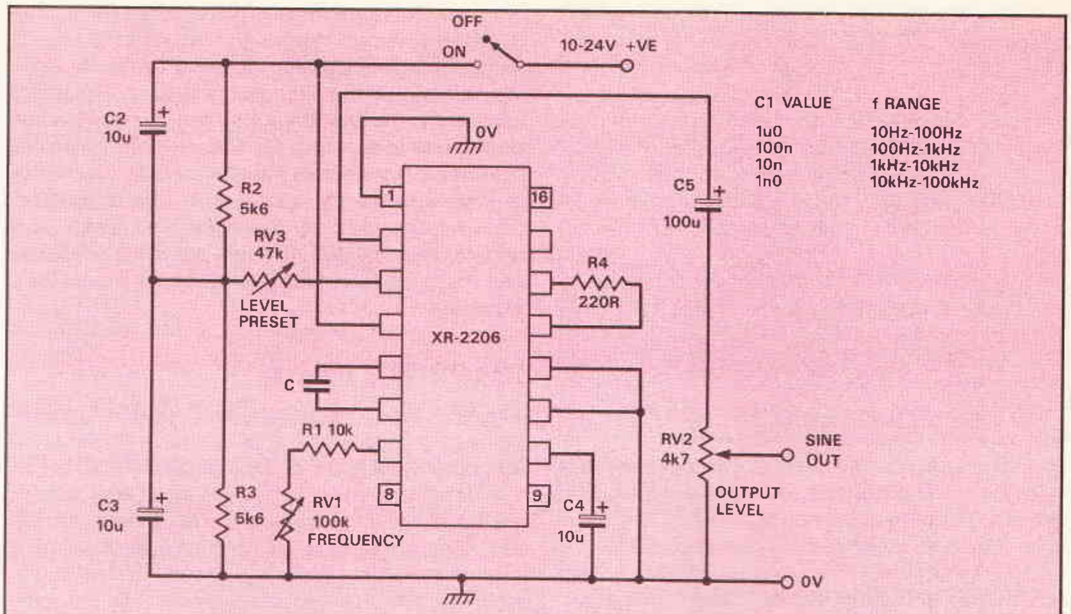


Fig. 8 Simple XR-2206 based wide-range (10Hz to 100kHz) winewave generator using a single-ended power supply

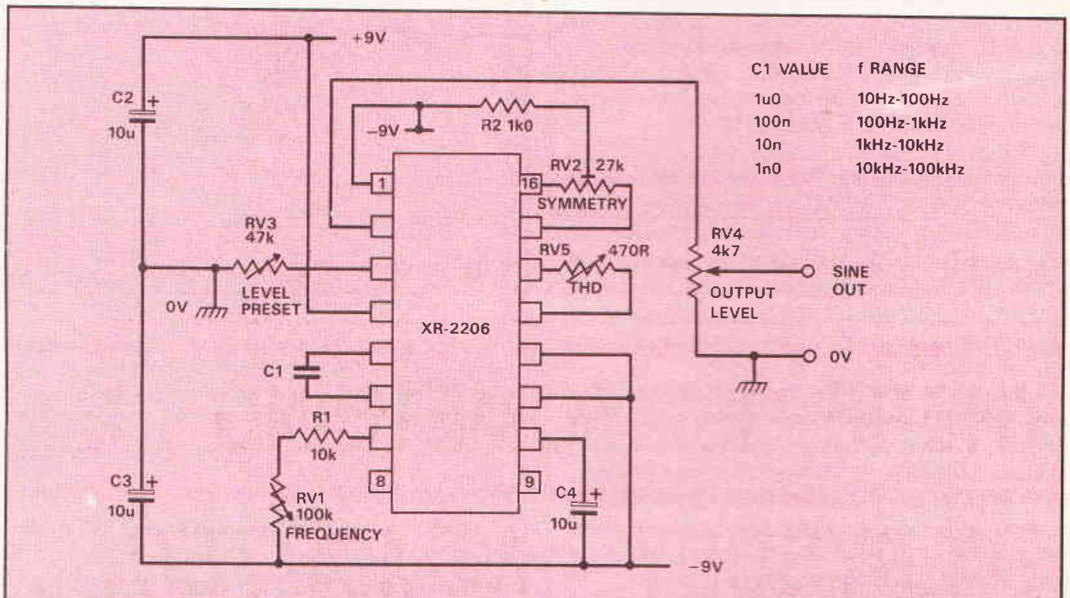


Fig. 9 High-performance XR-2206 based wide-range sinewave generator using dual power supplies

to 200k) is wired between pins 7 and 12 (the negative supply line terminal). The VCO generates a linear ramp waveform with a frequency of 1/RC Hz. When this ramp is rising the VCO switches Q1 on, and when it is falling it turns Q1 off. A synchronous square wave output is thus available at pin 11 by wiring this pin high via a 15k resistor, as shown.

The actual ramp waveform is fed into the 'multiplier and sine shaper' block and is subsequently made directly available at a high impedance level on pin 3, or in buffered form in pin 2. If pins 13 and 14 are open circuit this waveform is unmodified and appears as a linear ramp, but if a resistance of about 220R is wired between these pins the 'multiplier and sine shaper' block exponentially reduces the peaks of the input ramp waveforms and produces a sinewave output. This sinewave has a typical distortion of about 2½%, but can be reduced to 0.5% by trimming the pin 13,14 resistor value.

Figure 8 shows how the above points can be put to practical use to make a simple but useful variable-frequency sinewave generator that uses a single-ended power supply. The operating frequency is inversely proportional to the values of C1 and R1-RV1, and can be varied from 10Hz to 100kHz in four decade ranges by using the C1 values shown. The output amplitude is fully variable via RV2 but can have its maximum value preset via RV3. The waveform distortion is typically less than 2.5 percent.

Figure 9 shows how the circuit can be modified for operation from dual power supplies and how sinewave distortion can be reduced to a typical value of 0.5% by adjustment of preset controls RV2 and RV5. These two controls must be adjusted in unison to give minimal distortion when the circuit is first built, and need no further adjustment thereafter.

Note in the above two circuits that the maximum output level can be preset via RV3, which should be set to give a maximum output of less than 2V RMS, to prevent excessive distortion.

8038 Circuit

Our final circuit, Fig.10, shows how an 8038 IC can be used to make a wide-range generator that uses dual power supplies. This IC operates in roughly the same way as the XR-2206, but has its frequency controlled by the values of R1, R2 (these resistors should have equal values) and C1, also by the control voltage applied to pin 8 of the IC. The frequency is lowest when this voltage is close to the positive supply rail value and increases as the voltage moves downwards.

Thus in Fig.10, the frequency can be varied via C1 and RV1, and the minimum and maximum frequency range spans can be preset via RV2 and RV3 respectively.

Each span can in fact be varied over a very wide range, but in practice is best limited to the 10:1 span ranges indicated in the table. Note that preset pots RV4 and RV5 enable the sine waveform to be trimmed for minimum distortion.

Another point about the 8038 is that its pin 2 sinewave output terminal needs to be fed to the outside world via high-impedance buffer stage. In the diagram this is achieved via a 3140 op-amp, wired as a unity-gain voltage follower that drives RV6, which in turn acts as an output level control.

To initially set up the Figure 10 circuit, give C1 a 47n value, set RV1 to maximum and trim RV3 to set 1kHz. Now set RV1 to minimum and trim RV2 to set 100Hz. Repeat this process until no further adjustment is needed then trim RV4 and RV5 to give minimum sinewave distortion. The circuit is then ready for use.

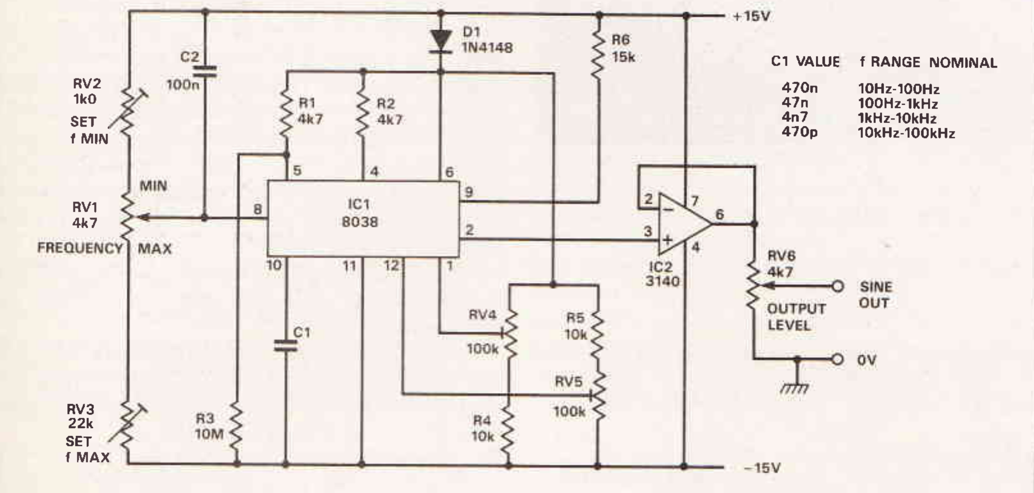
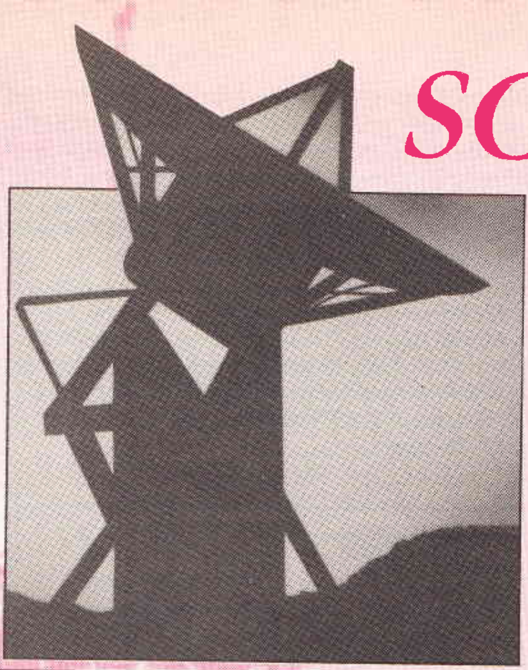


Fig. 10 8038 based wide-range sinewave generator using dual power supplies

ENCRYPTION SCRAMBLE

Jim Slater explains how cable and satellite broadcasters make mush out of a perfectly good picture



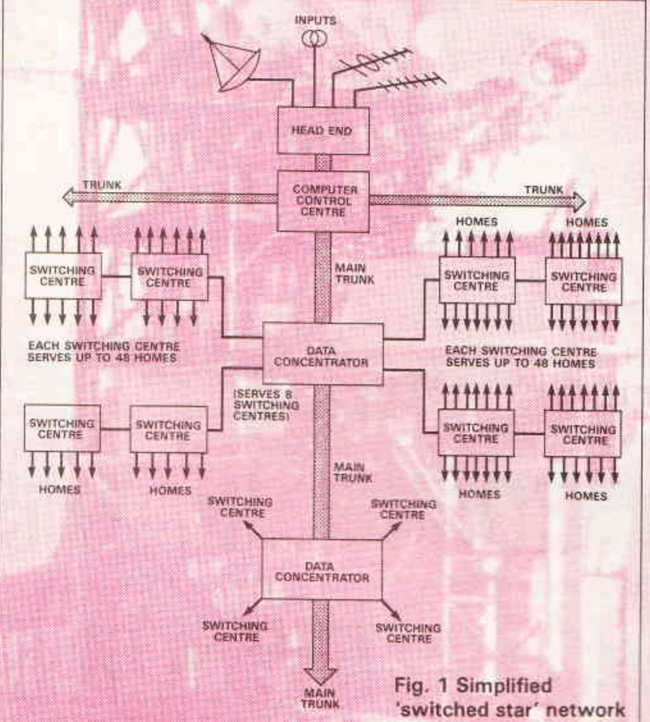


Fig. 1 Simplified 'switched star' network

Although engineers naturally tend to concentrate on the technical aspects of cable television, it is important to remember that the installation and operation of any cabled distribution system will depend on the availability of finance. Many local councils provide, as a service to their ratepayers, the capital cost of the necessary Community Antenna TV (CATV) equipment to enable their ratepayers to receive the basic television services provided by the broadcasters, and also ensure that maintenance is carried out at little cost to the viewer. However this type of operation has really depended upon the fact that the programmes being relayed were available free 'off-air' to the cable operator, since the costs of the broadcasters had already been covered by the receiving licence fee or advertising.

Once extra programmes such as feature films become available, their providers need to be paid, and some means has to be found of financing these programmes.

The simplest answer is to use the cable network to carry advertising on these extra channels. There is no doubt that the amount of advertising can be increased to provide some extra revenue, but it seems unlikely that this revenue will continue to grow to an extent sufficient to finance the dozens of different channels likely to be available to cable subscribers over the next few years.

Bring On The Sub

Opinion polls and practical experience over a number of years have shown that some viewers are prepared to pay a premium to receive extra services, especially if the new service offers something different from the main channels (recently premiered cinema films or live sporting events for example). If revenue is to be generated from such programmes, the programmes must be unwatchable to those who do not wish to pay a subscription fee. Although in theory it would be possible to achieve this discrimination between the two different kinds of viewers by simple switching on a perfect star-distribution system, where each viewer is directly connected to the 'head end', such a system would be completely uneconomic. It is therefore usual to encode or scramble the signals radiated from the head end, providing those viewers who choose to pay with an appropriate descrambling box to restore the pictures to normal.

Such subscription-television or toll-television falls into two main types of system. The first type is a regular subscription in order to be able to receive programmes on a particular channel.

The second type is known as 'pay-per-view' and involves the viewer in choosing to pay for individual programmes as they are shown. This usually means that some signal has to be sent from the viewer's home to the head end to indicate that the viewer wishes to watch the current programme — the head-end operator can then send an enabling signal to the viewer's receiver to switch on the descrambling circuitry and allow the viewer to watch. Before sending the enabling signal the operator will check to see that the subscriber's credit account is in order.

It will be seen that 'Pay-per-view' can only be adopted on systems where there is some form of communication back from the viewer to the head end or intermediate switching centre, so that we are generally speaking about switched-star systems such as that shown in Fig. 1 (based on Rediffusion system design). It is not strictly necessary to have interaction along the cable network for 'pay-per-view' to take place, since a simple system could be envisaged where a phone call to the head end would request that a particular programme be sent along the line, and the operator would then check on the credit status of the customer before switching through the appropriate programme — no use for large-scale commercial systems but feasible in a hotel, say.

Conditional Access

A fairly recent term embracing the various methods of pay-television is 'conditional access', where the viewer has access to programmes only when certain conditions have been satisfied. Although the most usual condition will be that money has to be paid, this is by no means the only possible arrangement. It could be that special programmes for the medical profession or containing lists of confidential information could be made available only to those who type in a special password.

The term 'scrambling' is generally used to describe the process by which the pictures are rendered unwatchable, whilst the additional term 'encryption' is used in more complex systems to cover the way in which various 'key' signals are transmitted along with the picture information to enable the decoder box to decipher the incoming signals, unlocking the system so that the pictures can be unscrambled.

Fig. 2 shows the basic principles of how any encryption and key distribution method of scrambling works.

We have already mentioned that scrambling is usually carried out to prevent viewers who have not paid for watching particular programmes but this is by no means the only reason. Some operators use scrambling as a sensible way of minimising their copyright liabilities. As an example, some European broadcasters are radiating by satellite services which are primarily or exclusively intended for reception by cable head ends. These operators encrypt their programmes so that they can tell accurately how many viewers are actually watching its programme services. This means that copyright payments need to be made for only the limited number of viewers connected to cable systems with the approved decoder, whereas if the programmes were not scrambled, the copyright-protection agencies would delightedly claim that payment was due for millions of off-air viewers all over Europe.

Political considerations can also give rise to scrambling, as can be seen by the fact that quite a few European governments (and not just those of the Eastern bloc) have insisted that transmissions from satellites are scrambled in order to prevent their own nationals from being able to receive them — perhaps in an attempt to protect their domestic television services from competition.

No practical technique of scrambling, even those using sophisticated encryption techniques, can be considered absolutely secure. Even the complex active line rotation systems described below can be cracked if sufficient time, money and computing power are devoted to the task. Some enthusiasts with considerable technical knowledge will undoubtedly obtain the same sort of illicit thrill out of trying to break into the more complex systems that computer hackers get from breaking security shells in main frames. But the cable operator is not too worried about these rare individuals and is concerned only to have a scrambling system that is secure enough to ensure that the average viewer will not be able to gain unauthorised access. To do this he must use a system with decoders of a design which ensures that it would not be worth while for a 'pirate' manufacturer to build them in quantity, and he should use an excryption system which allows the 'key' information to be changed so frequently that it is just not practicable for a 'pirate' viewer to keep up with the changes.

The scrambling and descrambling of most 'composite' television pictures (those colour pictures using NTSC, PAL or SECAM), generally gives rise to some loss of picture quality, and care needs to be taken by the operator to ensure that any degradations are kept to an absolute minimum.

Conditional Access Techniques

The very earliest techniques for preventing unauthorised access to television channels concentrated on removing the audio signals, presumably on the basis that viewers would not watch pictures without the sound. These days it is always considered essential to 'spoil' the pictures as well. One early method was to insert a second sound carrier to mask the audio information on the main carrier until it was filtered out, and another was to heterodyne the standard audio subcarrier so that it appeared on a higher frequency than the receiver was expecting. The viewer who paid to watch the extra channels would have the necessary frequency downconversion done in this 'descrambler' box.

Such methods are still used to scramble the sound part of a programme in addition to scrambling the video, and various subcarrier frequencies from as low as 12.5kHz to as high as 62.5kHz are used, but other more sophisticated techniques are also in use. Sometimes the conventional sound carrier is omitted and digital sound signals are sent in the line-synchronising periods using a lower-cost version of the 'sound-in-syncs' type of system used by broadcasters.

Traps

Probably the simplest method of preventing a viewer who has not paid to subscribe to various premium channels from receiving the pictures is to insert a sharply tuned notch filter into the cable system at the point where the customer's service drop is taken from the network, or at some other point on the customer's premises before the receiver. This fairly crude mechanism is usually a completely passive device made up from inductors and capacitors. It attenuates the strength of the premium-channel signal so that the receiver does not get enough signal to provide an acceptable picture. Such an arrangement of tuned circuits can be placed in series with normal cable or, preferably, shunted across the cable to ensure that signals at the frequency of the premium channel do not reach the customer's receiver.

Since it would be a relatively simple matter for any would-be 'pirate' customer to disconnect such a device or tamper with its tuning so as to minimise its rejection, traps have to be mounted in a secure environment, such as a sealed metal box.

Although it is technically very easy for the cable system operator to remove the trap if a customer wishes to subscibe to the service (and vice versa) the

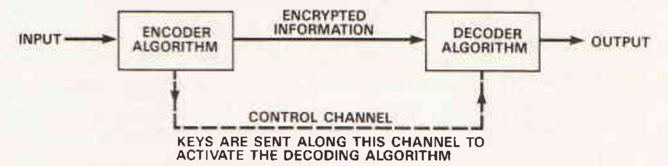


Fig. 2 Basic principles of any encryption and key distribution system

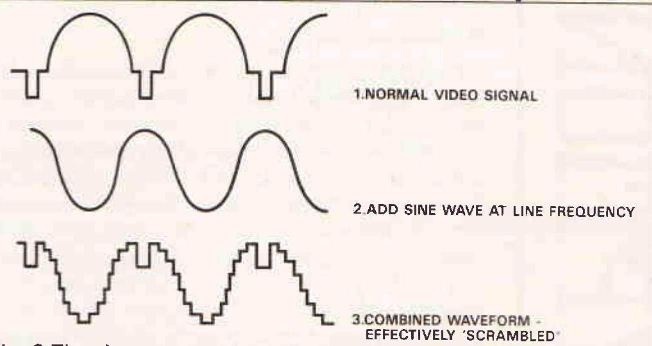


Fig. 3 The sinewave sync suppression technique

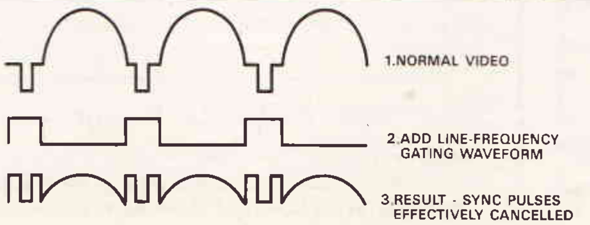


Fig. 4 The gated sync technique

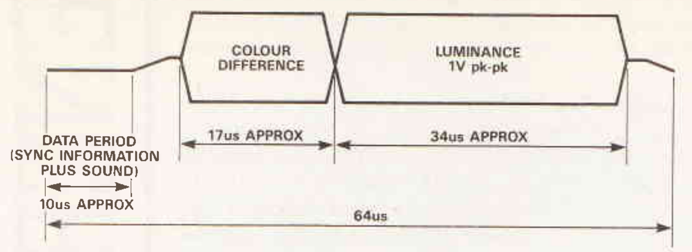


Fig. 5 Basic MAC line waveform

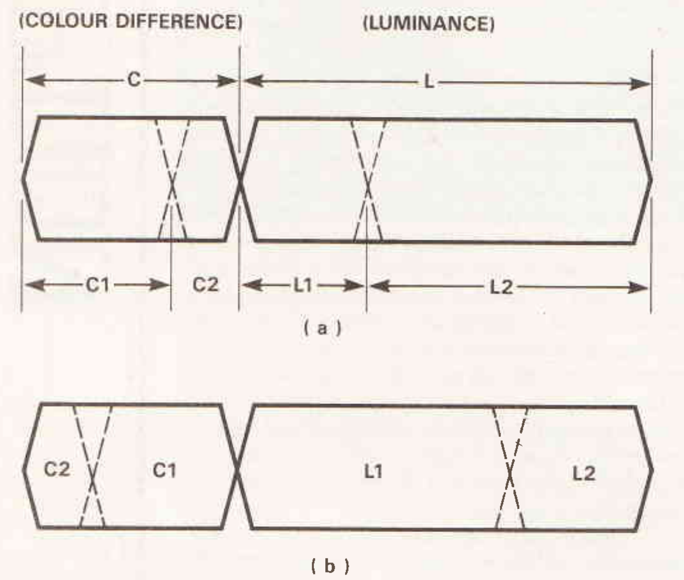


Fig. 6 Simplified diagrams of (a) non-scrambled waveform showing possible cut points in the case of double-cut component rotation and (b) waveform scrambled by double-cut component rotation

job involves a technician having to visit the premises on each occasion that a change is required — an expensive exercise, especially if the system offers a choice of premium channels on different frequencies. Where several premium channels are offered for a block payment, the frequency response of the trap can be arranged to cover a band of frequencies containing all these programmes.

Reverse Traps

If the cable operator inserts an extra radio-frequency 'spoiler' signal into that part of the frequency spectrum between the high-frequency edge of the vision signal and the sound carrier, it distorts both vision and sound signals and generally renders them unwatchable. Customers prepared to pay for the premium channel are supplied with a notch filter which cuts out the interfering carrier and restores the signals to normal. This method suffers from the same practical disadvantages as the normal trap, but in addition it is to be deplored because the addition of extra signals to any cable system is bound to increase the possibility of intermodulation products occurring, which can give rise to various forms of patterning interference or buzzes on sound.

Sync Attenuation Or Suppression

A very common technique is to reduce the sync pulse amplitude of the radio-frequency signals by attentuation at the head end. Sometimes the required sync pulse timing information (the excryption information) is then sent as an amplitude-modulated signal along with the sound programme signal, with approved descramblers using this timing information to trigger the generation of new sync pulses which are added to the radio-frequency signals in the descrambler box. More exotic versions of the same technique can vary the amount of sync-pulse attenuation from line to line in a pseudo-random manner, with the encryption signal telling the descrambler how to keep up with the changes in the transmitted waveform.

Such techniques are only partially successful, because many modern receiver designs have synchronising circuits that can keep a picture synchronised even if only a few properly timed synchronising signals are received from time to time (flywheel sync). In any case most television pictures contain enough repetitive information to enable some receivers to synchronise in the absence of perfect sync pulses.

Another rather more effective method of using sync suppression to achieve scrambling is to add a large-amplitude sine wave at line frequency to the baseband video signal (as in Fig. 3). Since the receiver sync-detection circuits will be looking for the most negative-going part of the demodulated video waveform (this usually being the bottom of the sync pulses) they will lock instead to the most negative part of the sine wave, and thus make nonsense of the transmitted picture. Once again the encryption information, telling the receiver how to compensate for the sinewave which has been added at source, is transmitted in the form of low-level amplitude modulation of the audio carrier.

Yet another method of providing scrambling by modification of the sync pulses is to gate-out the sync pulses on transmission (Fig. 4) by adding a line-frequency gating waveform of opposite polarity to that of the sync pulses, so that they are effectively cancelled out, or significantly reduced in amplitude. The inverse of the gating waveform is then transmitted as amplitude modulation of the audio carrier (or sometimes on a completely separate carrier). When this signal is added to the main carrier signal in the descrambling unit the sync pulses are effectively restored to normal.

Video Inversion

At its simplest, this technique merely takes the video signal, inverts it, and uses the decoder box to re-invert the signals for display. However, a static method such as this would rapidly be overcome by the addition of a very simple piece of circuitry in the receivers of would-be 'pirate' viewers. More sophisticated methods of this type have therefore been developed, where the video waveform is inverted line by line, or frame by frame on a pseudo-random basis, sometimes using scene changes in the transmitted picture to start a sequence of inversion. The information necessary to enable the receiver to follow the inversion sequence can be sent as coded information in the picture-blanking intervals, or can be built into the descrambler unit in the form of a computer program on an IC chip.

Some scrambling systems make life even more difficult for potential pirates by combining various techniques, and a combination of sync suppression and random video inversion can prove very effective.

Variable Line Delay

This technique introduces various delays into some of the lines of the television picture video signal on a preudo-random basis, and the encryption signal tells the descrambler to switch in various line delays to correspond with the transmitted picture.

Properly controlled this system can be very effective, giving rise to pictures that are just recognisable but of very poor definition, but unfortunate experiences when the system was first used in France (where pirate decoder designs appeared in amateur radio construction magazines as soon as the new service started), led to the system getting a reputation for poor security. Changes have now been made to the way in which the delays are implemented, which make the system far less open to abuse.

Hidden Channels

Some cable systems rely on the fact that they can use frequencies over the cable which are not permitted for over-air broadcast use, and which cannot therefore be received on an ordinary receiver. Thus a cable operator might transmit premium programmes on a frequency below the normal television band, and provide subscribers to this service with descrambling boxes that are just radio-frequency converters which will provide an output at a frequency suitable for use with a normal television receiver. The risk with this method of operation is that viewers may be able to get hold of multi-band receivers which could tune directly to the cable frequency, but in many countries this would be a difficult and expensive business for the would-be 'pirate' viewer.

Scrambling MAC Signals — Active Line Rotation

Many readers will know that the high-power Direct Broadcast Satellites such as the French TDF1 that is now radiating, and the British BSB satellite, do not use PAL or SECAM but a new higher-quality broadcasting system called MAC. The MAC, or Multiplexed Analogue Components type of signal is made up of individual components which are transmitted in time-division multiplexed form, so that a typical television line looks like Fig. 5. It has been found that it is much simpler to scramble and descramble a signal of this type without distortion occurring.

The technique used is known as Active Component Rotation, and Fig. 7 indicates how the basic scrambling process is carried.

The luminance and colour-difference components on each line of the picture are each cut into two parts, the cut points being determined as part of the encryption mechanism by a pseudo-random-number generator. Each of the two parts is then interchanged (effectively rotated about the cut point) so that the chrominance and luminance information on each line is scrambled before being transmitted. There is a choice of 256 cut points during each of the luminance and chrominance transmission periods.

When both luminance and chrominance signals are cut and transposed as described above, the technique is known as 'double-cut component rotation', or 'double-cut active line rotation', but the system allows for the simpler option of just the luminance component being scrambled, in which case the technique is called 'single-cut . . .'. The double-cut system is the most secure, but provision has been made for the simpler method because of fears that there might be problems when the double-cut scrambled signals are passed over less-than-perfect cable networks which could introduce amplitude/frequency-response distortion and line tilt. These faults could lead to problems of transients occurring at cut points when the scrambled parts of the picture come to be reassembled in the receiver. Theoretical work suggested that the line tilt would have to be less than about 0.5% if the components were to be put together without error when using a double-cut system.

Practical work on real cable systems showed that any transient effects due to possible problems with line tilt were masked by the small amounts of noise present in any such cable network, and no significant difference could be detected between the single-cut and double-cut forms of scrambling.

