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★ PRICES INCLUDE V.A.T. ★ PROMPT DELIVERIES ★ FRIENDLY SERVICE ★ LARGE (A4) S.A.E., 50p STAMPED FOR CATALOGUE ★

OMP MOS-FET POWER AMPLIFIERS HIGH POWER, TWO CHANNEL 19 INCH RACK

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ALL POWER RATINGS R.M.S. INTO 4 OHMS, BOTH CHANNELS DRIVEN

FEATURES: ★Independent power supplies with two toroidal transformers ★ Twin L.E.D. Vu meters ★ Level controls ★ Illuminated on/off switch ★ XLR connectors ★ Standard 775mV inputs ★ Open and short circuit proof ★ Latest Mos-Fets for stress free power delivery into virtually any load ★ High slew rate ★ Very low distortion ★ Aluminium cases ★ MXF600 & MXF900 fan cooled with D.C. loudspeaker and thermal protection.

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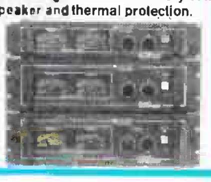

SIZES:- MXF200 W19"xH3½" (2U)xD11"
MXF400 W19"xH5¼" (3U)xD12"
MXF600 W19"xH5¼" (3U)xD13"
MXF900 W19"xH5¼" (3U)xD14¾"

PRICES:- MXF200 £175.00 MXF400 £233.85
MXF600 £329.00 MXF900 £449.15

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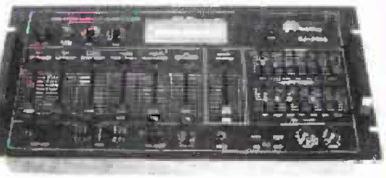

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SIZE: 482 x 240 x 120mm

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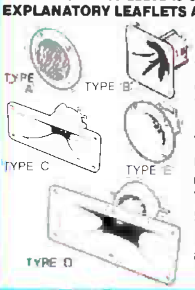

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THE VERY BEST IN QUALITY AND VALUE

Made especially to suit today's need for compactness with high output sound levels, finished in hard wearing black vynide with protective corners, grille and carrying handle. Each unit incorporates a 12" driver plus high frequency horn for a full frequency range of 45Hz-20KHz. Both models are 8 Ohm impedance. Size: H20" x W15" x D12".

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POWER RATINGS QUOTED IN WATTS RMS FOR EACH CABINET

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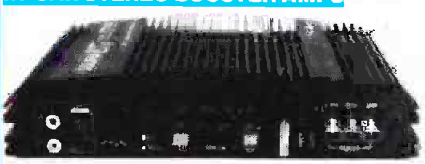

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150 WATTS (75 + 75) Stereo, 150W Bridged Mono
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ALL POWERS INTO 4 OHMS

Features:
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PRICES: 150W £49.99 250W £99.99
400W £109.95 P&P £2.00 EACH

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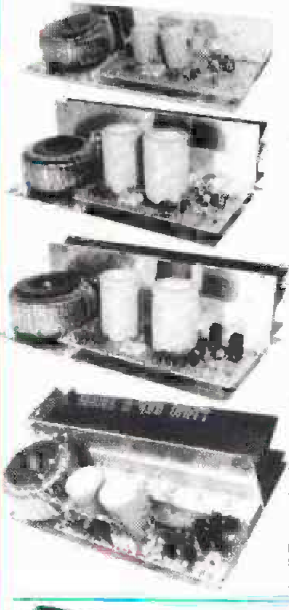
These modules now enjoy a world-wide reputation for quality, reliability and performance at a realistic price. Four models are available to suit the needs of the professional and hobby market i.e. Industry, Leisure, Instrumental and Hi-Fi etc. When comparing prices, NOTE that all models include toroidal power supply, integral heat sink, glass fibre P.C.B. and drive circuits to power a compatible Vu meter. All models are open and short circuit proof.

THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS



OMP/MF 100 Mos-Fet Output power 110 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 45V/uS. T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 123 x 60mm.
PRICE £40.85 + £3.50 P&P

OMP/MF 200 Mos-Fet Output power 200 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 50V/uS. T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 155 x 100mm.
PRICE £64.35 + £4.00 P&P

OMP/MF 300 Mos-Fet Output power 300 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 60V/uS. T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 330 x 175 x 100mm.
PRICE £81.75 + £5.00 P&P

OMP/MF 450 Mos-Fet Output power 450 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS. T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
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NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD - INPUT SENS 500mV, BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC.

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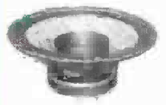
LOUDSPEAKERS



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ALL McKENZIE UNITS 8 OHMS IMPEDANCE

8" 100 WATT P C8-100GP GEN. PURPOSE, LEAD GUITAR, EXCELLENT MID, DISCO.
RES. FREQ. 80Hz, FREQ. RESP. TO 7KHz, SENS 96dB. PRICE £31.45 + £2.00 P&P
10" 100WATT S C10-100GP GUITAR, VOICE, KEYBOARD, DISCO, EXCELLENT MID.
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10" 200WATT S C10-200GP GUITAR, KEYB'D, DISCO, EXCELLENT HIGH POWER MID.
RES. FREQ. 69Hz, FREQ. RESP. TO 5KHz, SENS 97dB. PRICE £53.21 + £2.50 P&P
12" 100WATT P C12-100GP HIGH POWER GEN. PURPOSE, LEAD GUITAR, DISCO.
RES. FREQ. 49Hz, FREQ. RESP. TO 7KHz, SENS 98dB. PRICE £40.35 + £3.50 P&P
12" 100WATT P C12-100TC (TWIN CONE) HIGH POWER, WIDE RESPONSE, P.A., VOICE, DISCO.
RES. FREQ 45Hz, FREQ. RESP. TO 12KHz, SENS 97dB. PRICE £41.39 + £3.50 P&P
12" 200WATT S C12-200B HIGH POWER BASS, KEYBOARDS, DISCO, P.A.
RES. FREQ. 45Hz, FREQ. RESP. TO 5KHz, SENS 99dB. PRICE £71.91 + £3.50 P&P
12" 300WATT S C12-300GP HIGH POWER BASS, LEAD GUITAR, KEYBOARDS, DISCO ETC.
RES. FREQ. 49Hz, FREQ. RESP. TO 7KHz, SENS 100dB. PRICE £95.66 + £3.50 P&P
15" 100WATT P C15-100BS BASS GUITAR, LOW FREQUENCY, P.A., DISCO.
RES. FREQ. 40Hz, FREQ. RESP. TO 5KHz, SENS 98dB. PRICE £ 59.05 + £4.00 P&P
15" 200WATT P C15-200BS VERY HIGH POWER BASS.
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RES. FREQ. 39Hz, FREQ. RESP. TO 4KHz, SENS 99dB. PRICE £90.23 + £4.50 P&P
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ALL EARBENDER UNITS 8 OHMS (Except EB8-50 & EB10-50 which are dual impedance tapped @ 4 & 8 ohm)

BASS, SINGLE CONE, HIGH COMPLIANCE, ROLLED SURROUND

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10" 50WATT EB10-50 DUAL IMPEDENCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR.
RES. FREQ. 40Hz, FREQ. RESP. TO 5KHz, SENS. 99dB. PRICE £13.65 + £2.50 P&P
10" 100WATT EB10-100 BASS, HI-FI, STUDIO.
RES. FREQ. 35Hz, FREQ. RESP. TO 3KHz, SENS 96dB. PRICE £30.39 + £3.50 P&P
12" 100WATT EB12-100 BASS, STUDIO, HI-FI, EXCELLENT DISCO.
RES. FREQ. 26Hz, FREQ. RESP. TO 3 KHz, SENS 93dB. PRICE £42.12 + £3.50 P&P

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5¼" 60WATT EB5-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
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6½" 60WATT EB6-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES. FREQ. 38Hz, FREQ. RESP. TO 20KHz, SENS 94dB. PRICE £10.99 + 1.50 P&P
8" 60WATT EB8-60TC (TWIN CONE) HI-FI, MILTI-ARRAY DISCO ETC.
RES. FREQ. 40Hz, FREQ. RESP. TO 18KHz, SENS 89dB. PRICE £12.99 + £1.50 P&P
10" 60WATT EB10-60TC (TWIN CONE) HI-FI, MULTI ARRAY DISCO ETC.
RES. FREQ. 35Hz, FREQ. RESP. TO 12KHz, SENS 98dB. PRICE £16.49 + £2.00 P&P

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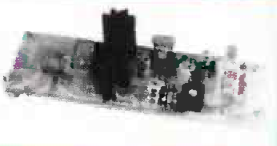

3W TRANSMITTER 80-108MHz, VARICAP CONTROLLED PROFESSIONAL PERFORMANCE, RANGE UP TO 3 MILES, SIZE 38 x 123mm, SUPPLY 12V @ 0.5AMP.
PRICE £14.85 + £1.00 P&P

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PHOTO: 3W FM TRANSMITTER

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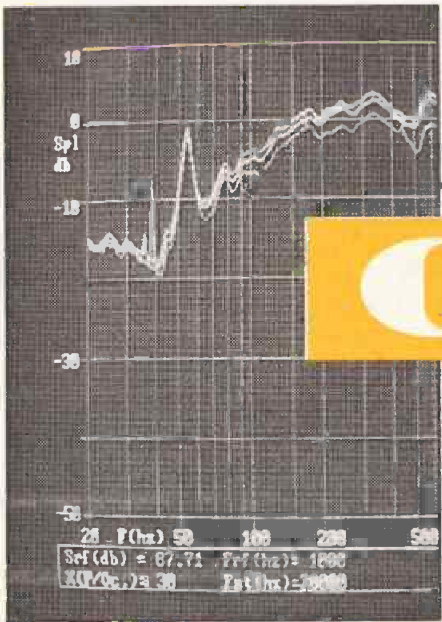
Volume 21 No.11
Nov 1992

Features & Projects



Page 32

Contents

Regulars

Editorial

by Paul Freeman

There is now no doubt in my mind that valve circuits strike a welcoming chord in the minds of many of our readers. The Hybrid Valve Amplifier presented in our September edition has caused a lot of interest. Despite one or two printing errors we would like to remind readers of the dangers of mains voltages, particularly DC. From a safety point of view, we would strongly emphasise that a project such as the Hybrid Amp should not be attempted by a beginner or those without a knowledge of audio designs. *MAINS VOLTAGES CAN KILL*. As the author has suggested, there are various safety proceedures to adopt when dealing with high voltages, two we pick out here - Work on a well insulated floor and work with one hand behind your back. This way no quick route through the heart is possible. High voltages and frequencies can be a source of intense interest, provided one has a knowledge of how this electric force can destroy life.

How high do we need?

Jeff Macualay also demonstrated in his Hybrid audio pre-amp last November that lower less shockable voltages could be used with valves, but unfortunately high output power from thermionic devices requires a higher voltage. There *are* semiconductors, notably FETs that emulate some valve characteristics, but still do not sound the same in audio circuits despite lower voltage working.

OPEN CHANNEL

Hot on the heels of all high definition television systems currently in development around the world (all of which, I might add, are reportedly getting further and further behind schedule), news that the European PALplus Consortium has recently demonstrated the final version of its development hardware must warrant a bit of interest this month.

PALplus is the rather novel method of extending existing PAL terrestrial transmissions, such that received signals will generate pictures in a wide-screen format (16:9). The exciting thing about PALplus is that the whole thing is based around existing 625-line terrestrial television standards.

It's not that PALplus is destined to compete with high definition television systems - far from it - because most manufacturers see it as a way of introducing wide-screen television receivers onto the market at reasonably high volume (for reasonably high volume, read reasonably priced). If wide-screen television becomes acceptable to the average viewer, then high definition television is just a step away.

Viewers who don't want to bother with upgrading their existing television receivers will still be able to watch PALplus transmitted signals, albeit in a letter-box type of picture on their screens.

Don't, however, all rush out to pester your local television salesman, down at the corner TV shop. PALplus isn't destined for launch until 1995, by that time my telly should be just about on its last legs and I'll consider getting a new widescreen jobby. I won t hold my breath.

Beatty Phones the Tube

For once, I'm not going to make fun of British Telecommunications. This is your month off, Sir Iain. While BT is not licensed to provide television over its installed subscriber local exchange circuits (that is, everyone's 'phone lines), it hasn't stopped development of a way to do it.