The use of multiplexed analogue component signals in broadcasting is fairly new, and the systems now being developed are expected to have to cope

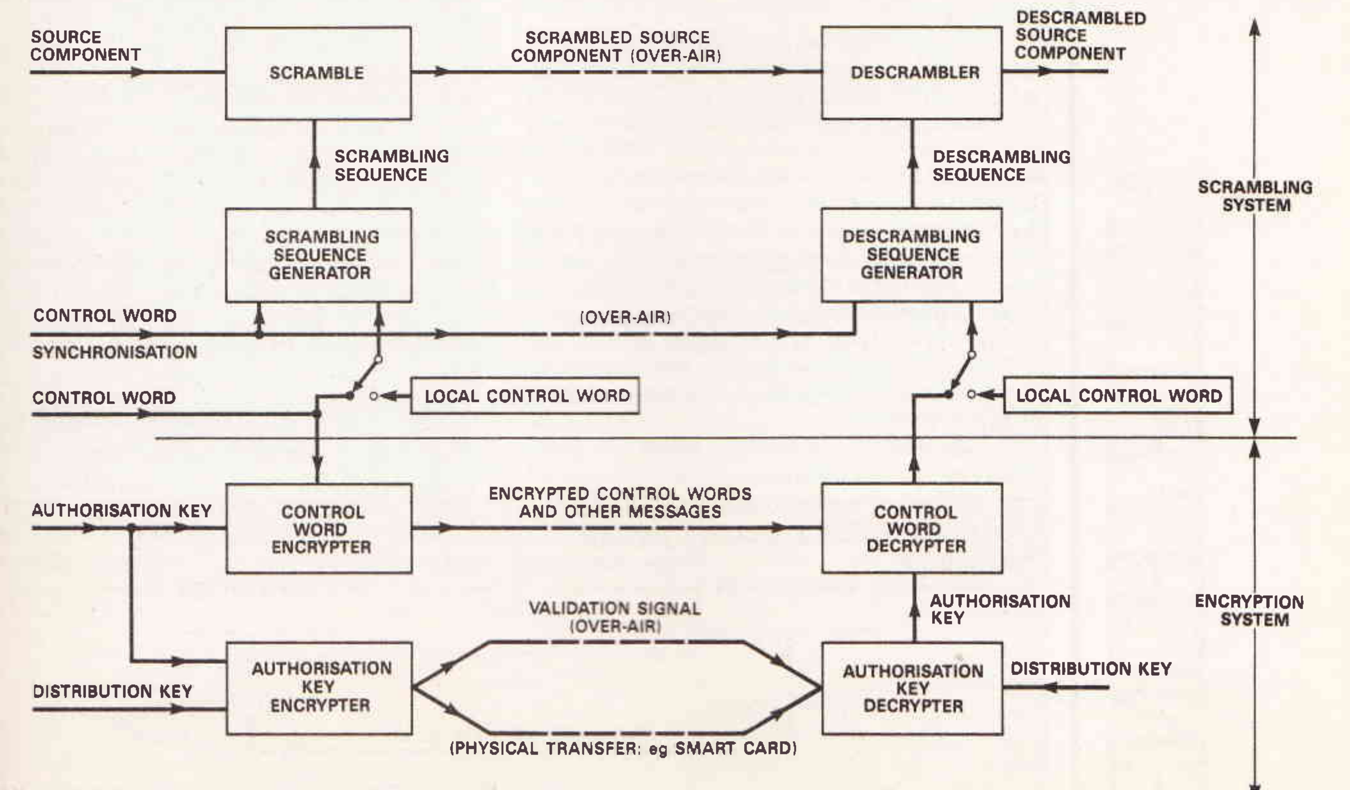


Fig. 7 Simplified block diagram of MAC conditional access system

ENCRYPTION

with whatever further developments come along in cable, satellite and terrestrial broadcasting in the foreseeable future. So it is perhaps not surprising that the conditional-access facilities that have been provided as an integral part of the MAC specification are extremely comprehensive, and for that reason, rather complex.

A simplified description of the conditional access system can be understood from Fig. 7. It will be seen that the top half of the diagram resembles Fig. 2 which showed in generalised form how any encryption and key distribution system works.

The luminance and chrominance components of the MAC signal are first of all scrambled as described earlier, cut points being selected in a pseudo-random binary sequence (PRBS). The actual PRBS point which is chosen at any instant is determined by a sequence of data known as a 'control word', which can be transmitted over the broadcast system (whether cable or over-air) in order to synchronise the decoding circuitry in the descrambling unit of the receiver.

Since it could be difficult to introduce scrambling to new or existing services that had not already made suitable technical provisions, many operators think that it would be wise to scramble all MAC signals, whether or not it is intended to charge premium payments for the particular service. If the service is to be free, then a predetermined 'local' control word is used as the encryption key. A receiver which sees an incoming signal encrypted with this 'local' control word will descramble the signal without further ado, so that the viewer will be able to watch the programmes without payment. If at some time in the future the operator decides that the particular programme is to be charged for, he then has the ability to change the control word, so rendering the programme unwatchable until the viewer takes steps to arrange payment for the programme. The idea of scrambling all programmes, free or not, gives the operator tremendous flexibility to cope with future needs.

Where a programme is to be charged for, the operator encrypts the control word by means of an 'authorisation key', and as a futher security measure this authorisation key is itself encrypted by a 'distribution key'.

The user cannot see a descrambled picture until his receiver is provided with the correct control word, and he will only be able to obtain this control word if he can decrypt the authorisation key which was used at source to encrypt the control word. To be able to decrypt the authorisation key, the use needs his own 'personal distribution key' (which might be built into the receiver or be a personal identification number that he types into the receiver) and also a 'validation signal', which is transmitted along with the programme. The various access control signals (the encrypted version of the control word and validation signal), are transmitted in the data burst of the MAC signal and are therefore readily available as an integral part of the MAC transmissions.

This 'built-in' scrambling ability of MAC transmissions is proving very popular with a wide range of programme providers, since MAC chip sets in receivers will already include descrambling facilities and no separate expensive descrambling box is required. For this reason many distribution satellite transmissions intended for reception at cable head ends use the MAC transmission format. The other benefits of using MAC, such as better noise performance and lack of cross-colour, are regarded as better noise performance and lack of cross-colour, are regarded as an almost incidental bonus. A group of European semiconductor manufacturers has designed the multi-standard MAC receiver chip set outlined below, which should enable the benefits of a complex scrambling and conditional-access system to be made available to satellite and cable system operators at a very low cost to the viewer.

Public-key Cryptography

Various methods of providing the necessary 'keys' can be envisaged, but a system known as *public-key cryptography* seems likely to gain widespread recognition among the European companies who are broadcasting via satellites to cable head ends.

The basic idea is shown in Fig. 8. The encryption key used at the transmitting end can be different from the decryption key used in the receiver. This means that one of the keys (the transmission key) could be made public, giving a great deal of flexibility to the programme-service provider, so long as the other key cannot be deduced from the public key. The decryption key could be embedded in a 'tamper-proof' silicon chip in the receiver, or could be read from a 'smart' credit card containing a microchip which the viewer would plug into his receiver.

The matched pair of keys is usually derived from two large prime numbers which are multiplied together, only the product of these being published. The basic security of such systems relies on the fact that it is extremely time consuming to factorise large numbers in order to determine the individual keys (as an example a 312-bit number may well take over 20 years to factorise using the fastest computers available today). No system is 'crack proof' however, and the systems currently being considered for use on cable systems have to take into account security, complexity and practicability.

It is interesting to note that system designers are also thinking of building a 'fall-back' or 'recovery' position into their security systems so that they are not left totally out of control if the system should be broken into. In the United States with the *Videocipher* system, pirates went to considerable technical lengths to extract keys from existing authorised receivers in order to duplicate these for use in 'pirate' receivers. This has left system operators in no doubt that their security systems must remain flexible if they are to outwit the illegal users.

Jim Slater's book ***Cable Television Technology*** *is published by Ellis Horwood Ltd, Chichester. ISBN 0-7458-0108-0.*

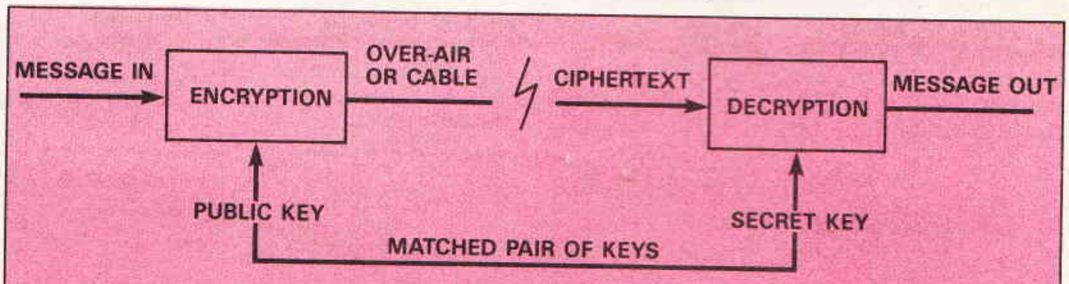


Fig. 8 Basic public key system

SIGNALS

EARTH CURRENT SIGNALLING

What is it? How did it become an essential part of trench warfare in World War I? George Pickworth covers the bases.

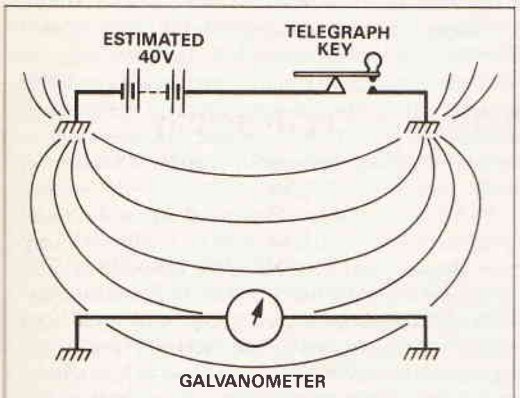


Fig. 1 Steinheil's early experiment 1838

Early pioneers in telegraphy demonstrated that it was possible to eliminate wires between equipment by using the earth as the conductor — earth current signalling.

The technology did not exist at that time to make a practical communication system. After Marconi demonstrated the potential for Hertzian waves, earth current signalling attracted little further attention until World War I when it became apparent that it was inherently suited for communication between the trenches and support positions. Moreover, technology had by then advanced to the level where it was possible to make a practical short range system. Under the prevailing conditions it is not surprising that the Allies and the Germans simultaneously developed similar equipment.

Earth current signalling gained distinction in many operations by maintaining contact with the forward positions when field-telephone lines were destroyed by shell fire, but (as far as the author is aware) this has been just about the only practical application for a practical system. With the end of static warfare it has no further role, but that does not necessarily mean that the system no longer has merit nor is incapable of development.

A few amateurs, mainly American, continued to experiment (especially during the Second World War when their radio transmitting licenses were withdrawn), but added little to experimental work conducted by the Signals Experimental Establishment earlier. That work still provides a sound base for further work.

Earth current communication has remained basically at a level comparable with radio before Sir Oliver Lodge demonstrated tuned radio systems at the turn of the century. It is therefore wide open to further investigation, not only with regard to potentially new uses but for the study of interesting natural phenomena such as whistlers, which apparently originate as electromagnetic waves but also become present as earth currents. Moreover, man-made very low frequency electromagnetic waves also seem to be complemented by an earth current.

Earth current signalling was conceived by Professor Steinheil of Bavaria in 1838. He observed that when a battery was connected to two earthed rods spaced some distance apart, the current does not take a narrow direct route between the two rods, but spreads over a wide area in a pattern that can be likened to the magnetic field of a bar magnet.

Steinheil connected a 'strong' battery, consisting of a number of Daniel or Bunsen cells in series, via a telegraph key to a pair of earth rods (a base) set 100m apart (Fig. 1). When the key was pressed, a current was detected by a galvanometer connected to a similar pair of earth rods (detector base) set parallel about 100m away. Changing the position of the detector base relative to the transmitter base, Steinheil was able to plot the current's distribution field.

Steinheil's galvanometer was only sensitive enough to detect current within a radius little more than the base length. Nonetheless, he believed that a progressively weakening current field extended to infinity and by using a stronger battery and a more sensitive detector, this field could be used for wireless communication. Unfortunately, the pioneers had no concept of signal magnification and their passive detectors lacked the sensitivity necessary to exploit the system.

A practical communication system had to await the development of the triode valve and active receivers 65 years later. These have proved Steinheil's theory basically correct. However, variations in the conductivity of the soil distort the current distribution pattern and low resistance pathways (such as streams) short circuit a large proportion of the current. Even so, infinite range is theoretically possible given a long enough base.

The Theory

A receiver base extracts current flowing through the earth by providing an alternative path. However, contact resistance between the earth rods and the soil means that this alternative path can have a resistance higher than the soil separating the two rods. This separation resistance can therefore be considered as a shunt across the receiver circuit. The overall resistance of the receiver circuit depends, however, on both contact resistance and the resistance of the actual receiver. Galvanometer receivers used with early DC systems had a resistance of several hundred

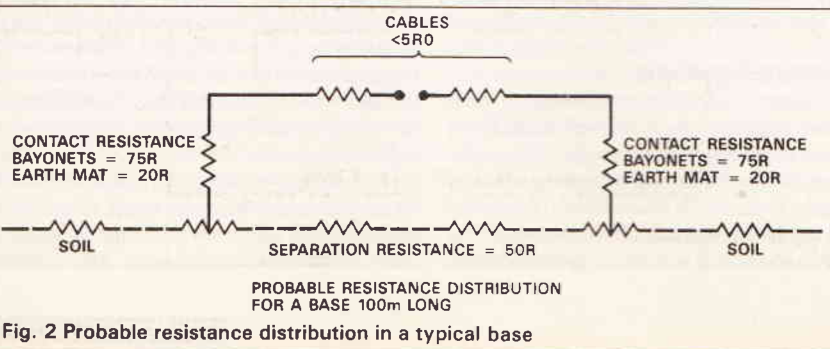


Fig. 2 Probable resistance distribution in a typical base

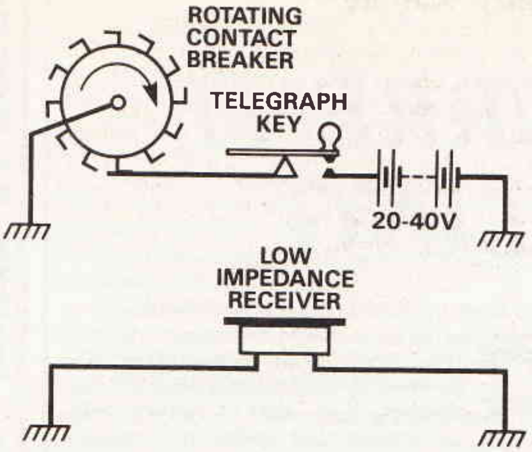


Fig. 3 The interrupter, Trowbridge and Bell 1882

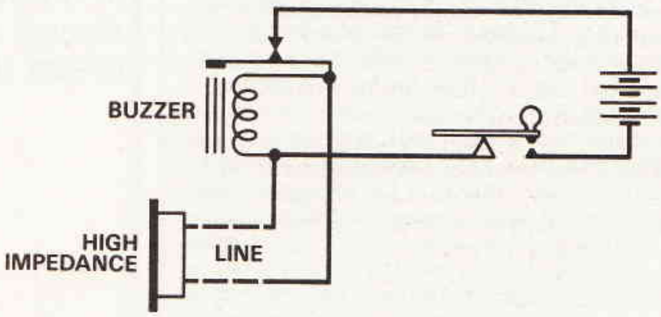


Fig. 4 The buzzer telegraph sender, Melhuish 1889

ohms. Obviously the lower the overall receiver resistance, in relation to separation resistance, the greater the current flow through the receiver. Figure 2 shows the system resistances.

Contact resistance is inversely proportional to the number of earth rods or the size of the earth mats. Separation resistance is directly proportional to the distance between the earth rods. Therefore, for best results, the base should have good earths and be as long as possible. These desirable parameters apply to both reception and transmission. In practice, the same base is used for both purposes.

When transmitting, the role of separation resistance is to cause the current to spread over a wide area. The voltage delivered by the transmitter must of course be high enough to cause a useful current to flow through the earth. Contact resistance dissipates power.

It is virtually impossible to measure separation resistance and contact resistance independently as they are to some extent interrelated, but they can be deduced by first measuring the overall resistance of a base with say two earth rods at each end, then progressively increasing the number of earth rods and remeasuring the overall resistance. A typical First World War base, 100m long and earthed at each end by three bayonets paced 1.0m apart, had an overall resistance of about 200R.

Further Investigation

Other investigators, including Armstrong and Laughter, followed up Steinheil's original work. Their results indicated that using DC and a galvanometer, communication was possible over a distance equal to the base length, typically 100 to 200m. Laughter favoured one earth rod embedded a few feet in the ground and the other sunk to a much greater depth, his reasoning being that "Lower stratas of earth would offer a good conducting medium while the top would act as a partial ground", but this was unsound and better results were obtained with large earth mats or multiple earth rods fairly near the surface.

It was reported that later Steinheil (with the co-operation of Preece), communicated over a distance of 5km, but the length of the base is unknown and the results do not seem to have been duplicated by other contemporary workers. Nonetheless, with a very long base and a large number of cells, this should have been possible. Otherwise little progress seems to have been made in extending the range of DC/galvanometer system.

Morse used copper plates immersed in rivers. With DC and a galvanometer he was able to communicate across a canal 27 meters wide in 1842 and across the Susquehenna River, a distance of nearly a mile, in 1945. His experiments showed that in water, range was only about one third of the base length.

In 1876, shortly after Bell developed the carbon microphone and telephone receiver, Fessenden and others showed that by substituting a carbon microphone for the telegraph key and a telephone receiver for the galvanometer, earth current telephony was possible over a range up to 100 meters. The original telephone receivers had a low impedance which probably accounts for the success of this early experiment, but the real significance of the telephony experiment was that a telephone receiver was found to be potentially far more sensitive than the galvanometer, and this suggested tone telegraphy as an alternative to DC systems. However, the problem was to generate AC or DC pulses at an audible frequency from DC power provided by Voltaic cells.

Enter The Interrupter

In 1882 Professor Trowbridge of Harvard University suggested the interrupter, a hand-cranked device consisting of a toothed wheel which operated a contact breaker as it was rotated, to chop DC into pulses of several hundred Hz which would be audible by a telephone receiver (Fig. 3).

Although the interrupter was a significant improvement on the DC system, the drawback was that numerous cells in cascade were required to provide a voltage high enough to cause a useful amount of current flow through the base. Although available power was a factor limiting the range of the system, there seems no evidence that hand-cranked audio frequency alternators were used by the pioneers: this seems to have been a WW1 development. The alternator predates the dynamo invented by Faraday in 1831.

The interrupter was soon surpassed by the buzzer (Fig. 4) which worked automatically from a low voltage supply and developed a high voltage pulse across its coils when the contacts opened and the magnetic field collapsed. Moreover, the buzzer could be tuned so that the pulses were at the optimum frequency for both the ear and telephone receivers.

Unfortunately, the range was still far too limited to be of any practical use for earth current communication, but the pulses were ideal for long distance land-line telegraphy. Moreover, the buzzer telegraph system was found to be more reliable than the DC system, and the tone far easier to read than the 'clicks' of a DC sounder or the swinging needle of a galvanometer.

Meluish, working with the Indian Telegraph Department in 1889, was quick to discover that the pulses had a remarkable ability to 'punch' through leaky or broken telegraph lines. As a result, the buzzer system was adopted by the British Army in 1890 and later, with the advent of field telephones, was integrated into several portable telephone sets such as the D MkIII, which allowed signalling by telegraph if the lines were damaged or too poor for speech.

By the turn of the century, Hertzian waves dominated the scene and up to the beginning of WW1 further earth current experiments seem to be purely academic. Nonetheless, a noteworthy advance was the use of an impedance matching transformer to match bases to more sensitive high impedance telephones.

A further development was to use a 'power microphone' passing several amps connected to the base through a step-up transformer: this was used in 'reverse' for reception. It attracted little interest at the time but 50 years later was resuscitated as the German Erdsprechgerat (Earth speech apparatus) used to maintain speech communication through leaky or broken field-telephone lines during WW2! A hand-cranked DC generator provided the power.

Magnifying Triode

Both the buzzer telegraph system and the Erdsprechgerat were essentially land-line systems with the ability to communicate through leaky or damaged field-telephone lines. While the sensitivity of the passive telephone receiver was adequate when used with this type of equipment, it was nowhere near sensitive enough for true earth current signalling where some method of magnifying the very weak earth currents was essential for the system to be of any practical use. However, the early pioneers continued putting emphasis on increasing the sensitivity of passive devices. The active detector (with infinitely greater sensitivity and which ultimately brought about a practical earth current signalling system) came much later as a result of experiments aimed at making radio receivers more sensitive.

Notwithstanding the dramatic developments in communication with Hertzian waves during the early part of the century, efforts to increase sensitivity of receivers had been directed towards increasing the sensitivity of passive devices which culminated with highly sensitive 8000R headphones. On the other hand, liquid (and later fused) silicon detectors (rectifiers), the best devices available at that time, were inefficient and in the quest for a better device, DeForest developed the audion valve.

The audion was improved by Fleming to become the triode shortly before the beginning of the First World War. This was an epoch making development because in addition to being a highly efficient detector, the triode was able to magnify weak signals and give a completely new dimension to earth current communication. Range was no longer limited by the sensitivity of passive receivers. In the light of the triode, the buzzer system was reappraised as soon as it was apparent that WW1 was developing into a prolonged static war and that field-telephone lines connecting the forward positions with support positions were vulnerable to damage by shellfire.

In spite of the buzzer's low power, signals were received on a two valve amplifier several hundred meters away. At first sight this may not seem significant, but under the conditions of the war it was pretty useful. A more powerful buzzer, known as the 'power buzzer' was developed very quickly and together with its French equivalent, the Parleur, were the principal earth signalling transmitters used by the Allies throughout the war. Hand-cranked audio frequency alternators were also developed and were employed by the French to complement the Parleur, but were used only to a limited extent by the British.

Trench Warfare

"Shelling had been so intense that neither cable or wireless communication was possible between the Australians, who had taken the (Hindenburg) line, and their supports. For several days earth signalling maintained constant communication with the rear and gave warning of several impeding counter attacks that were repulsed. After this and many other useful successes, earth current signalling was accepted to a much greater extent as part of the normal communications system." **Priestley 1917.**

The first practical operation with earth current signalling by the Allies was at Bermelles in January 1916. Two French hand-cranked alternators were installed in the forward trenches and their high pitched note received on a French two valve listening set at the rear.

The British power buzzer sets and the French equivalent could only transmit and separate receivers were required for two-way working. Valves and amplifiers were in short supply however, so during the early part of the war only one-way signalling was used. Fortunately, receivers became available in larger numbers during 1916 and the situation further improved in January 1918 with the issue of combined power buzzer/amplifier sets.

The power buzzers were designed to operate from a 10V accumulator and to generate about 70V in an open circuit, dropping to 20V when delivering 1A (Fig. 5). If extra power was needed, the input could be temporarily increased to 20V. Operators

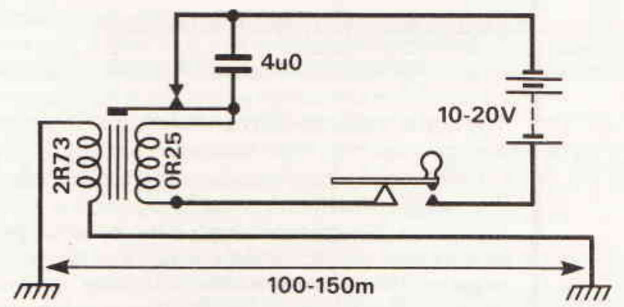


Fig. 5 Schematic of the power buzzer

were instructed to periodically reverse the battery connections to ensure uniform wear of the make and break contacts.

Optimum current of 0.5A was obtained when connected to a typical base with a resistance of 200R but the buzzer in the base could be overloaded if the resistance of the base was too low.

Stunning Frogs

The standard battery was the 10V Fuller Block Type BL, weighing 26½lb and with a capacity of 20Ah. This was sufficient for 6-8 hours continuous transmitting. Under normal signalling conditions, a life of 72-96 hours was expected.

A favourite way to test the battery was to place a frog near an earth rod and press the key. If the equipment was working correctly, the frog was instantly stunned, but recovered after a few minutes and hopped away as if nothing has happened. (*The Editor feels compelled to implore readers not to repeat this particular experiment at home.*)

Experiments indicated that frequencies between 500 and 800Hz spread furthest from the base and were fortunately within the most sensitive range of both headphones and the ear. To help operators differentiate signals from other stations, the buzzers were designed to give a choice of frequency. The

Parleur N 3 could be varied in seven steps between 300 and 800Hz by securing small blocks of different weights to the armature. British power buzzers were provided with three sets of armatures giving frequencies of 540, 640 and 730Hz.

Man-powered audio frequency alternators were sometimes used: power output was then limited only by the physical strength and endurance of the operators. The crank-handle was the simplest drive system and was used by the Allies, but when under fire in cramped conditions these machines were a disadvantage compared with the battery operated power buzzer. Another disadvantage was that the frequency generated by the alternator was determined by its speed. It was difficult enough to maintain a constant speed let alone a specific one. Moreover, alternators were much more complicated and expensive than the buzzers.

Alternators were also used by the Germans with larger devices operated by bicycle gearing capable of generating 150W. One captured at Vimy Ridge was driven by tandem bicycle gearing!

As for the amplifiers, the valves were generally limited to the French version and the British A version — they had more or less the same characteristics and could be interchanged. The British C Mark III amplifier had three valves, which was about the maximum, bearing in mind that they were not decoupled. Although designed for telegraphy, the Mark III amplifier could be used to amplify speech with fairly good results.

The Mark III dramatically improved efficiency by biasing the valves, reducing HT consumption from about 5.0mA to 2.6mA. The C Mk III had a tapped input transformer wound to provide input impedances from 50R to 3k0, selected by a stud switch. The low impedance taps were to facilitate matching the amplifier to bases having a wide range of impedances. The high impedance tap was primarily to amplify the audio output from radio receivers.

Transformer coupling was used throughout and the output transformer was designed for 60R impedance headphones which were more rugged than French high impedance types. The filaments required 4V and anodes 60-100V. High tension power was provided by a 'dry cell' HT battery. Various types were in service, varying from a very large 70V battery made up of 'X' cells, to a very small one consisting of 79 very small Ever Ready cells. A single 1.4V dry cell provided grid bias. The 4V 60Ah filament battery lasted 24-36 hours.

The 'bright emitter' valves required that the filament current be adjusted to a critical value relative to the HT voltage. If the filament current was too high the amplifier was noisy. If too low, less amplification was obtained. Careful setting for acceptable performance with the lowest current prolonged the life of both valves and batteries.

The Mark IV amplifiers could rectify RF signals and only required a tuning coil and antenna to become a radio receiver. RF input was direct to the grid of the first valve. Leaky grid rectification was employed with A Mark IV amplifiers but the C version employed 'slope' rectification, whereby the optimum operating condition was achieved by adjusting the valve's filament rheostat. This method eliminated any tendency for the amplifier to sing or crackle and was reported to be just as efficient as the grip lead detector.

Positive feedback, or regeneration, which dramatically increased the sensitivity of radio receivers was a later development.

Transmissions were mainly in the medium frequency band and required large antennas, but UHF spark transmitters using 1.0m square antennas were issued to the artillery.

Amplifiers were also used to detect currents leaking from enemy field-telephone lines. The Germans were apparently the first to develop this form of electronic intelligence gathering and it came as a shock to the Allies to discover that their communications were being intercepted. As a result, emphasis was laid on encoding all messages and special detachments were established to intercept enemy traffic and monitor allied signals.

Making Base

Practical considerations limited the length of a forward base to about 100 yards. One earth was normally placed close to the equipment, so that the base was formed by one long cable as this arrangement facilitated both laying out and inspection. Earths normally consisted of at least three and preferably four bayonets spaced a yard apart and aligned in a plane facing the earths at the opposite end of the base.

Bases had to be aligned more or less in the same direction as the current flowing through the earth. If the base was placed at an angle to the earth currents its effective length was correspondingly reduced and became zero at 90°. To facilitate alignment, maps and a compass were included with the equipment.

However, at rear stations it was usual to lay out several bases radiating from a common earth and selected by a commutator. This system was used for keeping up flank communications and also to suppress interference from leaky power lines, telephone lines, other stations and, surprisingly, wireless sets.

A typical 100 yard base at a foward position and a 150-200 yard base at the rear position provided reliable communication over a range of 2000 yds. Under ideal conditions, range was extended to 5000 yards. Maximum range was attained where the surface soil covered a substrata of chalk. Deep, damp, loamy soils were not so good as the current flow was not confined to the surface, and only a short range was possible in very sandy districts. Streams and metal fences were found to offer a lower resistance path than the surrounding soil, and so restricted range.

Two thousand yards was generally sufficient to maintain contact with the trenches. If this seems a small distance, it is poignant to remember that when an advance was made, often at the cost of tens of thousands of lives, it was invariably only a few hundred yards.

Next month the author describes his own earth current experiments.

Readers may be interested to know that examples of the power buzzers and amplifiers described are on permanent display at the Royal Signals Museum, Blandford Camp, Dorset. Admission is free.

ACKNOWLEDGEMENTS

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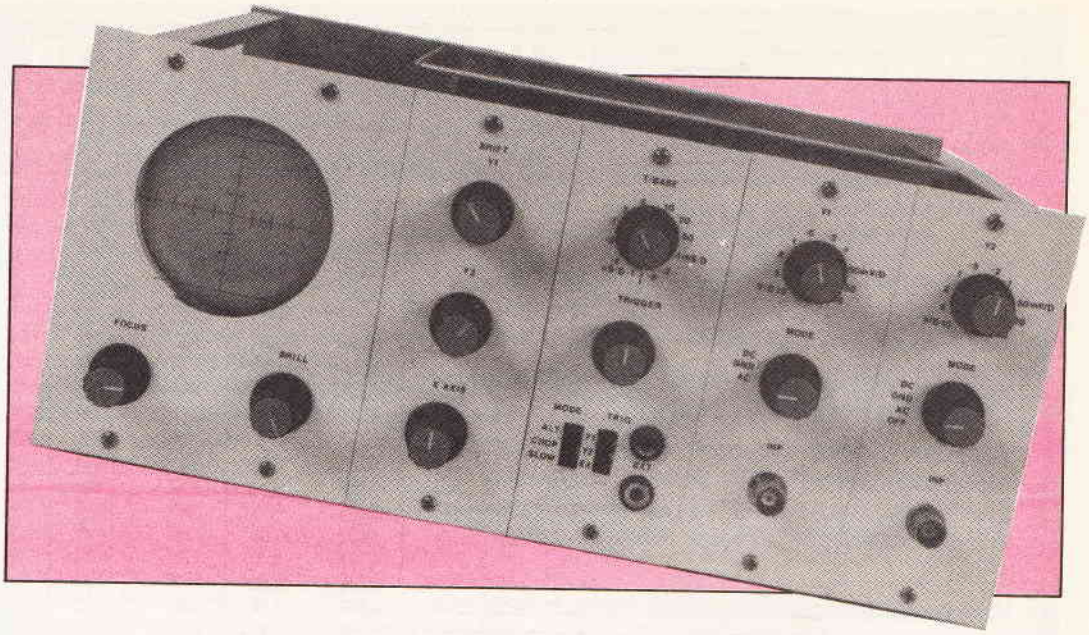


SUPERSCOPE

PART 1: Getting started

With low cost in mind, Dennis Stanfield shows that even building a dual beam 'scope for under £90 is possible

Having struggled along for some time with an ancient and absolutely huge Cossor "Oscillograph" (donated to a good cause by a radio ham friend) I finally recognised that drastic measures were necessary when it refused to trigger at much over 1MHz.

A quick look through the catalogue revealed that anything half-way decent by way of a replacement was going to be expensive — so the seeds of the DIYer were sown.

Originally conceived as a single trace 'scope with a bandwidth of 5-6MHz, this project has grown and grown to dual trace and with a viewable display extending to about 25-30MHz at 1 division.

In order to undertake such a complex project, there has to be some clear advantage to the constructor. In this case the major one is cost. A fairly basic 20MHz dual trace 'scope is going to cost in the region of £300, the prototype unit here cost a total of £85 excluding only the case and although the performance may be slightly more restricted it is more than adequate for the majority of workshop purposes.

It has been possible, in addition, to incorporate a few unusual design features such as plug-in modules which will allow the experimentation with alternative circuit configurations. It is hoped that constructors might also take advantage of this. Such modifications in future editions of ETI could be a component tester module for example.

The individual circuit blocks (Fig. 1) are constructed on plug in boards each of which carries its relevant controls and on the prototype, its own screening and section of front panel. These modules mount onto a motherboard which in addition to forming a backplane bus carries all the power supply circuitry. This configuration reduces interwiring to an absolute minimum and in fact the only wiring necessary is around the mains transformer and two ribbon cables, one to the tube and one to the brillance/focus controls.

Cathode Ray Tube

The prototype uses a VCR139A tube, a type which until recently was readily available but is now becoming more scarce. However Langrex Supplies Ltd (see Buylines) hold considerable stocks of this tube and will part with one (plus base) for a very reasonable price.

The adaptable design and the use of a self-wound transformer kit is however readily capable of modification to suit one of a number of tubes. Specifications of alternative tubes and suppliers are contained in Table 1. The use of a tube other than the VCR139A makes setting up and calibration slightly more difficult but with the correct voltages to the tube pins, it remains only to adjust X and Y gain. For the X axis there is sufficient adjustment in RV302/3 and RV204 to obtain calibration. The Y gain may be adjusted on the input boards by changing R413-415/513-515, reducing resistance and so increasing the gain. It is probably best to replace the relevant resistor with a 100-220ohm preset and when calibration is achieved measure and replace with a fixed component. There is some room for manoeuvre in changing R212 on the driver board but moving very far from the value specified will affect the frequency response curve. Again reducing R212 increases gain and vice versa. (DC gain equals R201+R202/R212).

The existing power supply produces correct HT voltages for an alternative DG series tube but a 3BP1 will require a greater negative HT and increasing the TS2 winding by about 30% is recommended along with the uprating of C104/6 to 600V types. Note that the effect of running a 3BP1 (or for that matter any tube) at less than the rated anode voltages (within reason) has the effect of increasing X/Y sensitivity but reducing trace brightness.

All the tubes other than the VCR139A require a 6V heater and TS4 should be increased to 30 turns.

The DG series tubes require a greater blanking voltage swing and the circuit shown in Fig. 4 may be

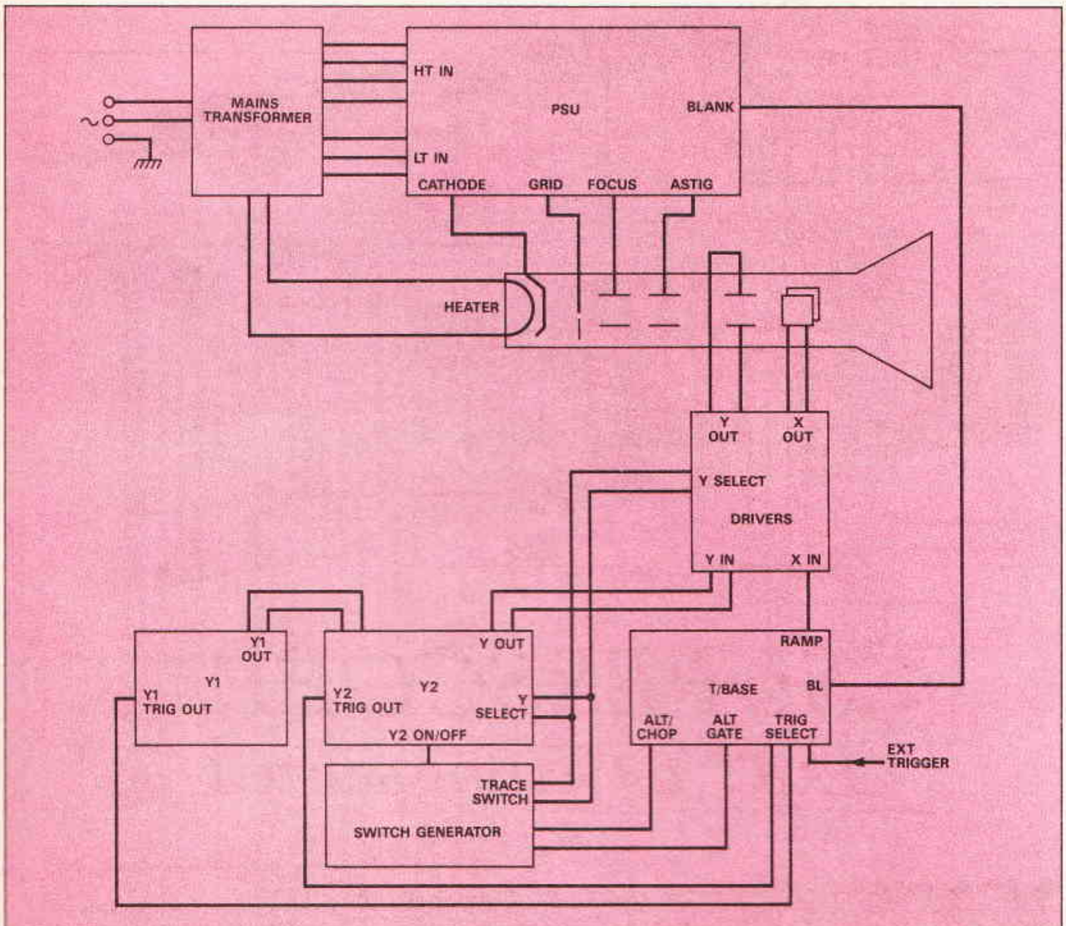


Fig. 1 Block diagram of the Superscope

built on a small piece of board and mounted piggy back on the motherboard replacing C108.

The only other point is to note the tube dimensions and pinouts. Note that alternatives are based on specification sheets only and no testing has been carried out.

Tube	VCR139A	3BP1	DG7-31,32,36
Dimensions (approx)			
Screen Dia	64mm	76mm	67mm
Tube Length	200mm	225mm	('36-295mm) 180mm
Max Volts			
WRT cathode Grid	-10	-50	-200
Anode 1	155	350	200
Anode 2	800	1500	800
Heater	4V	6.3V	6.3V
Heater TS4	20T	30T	30T
Beam Deflection mm/V			
XX	0.2	0.15	0.5
YY	0.2	0.2	0.2

TABLE 1 CRT Alternatives

Facilities

The Y1 and Y2 input attenuators offer 10 ranges from 10mV/div to 10V/div, the maximum input voltage being 100V p-p. Inputs may be AC or DC coupled or referenced to ground.

The Y2 channel may be switched out and the 'scope used in single trace mode. This is useful where maximum trace brightness is required — normally in dual trace mode each trace has only a maximum of 50% of the total available brightness.

Input is via a 50ohn BNC connector. The design of the input attenuator means that the impedance is non constant, increasing with decreasing attenuation. In practice however, this causes no real difficulty in everyday applications and the simplicity of construction and setting up is a joy by comparison with the usual serried ranks of trimmer capacitors.

The time-base has 15 ranges, 12 from 100ns/div to 0.5ms/div being selected by SW301 and a ×10 facility on the three slowest ranges selected by SW302A increasing scan time to 5ms/div. Triggering is from Y1, Y2 or an external input.

The dual trace may be either alternate or chopped, the chopped mode being selected automatically when the slow range is switched in.

Base Type	B12B	B14A	B12A
Pin 1	cathode	heater	heater
2	grid	cathode	grid
3	heater	grid	cathode
4	heater	–	anode 2
5	anode 1	anode 1	–
6	–	–	X1
7	Y2	Y1	X2
8	X2	Y2	anode 1
9	anode 2	anode 2	Y1
10	X1	X2	Y2
11	Y1	X1	–
12	–	–	heater
13	–	–	–
14	–	heater	–

TABLE 2 CRT Base connections

Construction

The transformer

The transformer is wound using wire/turns as shown in Table 3. The high voltage windings are laid first followed by the low voltage and finally the heater. Wind a layer of insulating tape between each secondary coil. Check all windings with a meter,

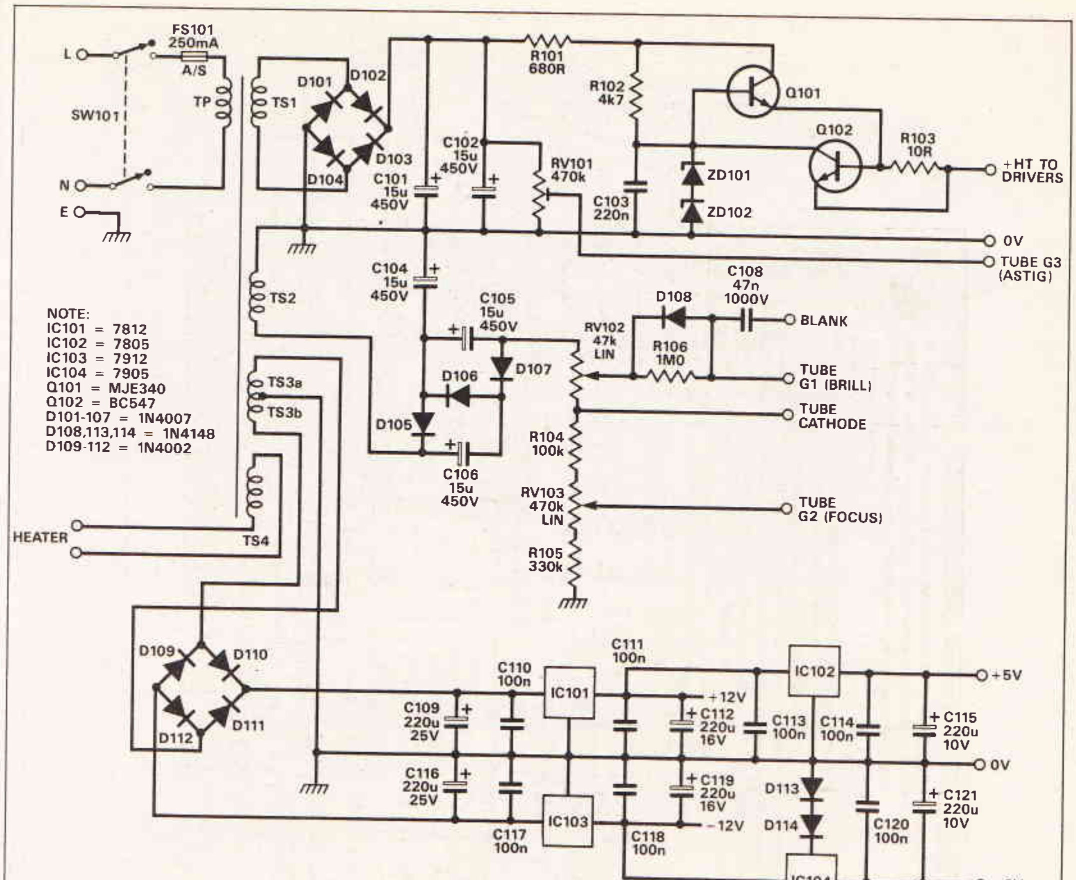


Fig. 2 Power supply circuit diagram

especially for interwinding shorts. The exhortation not to interfere with the primary winding in any way should be strictly observed for safetys sake. If all is well apply mains power — very carefully with mains pins shrouded and check that the AC voltages are about right +/− 10%.

Secondary	Turns	Wire	RMS Volts
TS1	850	36SWG	170V
TS2	850	38SWG	170V
TS3A	65	30SWG	13V
TS3B	65	30SWG	13V
TS4	20	24SWG	4V

TABLE 3 Transformer winding details

Motherboard

The sub-board sockets are mounted on the copper track side of the board at the dimensions shown in Fig. 5. Note that in the prototype these sockets (Maplin ref: JB99H) have a pin length of 6mm, this being critical if the case to be described later is to be used. The switch generator plug is mounted on the component side and is soldered in between the pins of sub-board socket 4 and should be mounted first.

Transistor Q101 requires a small heatsink, about 2 square inches of copper or aluminium bolted to its casing is sufficient. Be careful to orient all polarised components correctly as at high voltages you don't get too many second chances with a reversed semi-conductor or capacitor. Polarised capacitors can overheat and explode if reversed.

After a recheck of all your work if all is well connect the motherboard to the transformer and switch on. Check the various voltages as shown on the schematic and switch off. Note that the capacitors will retain considerable charge for some time so handle very carefully, if at all.

The leads to Y, Y1 tube pins should be separated from the ribbon and kept as short and as far away from other wiring and each other as the layout allows to reduce stray capacitance which would have an adverse effect on bandwidth. L101,102 comprise about 20 turns of 38 SWG wire wound on a ½W 100k resistor and mounted directly on the CRT socket.

The Driver Board

Construction is straightforward, again carefully noting component polarity and giving due care in handling IC201 which is a CMOS device. L203,204 are of similar construction to L101 but with about 30-35 turns.

It is most important that the output transistors Q201,2,7,8 are fitted with heatsinks before any HT voltage is applied otherwise their life will be spectacular but short.

After checking over the completed board, plug it into position 1 on the motherboard and with hook-up shown in Fig. 8, apply power. It should be possible to resolve a spot on the CRT screen and move it around using the X,Y1 shift pots. Reverse the connections to pins 5 and 13 of IC201 and the Y2 potentiometer will shift the spot. Again take care with components carrying HT voltages. Note that a bright spot should not be left in one position for more than a few minutes otherwise an ion burn to the screen may result.

The Timebase

The timebase is constructed on an identically sized board but with several small sub-panels soldered on to the front edge to provide mounting points for switches SW301-3 as shown in Figure 11. The wiring detail for switch SW301 is shown in Fig. 12. If possible, capacitors C301-4 should be close tolerance types for maximum timebase period accuracy. R302 should really be of 4k0 but no such preferred value exists. You could use 1% 3k9 + 100R. I used a 10% 3k9 which read high at 4k on my DVM. The correct values of C305A-C are determined on final setting up when the

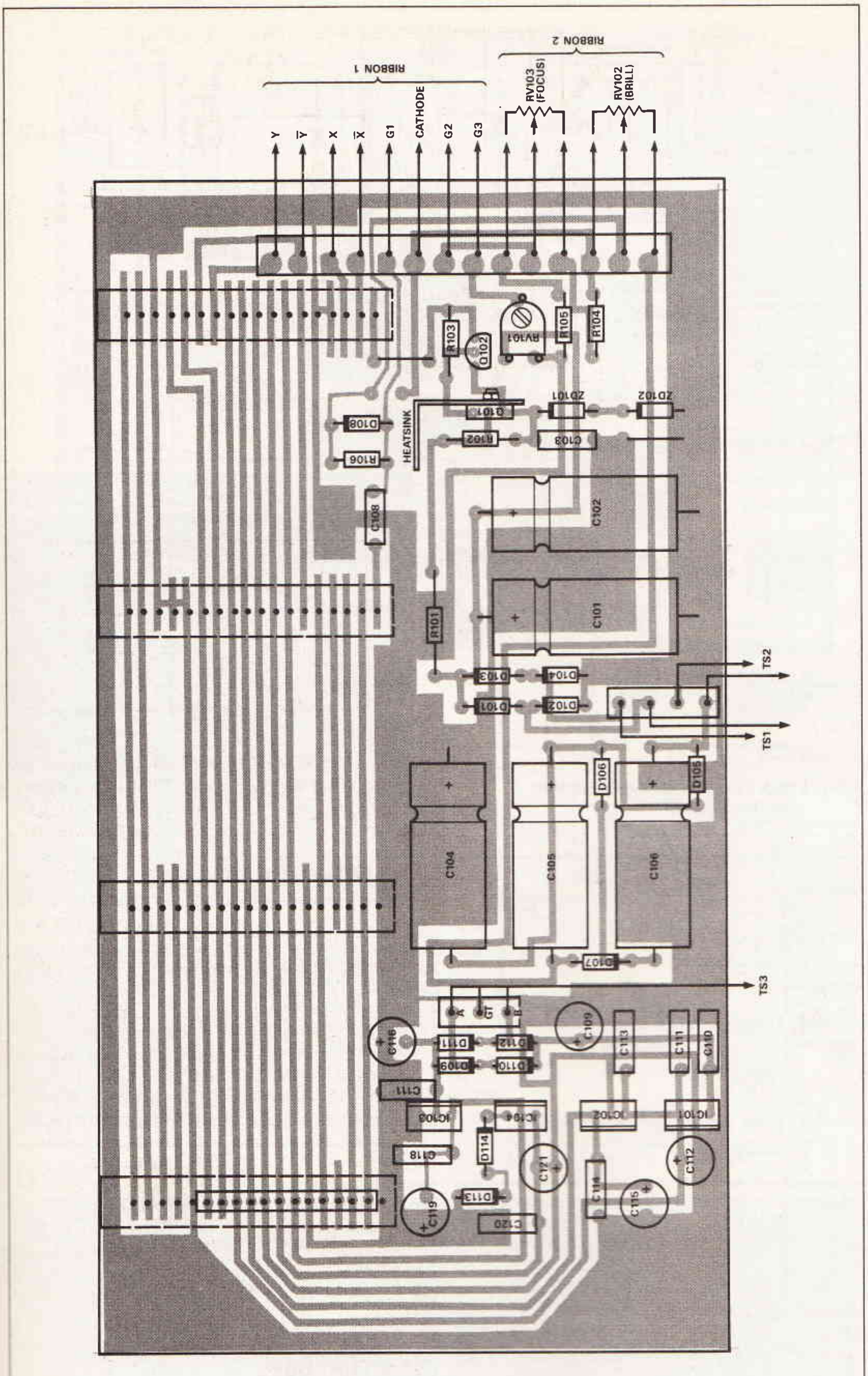


Fig. 3 Component overlay for the motherboard

input amps are available to display a waveform. The tantalum capacitors specified have a wide tolerance but with a selection ranging from 2μ7 to 4μ7 and some polyester padders it should be possible to set this range up accurately. On the prototype only two capacitors were necessary — 4μ7 + 3μ3. Set all presets to about mid-travel for now.

Give the board a final check over and plug in to position 2 on the motherboard. Using the same hook-up as before but omitting the flying lead to R225, switch on. A straight line trace should be displayed, its position being varied by the shift pots as described before. Adjust RV204 and 303 to make the baseline just slightly more than the width of the screen.

In part 2 of the article next month, the construction of the Y amplifier boards will be described along with the setting up and testing procedure.

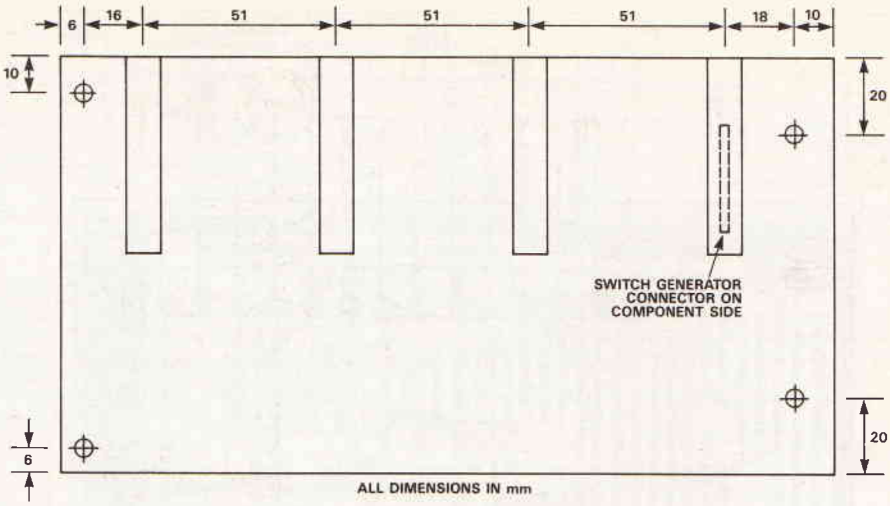


Fig. 5 Motherboard edge-connector mounting details

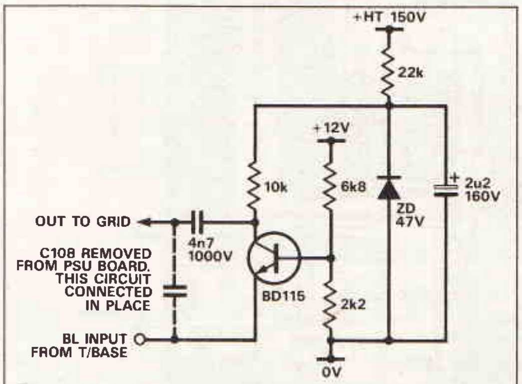
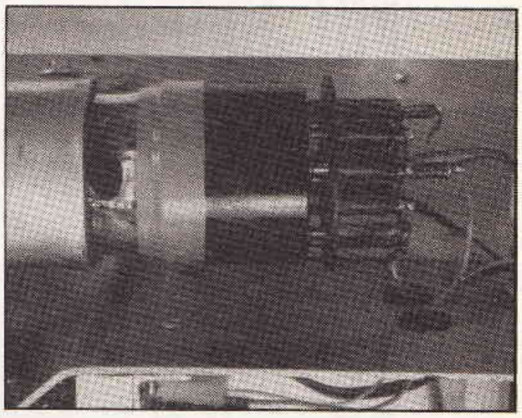


Fig. 4 High Voltage blanking circuit for the DG series tube


Tube Base detail

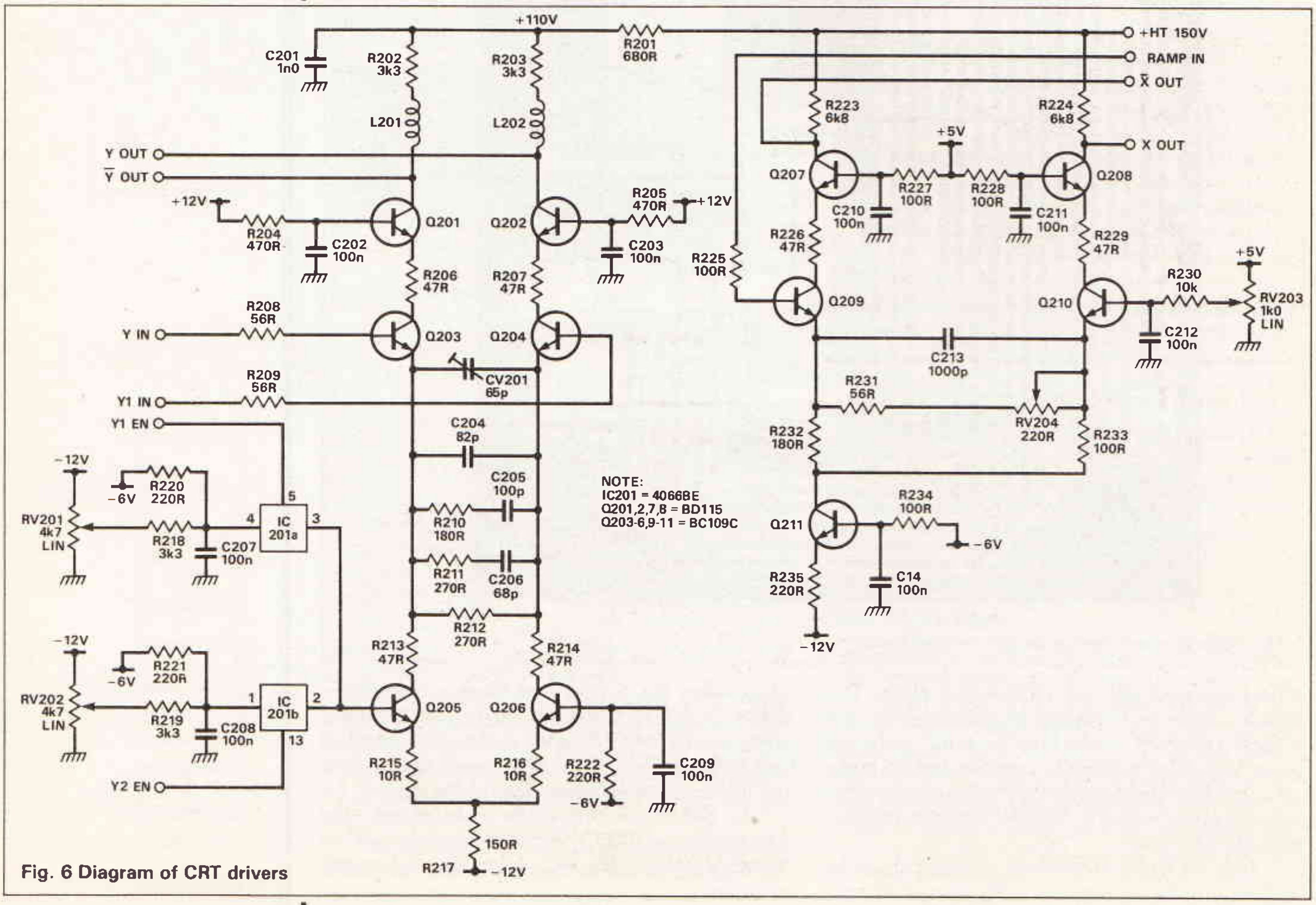


Fig. 6 Diagram of CRT drivers

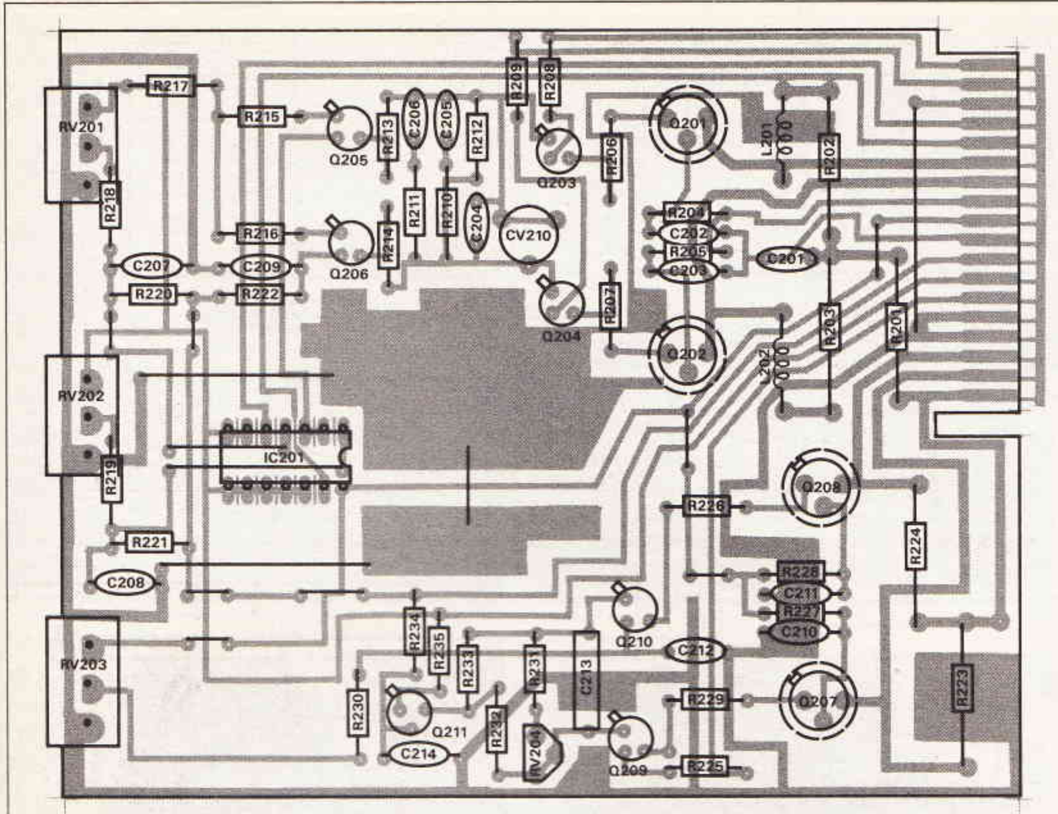


Fig. 7 The CRT driver overlay

Specifications

Bandwidth
0-6MHz −3dB for full screen
0-10MHz −3dB for 5 divisions
0-25MHz −6dB for 2 divisions
Risetime
18ns/division (1 Div = 6mm)

BUYLINES

The cathode ray tubes are available from: Langrex Supplies Ltd, 1 Mayo Road, Croydon CR0 2QP. Tel: 01-684 1166 for VCR and DG series tubes.