A new prototype system, currently given the meaningless name of assymetric digital subscriber loop, has been developed by the boys in the BT backroom which is able to cram a compressed video signal down a local line, alongside a standard speech circuit.

The video signal, which is compressed according to the Motion Pictures Expert Group (MPEG) format used in many computer multimedia and CD-I applications, isn't exactly cable television, but it does open the door to a rather better system of videophone than is currently doing the rounds.

This all ties in quite nicely with work BT has been undertaking with Motorola over the last few years, into the possibilities of video telephony. This work has recently culminated in the announcement that a complete suite of integrated circuits will be produced for launch early in 1994, to allow equipment manufacturers relatively easy access to incorporating multimedia into their products. With the chip set, it's not hard to visualise computers, telephones, videocassette recorders, CD systems and so on, all with the built-in capabilities of interactive video communications.

While this is the very first attempt to provide an integrated solution to multimedia communications, it won't be the last of course. Several other worldwide manufacturers - notably in the computing areas - are working on it. The fact BT and Motorola are doing it now and, more important, being seen to be doing it now is a significant advantage. They are setting the standards which other manufacturers may have to follow, and it's the set standards that will provide the key to multimedia's success. Multimedia, in various forms, has been around for a while now. We all know it's possible to have full motion video on a personal computer, provided you have the computer to do it, but being able to communicate those pictures with anyone who doesn't have the same computer and software has so far been elusive. Standards like MPEG, and chip sets like BT's and Motorola's will open the market up so that all personal computer users can access and communicate with any multimedia application.

As far as BT is concerned, this may be all a bit academic, as they may not be able to use the equipment over its own lines. Currently UK Government legislation is somewhat out of step with those of the rest of the world (so what's new?). In the US, telephone operators have recently been allowed to transmit television over 'phone lines. Liberalisation of European telecommunications networks looks set to enable many European operators to do the same. BT, on the other hand, is banned for at least seven years from being able to transmit television signals. Poor BT may be putting all this work into something it can't use. It's a tough old world, innit?

How Big?

The group formed from GEC and Plessey, GPT has announced a commercial application of 38GHz band communications. 38GHz radio, which has a wavelength around 1mm, has previously only been used in military applications. Following the band's de-mobbing to civvy street, however, GPT is the first company to develop and produce any equipment capable of operation.

Some three times the frequency of current satellite television systems, the new system (called Blacklite) provides multiple voice and data channels offering line-of-sight communications over distances up to around 20 kilometres. It's likely that systems will be used, in the short term at least, as a cheap alternative to leasing lines or cabling sites.

Meanwhile, Back At the Ranch...

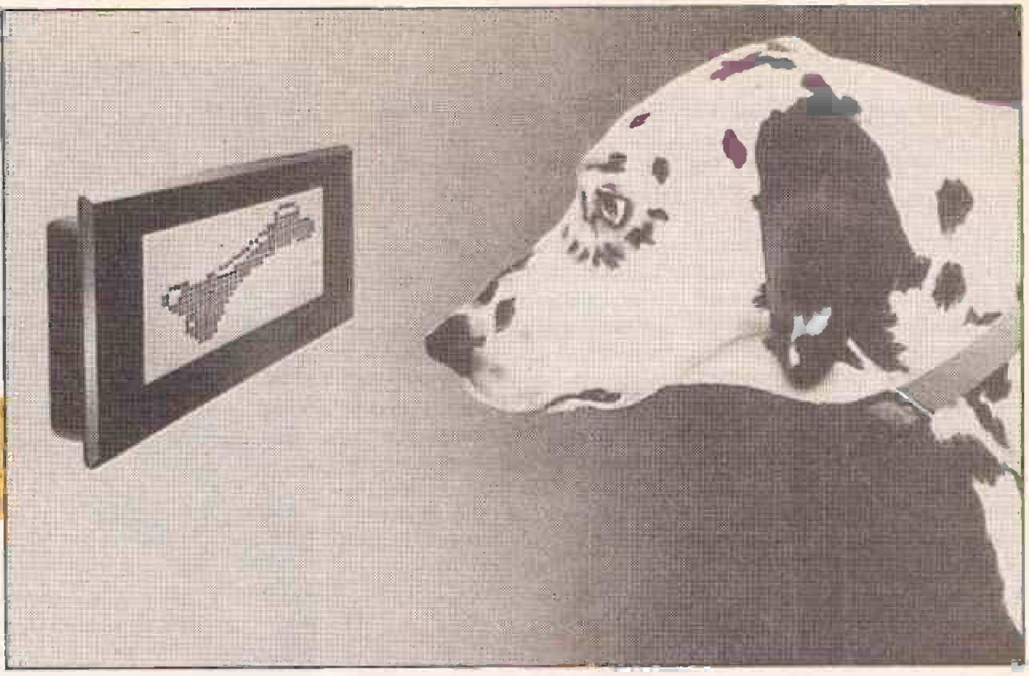
Readers of the last couple of issues of ETI might have noticed my attempts at portable computing/telecommunications. I was wandering around Ireland trying to find a telephone socket located near to a mains outlet, so I could plug both my computer and my fax/modem in at the same time. Last month I hit a problem in County Mayo, one of the most remote and beautiful parts of the island where, I found neither mains nor 'phone sockets.

I'm back home now and I'll dream of next year's hols.

Keith Brindley

ETI NEWS

SPOT THE DOT



The DMX 973, claimed to be the smallest LCD graphic module available, is part of the new 900 Series of modules designed and manufactured in the UK by Lascar Electronics.

With 70∞32 pixels, the screen uses the latest graphic controller LSI to create a compact interface module. Pin compatible with existing Lascar Dot Matrix Displays, and controller boards, it is expected to find applications in all types of intelligent instrumentation.

The Super Twist LCD provides a high contrast display with a wide viewing angle, while the standard LED backlighting allows use under differing light levels.

Mounting is simplified with a low profile bezel and window.

The 900 Series allows mixing of varying instrument types on the same panel, but with a conformity of appearance. The DMX 973 is available ex-stock from Lascar or their distributors.

RADIOFAX TO CLOSE DOWN

Radiofax, a shortwave science and technology radio station based in the Republic of Ireland,is to close down. The Department of Communications in Dublin has told the station that Radiofax is causing some embarrassment to the Republic. the department now wish the unlicensed activity to cease.

A spokesman for the station believed that the long term interests of Radiofax would be best served by closing down. He continued;

"We have contemplated ignoring the request, but there is hope that independent short wave licensing will be considered in the future. Unfortunately, we can think of no other place to go to that would allow Radiofax to continue to operate in a professional way".

"All the 44 people involved in Radiofax would like to thank our listeners for the three thousand letters of support for the project that you have sent us each year".

"If that number of letters went to Members of Parliament, then perhaps independent short wave radio would happen sooner rather than later", he said.

Radiofax commenced broadcasting on 1st April 1988 with its unique service of science, technology, media and technical news. The concept was welcomed enthusiastically by both professional and amateur users of the short wave bands as 'informative', 'imaginative', 'refreshing'; and generally seen as a worthwhile use of a few kiloHertz of increasingly moribund spectrum in the British Isles and Europe.

The station has continually applied to the UK Home Office for a licence since August 1986 but without success. Lord Thomson, Chairman of the IBA in October 1988 replied; "regret legislation precludes helping -wishing luck with this exciting project". The Radio Authority in May 1990 commented; "not permitted to authorise short wave but wish you well with the idea".

SONY ENDS SPECULATION OVER LASER DISC MARKET

Sony ends speculation about their entry into the laser Disc market, with the announcement that the MDP-650 Dual System Multi Disc Player will be launched in October.

Charlie Jones, Product Manager for Laser Disc, said "The time is now right to develop this market. There is a growing consumer interest in home theatre products and Laser Disc is the perfect audio/visual medium".

Speaking about the Laser Disc Industry, he said, "The formation of the UK Laser Disc Association and the pending release of large numbers of premiere software titles from a number of software houses is a clear indicator that both the software and hardware industries are committed to the future of this format".

The MDP-650 is a Dual Standard machine, which will replay both PAL and NTSC discs, a large number of which already exist in the UK.

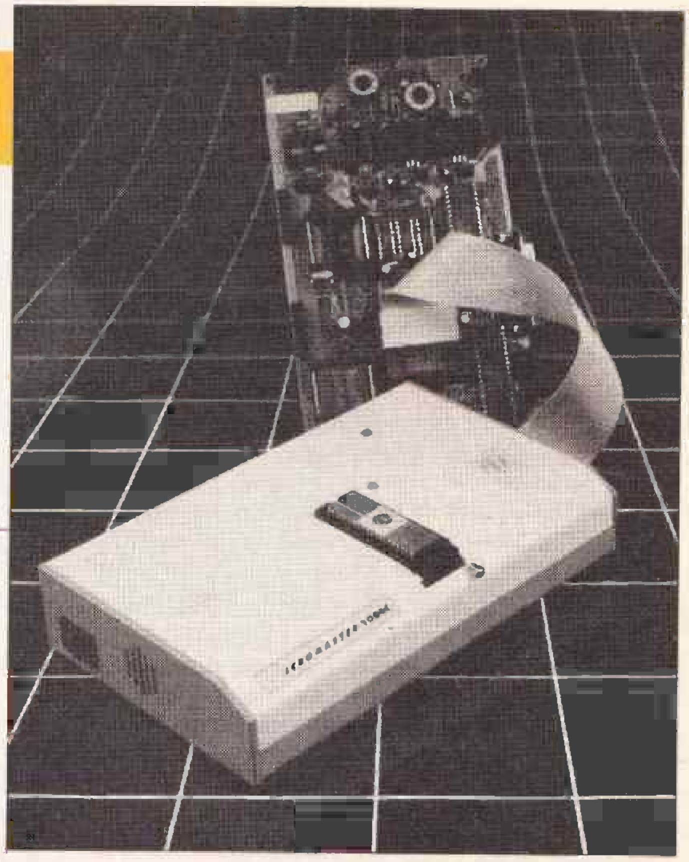
The latest innovations are incorporated in the MDP-650, including a Digital Servo to ensure the gain and servo control for each disc is checked and adjusted for operation. This reduces any adverse effects on the audio section of the player. Single bit technology in the D/A conversion section delivers the sound.

The MDP-650 incorporates a Dual Mode Shuttle which allows access to variable speed playback, cue, review and picture still. While a Music Calendar clearly indicates the tracks, the majority of controls are hidden behind a centrally positioned front panel.

With an optical digital and an RGB output to further enhance quality, the MDP-650 Multi Disc Player will sell for £599.99.

NEW RANGE OF PROGRAMMER/EMULATORS

Ice technology has announced the launch of a new range of universal programmers with built in emulation capabilities for the design engineer. While other programmer/emulators can only support EPROMs, the Speedmaster 1000E and Micromaster 1000E can program EPROMs, EEPROMs, Serial EPROMs, NVRAMs, PALs, GALs, EPLDs, PEELs, MACHs, MAPLs and can emulate ROM and RAM up to 128kbytes. The programmers come complete with software, manual, printer port cable, power supply and adaptor and emulator cable. The printer cable plugs straight into the standard parallel port of any IBM compatible PC without the need for any expansion card. Further details from Ice Technology Ltd, 0226 767404.



MAPLIN ESTABLISHES SERVICE IN SOUTHERN AFRICA

Maplin Electronics has announced the forthcoming launch of MAPLIN (South Africa) in Southern Africa.

As part of a continual expansion programme which has seen it's U.K. retail outlets increasing to 19: the opening of a custom-built, high tech distribution warehouse: and the award of the BS 5750 Certificate of Quality, Maplin's Managing Director, Mr Roger Allen says that "Maplin (South Africa) will commence business in November of this year and aims to provide both the hobbyist and professional the same service as has been provided in the U.K. for the past 18 years".

Roger Allen commented. "There are some 9000 British electronics magazines distributed each month in Southern Africa, but their readers face difficulties in sourcing suitable components and hardware to complete the projects that these magazines publish. Maplin (South Africa) aims to overcome these problems and will be distributing 10,000 Southern African editions of the new 1993 catalogue throughout South Africa, Namibia, Botswana, Lesotho and Swaziland at the beginning of November". The Southern African edition of the new Maplin catalogue will include a Rand Price Supplement as well as details of how to order goods from the new service.