The DG7 36 tube is supplied by: PM Components Ltd, Springhead Road, Gravesend, DA11 8HD. Tel: 0474 560521.

The transformer kit and wire is available from Maplin (Code YJ62S), likewise the edge connectors. All other parts should be readily available.

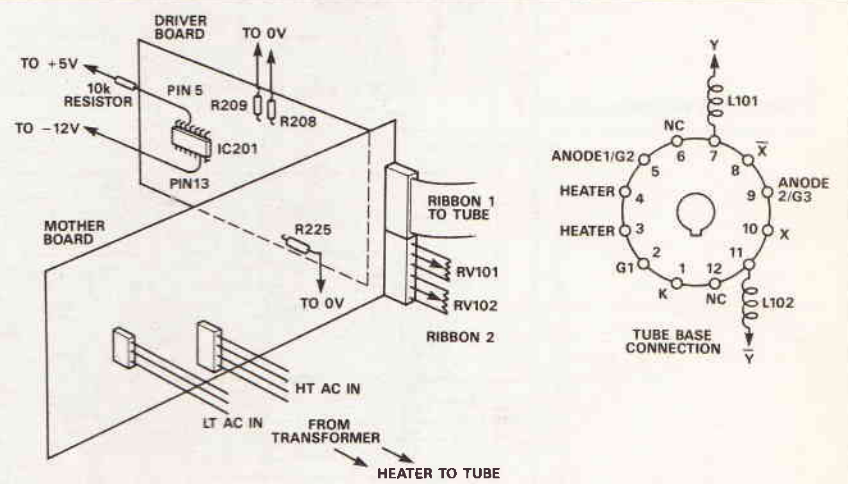


Fig. 8 Temporary testing hook up

HOW IT WORKS

The motherboard

The low tension supplies are straightforward using 78/79 series devices and copious decoupling. Note that the diodes in the common lead of IC104 increase the voltage to −6V to compensate for the offset voltage of the ICs used as input pre-amps.

Transformer secondary TS1 supplies the +HT circuit giving, after rectification and smoothing, about 220V positive.

This raw DC is fed to CRT anode A2 via RV101 which provides for adjustment of astigmatism in the display. The circuitry around Q101,2 is a series voltage regulator with current limiting which supplies 150V positive to the deflection circuits. In order to ease the load on Q101 resistor R101 drops some of the input voltage. R103 sets the current limit to about 70mA.

Secondary TS2 supplies a voltage multiplier circuit configured around C104-6, D105-7 which delivers about 450V negative into the divider chain RV102, R104, RV103, R105. RV102 is the brightness control and RV103 the focus. Trace blanking during flyback is coupled via D108, C108 etc, more of which later.

The deflection amplifiers

Both X and Y amps use differential amplifiers in a cascode configuration and are based on a design first detailed some years ago by Ian Hickman, suitably modified for this application. The X amplifier, due to the lesser bandwidth required, is considerably simpler and is driven by an unbalanced input to Q209. C213 provides a measure of frequency compensation and the gain is adjustable using RV204.

The Y amplifier is driven by a balanced input into Q203,4. The high gain from a cascode circuit is sacrificed in order to extend the frequency response of the amplifier and extensive frequency compensation is incorporated by the resistor and capacitor networks in the collector circuits of Q205,6. The inductors in the collector circuits of Q201,2 extend the frequency response slightly. VC201 is adjusted to give the best waveform on a high frequency square wave (around 5MHz).

The Y shift voltage is fed to the base of Q205 from IC201, a CMOS quad switch which is driven by antiphase square waves from the switch generator module (later) and selects one or other of the voltages set up by RV201 or 202.

PROJECT

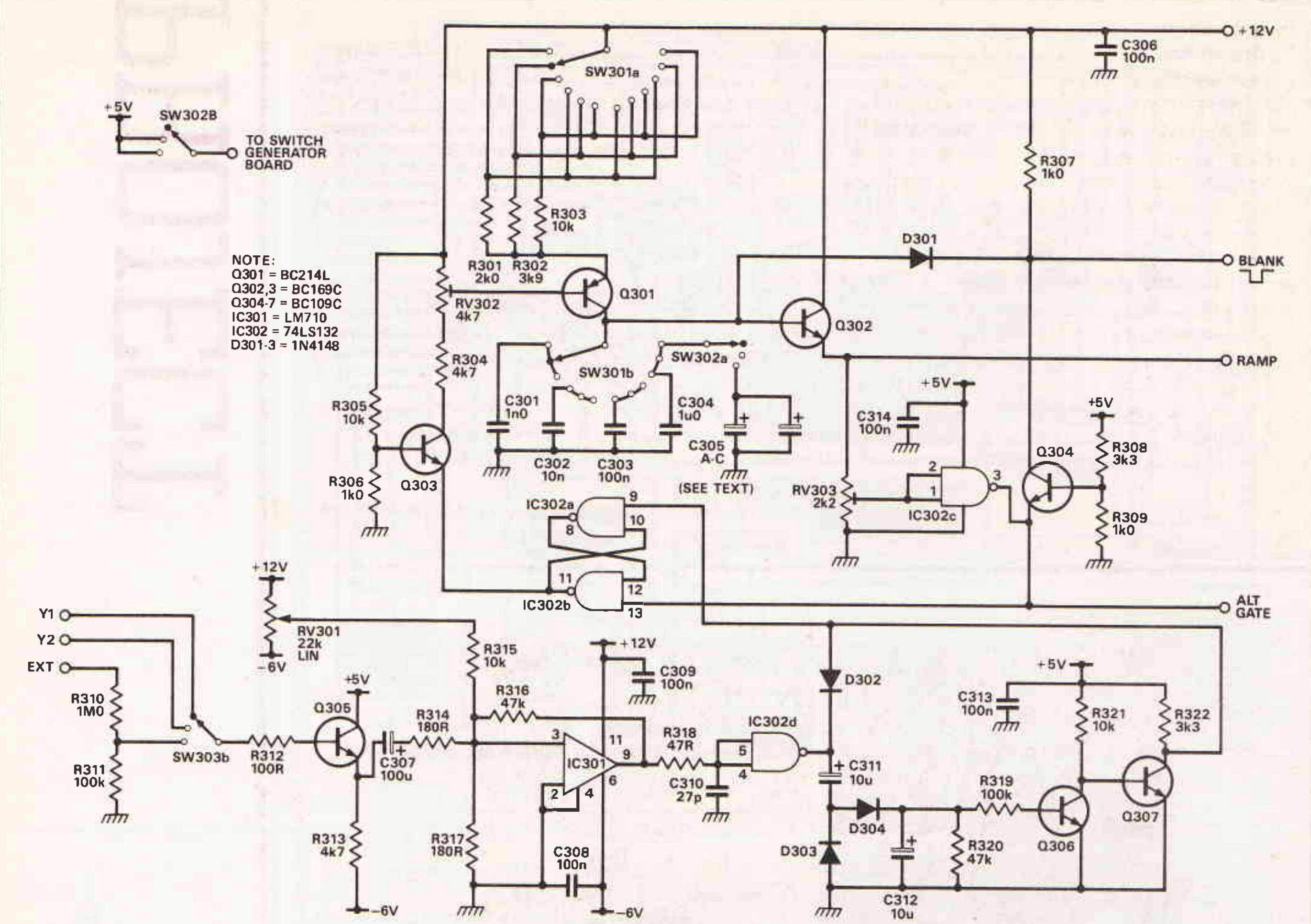


Fig. 9 The timebase circuit

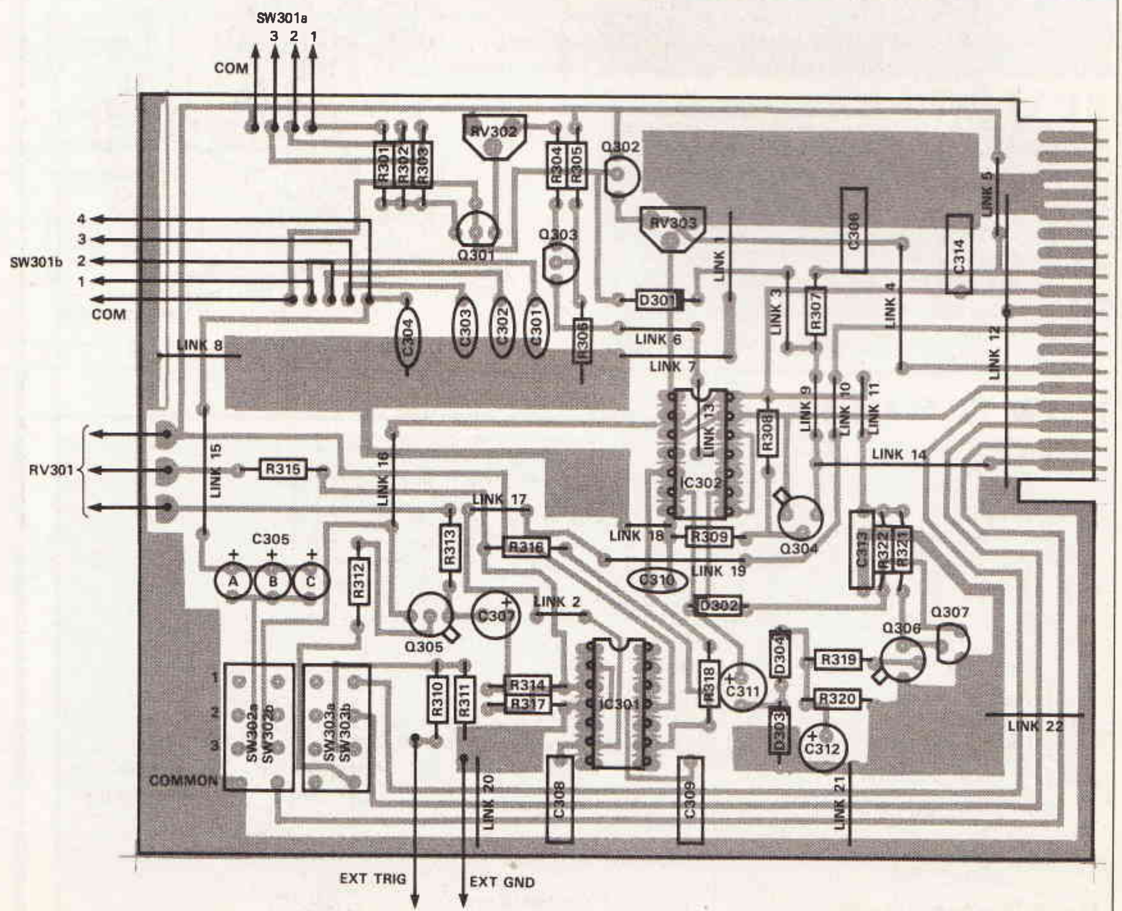


Fig. 10 Component overlay for timebase

HOW IT WORKS

The ramp generator

The ramp waveform is generated by the charging of capacitor, selected by SW301B and 302A through a constant current generator Q301. The rate of charging is determined by the resistance selected by SW301A and is adjustable by varying RV302. The constant current generator is switched on and off by Q303 driven by the set/reset flip-flop formed by IC302a,b. The emitter follower Q302 buffers the ramp generator and provides drive to the X deflection amplifier.

On receipt of a low going trigger pulse to pin 9 of IC302a the output of IC302b is switched low turning Q303 and Q301 on. The selected R/C combination begins to charge driving the deflection amplifier via Q302. When the attenuated ramp voltage fed to pin 1,2 of IC302c reaches about 1.7V its output goes low so resetting the IC302a,b flip-flop and turning off the constant current generator. The low going output of IC302c also serves three other purposes: (a) It provides the 'Alt gate' signal to the beam switching generator. (b) It turns on transistor Q304 which discharges the timing capacitor via D301, and when the voltage input to IC302C falls to below about 0.8V its output goes high again. (c) The high speed switching action of Q304 is used to provide a low going blanking pulse to the tube grid via C108.

Triggering

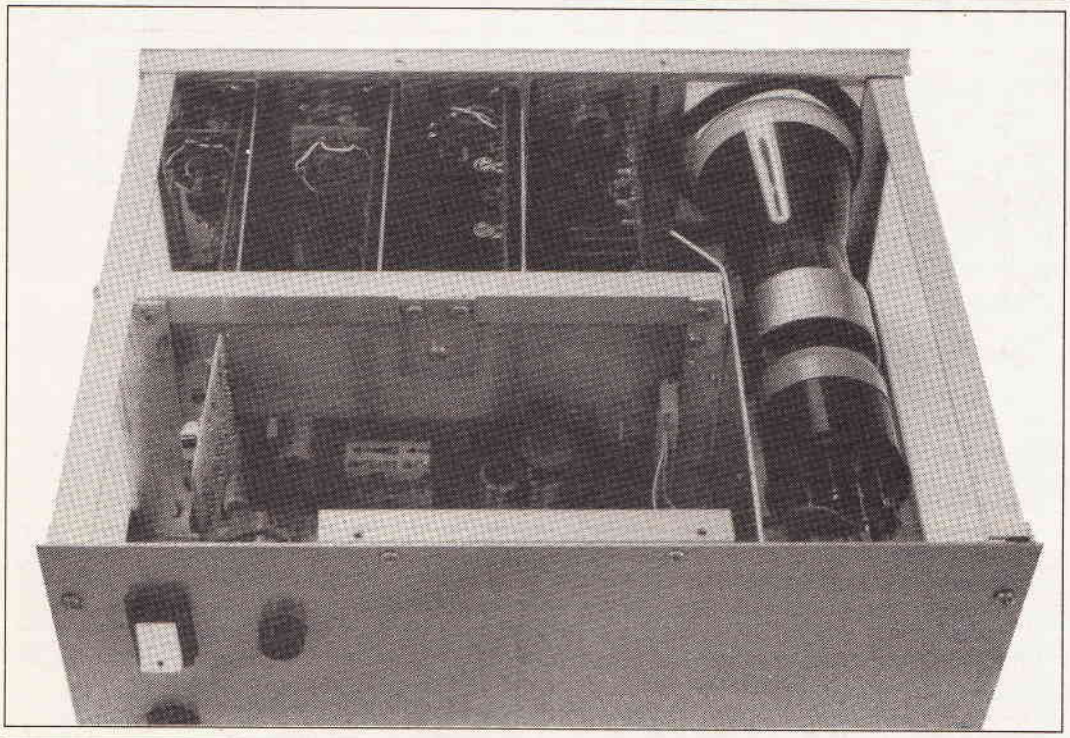
The trigger input selected by SW302B is buffered by Q305 and mixed with an adjustable voltage from RV301 at the input to IC301, a very high speed comparator with TTL compatible output. R316 provides a measure of hysteresis by introducing a small amount of positive feedback to ensure clean switching and R318/C310 filter any parasitics. The positive going output of IC301 drives IC302d, its low going output switching the constant current generator gating flip-flop via D302.

Bright line circuit

As long as a signal is passing through IC302d the action of the diode charge pump circuit configured around D303/4, C311/2 holds Q306 turned on and Q307 is switched off.

If the signal through IC302d ceases then C312 discharges in about ½ second and Q306 turns off. Base current is then available to Q307 via R321 and it turns hard on holding the input to IC302a low and therefore keeping the constant current generator permanently enabled.

If a signal is reapplied to the trigger circuit the diode pump circuit rapidly recharges and Q307 is again turned off.



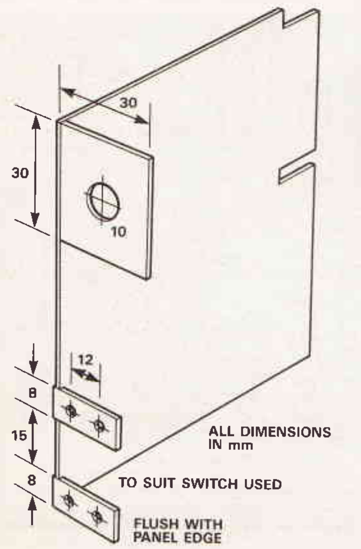


Fig. 11 Timebase PCB switch mounting sub board dimensions

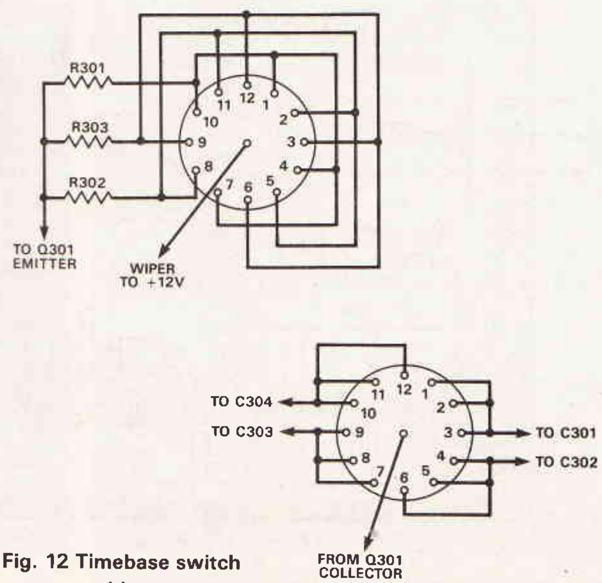


Fig. 12 Timebase switch wiring

PROJECT

PARTS LIST

PSU/MOTHERBOARD

RESISTORS (all ¼W 5%)

R101	680R,2W
R102	4k7
R103	10R
R104	100k
R105	330k
R106	1M
RV101	470k, preset
RV102	47k
RV103	470k

CAPACITORS

C101,2,4,5,6	15µ 450V
C103	220n Polyester
C108	47n 1000V
C109,116	220µ 25V
C110,11,13,14,17,18,20	100n polyester
C112,19	220µ 16V
C115,21	220µ 10V

SEMICONDUCTORS

Q101	MJE340
Q102	BC547
IC101	7812
IC102	7805
IC103	7912
IC104	7905
D101,2,3,4,5,6,7	1N4007
D108,13,14	1N4148
D109,10,11,12	1N4002
ZD101,2	75V 1.3W

MISCELLANEOUS

CON101,2,3,4	2×18W Edge connector
CON105	0.1" plug, 12-way
FZ1	20mm 250mA fuse and panel fuseholder
SW1	DP main on/off switch
CRT	VCR139A or alternative
T1	50VA Transformer kit and wire

THE TIMEBASE

RESISTORS (all ¼W 5%)

R301	2k, 1%
R302	4k (see text)
R303	10k, 1%
R304,13	4k7
R305,15,21	10k
R306,7,9	1k
R308,22	3k3
R310	1M
R311,19	100k
R312	100R
R314,17	180R
R316,20	47k
R318	47R

CAPACITORS

C301	1n polyester
C302	10n polyester
C303,6,8,9,13	100n polyester
C304	1µ
C305,A-C	See text
C307	100µ 25V
C310	27p ceramic
C311,12	10µ 16V

SEMICONDUCTORS

Q301	BC214L
Q302,3	BC169C
Q304,5,6,7	BC109C
IC301	LM710
IC302	74LS132
D301,2,3	1N4148

MISCELLANEOUS

SW301	Maka-switch assembly + 2 of 1P12W wafers
SW302,3	2P3W slide switches
Skts	2 of 4m panel sockets

DEFLECTION AMPLIFIERS

RESISTORS (all ¼W 5%)

R201	820R,2W
R202,3	3k3,2W
R204,5	470R
R206,7,13,14,26,29	47R
R208,9,31	56R
R217	150R
R220,21,22,35	220R
R215,6	10R
R218,9	3k3
R223,4	6k8,2W
R225,27,28,34	100R
R230	10k
R232,33,10	180R
R211,12	270R
RV201,2	4k7, 1in pots
RV203	1k, 1in pot
RV204	220R, preset

CAPACITORS

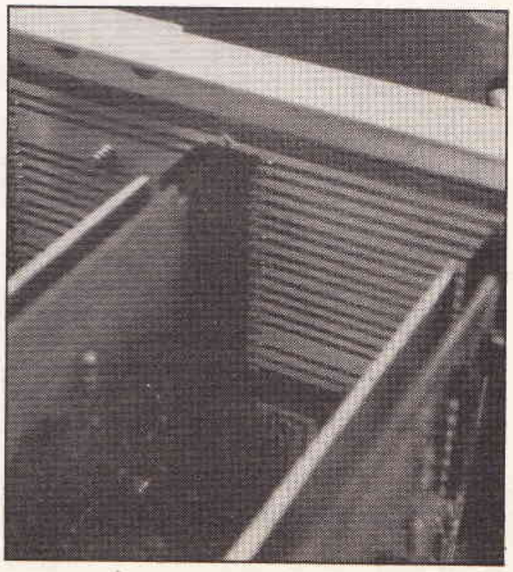
C201	1n, 160V ceramic
C202,3,7,8,9,10,11,12,14	100n polyester
C105	100pf
C106	68pf
C113	1n ceramic
C204	82p
CV201	65pf trimmer

SEMICONDUCTORS

Q201,2,7,8	BD115
Q203,4,5,6,9,10,11	BC109C
IC201	4066BE

MISCELLANEOUS

4×TO5 Heatsinks at least 47 deg/W preferably 25 deg/W.



Detail showing motherboard connections

PROJECT

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E9002-2	Superscope Mother Board	M
E9002-3	Superscope CRT Driver Board	K
E9002-4	Superscope Timebase Board	K

PCBs for the remaining projects are available from the companies listed in Buylines.

Use the form or a photocopy for your order. Please fill out all parts of the form. Make sure you use the board reference numbers. This not only identifies the board but also tells you when the project was published. The first two numbers are the year, the next two are the month.

Terms are strictly payment with order. We cannot accept official orders but we can supply a proforma invoice if required. Such orders will not be processed until payment is received.

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E8902-2	Ultrasonic Horn	D
E8902-3	Stepper Motor Driver Board	L
E8902-4	Quest-Ion (2bds)	K
E8903-1	Intelligent Plotter Solenoid Board	H
E8903-2	MIDI Programmer	L
E8903-3	Balanced Disc Input Stage	F
E8903-4	Digitally Tuned Radio	G
E8904-1	Camera Trigger	E
E8904-3	Intelligent Plotter Main Board	O
E8904-4	Kinetotie Tie Board	N
E8904-5	Kinetotie Control Board	E
E8905-1	Guitar Tuner	H
E8905-2	Camera Trigger Ultrasonics (2 boards)	F
E8905-3	Bench Power Supply (2 boards)	H
E8906-1	PC edge connector	F
E8906-2	MIDI converter CPU	N
E8906-3	MIDI converter keyboard	N
E8906-4	MIDI converter control	M
E8906-5	AF signal generator	G
E8906-6	Mini bleeper	C
E8906-7	Caravan heater controller	G
E8907-1	MIDI Patch Bay	G
E8907-2	Priority Quiz Switch	E
E8907-3	Camera Trigger Infra-reds (2 boards)	G
E8907-4	Aerial Amplifier main board	E
E8907-5	Aerial Amplifier power supply	E
E8908-1	Intercom master station	L
E8908-2	Intercom slave station	F
E8908-3	Intercom power mixer	E
E8908-4	Digital joystick-to-mouse conversion	H
E8909-1	Twin Loop Metal Locator	H
E8909-2	Trembler movement detector	D
E8909-3	Field power supply (spec 3)	C
E8909-4	Micro monitors active filter	F
E8909-5	Chronoscope auto-reset	C
E8910-1	Multimeter	H
E8910-2	MIDI Mapper	M
E8911-1	Smoke Alarm main board	F
E8911-2	Smoke Alarm power supply	F
E8911-3	Frequency Meter (3 boards)	O
E8911-4	Serial Logic Scope	L
E8912-1	Mains Failure Alarm	D
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E8912-3	Slide/Tape Synch	E
E8912-4	Pedal Power	L
E8912-5	Digital Noise Generator	K
E9001-1	20 metre Receiver	J
E9001-2	Wavemaker FG	L
E9001-3	Motorcycle Intercom	F
E9001-4	Low Voltage Alarm	C

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We have Casio's flagship synthesizer — the VZ-1, worth nearly £800, reviewed in Micro Music (Jan), plus a day's free studio time to professionally record your winning track at the ARC demo facilities which Micro Music looked at back in October/November's issue. There will also be a feature written on the day in the studio, so Micro Music, our sister magazine can offer you fame into the bargain!

Four runners up will each receive a Maplin 8-way MIDI THRU box and a year's subscription to Micro Music.

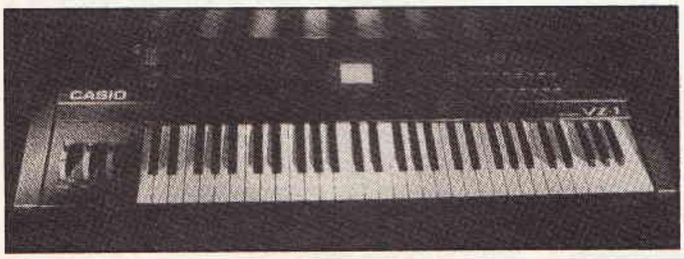
All you've got to do is send in a demo tape with your best song on it and the best one wins both the VZ-1 and a day in which to record the song professionally.

The rules are quite simple. Just send in a tape with one of your sequences on it, along with details of what computer, software, sound sources, effects etc were used on the composition using the cassette inlay provided.

The Rules

The piece of music must be no more than five minutes long and must be composed using a computer of some description or other.

Vocals and live instruments can be added but it's the use of computers and MIDI that are being judged and not how good a singer or guitar player you are.



One song per entry but you can submit as many songs as you like so long as each is accompanied with an official entry form. No Photocopies will be accepted.

The composition must be your own work. No cover version please unless they have been *radically* changed.

No employees of ASP, SM Distribution, WH Smith, Menzies, Caslon, ATC, Maplin Electronics or Stock, Aitkin and Waterman can enter.

Tapes must come to us at ETI (address at front of magazine) by final post on Wednesday 31st January 1990.

Regrettably tapes cannot be returned so don't send us your master tape, send a cassette copy.

Judging

The team of judges will consist of Darrin Williamson Editor of Micro Music, Matthew Wilkinson of ARC, Paul Wiffen — regular contributor to Micro Music and keyboard programmer to the likes of Vangelis and Stevie Wonder.

Entries will be judged on best use of what equipment you have and not on who has the most equipment.

So don't delay, get composing.

Name ....

Address ....

....

Daytime Phone Number..

Title of Piece ....

Computer Used ....

Software Used ....

....

MIDI Hardware used (if any) ....

....

....

Any other details of interest ....

....

....

TESTING TESTING

Mike Barwise continues his series on test equipment

TEST GEAR

When we looked at digital 'scopes last month we left one instrument out of the discussion. This is the LOGIC ANALYSER. There is nothing strange about the logic analyser: it is in principle just a fast digital oscilloscope. However, the task of recording and displaying signals in digital logic systems differs in some respects from that of looking at analogue signals.

Whereas the analogue signal can have a wide variety of amplitude and waveform, the properly digital system can only have a fixed amplitude (swing between logic LOW and logic HIGH) and one legal waveform (square wave). It is therefore possible to dispense with the complex, high precision vertical amplification system which characterises the analogue scope. All we need is a recognition of logic state, which can be displayed in any convenient manner. The bandwidth of the logic analyser is these days generally very much greater than that of the equivalent quality analogue scope. Bandwidths of 100MHz (10^8Hz) to 1GHz (10^9Hz) are now common in good quality logic analysers, as opposed to 20MHz to 60MHz for the analogue instrument. This is, however, quite recent. I remember when a 2MHz logic analyser was a costly piece of kit!

As well as being fast, the logic analyser has another major requirement. Whereas the analogue scope normally has two inputs and two traces (sometimes three), the logic analyser has between 8 and 64. This is necessary so you can observe the workings of today's 32 bit microprocessor systems. The high number of traces can be accommodated on a visual display because the vertical detail requirement is low compared with that of the analogue test scenario.

Successful use of a given instrument such as the logic analyser, is very much a seat-of-the-pants task. Logic analysers differ enormously in their facilities and methods of control, and correct application depends more on the job in hand than with any other instrument you will handle. You can use a meter, a scope, a spectrum analyser or whatever on a relatively unknown circuit with some confidence, but in order to use the logic analyser adequately, you must have a very good idea of what your circuit under test should do and how it does it. This is partly due to the enormous number of possible permutations of 32 inputs, and partly due to the operational complexity of modern logic systems. The logic analyser is thus more a diagnostic tool than an investigative instrument. The last point worth mentioning is how to interpret the quoted bandwidth when selecting a logic analyser. A 100MHz logic analyser actually samples at a maximum rate of 100MHz. Although the Nyquist Limit applies to analogue signals, it is not relevant in the context of the logic analyser, as a 50MHz signal for example, although recognisable when sampled at 100MHz, would not be displayed in sufficient detail to be useful. It is important to remember that we don't care about waveform: what we want to know is relative timings. A minimum useful amount of detail is provided when the logic analyser captures at four times the fastest rate in the circuit under test, and really a factor of 8 or 16 is necessary to determine the presence of marginal timing hazards. Thus our 100MHz logic analyser has in reality a signal bandwidth of about 6 to 12MHz or maybe 25MHz if you stretch the point, which brings it into line with the general purpose analogue oscilloscope. A word of caution: there are several cheap (about £400!) logic analysers around with sampling rates to about 20MHz. As you will see from the foregoing, these are all but useless for anything except fault finding on BBC Micros and the like. This kind of mistake can be very expensive. A reasonably good 100MHz machine will set you back about £2000, but it is totally wrong to assume the cheaper one will get you by. In analogue, a 20MHz scope is better than nothing. In digital, you are better off with nothing than the wrong tool.

Signal Generators

Moving on now to support equipment, we will consider signal sources and ancillary metering systems. Signal sources, more commonly known as signal generators range from the incredibly crude to the unbelievably sophisticated, and can cost from about two quid (for the bits: build it yourself) to in excess of £200,000 (that's right: nearly a quarter of a million!). The trick is to choose a suitable signal generator for the task within the limits of your budget. As we will see in a future issue, the performance required of any piece of test equipment is dictated by the overall precision of the whole measurement system including the system under test. It is quite daft to spend several thousand hard-earned greenbacks (sorry- nasty little brassy coins, I live in Scotland!) on a 6½ digit voltmeter (resolution 0.001%) if you are checking a batch of audio amplifiers which are resistors with a tolerance of ±5%. It is equally loony to try to find high frequency sub-μV signals using a cheap quality 20MHz oscilloscope. The same applies to signal sources, with the rider that they tend to be a lot more expensive than measuring instruments for the same order of performance. First of all though, lets look at why we need signal generators at all.

The very simplest scenario is the testing of an audio amplifier you have just prototyped. You want to find out how it behaves: its maximum output swing, its frequency response, its distortion. Normal signals your amplifier copes with (music, pop music, loud music) are not very good for checking the amplifier output. It is not enough to play a record into the input, shove a speaker on the output and listen. your evaluation will depend on all sorts of things, including whether you know the music already, how pleased you are with yourself for completing the construction job, whether your boss has just given you a raise (or the boot) and so on. In short, your judgement will be totally subjective. The objective test of the amplifier is to put in a known input and compare the output with it, O.K., so use a 'scope! The problem is that your music is constantly changing. You just don't have time to observe and compare the input and output signals before they have changed completely. What you need is a constant signal. It should be stable in frequency amplitude and harmonic content.

If you have a stable signal source you know exactly what is going into your circuit under test, so you can tell what the circuit is doing by comparing the output signal with the input signal.

DC References

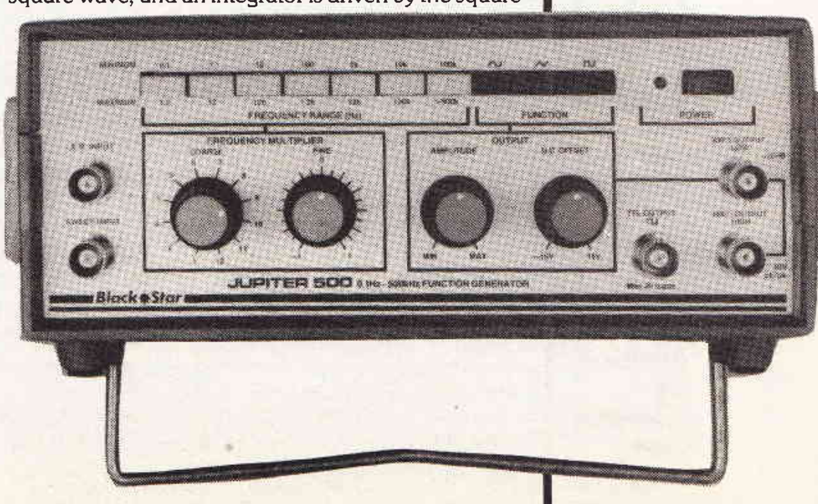
Lets look at a range of signal sources. The simplest, and probably the most costly and difficult to make well, is the DC Voltage Reference. From the user's point of view, this consists of a box with a controllable DC voltage at its output socket. This DC voltage output is free of ripple (cyclic variation) and noise (random variation) to a specified degree, and is normally capable of delivering a few mA of current without loss of precision (normally in the order of 1 in 10^4 or better). The DC voltage reference is used when setting up comparators, A/D and D/A devices and also when calibrating voltmeters, and 'scopes which have a precision at least one order lower than the reference. This is obviously not a power device. It is not suitable for use as a power supply, even to very low consumption circuits, and therefore is not what you would use to find out how circuit performance is affected by power supply voltage change. However, this job does not need this precision anyway: a stable power supply which is settable to about 1% would be perfectly adequate. In fact, for general reference purposes (digital 8 bit:1 in 256 or 0.4%), an ordinary fixed three terminal voltage regulator (78xx series) has quite adequate stability although its absolute voltage may vary from device-to-device over a range of about ±2%. However, a good quality 10 turn potentionmeter and digital volt meter can be added to produce a perfectly satisfactory general purpose 8 bit precision voltage reference.

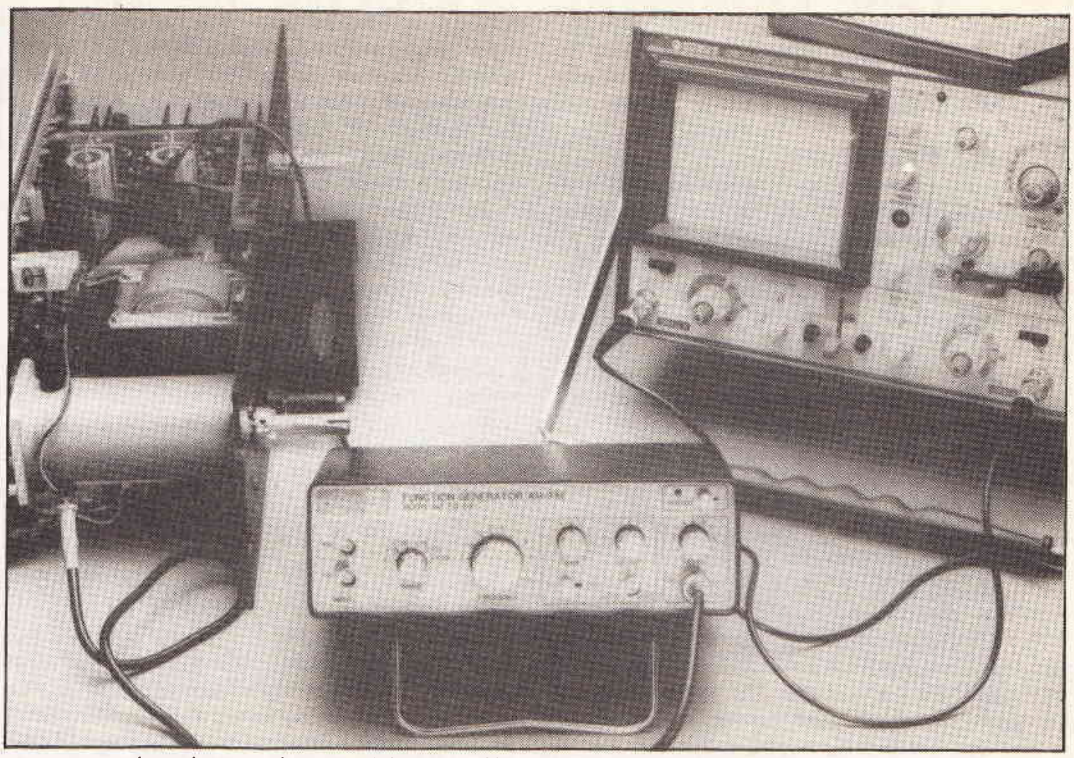
If you are thinking of spending the £800-£2500 needed to buy a high precision DC voltage reference, beware of systems with a built-in GPIB interface. This is a little microprocessor systems which allows remote programming by other instruments, and is very popular and convenient. However, I have never yet found a precision voltage reference with GPIB which did not also have a high level of digital noise superimposed on the output. I had to buy one in a hurry a couple of years back for an experiment at a major defence research centre, and GPIB was essential, as about 30,000 readings were to be taken, so automation was the only way. The output was, so noisy that we spent about a day and a half of our one week experiment modifying the voltage reference to get a clean output. We did not totally fix the problem even then, and that was equipment costing about £1200!

Waveform Generators

The next candidate in our lineup is the basic audio range signal generator. Modern ones usually produce sine, triangle and square waves, and many have an auxiliary TTL square wave output. The frequency range is normally about 10Hz to 500KHz, with some instruments emphasising the low end (down to 0.001Hz!) and some, the top (up to 2MHz). Output amplitude is normally adjustable over a range of about ±30V p/p to ±10mV p/p with 600R or 50R output impedance but many lower priced generators do not perform well at the low amplitude end of their range. There is frequently a DC Offset control, which superimposes a DC voltage on the signal (e.g. ±3V becomes +4/-2V when a DC offset of +1V is added). A very important point about the output of these generators is that it is +30V at no load. At any loading the output will be less than stated. When the output impedance Z_{out} (600R or 50R) is matched by the input impedance (Z_{in}) of the circuit you are driving, the output will have half the voltage swing (±15V). Z_{out} and Z_{in} act as a potential divider across the output of the signal generator.

The majority of affordable Sine, Square, and Triangle generators in the low frequency range (<2MHz) are in fact analogue oscillators. They either use transistors or op-amps to generate square waves and triangle waves. A bistable circuit produces the square wave, and an integrator is driven by the square





wave to produce the triangle wave. A low-pass filter is applied to the triangle wave to produce the sine wave. This is a very good method of generating very pure (distortion free) waveforms, but it suffers from one major limitation a lot of capacitors are used in the circuitry for timing purposes. Capacitors have the worst value tolerance of any generally used component, particularly large value capacitors (electrolytics). As the system timing is controlled by these wide-tolerance components, the frequency accuracy of the generator will necessarily be quite crude: the marked frequency on the control knobs and the real frequency can be quite different. This may or may not matter. When it does, there is another piece of test gear you can use to allow for it: the frequency meter but first, let us look at a kind of signal generator which does not suffer from this lack of frequency accuracy.

The most precise frequency standard in common use is the quartz crystal. This is a specially cut piece of guess what? That's right: quartz crystal. It exhibits the property of piezo electrical effect. When you bend it, a voltage is developed across the piece of quartz, and if you apply a potential across it, it bends. This can be put to good effect in an oscillator. The quartz crystal acts as a mechanical resonator which supplies the stabilising signal to the system. The output is a very stable sinusoid of a very precisely defined frequency (defined when the crystal was cut). It is possible to produce low frequency crystals, but they tend to be very big. I have a 3kHz crystal by Marconi's Wireless Telegraph Company (that was some time ago!) which is about 120mm long by about 2mm square, all in a glass tube about the size of those felt tip pens they label parcels with. High frequency crystals are a lot smaller. So the crystal gives us a precisely defined stable frequency, but you'd need an awful lot of different crystals to provide the range and resolution needed of your signal generator. There is a trick though, which solves this problem.

If you take stable constant amplitude sinusoids of different frequency and mix them (add them together), the resulting output is modulated (varies in amplitude) at a frequency equal to the difference in frequency of the two input signals. Put this output through a rectifier and low-pass filter and you get a pure signal at the difference frequency. For example, mixing 50Hz and 51Hz gives you modulation at 1Hz, which can be extracted as a pure 1Hz sinusoid. This signal could be used as one input to a second mixing process and so on. A fairly small selection of standard crystals can thus be used to generate a large number of alternate output frequencies by mixing and remixing frequencies. This is the basis of heterodyne frequency synthesizers, which are excellent precisely settable and stable instruments. They have only one major drawback: they cost the earth (often in excess of £5000). Heterodyne frequency synthesizers tend to output sinusoids only, and to operate in the medium to high megahertz bands, as their primary application is radio communications test and development. Some do, provide limited bandwidth square and triangle waveforms.

There is a final kind of signal generator which is mainly used at lower frequencies and is extremely versatile. It also costs more than you've got in the piggy bank. This is the digital waveform generator. It consists in effect of a digital memory store driving a digital to analogue converter at a crystal controlled rate. Absolutely any waveform may be stored in the memory, however complex (subject to the resolution of the D/A converter), and replayed repetitively. The sound sampler (if you're an electronic music fan) is just such an instrument, except that the test gear equivalent has a much more precise way of loading the memory with the relevant digital data. Normally the data is generated by input of the mathematical formula which describes the waveform, and frequently the standard ones (sine, square, triangle, sawtooth) are preloaded options. The digital waveform generator has a limitation on upper frequency of operation which depends on the number of samples you need to describe the waveform in sufficient detail. It is never perfect, as the nominally smooth line of the curve is in fact built of little steps. This is called quantisation distortion and effectively amounts to the addition of unwanted very high frequency components to the waveform. A low-pass filter at the output solves the problem, so long as the filter is very carefully tuned to let through everything you want and block everything else. Here lies a major contribution to the cost of the gear. The filter must be re-adjusted for every different output frequency and every waveform shape.

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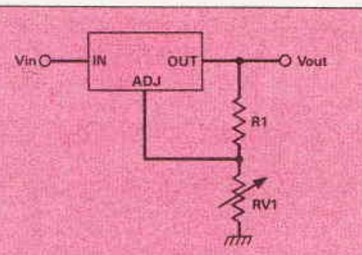
REGULATORS AND REFERENCES

This month, Paul Chappell reviews a variety of varied voltage regulators

Pressing on from the last brief survey of fixed regulators, we now come to the variable ones. These do much the same job as the fixed variety but instead of having their output voltage set during manufacture, the voltage can be varied by the user over a range of perhaps 1.5V to 30V. The voltage is usually set with a pair of resistors. Figure 1 shows the general circuit, applicable to most regulators.

One reason for choosing a variable regulator is that it is possible to set voltages which are just not available from fixed types. Or perhaps they are available, but you don't have them to hand. The range of voltages now on offer from fixed regulators is a good deal wider than you may think, if your main source of information is a general component catalogue. Did you know, for instance, that you can get a 4.6V regulator, or a 5.2V one? AT&T make both. Or if you'd prefer 13.8V you could go for the Lambda LAS15CB. But for a regulator of any old voltage that's always on hand when you need it, it has to be a variable one.

Another reason that might tempt you to go for a variable regulator is that it saves having drawers full of the various common fixed voltages. One type is all you need; just select the right resistors and it will be a 5V regulator, a 12V one, or 15V, or whatever you want. Finally, you might like to make a simple variable voltage power supply. Just replace R2 with a pot, as shown in Fig.1b, and you've got one.



VOLTAGE VARIABLE FROM Vref (USUALLY <1V5) UP TO Vref (1+RV/R1), WHERE RV IS THE TOTAL TRACK RESISTANCE OF THE POTENTIOMETER

Fig. 1 Basic circuit of a variable voltage regulator.

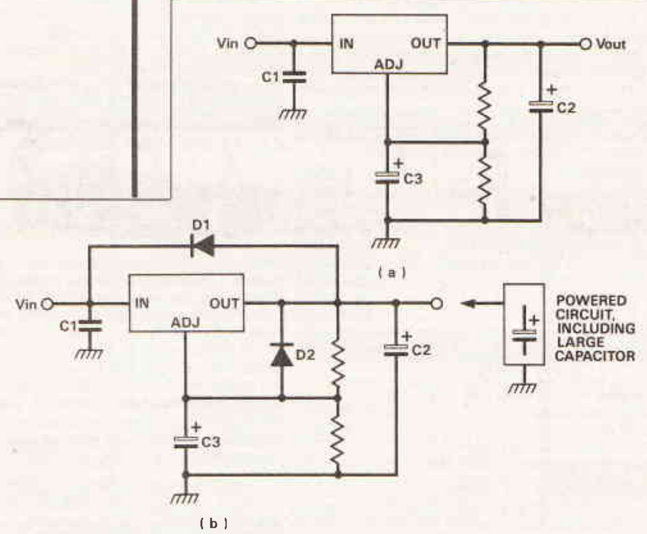


Fig. 2 (a) Circuit showing capacitors to improve performance. (b) Addition of diodes to protect the IC.

The way that almost all variable regulators work is like this. The internal circuitry establishes a fixed reference voltage (V_{ref} in Fig.1a) between the output pin and the adjust pin. Because the voltage is fixed, this sets a certain current to flow through R1. In case you've forgotten Ohm's law since your school days, I'll just remind you that the current will be $V_{ref}/R1$. This very same current will flow through R2, so the total output voltage will be Vref plus the voltage dropped by R2, which will be Vreg × R2/R1. Adding the two gives the rule of thumb formula shown in Fig.1a.

The reason the formula isn't entirely correct is that the current to operate the internal circuitry of the regulator IC is grounded via the adjust pin, and this also flows through R2, raising the voltage across it. So the rule of thumb formula is a slight under-estimate of the real output voltage. To be spot on, you have to add on I_{adj} × R2 to the value you get.

As an example, how about having a go with the LM317L, which is an adjustable regulator similar to the 78Lxx series fixed regulators. The output voltage can be set anywhere from 1.25V up to 30V. The adjust pin current is nominally 50μA, but the value could be anything up to twice this on some samples of the IC. It will be lower on others. The way to reduce

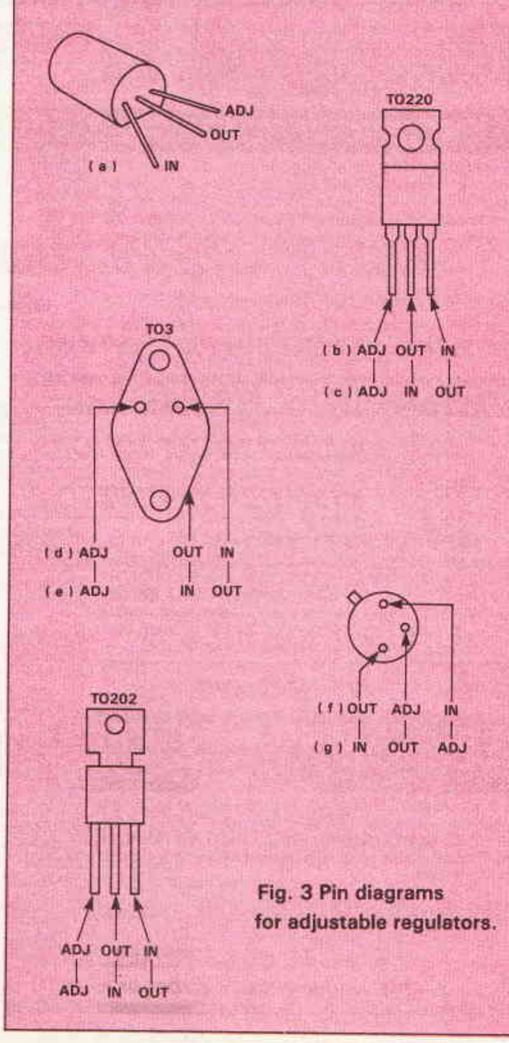


Fig. 3 Pin diagrams for adjustable regulators.

uncertainty about the adjust pin current's contribution to the output voltage is to swamp it out by making the current through R1 much larger say 5mA, the largest error we'll get from ignoring the adjust pin current altogether and by using the nominal 50μA value in our calculations, the error from this will be 1% or less.

We've decided on the current through R1 (5mA), and from the data sheet we know the reference voltage is 1.25V, so this settles the value of R1 as 250R. In real life we'll choose the nearest preferred value of 270R (or 240 if you have a stock of E24 resistors) giving a current of 4.6mA. Now we're all set to choose a value of R2 to give whatever voltage we need. It will be given by: R2 = (V − 1.25) × 2.16. V is the voltage we want at the output, and the 216 pops up because it's the number of ohms that will drop 1V at the current we've set with R1. Am I making this impossibly complicated? If you don't follow, forget everything I've said so far and work it out from this:

$$R2 = (V - V_{ref} \times (R1/V_{ref})$$

which is the general formula applicable to any old regulator. Just plug in the numbers and you're away.

OK, so we want a 12V output. Popping the numbers into the formula above gives a value for R2 of 2k3. The nearest E12 preferred value is 2k2, so that's the resistor we'll use. This will actually set a voltage of about 11.5V, which shows one of the drawbacks of variable regulators: unless you're well stocked with at least the E24 range of resistor values, or are prepared to trim the output voltage by combining R2 with a preset, you usually won't be able to quite hit the voltage you want.

Practical Matters

As with the fixed regulators, the variable ones often benefit from the inclusion of a pair of capacitors as shown in Fig.2a. Capacitor C1 is needed if the regulator is far from the power supply filter capacitors. C2 may be necessary for stability in some regulators, and in any case will aid transient response, so it's just as well to include it unless you're really miserly! For the LM317L, C1 would be 100n and C2 a 1μF tant. An optional extra is C3, which will help to reduce noise and improve ripple rejection. A tant of around 10μF will be suitable.

To protect the regulator, indeed any regulator against the condition where the output voltage may become higher than the input voltage, diode D1 of Fig.2b is included. Most of the time this won't be necessary: the condition usually occurs when the power is turned off, in which case the power supply fitted capacitors will ensure that V_{in} drops relatively slowly. Problems occur when there are large capacitors on the output side of the regulator which may hold up the output voltage after the input has fallen. If you're making a variable power supply for your lab, you won't be sure what will be connected to the output, so including D1 is a sensible way to avoid damage to the IC.

D2 will be needed, for much the same reason, if you use C3. It makes sure that the adjust terminal won't become higher in voltage than the regulator's output if C3 discharges slower than the filter capacitors.

Some variable Regulator ICs

As with the fixed regulators, there are scads of different types, and usually not a lot to choose between them as far as performance goes. Table 1 shows a selection of types and Fig.3 gives their pin connections.

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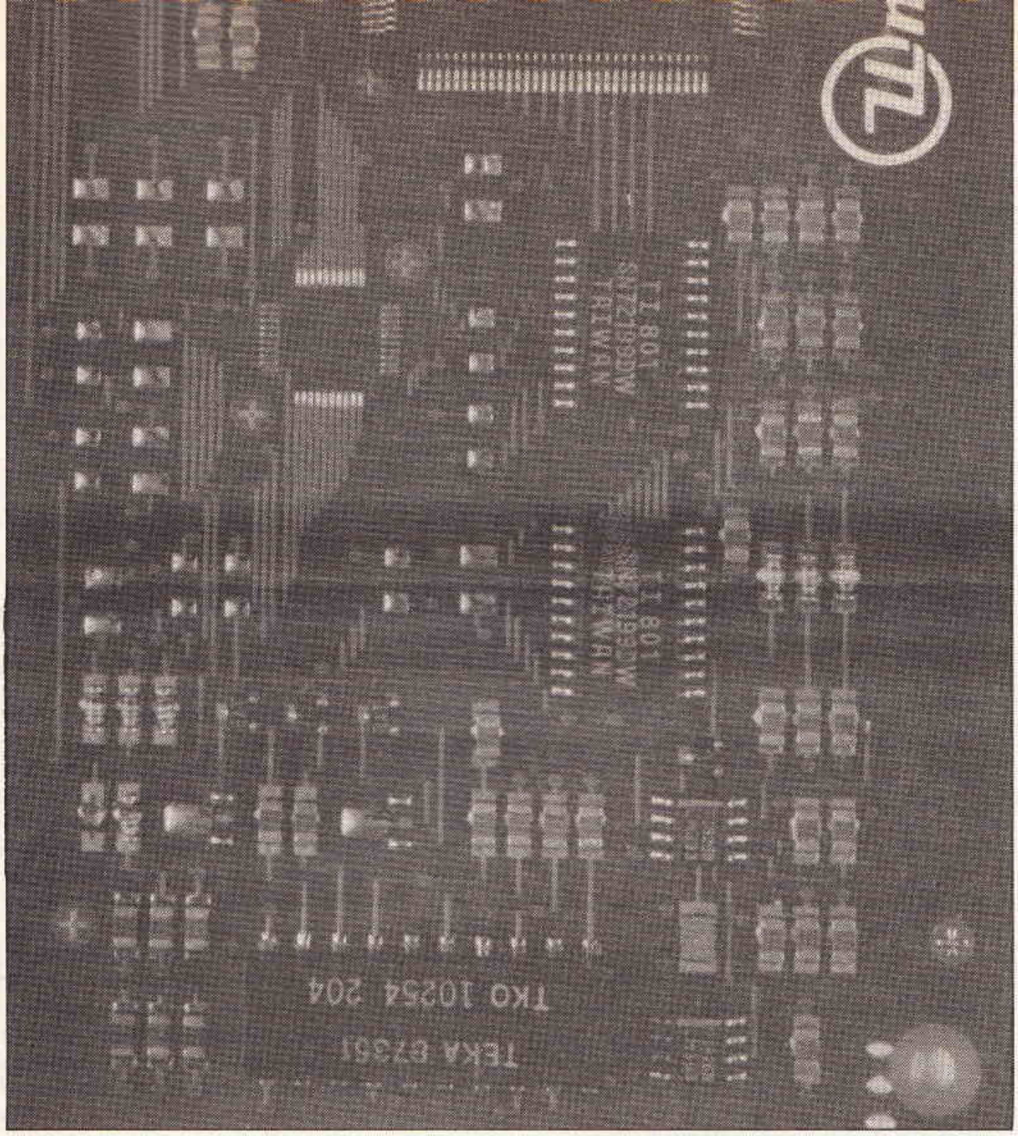


SURFACE MOUNT TECHNOLOGY

Small is beautiful, small is fiddly, small is surface mount. SM technology is a revolution in manufacturing and is hovering enticingly over the amateur market. Keith Brindley is our man with the microscope and mini soldering iron

For many years now, printed circuit boards have been made by one single technique. A copper conducting track sits on an insulating base material, holes are drilled through the copper and base to allow component leads to be inserted, and the leads are soldered to the track making up the complete electronic circuit (Fig. 1).

Since the advent of the transistor some forty years ago, such through-hole PCBs have formed by far the most popular form of circuit construction, be they for amateur, consumer or professional use. Many types of component have evolved or been specifically designed for mounting by through-hole PCB means; ordinary resistors and capacitors, transistors, dual-in-line integrated circuits and so on. Such components are now known as *leaded* components (as in having connecting leads — not as in leaded petrol).

Of course, there are many variations on this theme. For instance, the traditional through-hole PCB of copper on a rigid insulating base is often adapted by using a flexible base, used regularly on car dashboard displays and the like. Other types of PCBs, known as multi-layer PCBs (Fig. 2) have many layers of copper tracks laminated between thin rigid or flexible insulating layer. These are often used where assembly size need to be kept to a minimum — multi-layer PCBs of up to thirty layers are often used in military applications.

Recently however, a completely new style of PCB has come into regular use, where components are no longer mounted with connecting leads inserted through holes in the PCB but are instead simply mounted on the surface of the board prior to soldering. To be fair, such surface mounted assemblies (SMAs) aren't really a new form of PCB — hybrid circuits have been around 30 years or so relying on this method for component attachment. Hybrid circuits, though, are pretty specialised, having thick or thin-film passive components initially built up onto specially manufactured base *substrates* before components are surface mounted. Figure 3 illustrates the differences through-hole, hybrid, and surface mount PCBs.

On the other hand, SMAs, of a general-purpose nature are becoming extremely common, using readily available base materials such as copper-clad phenolic paper or fibre glass board, manufactured in common ways by photo-printing the circuit's track layout onto the copper, followed by etching away the unwanted copper. Of course, no drilling of holes or insertion of component leads through the holes is required. The components (SMCs) have no connecting leads and so are known as *leadless* components.

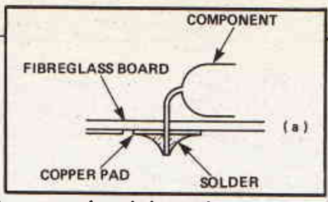


Fig. 1 A conventional through-hole PCB. A leaded component is inserted through holes in the board and soldered to the copper track on the other side

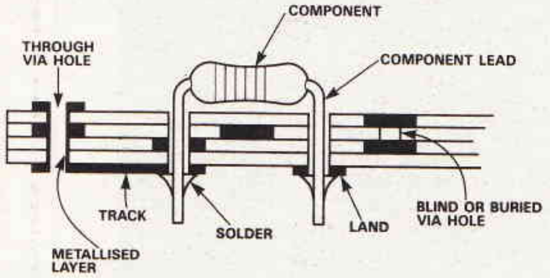


Fig. 2 Principle of a multi-layer PCB, where many layers of copper track are laminated together with insulating layers to form a single boards. Holes can either go right through the board, or merely between two or more of the layers

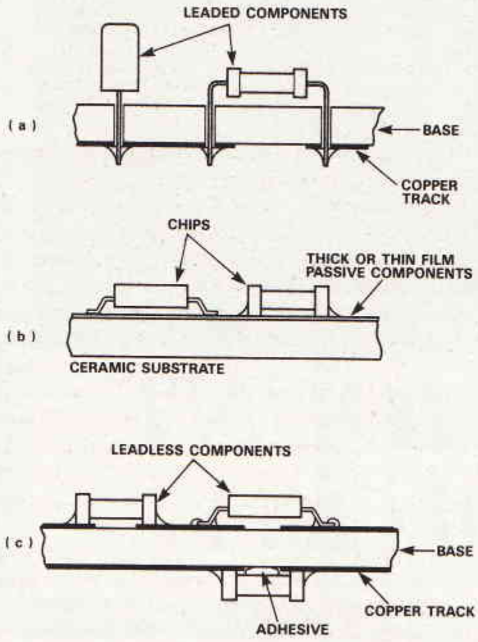


Fig. 3 Comparing through-hole, hybrid, and surface mount PCBs (a) through-hole (b) hybrid (c) surface mount

If you're not convinced it'll catch on, look at the graph in Fig. 4 which shows the percentages of electronics assemblies which contain SMCs, comparing through-hole assemblies with SMAs. By 1990 around half of all electronic assemblies will contain SMCs. Estimates close to 100% by the turn of the century have been made.