Maplin's Southern African customers will be able to order goods either by mail, telephone, fax or electronic mail. Orders received in their Cape Town offices will be transferred at the end of each working day to Maplin in the UK, who will dispatch within 24 hours to London's Heathrow Airport. With daily flights to Johannesburg and Cape Town, and taking into account the clearing of Customs in South Africa, customers should expect to see their goods arrive within approximately 7 to 10 days.

NEW COURSE MAY RE-SHAPE UK ELECTRONICS STUDIES

The success of a course pioneered by the University of Bradford could revolutionise future electronics studies in the UK.

As lecturers throughout the country strive to improve the popularity of traditional engineering courses, Bradford has rekindled the flagging interest in electronics by introducing a BSc in Electronic Imaging and Media Communications.

The unique format of the course offers students seeking careers in the media a combination of hi-tech skills and creative design.

Its popularity has 'astonished' lecturers at Bradford. More than double the planned number of students joined the start of the first course last October and there will be another bigger than expected intake this year.

There has been worldwide interest in the course - Brunei approves it for the education of television staff, the Australian Film, TV and Radio School finds it 'innovative and exciting.'

The course - masterminded by Professor David Howson has helped Bradford contribute to the ongoing expansion in Higher Education.

Professor Howson said the University of Bradford prided itself on its close links with manufacturing but when the UK electronics industry went into decline, with job prospects reduced, even electronic engineering courses as good as Bradford have been losing their appeal.

"Following a rethink of course strategy, we decided to look to the commercial users of electronics - such as the entertainment industry - and tailor courses to meet these needs."

"We have every expectation that our graduates will find a range of career opportunities available. The mixture of the artistic, the practical, the aesthetic and the technical, gives students a broad basis for any number of careers in television, film, radio, advertising, design, newspapers or the music industry."

The course has appealed to many students who would not normally consider a technical education. Forty per cent of the first year's intake were women - a figure which would be envied by traditional courses elsewhere.

The course is based in the University, but also involves staff from the School of Art, Design and Textiles at the adjacent Bradford and Ilkley Community College, where modern editing facilities have been installed.

Professionals from Bradford's National Museum of photography, Film and Television as well as Yorkshire Television and the BBC are all involved in the design and content of the course.

Its aim is to enable students to develop experience in, and understanding of, the information technology that underpins electronic imagery for the media and that generates, mixes and manipulates audio and video signals.

They are also encouraged to create imagery - both visual and aural - and gain an understanding of the power and role of imagery in society.

Although the course is delivered within three separate institutions, each with responsibility for specific aspects and disciplines, it has been conceived from the outset as an integrated whole.

The first year introduces relevant processes and techniques, based largely on practical experience. The understanding gained is placed in context through critical analysis and evaluation of media communications.

In the middle year, this knowledge is developed through projects, most of which are undertaken in groups and led by a tutor. The final year prepares students for professional practice.

Professor Howson said the enthusiasm for the course from all parties concerned had contributed to its success. It was also good for the students to be exposed to the different 'cultures' of each organisation and they had greatly appreciated this.

He said the popularity of the course showed how important it was for engineering education to move with the times.

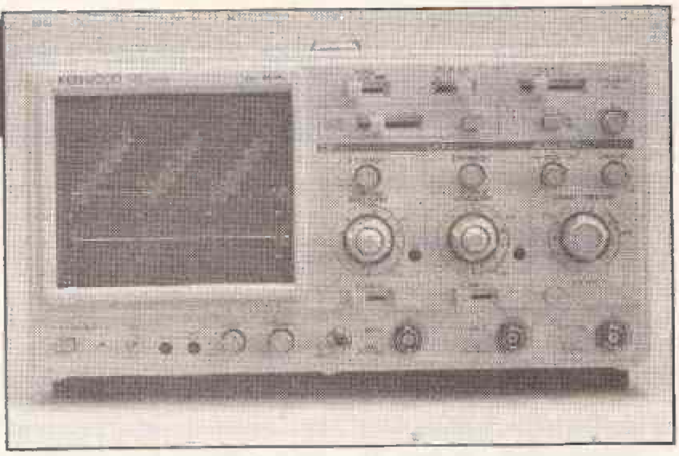
"The information technology on the course is geared to the creative work done by the students. People with no electronics or computing background - we have one student who originally wanted to do drama - are studying the technology because it helps them understand what they are doing creatively.

"This could be the way forward for electronics education into the next century. Hopefully other Universities will follow our lead in broadening the appeal and lightening the load of their technical courses.

"We had no idea there was such a large pent-up demand for courses like this. In no time at all it has grown into a major course in its own right."

For further information please contact Prof Howson on (0274) 384011 or the Press Office on (0274) 383088.

OSCILLOSCOPE BREAKS PRICE BARRIER

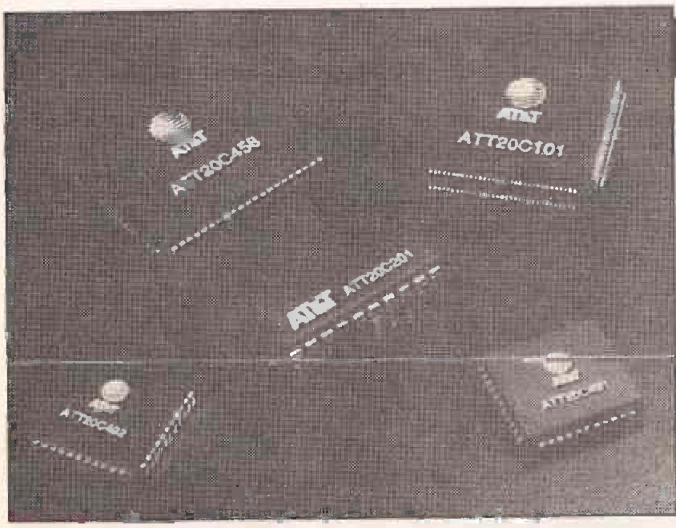


Analab, the specialist laboratory equipment supplier, are now offering a full specification Kenwood Oscilloscope at a price that is comparable with cheaper imported models. The compact CS-4035 oscilloscope allows educational establishments to purchase a high-quality product which incorporates many important features, including Kenwood's hybrid IC technology. This two-channel 40MHz model is highly sensitive and has a fast sweep rate together with instantaneous TV synchronisation switching.

Prices start at £295.

For further information contact Analab, on 0455-283486, for details of the 20MHz or 40MHz models.

CHIPSET FOR MULTIMEDIA



Designers of affordable, mass-market PCs and workstations can give their customers near photographic quality (24-bit) displays with AT&T Microelectronics' newest generation chip set. The new chipset will allow the production of a complete PC graphics subsystem using just 5 chips and occupying only 30 square centimetres of board space.

The AT&T range consists of a true-colour VGA controller, PC RAMDACs, a clock synthesiser and a workstation RAMDAC. A complete graphics board can be built from two DRAMS, a clock synthesiser and a RAMDAC all managed by a VGA controller. The DRAMs, VGA controller and clock synthesiser can be matched up with any one of three PC RAMDACs to provide three different PC graphics boards, without any change to the board layout or to the BIOS.

The graphics board chip count is so low because all the glue logic necessary to the subsystem has been moved to the VGA controller (ATT20C101) . It interfaces to the PC either via the CPU local bus or, so that the chip set may be used in add-on boards, through the PC/AT bus.

The controller also contains a CPU write buffer so that the CPU does not have to wait to write to screen memory - this gives a 30% speed advantage over non-buffered systems. The increase in speed makes the system suitable for multimedia applications

RAMDACs are available for 24, 18 and 8 bits per pixel systems. The 24-bit device is capable of producing over 16 million different colours - a finer spectral resolution than that of the human eye - putting near photographic quality images within the reach of mainstream PC designers. Existing 15/16-bit RAMDACs are only capable of generating 65000 colours - a far lower performance with very little saving in cost.

24-bit devices will be used in new designs, whilst the 18-bit RAMDAC will be used to upgrade existing 15/16-bit boards. The 8-bit device has been included for applications where true colour performance is not required.

Reader enquiries to: Vic Drake, Admail 4 International Ltd. Tel 0732-460424 or direct to: the AT&T Dataline 0732-742999 (voice) 0732-741221 (fax)

BR TELECOM TUNNEL LINK

BR Telecommunications Ltd (BRT), British Rail's telecommunications subsidiary, announced two strategically important orders today, thereby adding a European dimension to its 1993 growth plans.

The main order is for an international gateway exchange to handle European voice and data traffic. The exchange, to be supplied by GPT Communications Systems Ltd, is a powerful iSDX based switch.

In a separate but related move, BRT has signed a seven year lease with Eurotunnel for the provision of digital bandwidth from Eurotunnel's transmission system for the railways' operational purposes. This will enable BRT to link with both the French Railways' telecommunications network managed by SNCF and the rest of the European railway system. The digital links in Eurotunnel will be connected to BRT's own optical fibre network running from Folkestone to London.

The complete international telecommunications service is scheduled to come into operation at the end of 1993.

BRT applied to the Department of Trade and Industry in March for a public telecommunications operator (PTO) licence which would enable the company to compete on the open market with other PTOs. BRT's application covered both UK and international telecommunications traffic.

The orders underline BRT's commitment to the future development of their network. They will also help BRT to prepare for growth in the single European market of 1993 and beyond.

BRT will use 2x2 megabit links, transmitted via two physically separated fibre optic cables. The switch, to be based in London, is an International Gateway Trunk Exchange based on iSDX technology. It will link BRT's existing DPNSS based exchange network in the UK and a node on the SNCF communications network, in Paris. The link will operate the new European private network signalling protocol Q-SIG and is expected to be the first international application of Q-SIG anywhere in Europe.

In addition to the fibre optic link, BRT is also investigating the possibility of a microwave link across the channel. BRT and SNCF have recently conducted a feasibility study, carried out by a consultancy firm. The recommendations are currently being evaluated; a decision on the link is likely to be made later in the year.

WINDOWSAFE COMBATS WINDOW-DANGER TO CAR CHILDREN

Recently, the danger to young children from electrically-operated car windows has been back in the news - but it is not new. Children have lost their lives in previous years, when trapped by an accidentally-operated car window.

The Lazerline WindowSafe is designed to increase the safety of electrical windows, allowing the window to 'detect' an obstacle, and wind down again to free the trapped person.

If the window encounters resistance, such as a child's head, or indeed an adult's, while the winding switch is being operated, Windowsafe stops the window. The window then reverses 4 or 5 inches to free the victim. The window will then remain stationary until the switch has been released for several seconds, so that an accidental winding cannot be quickly repeated by, for instance, a toddler with her foot on the switch.

The standard model is installed in the window circuit, where it will protect all the electrically-operated windows in the vehicle. As an additional safety feature, the windows cannot be operated simultaneously, so that it is completely clear which window is being operated at any one time.

The protection may be temporarily overridden, for the safety of drivers in potentially dangerous situations, such as women drivers travelling alone at night, or in areas where there may be risk of attack. In some cases drivers have had bags or jackets snatched by thieves reaching through open windows while the car is stationary at lights. To override the protection, a separate switch such as the window washer switch must be operated at the same time as the window switch is in use. Installers can choose a suitable switch which is convenient for the driver without compromising the normal protection.

Further information on the Lazerline WindowSafe,, contact Lazerline on 0525 378267.

CABLE TEST

A low cost solution to cable fault location and measurement is now available from Alpha Electronics. The Faultman T5ll detects Short and open circuits, high resistance joints, transitions from high to low and low to high impedance plus shunt faults such as water in the cable. Applications include power, telephone, data and CATV/CCTV cables, aircraft and marine wiring and on-reel cable length measurement.

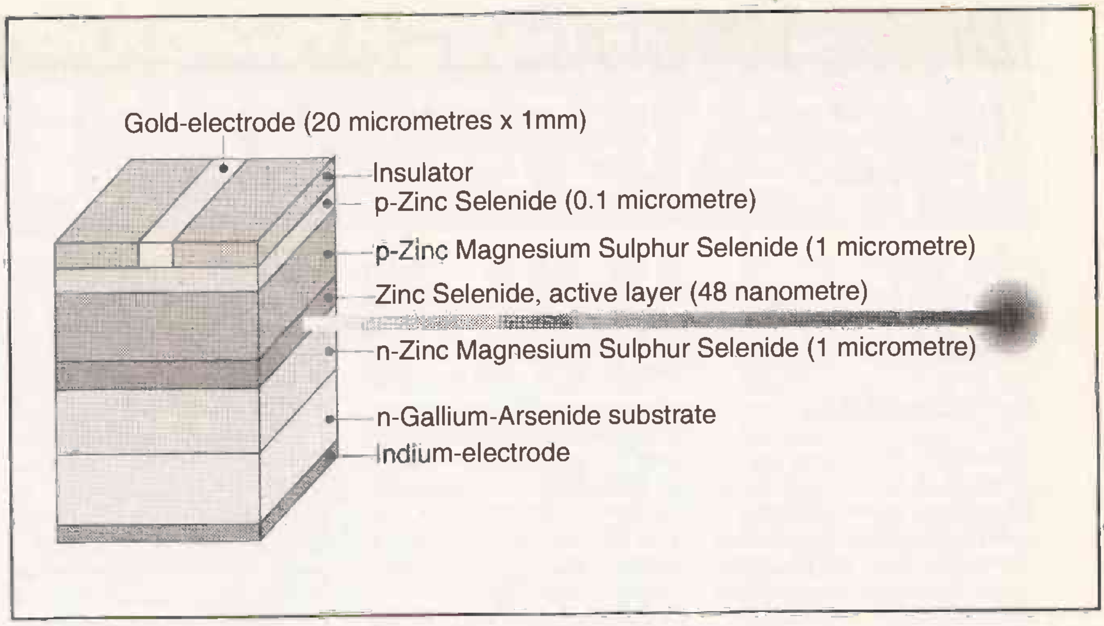
The T5ll uses a pulse-echo technique to provide a visual indication of faults on a clear, easy to read, liquid crystal display. The operating principle is that a pulse transmitted into a cable is reflected by any imperfection along the cable. The transmitted and reflected pulses are displayed with the position of the reflected pulse being used to determine the distance to the cable imperfection.

Adjustable to suit any type of cable this portable, hand held, battery-operated unit has four basic ranges to 300m. The Faultman comes supplied with batteries, test leads, carry bag and an operating manual containing typical cable dielectric values and how to determine an unknown value. Other useful accessories include safety fused leads and filters for use with live power cables. Price (exc. VAT) is from £775

For further information contact Fred Hutchinson of Quiswood Ltd on (0756) 799737

ETI NEWS

...Stateside...



True blue laser

Researchers in Japan, Europe and the United States have been racing to develop blue-laser technology.

Storage products today typically use red lasers with a wavelength of about 1 micron. With the blue laser under development by Sony, the storage capacity of a CD could be tripled. Specifically, the playing time for a 12-centimetre CD could be boosted to about three-and-one-half hours from the present 74 minutes.

The blue lasers could also mean higher-resolution printing and copying technologies, faster optical interconnects in future computers, and faster and more reliable fibre communications.

Other laboratories have produced blue-green lasers, which operate at a wavelength of around 490nm. But the lower wavelength of 447nm of Sony's blue laser light gives it a decided edge in the competition to produce such things as higher-capacity CDs.

Sony's new generation of lasers uses a crystal of Zinc Cadmium Selenide sandwiched between layers of Zinc Selenide. Stacked on top of a Gallium Arsenide substrate, a quantum well is formed that traps electrons and positively charged holes that are then stimulated electrically to produce the bluegreen or blue laser emission. A Sony spokesman said Magnesium was added to the Zinc Selenide thin films.

New superconducting wire

Researchers at Los Alamos National Laboratory have used a 'tube-withina-tube' approach in a new engineering design for high-temperature superconducting wire.

The result is a stronger, simpler wire that conducts electricity with more reliability than other designs under investigation, such as the so-called powder-in-a-tube scheme.

The new design calls for sandwiching a bismuth-based superconducting compound between concentric silver tubes. After a layer of superconductor is deposited onto a silver tube's outer surface, another tube of slightly greater diameter is placed over the bismuth layer. The entire three-layered structure is drawn down, compacting the ceramic and increasing the tube's length. It is then heated, causing the powder and the silver to bond into a single tubular structure. The hollow core - preserved by filling the inside tube with lead and then melting it off at the end of the fabrication process - allows the wire to be cooled by passing liquid nitrogen through the core.

New technique for depositing copper circuits on Teflon

A technique for directly depositing copper circuit lines on Teflon has been developed by researchers at Sandia National Laboratories and the University of New Mexico. The combination of copper conductors on polytetrafluoroethylene substrates (Teflon) is ideal for many electronic needs.

The new process consists of three steps: first, the parts of the Teflon surface where copper is wanted are irradiated. Second, the entire sample is subjected to a commercial etching solution which alters only the nonirradiated areas. Third, chemical vapour deposition techniques deposit a copper coating which adheres only to the etched areas, creating the desired pattern.

Although initial applications appear to be in making printed circuit boards, where copper strips connect a variety of microelectronic devices, the technique may also have applications in the microelectronics themselves. Sandia's Microelectronics Development Laboratory is exploring copper interconnects as wiring for next-generation computer chips, as part of an advanced manufacturing initiative programme for the Department of Energy.

Semi conductor etching

Researchers at Cornell University have discovered a novel approach to overcoming typical problems with semi-conductor etching. Sometimes mask edges are not smooth enough, the etch mask is not strong enough to withstand the high temperature or chemistry of the etching environment, or the mask cannot be removed after the etching is finished.

Cornell researchers, have discovered a way to use a form of semi-metallic amorphous Carbon that has ultra-smooth etched facets, can endure the most intense etching environments, and can be fully peeled away when etching is complete.

The semi-metallic amorphous Carbon thin film may be broadly applicable to a wide range of semiconductor processing applications. The etch mask performance is now being studied at submicron dimensions, which is critical to current industrial needs.

The carbon material is also conducting, unlike many other carbon films, which are insulating. The carbon is also environmentally safe.

READ/WRITE ETI Letters

Hybrid Power Amp Comments

As an old codger who was in short pants in the 1930's may I comment on Jeff Macaulay's Hybrid Power Amp design in the September issue. Unfortunately one or two errors seem to have crept in.

Firstly, C3 on the drawing is labelled 220u, 63Volt, although it is on the 350 Volt H.T. rail! Surely, this should be 450 Volts and is, presumably, the big blue one on the top of the chassis in front cover photograph.

Secondly, the wiring from T3 to the EL34 heaters -it is not good practice to earth one side of the 6.3 Volt line. Far from cutting it back the centre tap of this winding should be connected to earth, leaving the heater line as a balanced pair. This will give the lowest hum level.

Thirdly, R11 1k0, across the secondary of the output transformer would appear to be superfluous as it is shunted by the loudspeaker, probably 8 Ohms, and also by the very low resistance of the output winding.

Finally, why did Jeff not adopt the Ultra-linear configuration for the output stage? This circuit was originally patented by the famous Alan Blumlein in 1937, and was 'rediscovered' by Hafler Keroes in the USA when they described it in 'Audio Engineering' of November, 1951. Whether they were aware of the Blumlein patent or hit on the idea independently I do not know, but they did not refer to him in their article. Incidentally, I believe I am right in saying that the EL34 valve was introduced mainly to meet the demand for output valves for this circuit which, by 1956, was becoming very popular.

Sorry to be so critical but I thought I should draw attention to these details. No doubt Jeff's design will give excellent quality reproduction.

Cyril Gott
Southhall, Middlesex.

Jeff Macaulay replies:

Thank you for your letter regarding the Hybrid amp. I'll try to answer your queries in the order you've posed them.

First the unfortunate transposition of C3 and C4. Needless to say the 400V cap needs to be connected across the HT. supply. And yes it is the big blue one you can see on the photograph! Whilst on the subject the transistors used in the circuit are MPSA92's and not MPSA42's as detailed in the article.

Second the heater wiring. I tried earthing the centre tap of the transformer and leaving the heaters floating. In truth there was no discernable difference in hum level regardless of how this was connected. Instead I've followed the more recent practise of connecting one side of the heaters to the same potential as the valve cathodes, in this case 0V.

R11 prevents the output stage from oscillating when the speaker is disconnected. This is not simply a foilble of this circuit, nearly all transformer coupled output stages need similar treatment to prevent oscillation.

I was not aware that the ultra linear circuit was patented by Blumlein but I can't say I'm surprised. His audio works were prolific. Indeed we still use the basic stereo system which he invented in the early thirties. I have however read the Hafler and Keroes article you mention.

I tried the ultra linear configuration. together with the triode connected output stage and pure class A operation. Engineering is always a matter of compromises and I selected the ones that gave me the mix I wanted. Specifically the extra performance that I expected from this configuration was not forthcoming. Not that I am implying the technique is in any way suspect simply that the extra expense and trouble didn't prove worthwhile in this design.

Hoping this answers your enquiries.

J P Macaulay
Yapton, Sussex.

No Projects for Amiga Computers

I noticed in your magazine project index that you have apparently never featured any projects specifically for the Commodore Amiga computer. Is it possibly the most popular home computer in the UK? Although it is often regarded as a games machine, the possibilties for add-ons and gadgets are practically endless. Particularly as its capability to create sound and music are very impressive.

As I read through the project index I noticed that you have published projects for just about every obscure computer imaginable. Is there some form of copyright which prohibits you from publishing projects for the Amiga?

Over the past year I have built my own sound sampler, MIDI interface, ROM switcher link cables and many more.

Most of these examples have come from public domain discs which apparently carry no copyright.

I am sure that many people out there would be extremely interested in these projects should the designers submit these projects for publication.

D J Butcher
Wakefield, West Yorks

It is arguable whether the Amiga is the most popular home computer. I would have thought PCs and their clones must be very popular now the price has become affordable. When you mention 'obscure computers' we must remember over the 20 years ETI has been going, various computers have come and gone and were very popular for short periods of time. It is no wonder that in this rapidly changing field of electronics certain projects have become 'old hat'.

Yes it is surprising that contributors over the years have not provided projects for the Amiga as there is nothing to prohibit them. -Ed.

Rear Bike Lamps

A brief reply to a letter on the subject of rear bike lights by Mr I Field which you published in the September issue. I have no comment about most of it, but:

No, the bike light design is not a 'bucking regulator' but a flyback converter. A buck regulator gives an output voltage below the input voltage, while a flyback converter can provide a step up.

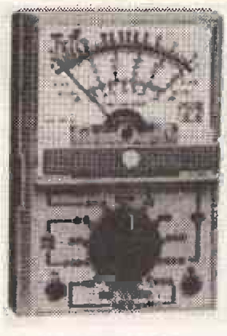
There are many ways to solve a similar problem, and other converter designs would be suitable. I used the design I did to avoid fiddling with hand-wound magnetic components, which may not work at all if wound incorrectly. Instead, my design uses a standard inductor costing about 35p. If you fit the components on the board correctly it is obliged to work.

Just a thought about multiple output windings from a switched mode converter - unless the output windings are wound together the output from each one will be different. To equalise the output current from two windings, either the windings must be in a magnetically equivalent place, or they must be bifilar wound. This normally means that you twist two strands of wire together before winding. This technique can be a boon in designs where it is essential, but it is worth considerable effort to avoid the necessity.

Author of LED Bike lamp
Andrew Armstrong
Leighton Buzzard, Beds

ESR ELECTRONIC COMPONENTS
Station Road, Cullercoats,
Tyne & Wear NE30 4PQ
Tel: 091 251 4363 Fax: 091 252 2296

TEST AND MEASUREMENT



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22	£0.05	£0.05	£0.09	–
47	£0.06	£0.06	£0.11	–
100	£0.06	£0.09	£0.11	–
220	£0.09	£0.12	£0.31	–
470	£0.15	£0.19	£0.57	–
1000	£0.22	£0.29	–	–
2200	£0.37	£0.57	–	–
4700	–	£1.11	–	–

ELECTROLYTICAL AXIAL CAPACITORS

uF	16V	25V	63V	100V
0.47	–	–	–	£0.15
1.0	–	–	£0.10	£0.10
2.2	–	–	£0.10	£0.10
4.7	–	£0.09	£0.10	£0.10
10	–	£0.12	£0.12	£0.12
22	–	£0.09	£0.13	£0.17
47	£0.10	£0.11	£0.16	£0.20
100	£0.10	£0.13	£0.11	–
220	£0.09	£0.12	£0.21	–
470	£0.21	£0.24	£0.69	–
1000	£0.33	£0.40	£1.05	–
2200	£0.52	£0.64	–	–
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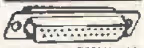
D CONNECTORS



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Thinking Small

Douglas Clarkson delves into the micro-cosmic world of Nanotechnology

Science investigates structures over a large range of scales. Work is undertaken at the scale which the human eye can see. This acheived down to the level of the cell with the aid of a clinical microscope and down further to the level at which individual atoms can be distinguished. There is even a scale below this at which sub particles are detected by means of their interaction with larger scale matter.