Not every country has yet realised the advantages of SMAs. Some, notably the USA, have been extremely slow to cotton on to the fact that surface mount technology (SMT) represents the next phase of electronics manufacture. Japan (as you might expect) most certainly has — with as much as 50% of assemblies manufactured by SMA means for some years now. There's no doubt that if you haven't seen a surface mount PCB yet, you soon will.

SMA Advantages

It's difficult to quantify every advantage which SMAs have over through-hole assemblies: there are so many. The main two are:

- *miniaturisation* — a number of factors go towards the size reduction which SMAs allow. SMCs are much smaller than their leaded counterparts (simply because they have no leads) and as a result are lighter too. High-density integrated circuits are able to have a considerably greater number of connection pins, more closely spaced. SMAs can have components mounted on both sides of the board.
- *cost reduction* — components have no leads so are cheaper to make. On assembly, difficulties experienced in inserting component leads through holes in the board are eliminated, so faster and cheaper assembly is possible. The lack of leads means that robotic assembly methods are cheap and labour costs are drastically cut.

Indeed, the only real disadvantage of SMAs is the fact that components, particularly complex integrated circuits, are difficult if not impossible to assemble and solder in by hand. For anything but the most simple of SMA, machine-aided assembly and soldering is required. Assembly machines are available from simple microscope attachments through to fully automatic assembly machines (see later), which require little or no human involvement apart from ensuring a supply of components. The simpler assembly requirements of SMCs over leaded components means that these machines aren't as expensive as you might think either, and even small manufacturers can find it an advantage to change from through-hole to surface mounted assembly techniques.

SMCs

What about the components themselves? What is available and what packages do they come in? Figure 5 shows a selection of common shapes. By far the most popular are the *chip* passive and active devices (resistors, capacitors and diodes). The name *chip,* incidentally, derives from the fact that they look like a chip of material, rather than being an integrated circuit type of chip. They are also sometimes called *cubic* — technically incorrect as they are rectangular prism shape.

Another component form worthy of note is the *small outline* range of active devices. Simplest of these is the small outline diode (SOD). Next in the range are small outline transistors (SOT), followed by small outline integrated circuits (SOIC). SOICs are usually categorised by the number of terminals, so an SO14 package has 14 terminals, as SO8 has 8 terminals.

All these small outline devices are derived from standard components available in through-hole form which have been adapted. In effect they ae smaller versions of their leaded counterparts, often having the same generic number (4148, 741 and so on). Although they are still classed as leadless components, again a misnomer because they do actually have small mounting leads usually of a dual-in-line nature (these serve a specific purpose which we'll look at later). Dimension of these mounting terminals are such (0.015 inch wide, on 0.05 inch centres) that they allow, with extreme care and a miniature bit, hand assembly and soldering.

A more miniaturised development of the SOIC is the *flat-pack* component form where typically all four sides of the body have small mounting terminals (forming a quad flat-pack IC) on typically 0.025 inch centres — too small for unaided hand assembly and soldering.

There is also the group known as chip carriers. There the word chip does refer to a silicon chip (integrated circuit). As far as general purpose surface mount PCBs are concerned, the only type of

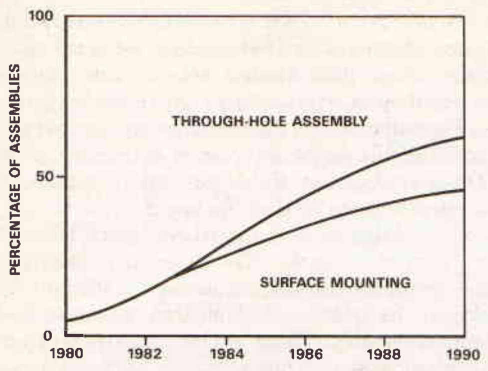


Fig. 4 Percentages of electronic assemblies containing surface mount components with those using through-hole components

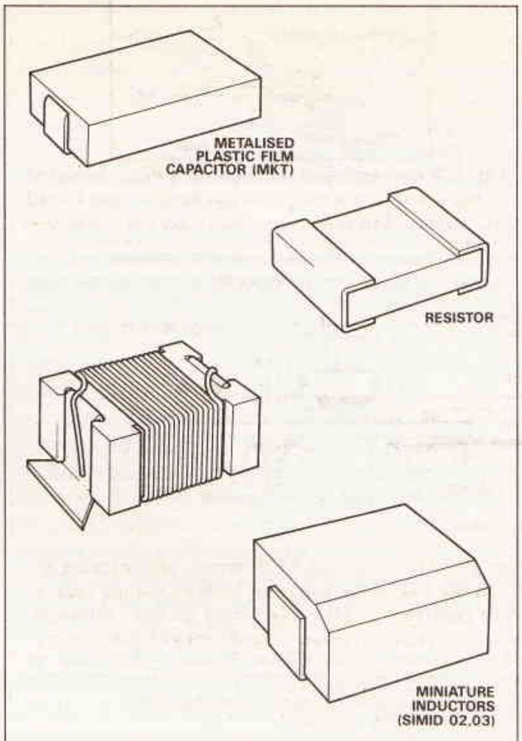


Fig. 5 Common surface mount component shapes

common chip carrier is the plastic leaded chip carrier (PLCC). This is basically a plastic body housing the silicon integrated circuit, with J-shaped terminals from the side of the body hooking round underneath, as in Fig. 6. Another type not used in general-purpose surface mount PCBs but worth a mention, is the leadless cermaic chip carrier (LCCC) — which uses a ceramic body to house the integrated circuit chip and metalised terminations instead of terminals. LCCCs are used in more professional applications — particularly military.

Miniaturisation of SMCs even further can only result from the ability to mount the integrated circuit chip directly onto the board. In hybrid assembly, chip-on-board (COB) (sometimes called bare chip-and-wire) technology is not new — although it is an exacting procedure not lending itself to large volume manufacture, as each terminal of the chip requires to be individually and sequentially soldered onto the board.

Component manufacturers have attempted to get round the problem in a number of ways, the most successful appearing to be tape automated bonded (TAB) integrated circuits, sometimes known as mikropack components. These are bare semiconductor dice mounted onto polyimide film tape reels, then having connection terminals etched on by the manufacturer. The user merely reels the required number of components off the reel, places them in position on the PCB, and mounts them onto the board surface in a single soldering operation. Soldering of TABs can be by a number of means, the most straightforward being the heated collet, which is basically a soldering iron with an open square bit, fitting over the TAB device, so that the bit heats only the terminations. Fairly accurate control of bit temperature is required, meaning a thermocouple and control circuit, but TAB devices with many hundreds of terminations may be soldered onto surface mount PCBs in seconds.

TAB components represents the current state-of-the-art in component miniaturisation, and are finding their way into more and more appliances. Nowadays, only high-volume mass-produced appliances such as digital watches, pocket calculators, smart-cards and so on are benefitting, but in the future, all areas of electronics will undoubtedly feature them.

Component Handling

Because most surface mount PCBs are made with the aid of machine assembly, the subject of how to handle the components and ensure they are at the assembly point when the machine requires them, is of vital importance. As you might expect, there's a number of handling methods. The first, we've already seen, is taped and reeled components.

Reeled taping of components is not restricted to TABs. All surface mounted components may be taped on a reel — indeed, this is often one of the major design factors for SMCs. Tape can be of paper type but more often is of a blistered polyimide construction, shown in Fig. 7. As the tape is sprocket driven, taping of components aids PCB assembly as components can be fed to the assembly point one after the other, as fast or as slowly as the machine can cope. Further, each component is guaranteed to be right way round. Different tape widths are available for different component dimensions, following the major widths of photographic film (8mm, 16mm, 24mm and so on) for the obvious reason that the required sprocket drive mechanisms are readily available.

Other means of handling components include magazines (Fig. 8). Many types are used, but all have the disadvantage of holding limited numbers of components. Where taped and reeled components may be reels of many thousands of devices, magazines only hold a hundred or so components at most. Also, each magazine is specific to particular assembly machines.

Simple two-terminal, non-polarised components are sometimes handled in bulk. They are typically poured into a hopper on the assembly machine and simply vibrated to the assembly point. Although on the face of it this seems a perfectly good means of handling, component dimensions must be strictly maintained as the vibratory feeder system will only handle one particular size of component. Each different size of component requires a different vibratory feeder.

Assembly

Unless hand-assembly of components is to be undertaken, an assembly machine will be used to position the components onto the surface of the board. Component positioning is commonly known as placing, and so assembly is more often called component placement.

Generally, the major part of the assembly machine will be formed by a placement head which

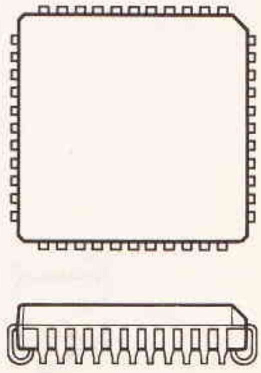


Fig. 6 Plastic leaded chip carriers (PLCCs) house chip integrated circuits, and have J-shaped terminations

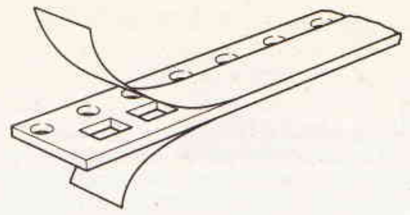


Fig. 7 Taping methods for surface mount components (a) paper tape (b) plastic blister tape

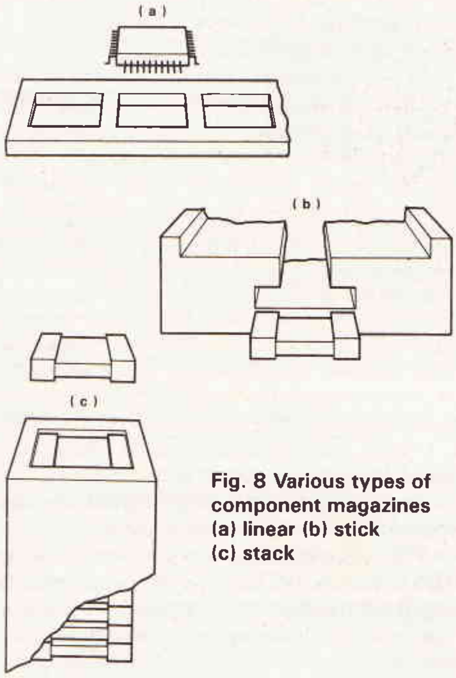


Fig. 8 Various types of component magazines (a) linear (b) stick (c) stack

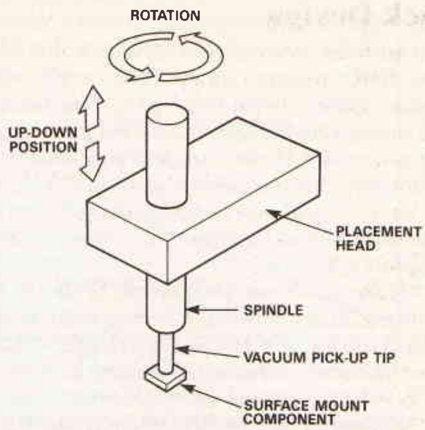


Fig. 9 'Pick and place' placement head

selects the next component to be mounted onto the PCB then mounts it. The operation is often called 'pick and place' for this reason. Figure 9 shows the basis of such a placement head, where a vacuum tip holds the SMC, and a spindle assembly allows rotation and up and down motion.

Because of the small size of components, placement must be highly accurate (as high as ±0.05mm for some types of components — generally, the more terminals a component has, the more accurate placement must be. Such high accuracy cannot always be obtained by purely mechanical means, vision is used in some assembly machines, where a camera monitors the PCB and the placement head to aid accuracy. PCBs must feature a machine-recognisable mark (known as a *fiducial* which allows the machine to correct for any mechanical tolerance under microprocessor control.

Soldering

It is usual to solder the whole PCB at one time — known as mass soldering. Industrial mass soldering machines used for through-hole PCBs *can* be used for surface mount PCBs as long as the surface mount components themselves allow this. The problem with conventional through-hole soldering machines is that they leave a considerable amount of solder behind after the soldering process. Such machines rely on the mounting of components first, followed by the simultaneous application of solder and heat to form the required joints between components and PCB track, and so they are sometimes known as CS processes (component/solder). The most common CS soldering process for through-hole PCBs, wave soldering has the assembled board passed over a wave of molten solder.

There are two problems when attempting to CS solder surface mount PCBs.

First, SMCs are mounted on the same side of the board as the track. So to wave solder a surface mount PCB, the board must first be inverted before soldering. By the law of gravity, components will fall off! If wave soldering machines are to be used for soldering of surface mount PCBs therefore, components must first be stuck to the surface of the PCB with adhesive.

Second, some components with small closely-spaced terminals cannot be soldered by wave soldering, simply because the excess solder which is feature of the process bridges the terminals, causing short circuits.

With a few exceptions, therefore, most surface mount PCBs are soldered by other means. Usually, these rely on adding a small amount of solder first, in the form of solder paste, then placing the component, finally heating to melt the solder. Such processes are sometimes called SC processes, although the name reflow soldering is often incorrectly given (reflow refers to the re-heating of previously applied solid solder — not solder paste). Addition of solder past first means that an accurate dose can be applied — avoiding the bridging problems of wave soldering. The process also avoids adhesive as the PCB doesn't need to be inverted.

A number of methods of SC soldering processes are available, of which infra-red heating elements and heating by the latent heat of evaportation (by immersing the assembled PCB in the vapour of a heated liquid) are the most common.

Either way, if a surface mount PCB is soldered by CS or SC means, adhesive or solder paste must be applied at the assembly stage. The two methods are illustrated in Fig. 10. Actual application of either adhesive or solder paste is formed in one of three different ways, shown in Fig. 11. These are:

- *screen printing* — a nylon mesh screen is impregnated with a negative of the pattern of adhesive or paste to be applied to the PCB and is then stretched over the PCB. A squeegee (rubber block) is used to force adhesive or paste through the screen where the negative pattern does not exist, thus forming a positive pattern on the PCB.
- *pin transfer* — pins are dipped into the adhesive or paste reservoir, then applied to the PCB, leaving small dots of adhesive or paste on the PCB.
- *nozzle dispensing* — syringe-type nozzles pump adhesive or paste directly onto the PCB.

After application the components must be immediately placed, then the PCB should be allowed to cure before heating or soldering.

Track Design

More so than conventional through-hole components, SMCs require that the PCB track layout be designed extremely carefully. SMCs are small and have closely situated terminals so the track needs to be very accurate. Further, track dimensions depend very much on the soldering process used. If the PCB is to be wave soldered (a CS process) component lands will need to be larger than those of an SC soldered PCB.

Figure 12 shows component lands for small outline transistors. The inner shaded area represents the land size for a PCB which is to be SC soldered, while the outer shaded areas indicate land sizes for a PCB to be CS soldered.

Small outline integrated circuit: width depends on the number of pins (SO4 to SO16=4mm, SO20 to SO28=7.6mm), so land positions vary accordingly. Pin spacing for all SOICs is 1.27mm. Land centre-to-centre spacings are:

SMC	SC soldering	CS soldering
SO6 to SO16	5.1mm	5.8mm
SO20 to SO28	9.6mm	10.2mm

PLCC land dimensions are shown in Fig. 12. Numbers of lands along each edge depend on individual PLCCs. As PLCCs (with only a few exceptions) need to be SC soldered, dimensions are fixed and no options are given.

Thermal Considerations

There are two important considerations to bear in mind for surface mount PCBs. First, the miniaturisation creates a secondary problem — heat. The smaller and closer together components are, the hotter the assembly gets. Supplementary heat extraction in the form of heatsinks and fans may be needed.

However, the second heat consideration is by far the most important. It is caused by the different thermal coefficients of expansion (TCEs) of components and circuit board base materials, and is often called *thermal mismatch*. To see how important it is, you have to consider the soldering process. As the solder melts, both PCB and components are at the soldering temperature (around 200°C). As the assembly cools, the board and the components contract at different rates due to the different TCEs. Significant stress on the soldered joints results, which can fracture the joints.

The problem is specifically a surface mounted one, because although thermal mismatches ocur between leaded through-hole components, the leads themselves are compliant did flex, taking up any differences in length automatically. Many surface mounted components have no such in-built compliancy, as they are leadless.

In the extreme, the best solution is to use a PCB base material which has the same TCE as the components. Substrates such as alumina and beryllia have been used which do just that, and form the only solution where extremely large variations in temperatures are likely to occur (space, military and so on). As you might expect though, substrates like these are expensive and difficult to manufacture, unlike fibre glass PCBs.

Fortunately however, simpler alternatives have been developed for general-purpose SMAs. The first simply ignores the problem. Small two-terminal components (up to about 6mm in length) such as chip capacitors and resistors, can be used without problem because the even smaller difference in length due to thermal mismatch is absorbed by the solder joints. Low complexity circuits (without complex integrated circuits), should suffer no joint fractures.

Where ICs are required in a circuit, small outline devices, PLCCS and TABs can sidestep the problem. Such SMCs have terminals, albeit small, which allow a compliancy which prevents damage by thermal mismatch.

Amateur SMA

As far as amateur production of PCBs is concerned, it'll probably be a little while before surface mount PCBs become the norm. Readers will appreciate from this feature that assembly and soldering of the small SMCs is no mean feat by hand. For a good few years

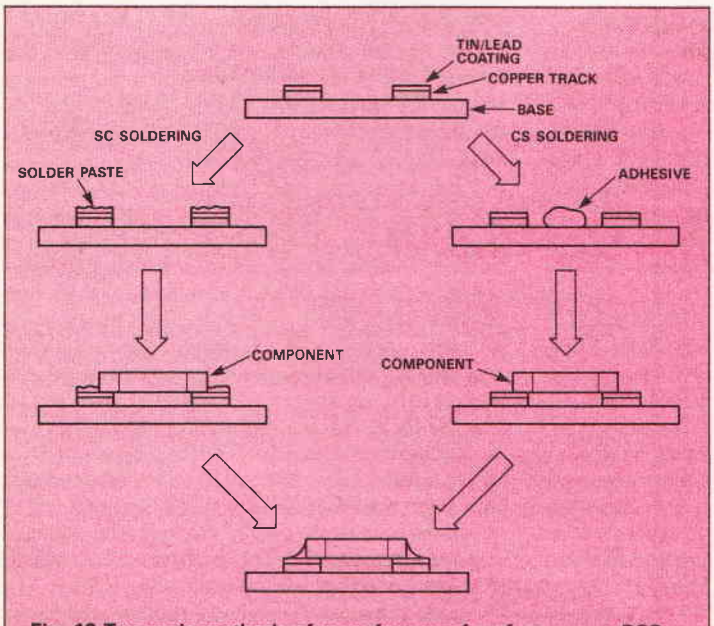


Fig. 10 Two main methods of manufacture of surface mount PCBs (left) applying solder paste, followed by component placement and SC soldering (right) applying adhesive, followed by component placement and CS soldering

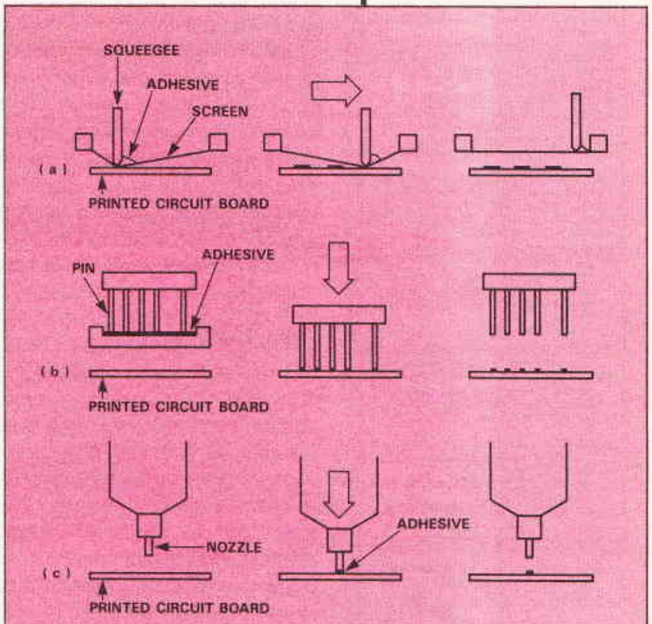
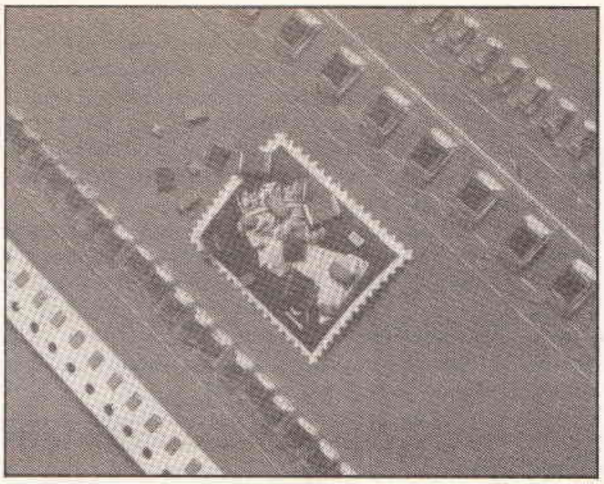
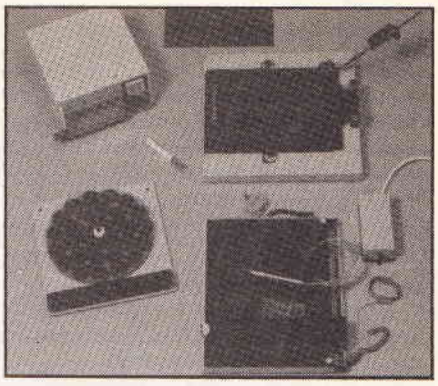


Fig. 11 Three methods of applying adhesive or solder paste to the surface mount PCB (a) screen printing (b) pin transfer (c) nozzle dispensing





Starting from 12 o'clock — clockwise: stencils and squeegee; stencil printer; placement table and vacuum pen; rotary component carousel; infra-red oven

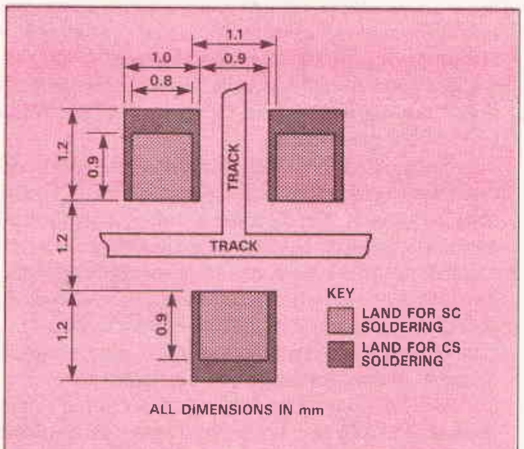


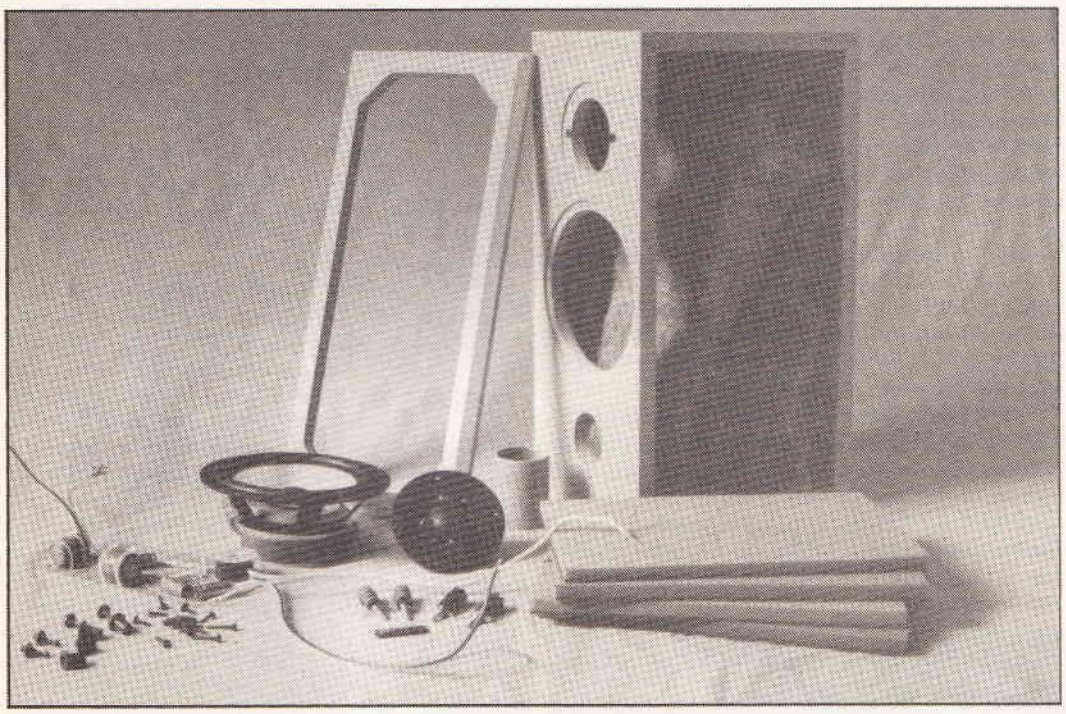
Fig. 12 Land sizes for small outline transistors

yet, through-hole PCBs will be used in ETI, and its ilk. However, like it or not, as worlwide industrial production of PCBs goes towards surface mount processes, it will be simple fact that fewer and fewer leaded components will be available for amateur use. Eventually of course, none will be left and only SMCs will be around (and this may be in the not-so-distant future — so watch this space!).

Some suppliers are already gearing up to hand production of surface mount PCBs, and tools are already available. Specially shaped soldering iron bits, allowing simultaneous soldering of all terminals of small outline components and so on will form the amateur's main arsenal of tools. Magnifying glasses are also extremely useful purchases! With such tools, and a reasonably steady hand, hand soldering of even the most complex of TAB integrated circuits is not outside the realms of possibility.

ETI

DIGITAL 90 SPEAKER KIT



REVIEW

Colin Shelbourn reviews an improved speaker kit from Wilmslow Audio

There is something enormously satisfying about building your own loudspeakers. It's partly the sense of achievement, partly the knowledge that you're saving huge amounts of money, but most of all it's the feeling of smugness as you demonstrate them to hi-fi minded friends and subtly point out that you built them yourself.

All this turns to ashes however, if a hi-fi friend turns round and says, "Ah yes, but *my* speakers have got the latest metal dome tweeters." Curses. No matter how satisfying, your own speakers never sound the same again.

The problem with DIY speakers is that, whatever their sonic merits, they often seem to miss out on the latest trends and technology. Enter the Wilmslow Audio Digital 90. In terms of the drive units used, this must be one of the most up-to-date DIY designs currently available.

The Digital 90 has been put together around an Elac 25mm metal dome tweeter, a unit which has appeared in a number of favourably-reviewed speakers in the last year or two — including models from Musical Fidelity, Monitor and TDL. Wilmslow has been offering it as an upgrade kit for some months now, but this is the first time it has been used it in a complete loudspeaker. It is paired with a 170mm polypropylene bass/mid unit from Scanspeak (a Danish manufacturer better known for its D2008 tweeter used by Linn, Naim, Spendor and a few others). The drivers are linked to the outside world via a ready built third-order crossover and mounted in a 15-litre reflex-loaded cabinet. All good upmarket stuff and obvious DIY competition for speakers like the Musical Fidelity MC-2 and Celestion SL6. The kit comes with a flatpack cabinet (including a frame for the grille), reflex tubes, acoustic panels and wadding, and all the necessary connectors and screws. There's even grille cloth and a pair of little stick-on badges. As kits go, it is not cheap — it costs £259 including VAT.

My speaker projects usually start out with a large sheet of plywood or chipboard and get messier from there onwards, so building the 90s felt like cheating. The cabinets are made entirely of Medite, a smoother, high density version of chipboard which is far nicer to work with and easy to paint or veneer. All the cabinet panels are supplied fully cut and drilled. All you have to do is slot 'em together and provide the glue and a few tools.

The instructions all seemed straightforward, so once I had checked that everything fitted and there was nothing missing, I got out the stopwatch and started gluing.

It really was kitchen table stuff. Wilmslow suggest that whilst the glue sets, you can hold the cabinet together with masking tape, though a set of clamps would come in handy. The cabinets went together like a dream — the only problem arose when I came to fit the crossovers. The instructions blithely tell you to: "fit crossover network to back panel as shown in diagram". Screws are supplied, but what they don't warn you is that screwing into Medite is a pain. Also, the screws supplied were too long; if I had tightened them down they would have come through the back panel. On my second cabinet, I drilled some pilot holes first and smeared Vaseline on the screws to make them go in easier. (This always looks a highly suspect practice, so make sure that no one is watching you.)