Working upwards to larger and larger scales - Cosmology works upwards to encompass planetary systems, galaxies and clusters of galaxies. The world around us and indeed the bodies of which we are made manifests life forms through an assemblage of what are to us - small structures - living cells. Science has very much been an onlooker at this level of life. It has patiently observed the secrets manifesting at this level. It has tried to manipulate them in crude ways.

A few scientific 'celebrities', however, are beginning to think unthinkable things about the scale of matter which science and technology may be able to manipulate. This is the subject called nanotechnology. In 'The Engines of Creation' by K. E. Drexler, the author very much in the way of 'selling' the possibilities of nanotechnology, leaves many gaps in perception as to how nanotechnology can be implemented as a scientific reality. Perhaps this gap in perceptions is very much like that Faraday could have met if he had predicted the developments of his first electric motor. It is difficult to see too far ahead.

The sphere of nanotechnology relates to small structures. In one 'thought' example it relates to a 'machine' which can be introduced into a cell to repair damaged strands of DNA. It relates to a 'machine' which can construct arrays of atoms in a precise pattern in accordance with pre-programmed instructions and so create structures with wholly new properties and functions.

Side of cube	No of atoms in 1 dimension of cube	No. atoms in cube
1cm	50000000	125000000000000000000000 (1.25×10^{23})
1mm	5000000	125000000000000000000 (1.25×10^{20})
100micron	500000	125000000000000000 (1.25×10^{17})
10micron	50000	125000000000000 (1.25×10^{14})
1micron	5000	125000000000 (1.25×10^{11})
100nm	500	125000000 (1.25×10^{8})
10nm	50	125000 (1.25×10^{5})
1nm	5	125 (1.25×10^{2})

Table 1: Atomic representation of matter

This new nanotechnology is still very much a thought experiment - and one which relatively few people are undertaking. There are several aspects of nano-technology which can be identified. One is technical practicality, another is social/economic/military implications if the technology works and one is aspects of control of the technology if proved. For like all technologies - they can be used and abused for the common good.

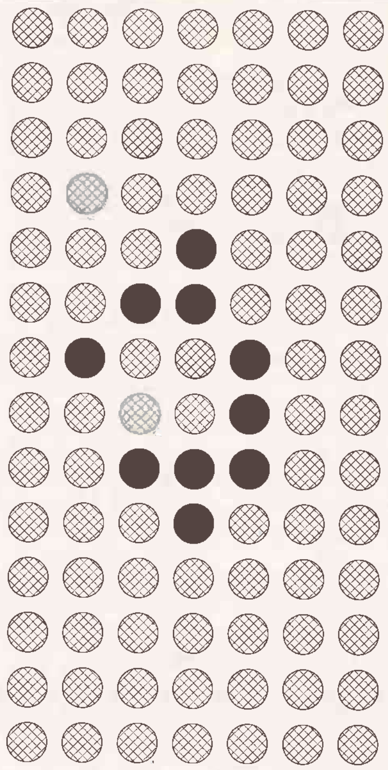


Fig.1 Arrangement of atoms on a surface to form an attractor site for a specific molecule.

First Thoughts

'Engines of Creation' is very much written in the style of a what the technology will probably be able to achieve rather than how such elements of technology can be fabricated. There are no guidelines as to how to fabricate the first clever assemblage of atoms into an intelligent 'entity' programmed to undertake specific tasks. Perhaps this is what the author delivers on the lecture circuit of North America. This must at present remain an area of creative speculation as to how such structures could be created.

Technology is reaching down to smaller and smaller levels. The requirements of micro circuit fabrication have led to technology which can move individual atoms into user defined patterns. It was researchers at IBM who recently formed the IBM logo in atoms on a substrate material.

It is important,to examine structures in respect of scales and sizes to see just where nanotechnology could be going. Table 1 shows a range of structures starting with a cube of side 10mm and work down in powers of 10 to smaller and smaller structures. It is assumed that the atoms of which the device is structured are spaced 0.2nm apart (1nm = 10^{-9}m).

The question presents itself, what is the smallest level of manufacture that can result in stable man-made units of matter. The techniques of silicon fabrication already use separations of active length of 0.25 micron. Within a few years this type of fabrication technology will probably have achieved fabrication at the 0.1 micron (100 nm) level. This means that the separations in wafers of semiconductor materials will be some hundreds of atoms wide.

The object behind such fabrication technology is primarily to harness current and voltage effects within a static array of material. The perceived goal of 'nanotechnology' is something more fundamental. The aim of nanotechnology is to produce 'atomic' machines capable of undertaking useful tasks such as the assembly of atomic structures to a specific formula or the modification of existing structures in a predetermined way. This might well be the dreamer's end point.

There may in the process of developing such technology be a natural progression in the level to which miniaturisation can proceed.

It is perhaps useful to anticipate some kind of nanotechnology machine in action. This does not give any clues about how such a machine could be created in the first place. It is like describing to someone how a radio receiver works where the technology does not exist to build one.

Suppose, a specific molecular structure is to be constructed. This molecular structure is to be built from a set of raw materials. The first requirement for fabrication is to have some kind of 'atomic hook' or 'atomic attractor' to pull in molecules or atoms as the building blocks of the system. Figure 1 shows a notional surface with a specific arrangement of atoms which act as a specific attractor for a specific type of molecule required to initiate the fabrication process. It is assumed that such highly selective attractor units can be thus structured. The more complex the molecule being attracted,the more complex the attractor site. Having attracted the molecule to the face of the device, the molecule bonds chemically with the atoms in the core of the attractor, leaving the attractor site depleted as shown in Figure 2. The attractor site is now depleted but can presumably be replenished from supply molecules which are now preferentially attracted to the attractor site.

This is an example of nanotechnology acting as some kind of exotic or designer catalyst where the action of the machine is highly localised but the activity can be spread over a large number of sites on a specific fabricated surface. This simple type of building block which can be identified as a mere cog in the gears of a more general nanotechnology machine may in its own right have great importance as a 'smart catalyst'.

Moving Machines

Nanomachines are also considered to have moving parts which allows for movement of materials over its surface and within its structure. While these ideas have been suggested, it is not known how practical such structures could be to fabricate.

K.E. Drexler proposes, structures of millions of atoms with large numbers of moving parts - up to 10,000 where each moving part is made up of hundreds of atoms. These complex structures - called advanced assemblers - can be thought of very much like a micro scaled industrial robot which picks up items to be assembled and pieces them together. In the case of the advanced assembler, fabrication is taking place at the atomic level.Such a device, cannot be realistically controlled by external signals. It requires its own intelligence to be built in some coded form. This is another great challenge!

The working advanced assembler is in many ways a thought experiment since the technology to assemble an assembler is not demonstrable. Yet this concept in nanotechnology describes perhaps the most ambitious scheme for the construction of man-made machines.

If such machines are viable, then their development will probably go down some path of initial very simple function with in time an increase in the complexity of the function which they can undertake.

Figure 3 shows a conceptual 'slice' through a nano machine - the thinnest parts of structures are perhaps 100 atoms wide. Such machines would have many moving parts.

Applications

If such technology is possible, there are a number of very significant implications. The technology makes possible specific assemblage of atomic/molecular structures from a 'soup' of raw materials. This can very reasonably expected to give rise to both new materials and also alternative pathways to synthesise existing materials. Such systems can probably be used for pollution control - where specific heavy metal atoms can be removed from solutions and damaging pesticide molecules 'grabbed' by an assembler and its structure changed to a safer one. In the extraction of raw materials such replicators may even be possible to assemble crystals of pure elements as they pick out specific atoms and construct precisely defined arrays of such atoms.

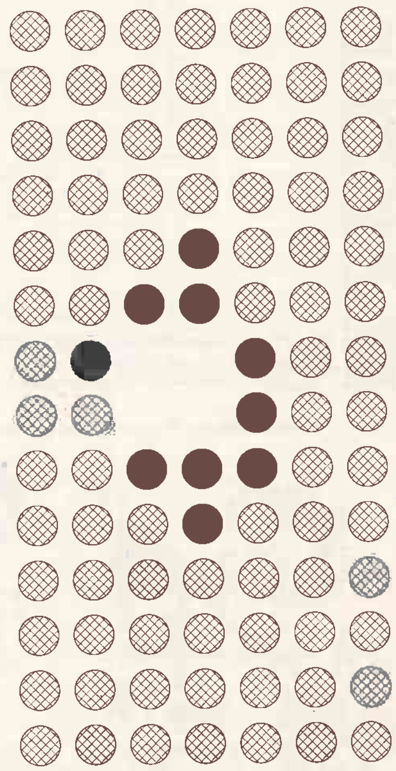


Fig.2 Attractor site with donor atoms stripped off.

There are even over the horizon ideas about manipulating DNA within living organisms. This would require a very advanced state of machine to carry out this function.

Possession of general nano devices, if they could be created, would be the ultimate wealth creating systems and could cause turmoil in a future more advanced technological society. Those economies which did not possess them would be at severe disadvantages.

There would seem to be the option of a 'hard wired' assembler or a 'programmable' assembler where in the first instance the array of atoms is somehow programmed to do just one thing but in the second case some instruction is passed to the assembler - very much like a new knitting pattern to a knitting machine. It may be possible to code large polymer molecules with atomic code arrangements which can be read by assemblers.

Looking at how natural evolution has worked at a nanotechnology level, instructions to replicate have been contained within the cellular level within DNA structures. While future directions in genetic engineering seek to unravel the mystery of DNA coding, there is the possibility of engineering nanotechnology assemblers being able to inspect and modify DNA structures. This would have far reaching consequences for us all. It is therefore a technology which needs a large element of control. While it would be possible to increase crop yields by creating superior plant strains, the technology could also be used to devastating effect in other directions.

The full development of nanotechnology is not likely to take place for perhaps 100 or 200 years so there is plenty time to write books and articles about what might or might not be possible. With the general developments of science we are witnessing, there is a sure but steady move down to control smaller and smaller levels of structures which in turn give control over larger and larger ranges of processes.

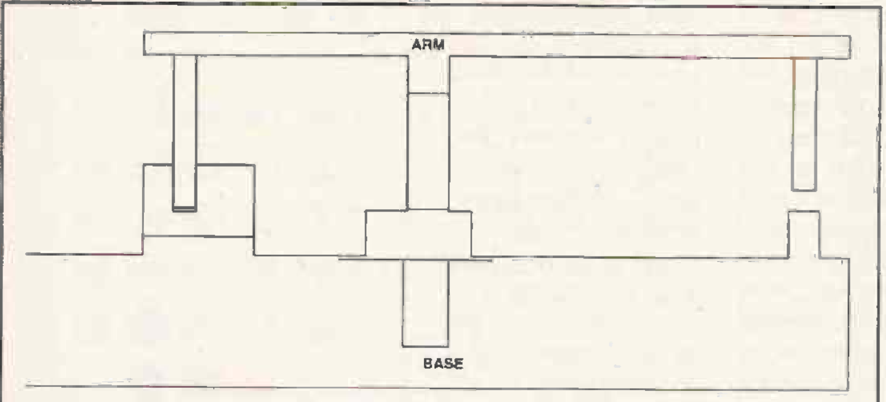


Fig.3 Cross section through a nano machine. A typical 'thin' structure would be about 100 atoms wide.

Human Control

There has been a great reluctance at present even to accept the very first offerings from genetic engineering - the first wave of artificially modified DNA structures. The public - and experts too - are very wary about letting man be 'creative' with Nature. There seems no doubt that this debate will develop significantly in future years. The public will very shortly be faced with the decisions about what is OK and what is not OK in terms of what is let loose out of the laboratories into the ecosphere. It seems likely that the development of nanotechnology will in future years provide a great abundance of test cases for sanctioning DNA modifying systems. Once the technology becomes proven, it could only be controlled with great effort.

Nature, is of course a marvellous testament to the success of carbon based life forms using its own brand of 'natural' nanotechnology to evolve and reproduce. Mankind is seeking in many ways to control and direct this happy success to his own ends. There may come a time when he develops the ability to construct a whole new diversity of 'nano entities' which have been artificially produced. If such possibilities are real then this could be the ultimate test of human responsibility.

The Ten Year Capacitor

A long term study of charge decay by E.F. Gunnton

The title of this piece may appear strange but essentially it is an investigation into one property of a capacitor.

Most of you will know that a capacitor charges and discharges according to the exponential law. The author is unnaware of any written work which gives actual detailed meaured values of any experiment done to prove this fact. It is the purpose of this article to rectify this situation.

The figures presented although as far as practical, are true and correct they must be considered as within the limits achievable by the home hobbyiest and not as definitive fact.

Why this extremely long experiment was carried out is not important here, what is important is that the results do indeed correspond with theory and practice.

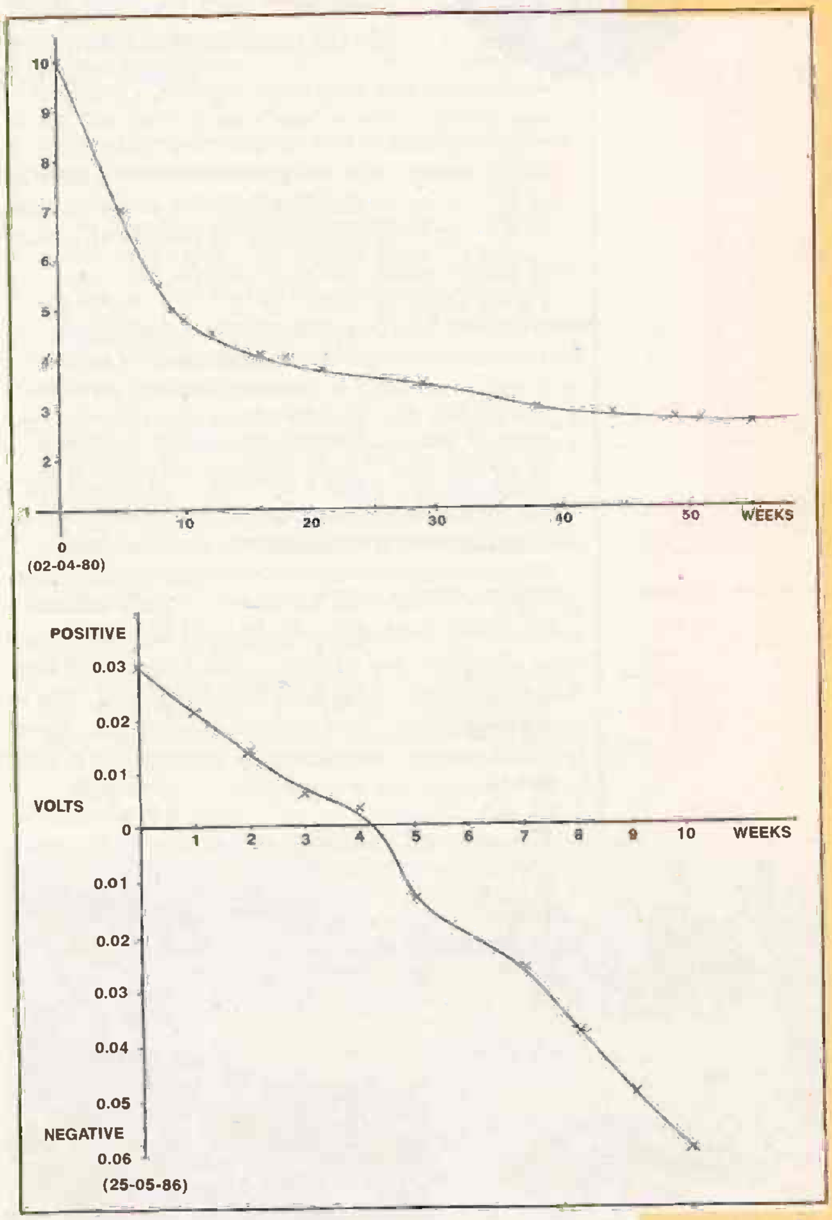
The relevent information is given in the graphs. Measurements were taken approximately each week with a high impedance digital voltmeter. The capacitar was initially charged to its working voltage by gradually increasing the direct voltage applied to it. No resistor was inserted to limit the charge, and no resistor was used to measure the discharge.

Through-out the experiment careful precautions were taken not to short-circuit the capacitor and at all times the voltmeter was allowed to warm-up for exactly the same time for each measurment - 30mins.

The final graph has not been given, as the x axis would be far too wide when compared with the smaller voltage y-axis. However the start where the curve decreases positively and the transition from positive to negative values are shown here. One or two points will be of interest. For example the transistion from positive to negative values of the voltage is fairly obvious but although the polarity changes, why does the negative value decrease towards zero? Also, two values, were the same? Reading error? Enviromental variations?

Finally, would the curve. if plotted in full, be more-or-less an exact fit to the standard exponential curve as defined by the equation $y = a^x$. And would discharging the capacitor via a suitable resistor alter the curve? The negative values rose to a peak of -0.386V before tailing off to zero (*Looks like an extremely damped oscillation - but oscillating with what over such a long time - **Ed.***)

This piece is not to be taken as the definitive experiment on capacitors, but it is hoped that it may spark investigation by many readers into the fundamentals of the hobby.



Capacitor Specification

Manufacturer: General Electric (1974)
Capacity: 100,000μ (0.1F)
Working voltage: 10volt
Approx 70mm diameter x 140mm

Voltmeter Specification

Manufacturer: Digital Measurements. Five Digits referenced to a standard 1.0193 volt cell.

Ranges input

Impedance: 39,999
3.9999
0.39999

All ranges are FSD with input impedance greater than 100M

Auto Protection

ETI Project Update with cover PCB

A cunning car alarm using the battery earth strap as a sensor. Original design and development by Phil Wait. Mods and suggestions by Geoff Martin.

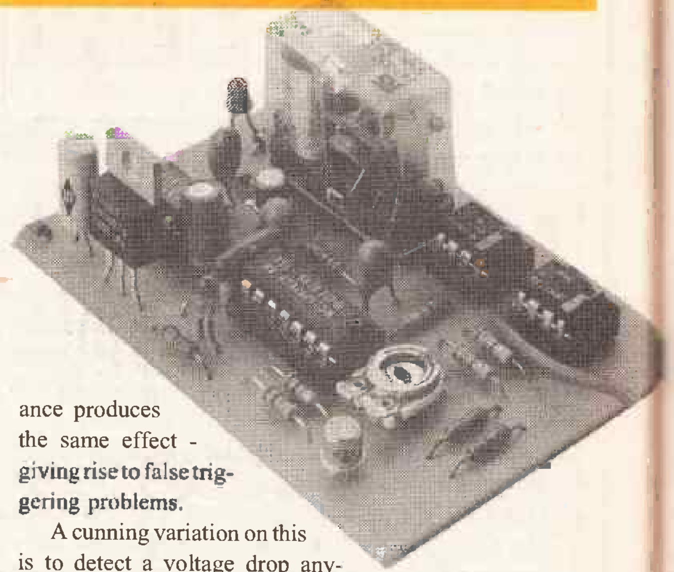
Way back in 1981, we presented a project for a car alarm. Now ETI provides a PCB on the front cover, we thought it opportune to give newcomers the chance to build this project with optional modifications. Firstly, here is the original text.

A significant proportion of cars are stolen at least once in their lifetime. The thieves are generally 'joyriders' who use them for a few hours and then abandon them after vandalising such items as wheels, seats, stereo/radios and so on. If you fit a good, reliable alarm you're bound to deter all but the most determined of criminals - who are usually professionals out to 're-do' the car or strip it completely for parts. There's almost nothing that will stop the latter type of thief - alarms, steering locks or any other deterrents notwithstanding.

Early car alarms were-electromechanical by nature. They generally had a balanced cantilever or a pendulum with a switch contact attached. Any movement of the vehicle would close the contact and latch on a relay sounding the horn. Simple and effective - but prone to false triggering. They've all but disappeared. Others operated from a series of hood and door switches, but installation often proved a major undertaking.

Drop Detectors

Later alarms became more sophisticated - one type sensed the slight voltage drop pulse that appears across the vehicle battery's terminals when a load is connected - such as a 'courtesy' light being operated when a door is opened. Reliability often proved a problem with these alarms as they depended on the internal resistance of the battery, which causes the voltage drop pulse following the connection of a load (the battery terminal voltage drops momentarily and then rises again). Any variation in the terminal clamp resistance produces the same effect - giving rise to false triggering problems.



A cunning variation on this is to detect a voltage drop anywhere in the vehicle's electrical system. The battery 'earth' strap has a small, but finite, resistance. Any load on the battery will cause a current to flow through the earth strap (since the vehicle's chassis is used as the return circuit). The current causes a small voltage drop across the earth strap resistance. This is detected and used to trip the alarm circuit that sounds the horn. A thief entering the vehicle will inevitably operate a 'courtesy' light or something that draws current, thus tripping the alarm. As the 'sensing' input is essentially a very low impedance input, false triggering from magnetic induction or other sources is avoided. Other voltage drop sensing schemes essentially have a medium to high input impedance, hence their susceptibility to false triggering.

Pulsed Protection

The sense and trigger circuit detects when the voltage drop across the battery earth strap rises above a predetermined amount. When triggered, this then arms the entry/exit delay. If the alarm does not remain triggered after the delay period nothing further will happen. If it does remain triggered, the delay circuit will trip the latch and start the alarm period timer. The alarm trip indicator will also light. When the alarm period timer is activated the relay driver is also activated. The relay pulser will then turn the relay on and off at one second intervals, pulsing the horn on and off too.

The relay pulser circuit operates continuously and flashes a dash-mounted LED to indicate that the alarm unit is 'armed'.

After the alarm period timer completes it's period, the relay driver is turned off and the will cease pulsing on and off. If someone attempts to steal your car, trips the alarm and then abandons the attempt, the alarm trip indicator LED will remain on, telling you that the alarm was tripped in your absence.

Construction

Our prototype was constructed on a PCB; while this is not

PROJECT

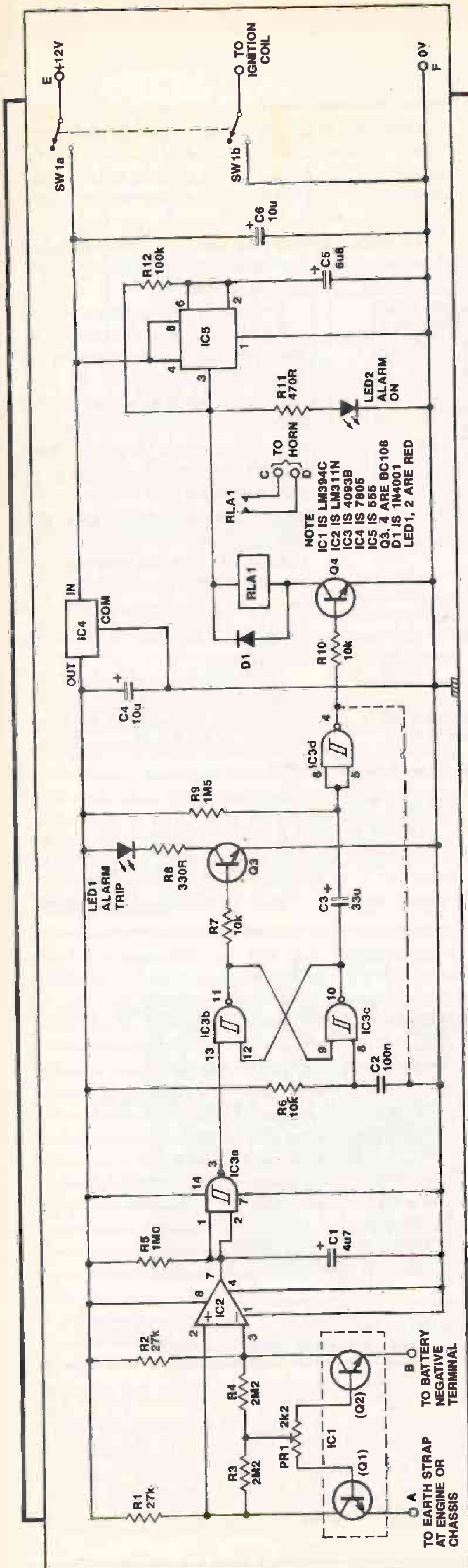


Fig.1 Original circuit diagram of the ETI Car Alarm

HOW IT WORKS

The current in the earth strap is sensed by a pair of transistors connected in a common base configuration.These two transistor Q1 and Q2 are encapsulated in an integrated circuit package (IC1) and are on a single chip of silicon, ensuring that they have very closely matched characteristics. The base-emitter voltages of each transistor will track within 50uV of each other, a characteristic which is exploited here.