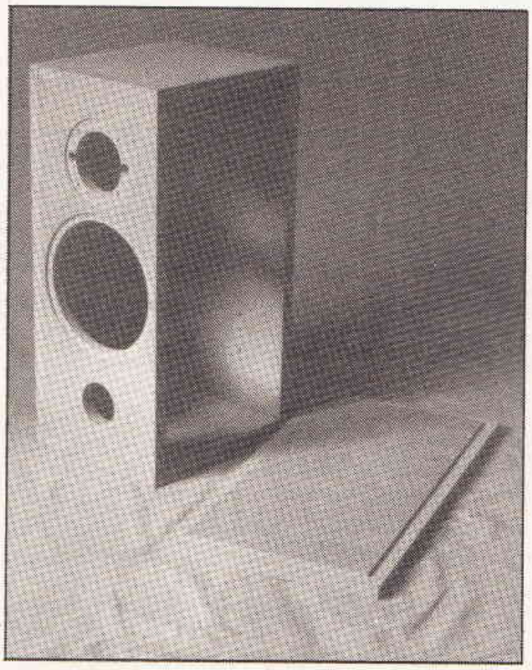
Wilmslow supply two types of acoustic treatment: 'Wacoustic Panels' for the walls (these are self-adhesive bitumen and foam pads which simply press into place) and Acoustimax wadding to lightly fill the interior. I was surprised at the lack of any internal cabinet bracing. If I had built these for myself, I would have been tempted to fit a vertical figure-of-eight brace, to stiffen up the top, base and side walls. Maybe even an additional shelf along the back panel. Possibly the Wacoustic panels are good enough to keep panel resonances under control. Me, I prefer belts and braces.

The crossovers connect to two pairs of binding posts on the back panel; that's right, the Digital 90 comes ready for biwiring. All praise to Wilmslow Audio for leaping on this particular bandwagon so quickly.

The Elac tweeter comes with its own thin gasket to ensure an airtight seal, but the Scanspeak unit is devoid of such frills. The instructions suggested bedding it into a layer of glue. Frankly, I would be reluctant to start hurling glue around £40 worth of drive unit. I used a thin ring of Blutak.

An additional niggle here; the Scanspeak is a fairly heavy drive unit and I would have thought needed something more substantial to hold it in place than six small woodscrews. The usual practice is t-nuts and bolts. Failing that, how about those double threaded chipboard screws?

Crossover apart, I encountered no problems in building the speakers. Anyone who can identify the business end of a screwdriver could have them built in about five hours. The only bit which looked tricky was fitting the grille fixing pegs to the grille frame. This requires some careful drilling and — mostly due to time — I skipped it. The speakers look good enough with the grilles off.



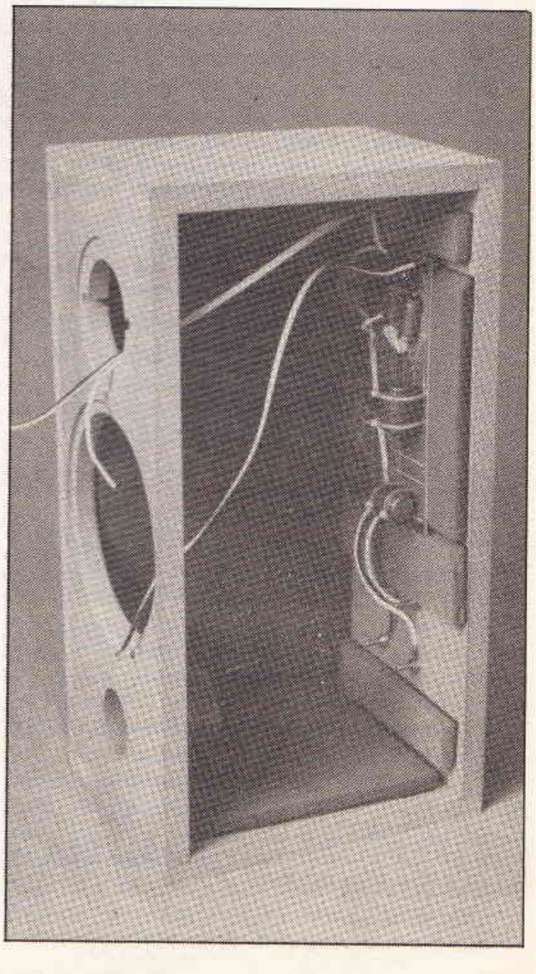
Anyway, enough of nit-picking. How did they sound? Well, this took a while to find out. Wilmslow don't offer any specific recommendations regarding placement ("Use them where they sound best," said Dick Stephens, Wilmslow's MD). I used them on a pair of Russ Andrews Torlyte stands, which are very light but tremendously rigid. They're spiked top and bottom and lift the speakers 14 inches off the floor. After some moving around — to the detriment of my carpet — I eventually settled on placing the speakers quite close to a rear wall, toed in to fire directly at the listening seat. Your combination of depraved tastes and room may require something different however. (As with all their designs, you can hear them for yourself in a dedicated listening room at Wilmslow Audio.)

Finally I was ready to go. I never believe anything I read in the hi-fi press, so I was sceptical of the benefits of bi-wiring. I began by using the 90s in conventionally wired mode. Once I got used to the sound, I added the extra cables and removed the links between the terminals on the back of the speaker. (Incidentally, have you ever tried fitting two lots of speaker wire into a banana plug? When are amplifier and plug manufacturers going to catch up with bi-wiring?).

Hmm! So much for scepticism. Bi-wiring made the speakers sound dramatically clearer and more immediate. Have we really been listening to muddy speakers for all these years for want of such a simple modification?

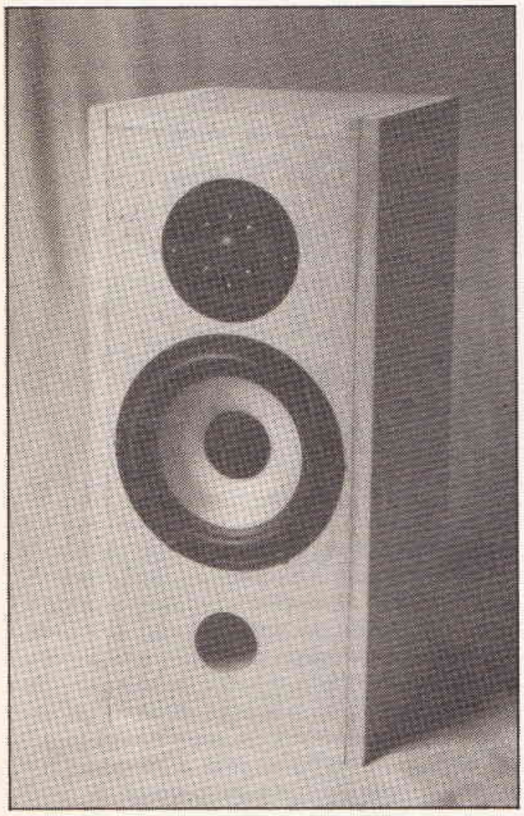
My hi-fi is probably the sort of middle range system the Digital 90s can expect to end up in — Musical Fidelity A1, Rega turntable and Yamaha CD player. The 90s are about average sensitivity, so the A1 had to work a little harder than it was used to, but at least that meant it was turning electricity into music instead of heat!

I have a marked aversion to the sizzly, over-bright treble that seems to afflict the majority of hi-fi loudspeakers. I like detail and clarity, but I don't like to feel I'm being raked with a laser all the time. The 90 came as a huge relief. The treble was clear and delicate, but it didn't shout at me or draw too much attention to itself. First points to the Elac. My only criticism is that it sounded 'wispy' at times, emphasising breathing noises. Further down the range, the 90s didn't have deep bass in abundance — I heard drum rolls but didn't feel them — but then I suppose you can't expect too much for a cabinet only 19 inches high. The bass had a curiously rubbery quality, but it seemed to improve the more I played them. The speakers were good at getting to grips with 'tactile' sounds — the resiny sound of bow strings, for example — but had a tendency to sound a little lightweight, until some real bass came along and I started to think that they weren't so bad after all. Not



the most exciting speakers to listen to but they always sounded natural, relaxed and on the whole self-effacing. A good speaker for classical music or acoustic instruments.

The Digital 90 is a high quality speaker which can more than hold its own against ready-built, commercial models at or above its price level. By going the DIY route, you're not restricted in how your speakers are going to look; Wilmslow sell a range of iron-on veneers and Medite takes paint easily (you can achieve an interesting marbled effect simply by staining and varnishing). Additionally, the speakers are easy to modify is you want to try out the latest hi-fi 'tweak'. Personally, I wouldn't dream of buying a ready-built alternative. Constructing is more satisfying than merely consuming any day.



Extended listening to the 90s led to a vague dissatisfaction with the treble, which seemed to be playing separately from the mid and bass. Changing the phase of the Elac drive units didn't appear to change anything. Finally a couple of small modifications which the constructor may find worthwhile. (Wilmslow's instructions suggest both units are wired in phase with each other).

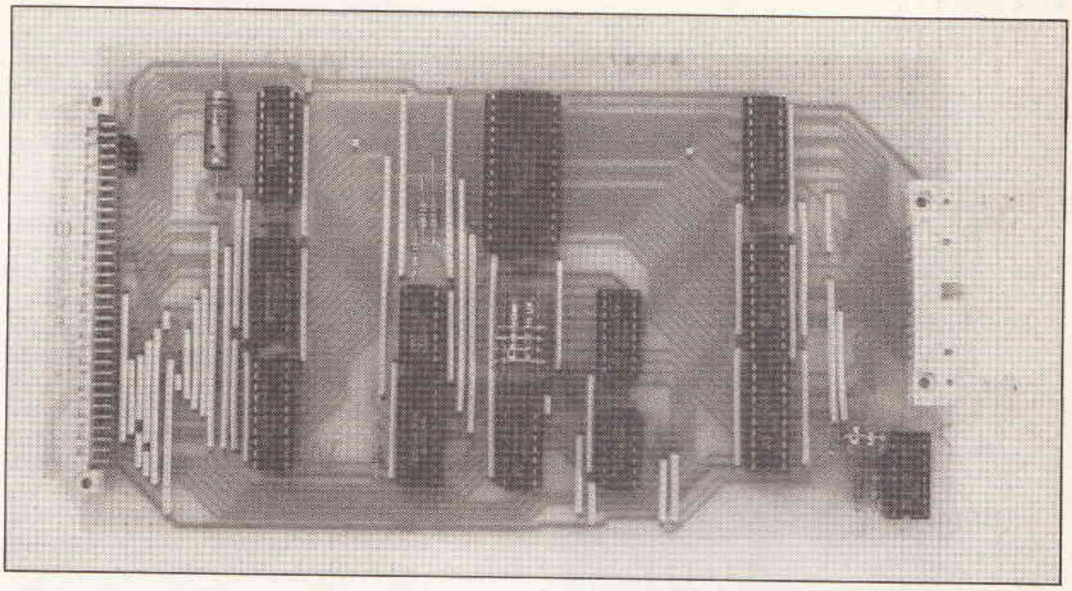
The bass can sound waffly in some locations. This is possibly a function of room, furniture, and, or musical tastes. Testing the response of the 90s (using an Apple Macintosh and MacRecorder program as a rather expensive sine-wave generator) I found that it falls off quite quickly below 68Hz. Blanking off the reflex port got rid of the waffle without losing much in the way of bass and, to my ears, the whole system sounded a lot cleaner.

SPECIFICATION

Cabinet volume	15 litres
Response	40Hz-20kHz (no tolerances given)
Sensitivity	86.5dB 1W/1m
Power handling	100 watts
Dimensions	480mm high × 220mm wide × 250mm deep

ETI

EPROM EMULATOR



A 32k EPROM Emulator which can also be used in 6502 or 6809 home computers, Mike Bedford explains

A number of years ago we published the design for an EPROM emulator capable of emulating the 2758, 2716, 2732, 2532, 2764 and 2564 EPROMs together with the A-suffix variants (1,2). This card adhered to the Tanbus specification and was therefore aimed primarily at the then large bunch of Tangerine Microtan devotees. Subsequently this same card has been used as a constituent part of the ETI Stand-Alone EPROM Programmer / Emulator (3,4). The design for this unit made provision for a forthcoming MKII emultor card, this new board being the subject of this article.

Having 32K bytes of memory compared to the 8K of the original emulator, the MKII card is able to emulate the EPROMs listed above plus the 27128 and 27256 (together with their A-suffix variants). Furthermore, it increases the internal memory of the Stand-Alone EPROM Programmer / Emulator to 6K hence allowing EPROMs up to 27512 to be read into the unit. Of course, since the stand-alone unit was designed around the Tanbus specification this card will plug straight into a Microtan if there are any Tangerine enthusiasts still out there. Also, with a bit of extra work, primarily on the mechanical side, this card could be used with any other home computer based around a 6502 or 6809 processor. The BBC comes into this category and is probably the most likely application of this card other than as a part of the ETI Stand-Alone EPROM Programmer / Emulator.

Apart from the increased memory size there are a number of other differences between the MKI and the MKII emulators. The underlying philosophy of the current design is KISS (Keep It Simple Stupid)! One major difference between the two emulators is the battery back-up of the RAM. The MKI design used CMOS RAM(as an option) with a switchable on-board battery supply and gating of the $\overline{CE}$ signals to prevent false writes at power on/off. In accordance with the KISS approach, all this complication has been done away with and the MKII emulator RAM is not backed up. In justification of this apparent backwards step is the fact that 5 years ago most Microtan systems had cassette decks as mass storage and anything to avoid repeated loadings was much appreciated. With today's abundance of floppy (and even hard) discs, loading code is not accompanied with the same feelings of trepidation and dread!

One result of battery backing up the memory of the MKI design is the extra propagation delay put into the $\overline{CE}$ signal by virtue of it being gated on power-down. This was further aggravated by the address decoding required to split the $\overline{CE}$ out into separate signals for each of four RAM chips. In the new design neither of these restrictions apply (thanks to bigger RAMS) and the $\overline{CE}$ and $\overline{OE}$ circuitry is generally much simplified hence giving a much more acceptable access time (also of course the available speeds of 62256s are much greater than those which were available for the 6116). In passing, the eagle eyed constructor of the Stand Alone EPROM Programmer / Emulator will have noticed that there is no 'Emulate' signal on this emulator despite the fact that the programmer's mother board does route signal of this name to the emulator slot. At the time of designing this mother board it was envisaged that part of the emulator simplification process might involve the use of such a signal rather than the automatic approach used on the MkI card. In fact this hasn't been done and the access rules are the same ie. the target system has access to the memory via the emultor pod unless the host (ie the Stand Alone Programmer / Emulator) tries to access it in which case it gets priority.

Construction

This really shouldn't cause any difficulties. With the exception of configuring the links to the required address range and a word about the pods, there aren't any special instructions. Figure 3 shows the five ways LK2 and LK3 may be configured by give 32K of contiguous memory. There are other addressing possibilities in which the 32K is split up into as many as four separate blocks and Figure 3 (f) shows the generalised linking information which will be required to do this. If configuring to use non-contiguous blocks of memory, it must be ensured that none of the blocks picked have addresses which are identical except for bit 15 as these whould end up mapping onto the same place (so for example the \$0000—\$1FFF blocks are an illegal pair). Also, if using non-contiguous blocks the constructor will have to work out the required Link 3 configurations himself — having read the how it works section this should't be too difficult. If you are thinking of using adjacent blocks, there are some options for which it won't be possible to come up with

PROJECT

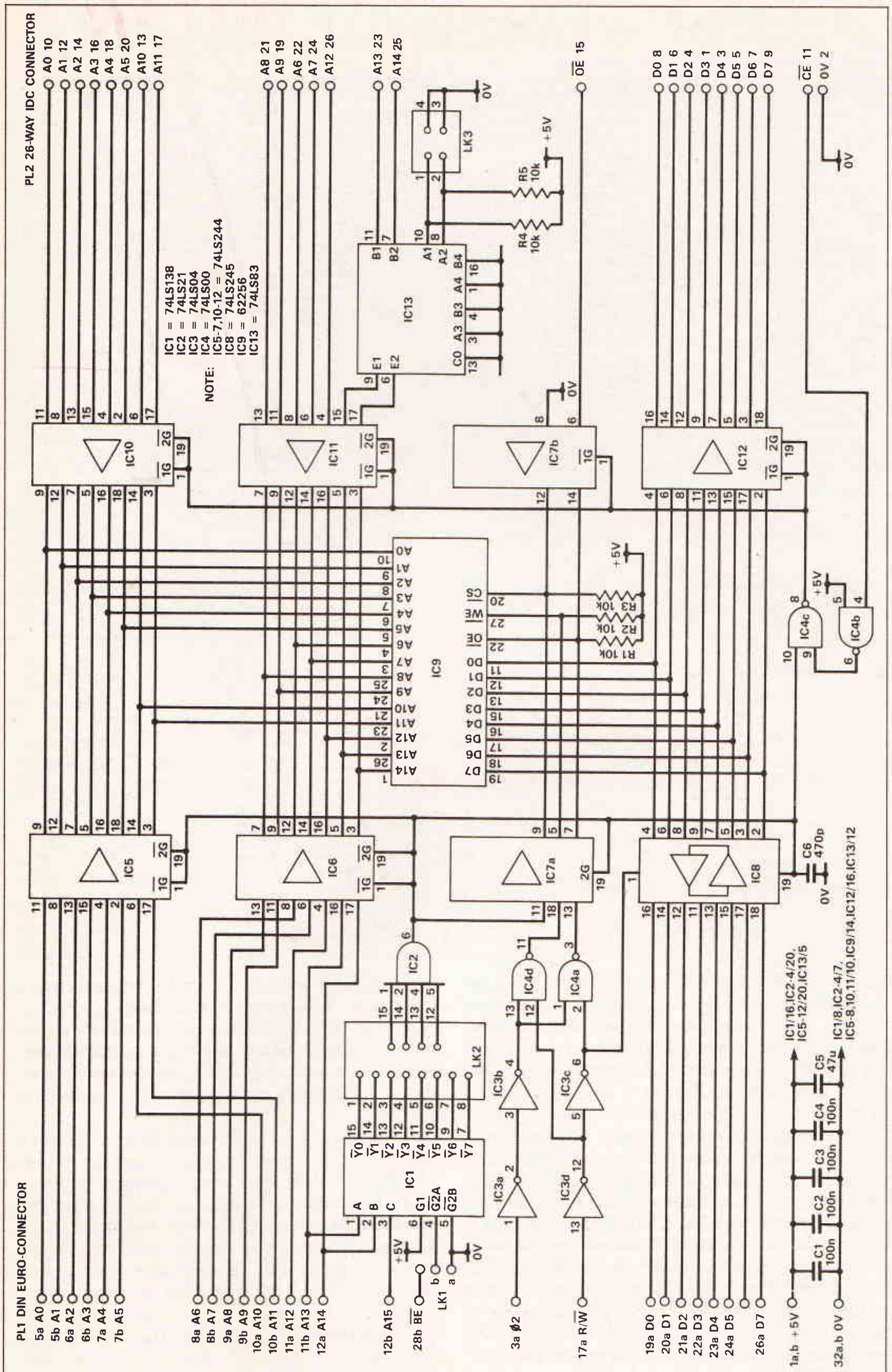


Fig.1 Mk II Emulator card for stand-alone EPROM Programmer/Emulator circuit diagram.

an LK3 setting to put the blocks in the same order from the target port. This shouldn't really matter too much as software loading into non-contiguous memory on the host will have to be aware of the discontinuities so could just as easily take account of the order at the same time. The other link which requires configuraton is LK1. If set to (b) the $\overline{BE}$ signal will be active and this signal must then be low in order for the card to be addressed from the host port. This option is used in a multiple page address map, something which is used to increase the addressing capacity of an 8-bit computer beyond 64K. If LK1 is set to (a), the card is always available to the host port. The section entitled Stand Alone Programmer / Emulator Memory Configuration explains the arrangement of all these links for use in this piece of equipment.

Coming to the pods, at least one will be required and possibly all four depending on the EPROMs to be emulated. Most of the connections between the

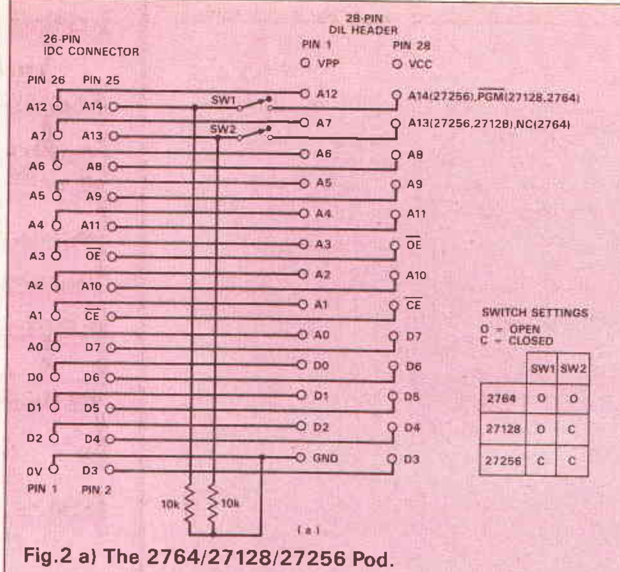


Fig.2 a) The 2764/27128/27256 Pod.

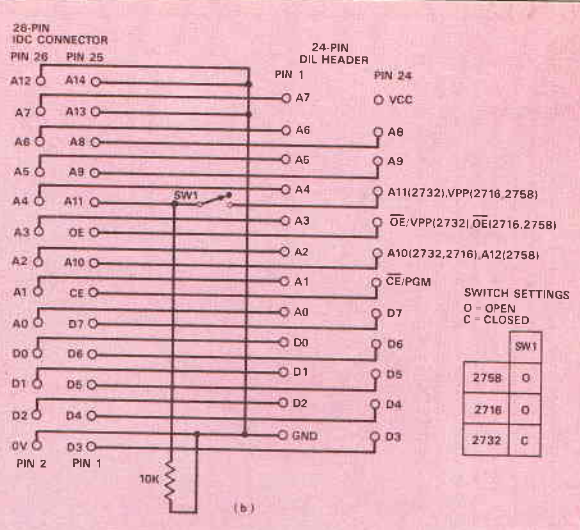


Fig.2 b) The 2758/2716/2516/2732 Pod.

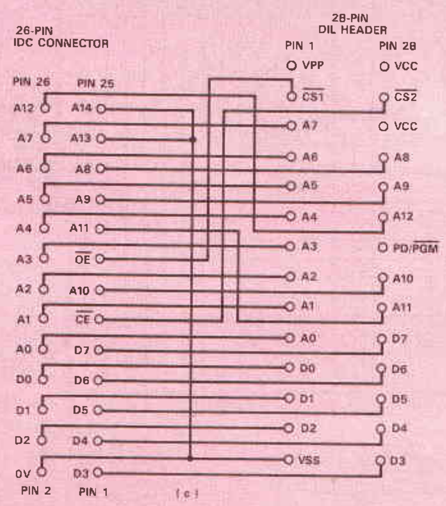


Fig.2 c) The 2564 Pod.

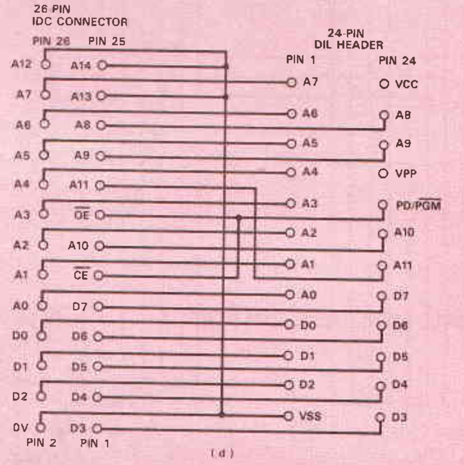


Fig.2 d) The 2532 Pod.

KIL header and the IDC cable connector will be correct (but possibly mirror-imaged or upside down if done absent mindedly!) if the ribbon cable is connected straight through between the two connectors. Although it isn't pin 1 to pin 1, pin 2 to pin 2 . . . pin 26 to pin 26 this is only because the numbering convention on the IDC cable connector is different to that on the DIL header. The switch and resistor(s) (where needed) can be easily and neatly accommodated inside the cover of the DIL header (if using the type recommended in the parts list) and gives a very acceptable result. Figure 4 shows how this is done. Since this method of construction is so successful and since 1 way DIL switches are not made I think it would be advisable to use a 2-way DIL switch on the 2758/2716/2516/2732 pod and forget about one of the gangs thereafter. On the fitting of IDC connectors, special and very expensive tools are supposed to be used. I have found that a metal-working vice can be used quite successfully but the would-be constructor is strongly advised against attempting the operation with a block of wood and a hammer! I should say that it was originally intended to use an IDC type of DIL header but found that for some strange reason they are designed so that conductor 1 of the ribbon cable cannot be connected to pin 1 (or actually the diagonally opposite one which is really what is required) but instead goes to pins 28/24 (or the diagonally opposite one). However, on thinking about the situation it was decided that the convenience of using an IDC connector here is much reduced by the fact that not all of the conductors do go straight through and also, in an application such as this where the header will be frequently plugged in and out, a solder type of DIL header will be more robust. This being so, a solder type of DIL header must be used.

Aspects which could be described as tidying up are often overlooked by the home constructor. Labelling the pods comes into that category but could save a lot of time in the long run. In 3 months time how many people would be able to remember which pod is which or how to set the DIL switches? The DIL header cover has sufficient room on its top face and sides to do quite a good labelling job. Using Dymo tape, strips of 8 characters may be accommodated on the 28 pin header. The two labels I have used on the 2764/27128/27256 pod are as follows: '2764-256' and 'OO/OC/CC' the latter indicating that switches 1 and 2 should be open/open, open/closed and closed/closed for the 2764, 27128 and 27256 respectively. I strongly advise doing something on these lines.

A final point about the pods concerns a couple of EPROM types which have been mentioned in the series of articles on the EPROM programmer but for which pods have not been presented here. These are the 68732 and 68764. It is thought unlikely that many readers will want to emulate these rather unusual devices but with a bit of thought, pods for these (or

PARTS LIST

RESISTORS	
R1,2,3,4,5	10K, ¼W, 5%
CAPACITORS	
C1,2,3,4	100n, ceramic
C5	47µ, 16V, axial electrolytic
C6	470p, ceramic
SEMICONDUCTORS	
IC1	74LS138
IC2	74LS21
IC3	74LS04
IC4	74LS00
IC5,6,7,10,11,12	74LS44
IC8	62256
IC9	74LS245
IC13	74LS83
MISCELLANEOUS	
PL1	64-way a+b DIN 41612 plug with 90 degree solder pins
PL2	26-way male IDC connector with latches and 90 degree pins
LK1	3-way 0.1" pin strip and shorting link
LK2	Wired on 16 pin DIL header
LK3	Wired on 4 pin DIL header (Cut down 8 pin header)
IC Sockets	3×4 pin, 3×16 pin, 7×20 pin, 1×28 pin, 1×4 pin (cut down 8-pin)

PCB
Wired for links

(27256/27128/2764 Pod)
26-way IDC cable connector (female)
28-pin solder type DIL header
26-way 0.5" pitch IDC ribbon cable
2-way DIP switch
2 × 10K, ¼W resistors

(2732/2716/2758 Pod)
26-way IDC cable connector (female)
24-pin solder type DIL header
26-way 0.5" pitch IDC ribbon cable
switch – ordinaryminiature toggle or use 1 gang of 2-way DIP 1 × 10K, ¼W resistor

(2564 Pod)
26-way IDC cable connector (female)
28-pin solder type DIL header
26-way 0.5" pitch IDC ribbon cable

(2532 Pod)
26-way IDC cable connector (female)
24-pin solder type DIL header
26-way 0.5" pitch IDC ribbon cable

any other obscure EPROMs up to 32K) could be made by following the principles seen in the design for the other pods.

Memory Configuration

The diagram below shows the actual memory map of the stand alone EPROM programmer / emulator as originally intended together with the three options for the pseudo memory map. The pseudo map is the way the user sees the RAM thanks to some 'jiggery pokery' by the firmware. One of these three options is automatically selected at power on depending on whether one of the two emulator cards is detected.

Now when the firmware for the programmer was written the hardware of the MKII emulator was not complete and as such option 3 was not incorporated. Unfortunately, now the MkII card does exist, the author of the firmware is unable to commit to making the necessary modifications. This being the case, the builder of this MkII emulator has two alternatives for its incorporation into the stand alone programmer. The simplest alternative is to use it in place of the 32K block of memory on the SBC. The only disadvantage of this approach compared to the original plan is that it doesn't give the additional advantage of being able to program 27512s as a single block. The emulation capabilities are un-affected, the 27256 may still be emulated and a 27512 is still programmable but now it has to be done in two halves. In order to do this LK2 and LK3 should be configured as shown in Figure 3(b) hence setting up the required $2000 base address and LK1 should be set to (b) hence disabling the $\overline{BE}$ input. Also the RAM chips H1, K1, K2 and L1 should be removed from the SBC card and pin 11 of IC C2 (74LS04) (also on the SBC) should be disconnected from the $\overline{BE}$ input and tried to +5V. If the user finds the programming of 27512s in 2 blocks too much of a hassle then alternative 2 is to configure it as originally intended but this is more of a challenge. The recipe is this: firmware source listing from Gordon Bennett and a bit of time and effort with a 6502 assembler which is what you supply. If this approach is taken then LK1 (a) need selecting but LK2 and LK3 are still configured as in Figure 3 (b).

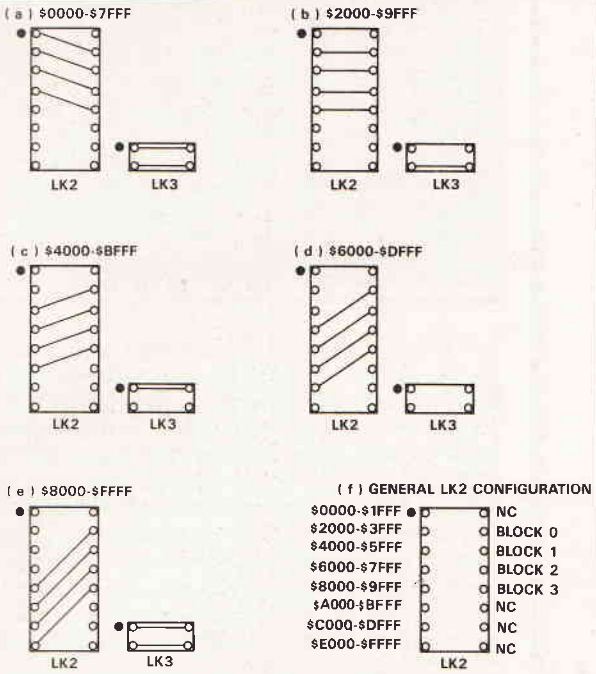


Fig.3 Address links.

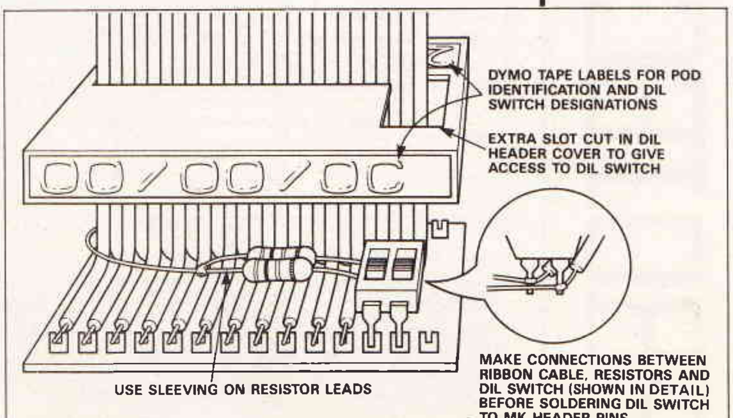
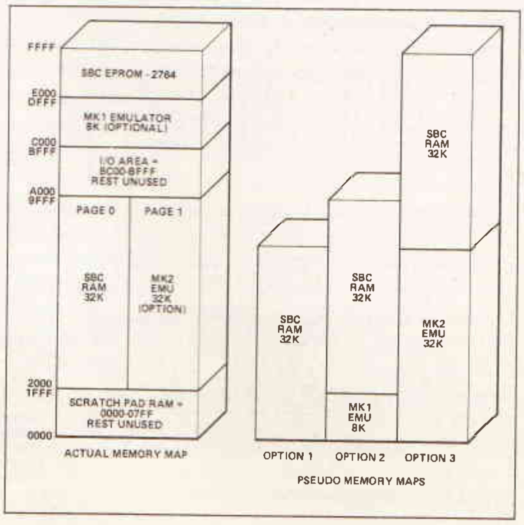


Fig.4 Mechanical detail of Pod.

HOW IT WORKS

Essentially an EPROM Emulator is a block of RAM arranged to be dual ported such that the address, data and control busses may be under the control of either the host system (in this case the Stand-Alone EPROM Programmer / Emulator) or the target system (ie the system containing the EPROM to be emulated). The block of 32K RAM is provided by a single static RAM chip. It is interesting to reflect on the fact that only 5 years ago, the MkI design required 4 chips to give 8k. The dual porting is achieved by connecting each signal pin on the RAM to two tri-state buffers. The host bank of buffers (ie IC5, IC6, IC8 and half of IC7) is enabled by the address decode circuitry for the host port (described later) but has the addition of C6 to 'capture' short duration transients and so prevent false enabling of the buffers during the address setup period of a memory cycle. This is something which doesn't matter in a straight memory card as it doesn't upset things if the buffers are enabled for the odd nano-second during the address setup time. The enabling of the host buffers coincides with the disabling of the target buffers and this would cause a problem as it could happen at any time in the target system's memory cycle. The other bank of buffers (ie IC10, IC11, IC12 and the other half of IC7) is enabled by the $\overline{CE}$ signal on the emulation port but only if the $\overline{CE}$ condition does not exist on the host side. Since the address and control signals are inputs to the RAM, they are connected to the outputs of buffers (IC5, IC6, IC7, IC10 and IC11). The data bus signals may be inputs or outputs but since one port is emulating an EPROM which has no write facility, they are outputs as far as this port is concerned. This being the case, the RAM data pins connect to the inputs of buffers on the EPROM port (IC12) whereas the corresponding buffer for the host port is bi-directional (IC8). The direction of this buffer is controlled by the R/$\overline{W}$ signal on Tanbus. The reason for 2 of the Tanbus signals (R/$\overline{W}$ and 02) having an extra inverter is to adhere to the normal practice of limiting the loading on the bus which is specified (in the case of Tanbus) as 1 LS TTL per input. Turning to the RAM control signals, $\overline{CE}$, $\overline{WE}$ and $\overline{OE}$ are required. $\overline{CE}$ and $\overline{OE}$ are available directly on the EPROM port as these signals are common to most EPROM types. Since EPROMs are read only, the $\overline{WE}$ signal is not connected to a target buffer. As with $\overline{CE}$ and $\overline{OE}$, the $\overline{WE}$ signal is pulled high via a resistor at the RAM side of the buffers to keep the signal non-active. Failure to do this could result in data corruption between memory accesses (inputs that float high should not be relied upon). It will be noticed that the $\overline{CE}$ signal from the target port is not actually switched through a buffer on the RAM but instead a permanent 0V is switched onto the RAM's $\overline{CE}$ pin. Since the buffer can only be active when $\overline{CE}$ is low, the result will be the same. This prevents loading the EPROM with more than 1 TTL input on its $\overline{CE}$ pin. Things are not quite so simple from the Tanbus port. The $\overline{CE}$ is derived from a decode of the top 3 address bits hence allowing the card to be located at any 8K boundary. These address bits are fed into IC1, a 3 to 8 line decoder which gives a low at one of its outputs for each combination of inputs (ie for each 8K block). Since 4 such blocks are needed to make up 32K, 4 of these 74LS138 outputs are fed via the addressing links LK2 to the inputs of IC2, a 4 input AND gate. Since an AND gate can be represented as an OR gate with all inputs and output inverted a low level output exists if any of the inputs are low thus fulfilling the requirements for $\overline{CE}$. This addressing scheme allows the 32K memory to span address \$8000. The RAM chip is not necessarily accessed in the expected addressing order. Lets take a base address of \$2000 as an example. The \$2000-\$3FFF block goes into the RAM at this same address range as do the \$4000-\$5FFF and \$6000-\$7FFF blocks. The \$8000-\$9FFF block ends up in the RAM at \$0000-\$1FFF. In a pure memory card this wouldn't matter. Certainly the RAM is filled up in an unexpected manner but the same is true for read and write functions and everything cancels out. The 32K unique addresses are in there somewhere. In an emulator, the RAM has to be read in a linear manner from a different port, something which would not happen without IC13, a 4-bit binary adder (we are only using 2 bits). This adds A13 and A14 of the host port base address (which is set up on LK3) onto A13 and A14 of the target address, throwing away any carry (we only have 32K of emulator memory). If the reader doubts the effectiveness, I'm sure a few minutes with a pen and paper will serve to prove that this chip does cause the data to be read out of the RAM from the target port in the same order it is put in from the host port. Since it was designed around the 6502 processor, Tanbus does not have $\overline{OE}$ and $\overline{WE}$ signals but instead has a R/$\overline{W}$ signal. The circuitry comprising the two NAND gates (IC4) and one of the IC3 inverters is the standard method of generating $\overline{OE}$ and $\overline{WE}$ from R/$\overline{W}$ and 02. To complete the circuit, C1-C4 and C5 are decoupling and reservoir capacitors respectively and adhere to standard digital design practice.

Moving away from the main card, the pods are mainly passive, connecting the appropriate pin on the emulator card to its equivalent on the DIL header and if a pod were being made to emulate the 27256, there would be nothing more to be said. With all other EPROMs, there will be some unused address inputs to the emulator card. If such inputs are totally unused on a particular pod they are connected to 0V to ensure that the target system sees the bottom EPROM sized block within the 32K (what most people would expect). Since we've tried wherever possible to make universal pods which cope with a number of EPROM types things become slightly more complicated. Where a number of EPROMs are accommodated with the one pod, we could connect the unused address lines on the smaller EPROMs through to the DIL header only if the pin in question is unused on the smaller chip or is held low (this is the case with AR on the 2758). If the pin is held high on the smaller device (like VPP on the 2716) it must be isolated by a switch. When the switch is open, the address input would tend to float high so pull down resistors have been included to prevent this. Pin 26 on the 2764 seems to contradict this, being a No Connection and being isolated by a switch. The reason for this is that some manufacturers do state that this pin should be held high and for this reason many boards accommodating 2764s will have +5V on pin 26.



I would like to express my appreciation and thanks to Gordon Bennett. who gave valuable assistance in the initial testing of the prototype.

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- Versatile EPROM Emulator. Part 1. Mike Bedford. ETI, July 1984, pp 22-26.
- Versatile EPROM Emulator. Part 2. Mike Bedford. ETI, August 1984, pp 50-52.
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- ETI Stand-Alone ERPOM Programmer. Part 2. Gordon Bennett. ETI, February 1989, pp 46-51.

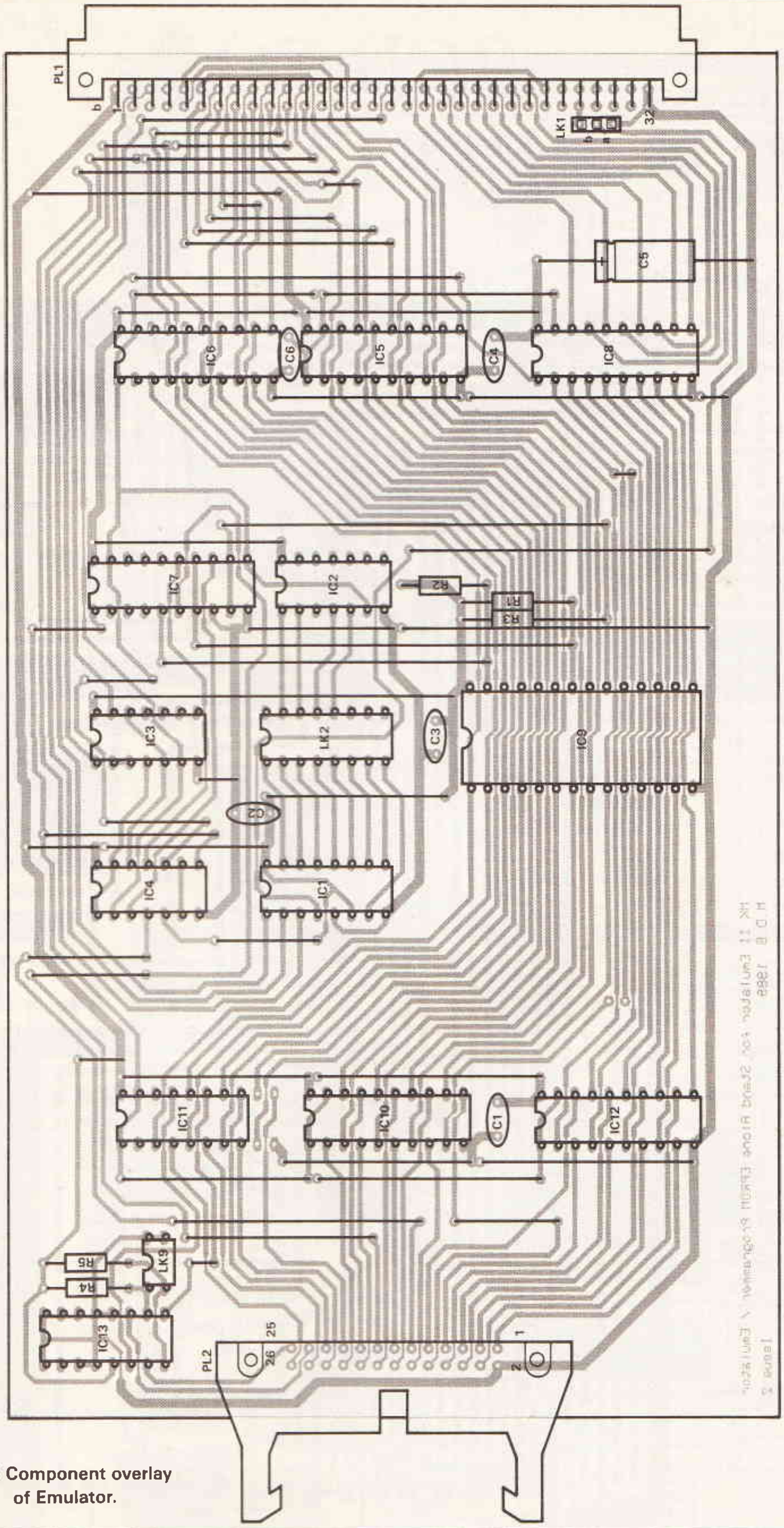


Fig.5 Component overlay of Emulator.

BUYLINES

We don't believe there should be any difficulties in obtaining any of the components used except for a suitable 24 pin solder type DIL header. When the prototype was made there was a 24 pin version of the suggested 28 pin header from Maplin. This has now been discontinued. Certainly 24 pin solder DIL headers are available elsewhere (eg Electromail Tel: 0536 204555) but I haven't been able to find another with a high profile cover which will neatly house resistors and DIL switches. The remaining components are straightforward and may be bought from most of the normal sources. It would be worthwhile shopping around for 62256 as this is quite an expensive part from certain places. The PCB is, of course, available from the ETI service.

OOPS!

In-car Power Supply (January 1989)
Fig. 3 shows the front view of the 317 regulator with the pin-outs reversed. The photograph, circuit and overlays are all correct showing the ledge at the front of the device.

Audio Design MOSFET Amp (May 1989)
For home constructors of the power amp PCB (Fig. 8), the copper area connecting the negative of C7, C14 and R20 is a 0V #2 connection and should be linked to the 0V #2 copper area at the junction of C16 and C18+. Hart's kit PCB has a ground plane and no mod is necessary. Note that the preset at the bottom right of Fig. 8 takes the place of an external RV3 rheostat when bench testing and is not normally required. In Fig. 7 R14 is not shown — it should be in series in the negative feedback line between C8 and D3. Also in the parts list C20 is 100uF and R9 is 2k2.

Bench Power Supply (May 1989)
In the Parts List, Q3,4 should be BC237 not BC307. The value in the circuit diagram is correct.

How To MIDI A Piano (June 1989)
In Fig. 5 the connection from pin 19 of IC8 (MREQ) should go to pin 12 of IC7a, not pin 13 as shown. The component overlay is correct.

MIDI Patchbay (July 1989)
Figure 3 shows Q1-6 as npn transistors. They should in fact be pnp and their emitters should be connected to R2-12 respectively (R12 is unlabelled). Although the bases are all connected together they should not be connected to their emitters.

Reflex Action (July 1989)
Two lines in the listing on page 30 need amendment. Line 180 should read

```
180 PRINT "Enclosure volume=";vb:PRINT"tuned to";fb;"Hz":PRINT" -3db at "; f3:PRINT "Ripple=";r;"db"
```

Line 280 should read

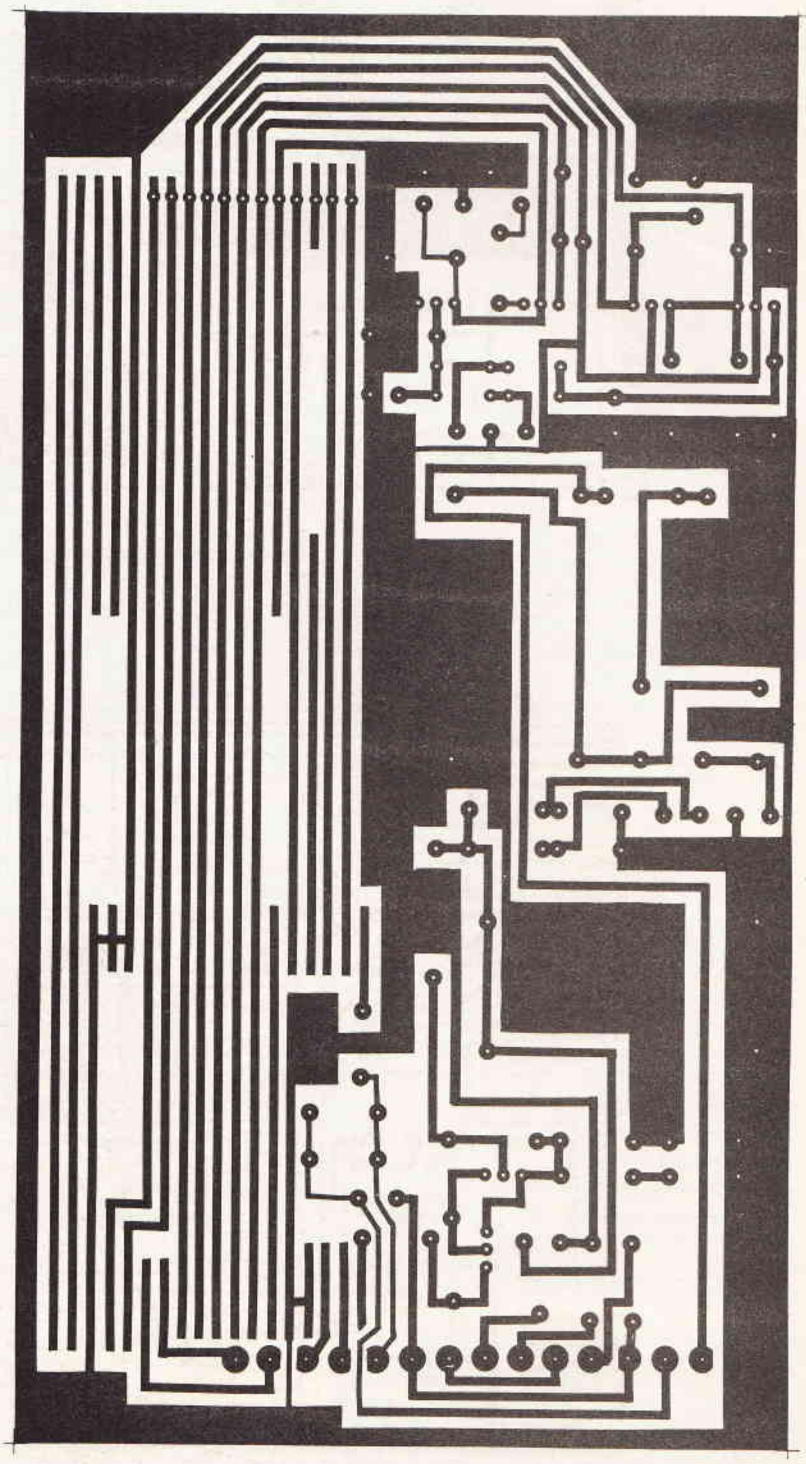
```
280 1=(2700*a)/(vb*fb 2))-0.96*(a 0.5)
```

Chronoscope Revisited (September 1989)
In the paragraph headed 'Connections', D10 should read LED8 (on the sensor board). Also in Fig. 2, IC10 is shown reversed. The notch should be next to R49.

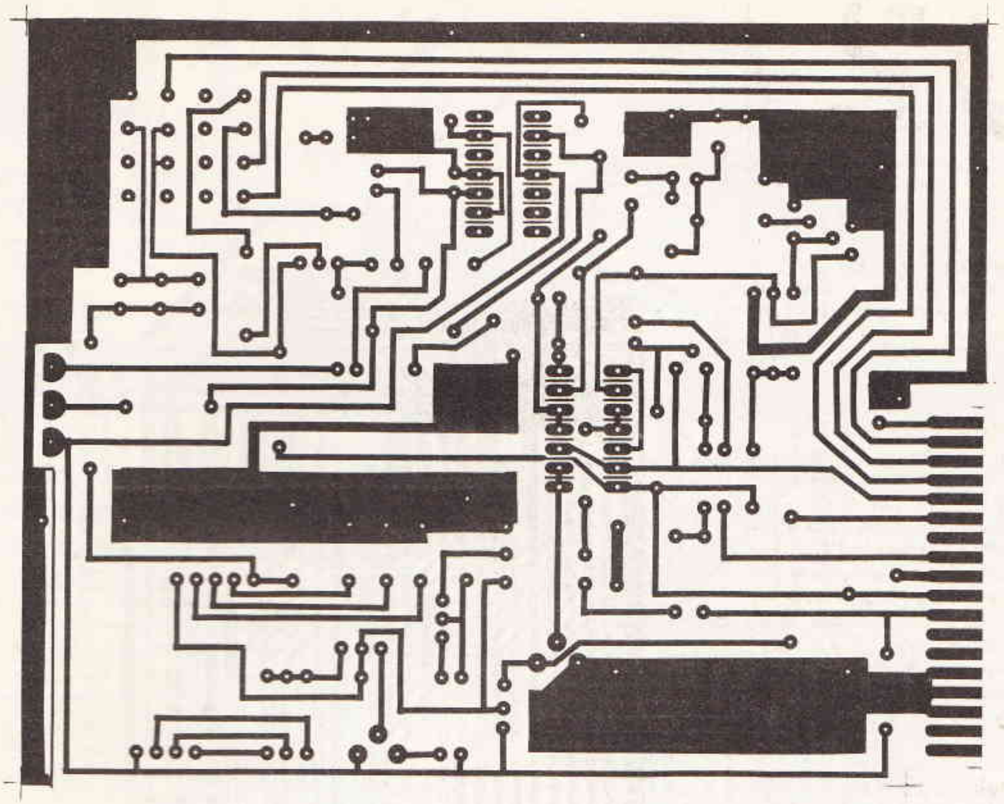
Field Power Supply (September 1989)
Figure 2 was printed with the artwork densities reversed, rendering a trifle tricky to interpret. It was reprinted together with a omitted col winding data on P62 of the October 1989 issue. A free photocopy is available from ETI Editorial on receipt of an SAE.

Twenty metre receiver (January 1990)
The foil shown on page 61 was the wrong side. Constructors photographing this foil must use the other side when making a PCB.

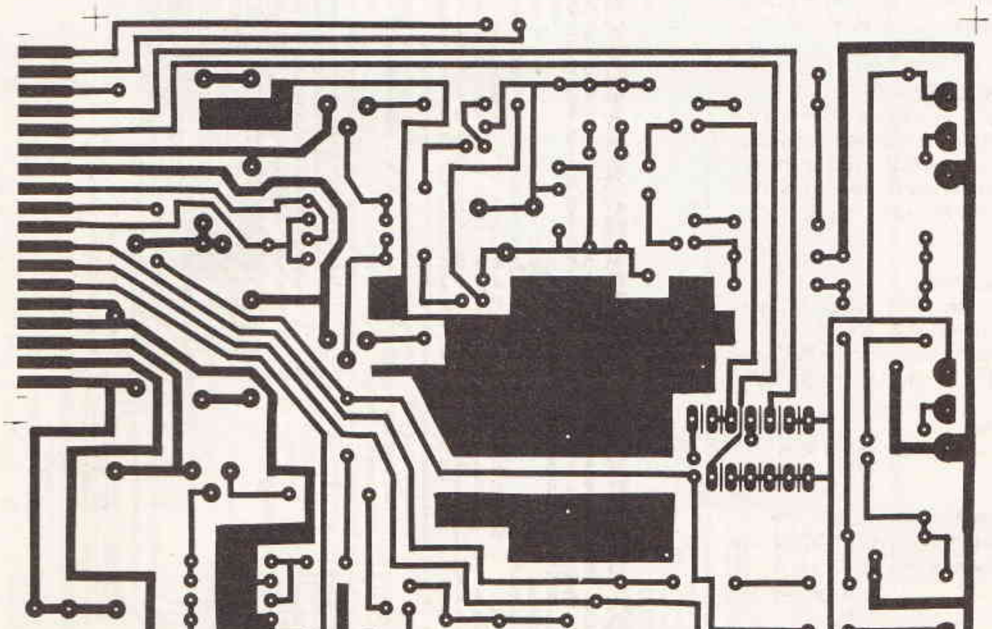
PCB FOIL PATTERNS



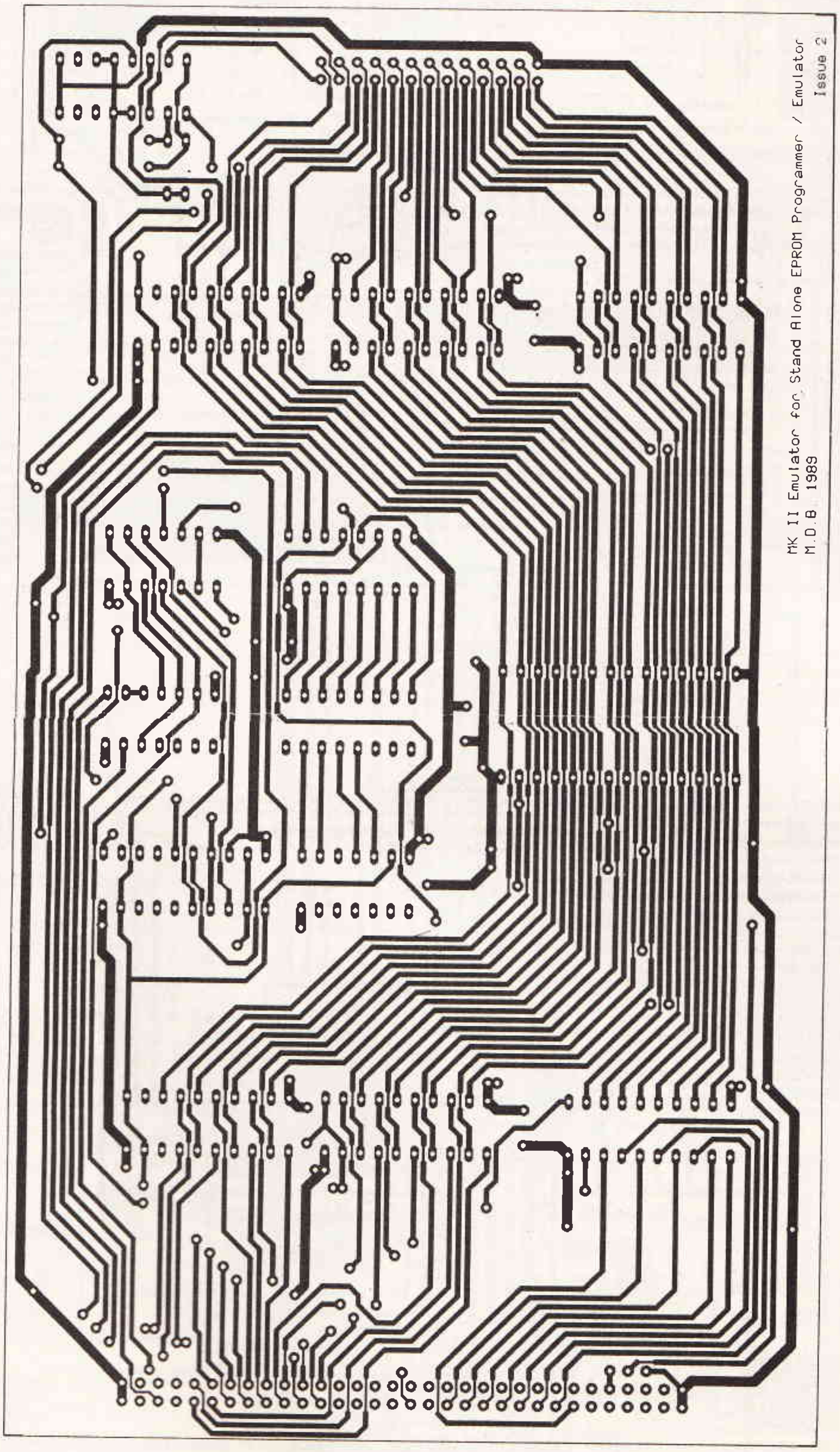
The motherboard foil for the Superscope



The Superscope timebase foil



Superscope tube driver foil



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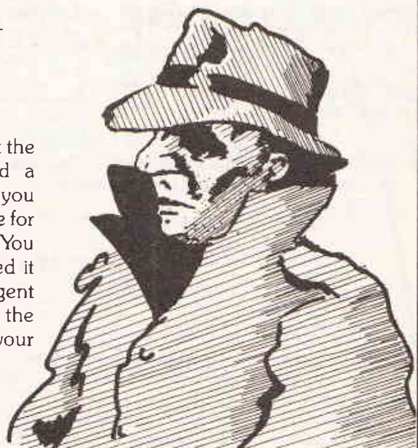

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NEXT MONTH

Coming soon in our March issue will be another batch of features and projects designed to keep you going through the winter months.

We start a new series from John Linsley-Hood on some basic techniques for radio reception with plenty of circuit ideas. There will be more on Superscope, adding the Y input amplifiers and we launch another major project for all you amplifier fanatics, a computer controlled graphic-equalised base amplifier. If that's a mouthful then look out for 'The Business'.

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Those with correct answers will all be sent the latest Maplin Catalogue.

LAST MONTH

In January we featured articles on baffling a speaker, making a signal generator and a twenty metre radio receiver. Also featured, was an interesting article on patenting your inventions. We have been informed that the three month extension period mentioned in the article, in order to present the provisional patent in its final form, disappeared on 1st July 1978. The Institute of Patentees and Inventors has now moved to: Suite 505A, Triumph House, 189 Regent Street, London W1R 7WF.

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