When no current is being drawn from the battery there will be no potential drop across the resistance of the battery earth stap (ignoring the miniscule current drawn by this alarm). Thus the emitters of each transistor in IC1 will be a the same potential. As the base-emitter voltage of each is virtually identical the collector currents will be identical. Thus initially, the collector-emitter voltage of each transistor will be the same.

When current is drawn from the battery (when a courtesy lamp is operated), a small voltage drop will appear across the battery earth strap. Thus, point A (emitter of Q1) will be raised to a higher potential than pointB(emitter of Q2), That is, point A will be more positive than point B. The voltage on the collector of Q1 will thus rise (a common base amplifier is a non-inverting amplifier].

The voltage on the collector of each transistor in IC1 (Q1 and Q2) is initially set by a preset, which varies the current fed to each base. this compensates for any slight mismatch between Q1 and Q2(the DC gain of this circuit is very high) and also acts as a 'sensitivity threshold' control by introducing an offset which must be overcome by a certain level of current through the battery earth strap before the alarm will trigger.

The voltage difference between the collectors of Q1 and Q2 is monitored by a diffential input comparator (IC2). When the voltage on its inverting input exceeds the voltage on its inverting input the comparator's output switches high. IC2 has an open collector output requiring an external load resistor (R5) When the output of IC2 is low the timing capacitor, C1, is held discharged by IC2's output circuitry. When the alarm is tripped and the output of IC2 goes high C1 starts to charge through R5. After a time determined by the time constant of R5 and C1 the Schmitt gate IC3a toggles over and its output, pin 3, goes low.

The schmitt gates IC3b and IC3c form a latch circuit. On power up, the latch is autouiatically reset by R6 and C2 placing a momentary low on pin 8.The output of IC3c is high and the output of IC3b is low, Q3 is turned off and LED1 is not lit.

When the output of IC3a goes low-the latch toggles over. The output of IC3b goes high, turning on Q3 and lighting LED1. The output of IC3c goes low at the same time. The latch remains in this state until it is reset when the power is turned off and then on again.

Before the alarm is triggered the output of IC3c is high and the input of IC3d is held high by R9. As IC3d is wired as an inverter its output is low and Q4 is turned off. When the alarm is triggered the output of IC3c goes low, and since C3 is discharged, the input of IC3d is pulled low, its output goes high and Q4 is switched on, allowing the relay to operate.

The timing capacitor, C3, slowly charges through R9 and, after a period determined by the time constant of C3/R9, IC3d switches over, turning Q4 off again and stopping the horn.

The relay RLA 1, and therefore the horn, is pulsed on and off about once per second during the horn timing period. IC5 is a 555 timer wired as a free running oscillator. The frequency of oscillation is determined by the time constant of R12 and C5. As the 555 is capable of driving quite high currents it is connected directly to the relay, which is then switched by Q4. Ino ther words, the 555 pulses the supply to the relay.

The output from the 555 is also used to pulse LED2 (mounted on the dash) as a warning to would-be car thieves and as an indication that the alarm is on.

A three terminal regulator, IC4, drops the battery voltage down to 5V to supply the sense and timing circuit. This protects against false triggering from battery voltage variations and also helps to remove noise from the supply.

absolutely necessary - the project could be constructed on matrix board - a PCB does reduce the possibility of wiring errors which have to be sorted out when you first power up the project.

There is no particular order for assembling the components but it is usually easier to solder the resistors and capacitors in place first. Take care with the orientation of the tantalum and electrolytic capacitors. Follow with the semiconductors. Again, watch orientation of these components. The relay should be mounted last of all.

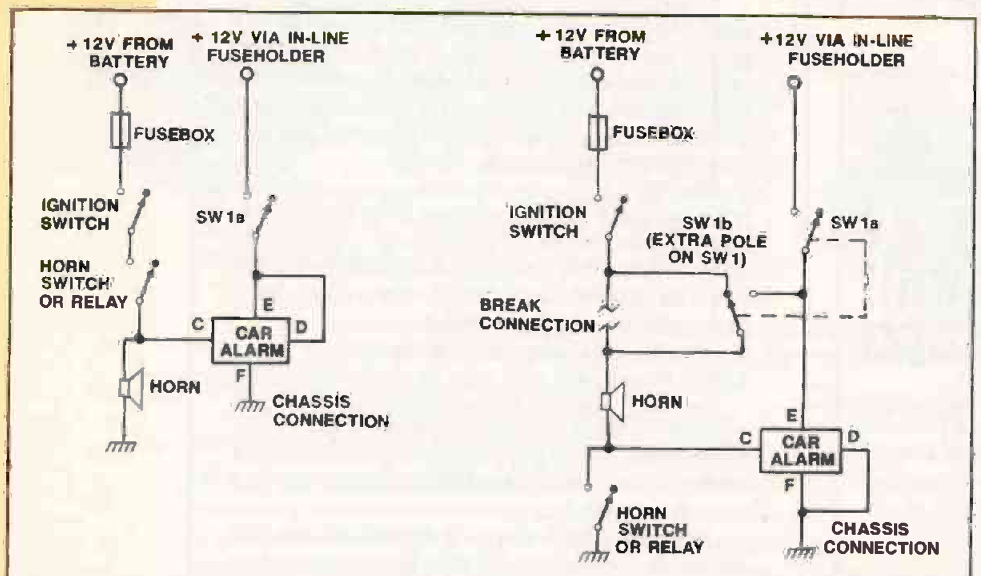


Fig.2 Common horn circuits and how to connect the alarm to them. The circuit on the left will have only one wire from the horn. The one on the right is found in cars such as the Leyland Mini and is rather more complex.

The completed board can be mounted in any convenient case - we housed ours in a diecast box measuring 120x40x95mm. A diecast box was chosen because it can be effectively sealed against the ingress of dirt, moisture and other undesirable substances.

We mounted the PCB on the underside of the diecast box's lid and fitted a 10-way terminal block on the outside of the lid for all the external connections. Leads from the PCB to the 10-way terminal block are passed through grommetted holes.

Installation

First, mount the two LEDs on the dash in convenient positions where they can be seen from outside the vehicle. The alarm is switched on by a concealed switch which may be located under the dash or under the driver's seat. Alternatively, an externally mounted keyswitch may be used. if you install the latter, entry and exit delay may be reduced to about half a second by changing the value of C1 to 1u.

We used a two-pole switch for SW1, one pole to switch the supply to the alarm, the other to short out the points when the alarm is switched on.

Thus, if somebody does gain entry to the car and ignores the alarm or disconnects the horn, they will not be able to start the car even if they hotwire the ignition!

Connection to the earth strap is quite straightforward. Take a wire from terminal A and solder it to the end of the earth strap. A wire from terminal B is soldered to the battery terminal connection. It's a good idea to keep these leads fairly short to reduce noise pickup. Ours were about 1m long.

The positive supply, via the alarm switch, should be taken through an inline fuse holder, directly from the battery positive terminal.

The output from the alarm is a pair of switched contacts, which operate the horn by bypassing the horn switch or, on some cars, the horn relay. We have shown two common horn circuits. In the first circuit the horn switch is bypassed by the relay contacts. The second circuit is a little more complex and requires an extra pole on the alarm switch.- If you want to short out the points as well you will need a three pole double-throw switch. Make sure you break-the connection from the ignition switch to the horn as shown, or when you switch the alarm on you will also switch on the ignition!

Try to make all wiring as neat as possible and try to blend it in with the car's wiring so it is not obvious to a thief what wire he has to pull out to stop the alarm.

Setting Up

When all the wiring is complete, all that remains is to set the sensitivity preset. Disable the entry and exit delay by removing C1, or alternatively connect a high impedance voltmeter across C1. With no current being drawn from the battery, adjust PR1 until the alarm just fails to trip or C1 fails to start to charge. Note the position on the preset. Turn on the interior light and the alarm should trip. If it does not, check your first adjustment; if it is correct, you probably have the leads to the earth strap and the battery negative terminal swapped.

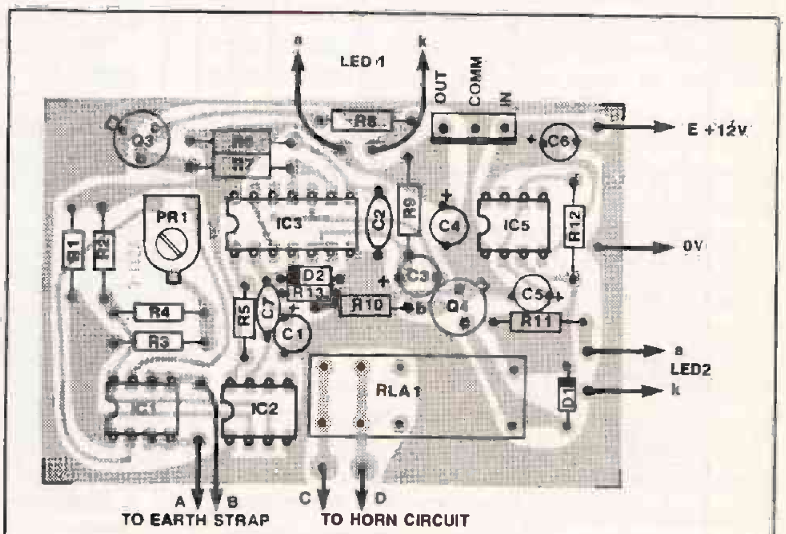


Fig.3 Component overlay for the Car Alarm. There are a lot of polarised capacitors so make sure you get them all the right way round.

PROJECT

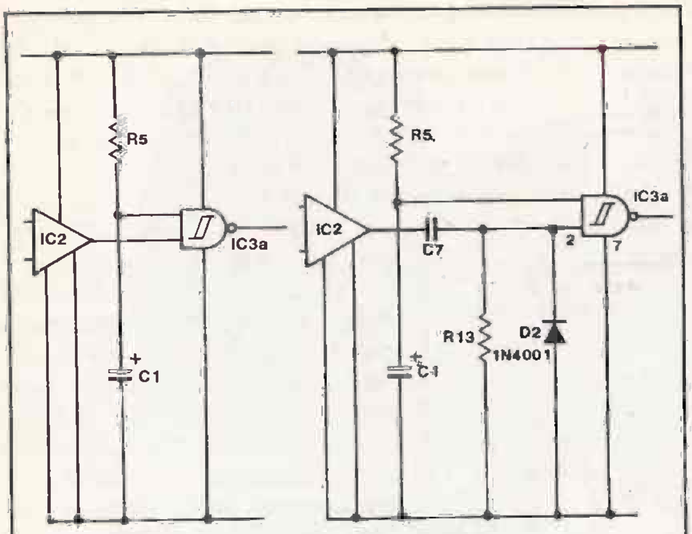


Fig.4a Modification to original circuit for instant alert of entry
4b Addition of differentiator circuit to sense only a rise in current

Turn the preset until the alarm just won't trip or C1 doesn't charge when the interior light is turned on. Note this position. The correct position for PR1 is midway between these limits, for reliable operation.

Next check-that the alarm doesn't trip on the car radio, or the electric clock. Some mechanical clocks are rewound by a motor every few hours, or even days, and these are often a cause of false triggering. If false triggering occurs from the radio or the clock, reduce the sensitivity. In some extreme cases it may be necessary to use a higher wattage interior light, though we found operation to be extremely reliable with a 5W light, and there was sensitivity to spare!

Modifications

In the original article, the output of IC2 is connected via a timing network (R5/C1) to IC3a input. This produces the effect of providing not only a delay on the alarm to get out of the vehicle but also a delay to get in - which includes the thief. So the thief could get into the car quickly and shut the door without sounding the alarm - provided he knew of this. This option if it is required by providing a wire link in place of C7. Remember to solder a small wire link between pins 1&2 of IC3 on the solderside of the board if you adopt this approach.

An alternative to this is to connect the timing resistor/capacitor (C1/R5) to pin 1 IC3 only and take the output of IC2 to pin 2 IC3. (See figure 4a). This way the output of IC3a will only go low when C1/R5 has charged to the switching level irrespective of the output of IC2. What it now means is that there is a suitable delay to arm the alarm, get out and shut the door and so when a thief comes along the immediate opening of the door will set off the alarm.

A drawback to this one is even the legal owner will suffer the same effect of the horn blast as the door is opened. However as the owner knows where the disabling switch is, the tooting horn can be quickly stopped (A small price to pay!).

Now we know what you're thinking - If the project was an infra-red remote controlled alarm, the system can be disabled before entry. The answer to that is we have a 3"x2" board on the front cover and this simpler project fits the bill with a bit of squeezing. It is also a question of time before thieves have an infra-red remote controlled handset to disable the alarm and unlock the door.

You may also find, depending on the resistance of the relay coil used (the higher the the better) that the on/off time of the horn will be affected when the relay comes into operation. Experimentation with larger R12/C5 values could solve the problem.

Rising To The Current Situation

Another more recent problem with regard to car technology is the thermostatically controlled cooling fan. It may be that on some hot days you leave your car with the cooling fan still running (assuming your car does this - If not,ignore this section with the exception of the last sentence). In this situation when arming your alarm, the input pair of transistors Q1,Q2 will detect a heavier than normal current flowing and send IC2 output high. The horn will then 'beep beep' when the delay period of C1/R5 has timed out. Not very successful as an alarm!. What we want is an alarm that will trigger to a rise in current only when the door is opened and not a fall. That way the fan motor can run and drop out when convenient without triggering the alarm. A simple solution could be a clamped differentiator network (R13/C7/D2). Figure 4b shows that a rising output from IC2 will produce a spike to feed the Schmitt trigger and thus an output pulse from IC3a. Any falling voltage will be suppressed by the diode clamp D2. Provision has been made on the PCB for this if you want to experiment. The modified overlay diagram shows this. Remember to put in a wire link in place of C7 if this modification is not wanted.

BUYLINES

All parts are still readily available. IC1 comes from various suppliers (Electromail and Farnell and Cricklewood) but will vary in price considerably - shop around for the cheapest.

PARTS LIST

RESISTORS (all 1/4watt,5%)

R1,2	27k
R3,4	2M2
R5	1M0
R6,7,10	10k
R8	330R
R9	1M5
R11	470R
R12	100k
R13	1m
PR1	2k2 miniature horizontal preset

CAPACITORS

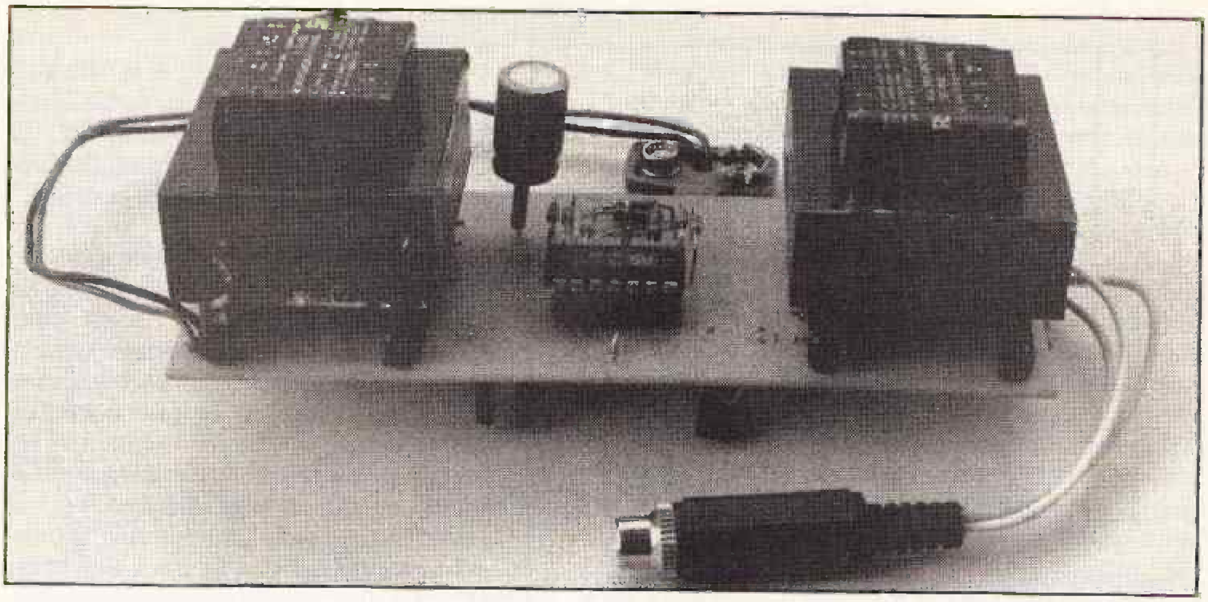
C1	4u7 16V tantalum
C2	100n polyester
C3	33u 16V tantalum
C4.6	10µ 16V PCB electrolytic
C7	100n

SEMICONDUCTORS

IC1	(=Q1,2) LM394C
IC2	LM311N
IC3	4093B
IC4	7805
IC5	555
Q3,4	BC108 (or any low power NPN silicon transistor)
D1,2	1N4001
LED1,2	0.2' red LED

MISCELLANEOUS

RLA 1	12V DPCO PCB-mounting relay
SW1	DPST or 3PST toggle switch
case	
10-way terminal strip.	



A Quick-Build Hemisyn

A cheap easy way to see if brainwave patterns can be altered. A report by Harry Hodgson.

The elegant circuit design by Aubrey Scoon, in the August 1991 issue, gives precise difference frequencies, and is repeatable exactly because of its crystal controlled logically derived audio. This aids serious experimentation.

However, to build the project requires the expenditure of a fair amount of gold, before one can find out if the idea works. I pondered on how I could lash up two audio oscillitors, as cheaply as possible and with the minimum of mental effort, to try out the idea.

It eventually came, to my mind a circuit I had seen over thirty years ago. It used a transformer primary as the inductance in a series LCR circuit in an astable cross-coupled multi-vibrator, OC71s doing the switching. The transformer was wound on a Ferroxcube pot core and the frequency was in the audio range. Not wishing to wind a special transformer, I tried a 230:6volt heater transformer and the circuit worked, but having no use for it I forgot about it until now. This time I used an RS Components 0-120V, 0-120V: 15-0-15V transformer. The subminiature mains transformer 0-240V: 20-0-20V is smaller, lighter and works just as well but it costs more. If you have to buy the transformers, then when you decide to scrap the circuit, at least you will have two useful items. I used a 741 initially because it was handy. The two diodes, back to back, limit the voltage swing on the op-amp inputs. I thought it sensible to put a 1k0 resistor across the diodes to give a DC path when they go non-conducting.

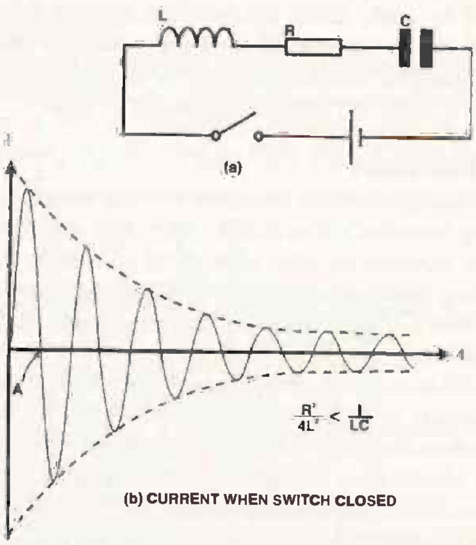


Fig.1 LCR oscillatory circuit

However, the circuit works just as well without it, although the period changes by about 0.1ms (handy for tuning).

The circuit was rebuilt using a TL072 to give a neater layout, but the higher transition frequency of the j-FET caused oscillations on one edge of the output square wave. This was prevented by adding a 1n0 capacitor across the op-amp inputs. A further rebuild using a 747, instead of separate 741s, worked first time like the prototype.

The in-ear phones were a cheap 32ohm type (£1 at the local market), and a 6k8 resistor in series gave an adequate sound level. It was found that loading the secondary changed the primary inductance and so varied the basic frequency of

PROJECT

oscillation. The other secondary (of the variable oscillator) has a 1k5 plus 4k7 preset across it and this gave a frequency change of about 7.5Hz. The two oscillators are matched as near as possible by adjusting the series capacitor. Initially, try each capacitor, of the same value, with each primary of both transformers, noting the frequency. Choose the combination that gives one frequency slightly below the other (about 4Hz or a bit more). The higher frequency oscillator is to be the variable one and the lower frequency oscillator can have its frequency lifted by loading the other secondary. In the prototype this required a 4k7 but in the final circuit none was required. Try two 100n in series as this may give a closer match. Although the circuit of Figure 2 shows 47n in both circuits, I ended up with two 100n in series for one and a 47n+10n+2n2 for the other. Always have the phones in circuit or shorted out, so that the loading is present, when adjusting the frequency. I can not give any scientific reason for choosing a frequency of around 340Hz; it sounded alright. 400Hz seemed too high and 200Hz required too great an

c Circuit

inductance change for this method of control. All measurements were of the output square-wave of the op-amp. With a time-base speed of 0.5ms/cm, it is possible to measure to 0.05ns. The final frequencies with the phones connected, were circuit B-2.96ms (337.8Hz) and circuit A-2.05ns(350.8Hz) to 2.92ms(342.5Hz). This gives a 'beat' frequency of 13Hz(alpha) to 5.3Hz(theta).

Construction

The PCB has been designed, using links, to allow the use of either primary alone, both in series or both in parallel. The last two are to allow the constructor freedom to experiment with, and is indeed encouraged to try other configurations. There is a link to be fitted on the transformer side of the PCB to connect the two - Vcc. lines. The 220µ capacitor may seem large but it is necessary to keep the ripple to around 20mV. It also enables the use of a high value potential divider, which keeps the current drain low and allows the use of a PP3 battery. The positive aud negative tracks have large loops soldered into them to give secure points for the attachment of meter or oscilloscope leads. Although I used a horizontal preset for frequency variation, solder pads have been added to fit the RS. finger adjust potentiometer if desired. There are other spare pads added for experiment. The 1.0mm holes for the transformer pins may need some enlarging for an easy fit.

As it is for experimental use only, no box has been specified and in fact it stands neatly on the two transformers. Drawing around 1.5mA at 8.5volts, a PP3 should last a few hours - certainly long enomgh to enable an assessment to be made of its effect.

Calibration

Not having a frequency meter, I had to measure the period of the square wave. The oscilloscope was checked against a crystal calibrator for each range used. An electronic organ could be used as a tone source to find and adjust the basic frequency.

A range of keyboard notes is given in Table 1.

HOW IT WORKS

The LCR circuit of Figure 1a, when an EMF is applied, gives an oscillatory current, if R2/4L2<1/LC (forget in this case), dying away exponentially as in Fig.1b. By using an op-amp to sense the zero-crossing of the current at point A and so change the polarity of the EMF, the first half-cycle of the waveform will be repeated in the opposite sense and so on. The 15volt secondary provides an isolated output for the earphone. Loading the other secondary gives a means of limited frequency variation.

TABLE 1		
B3	246.94Hz	
C4	261.63Hz	Middle C
C#4	277.18	
D4	293.66	D1 Guitar
D#4	311.13	
E4	329.63	
F4	349.23	
F#4	369.99	
G4	392.00	G1 Guitar

PROJECT

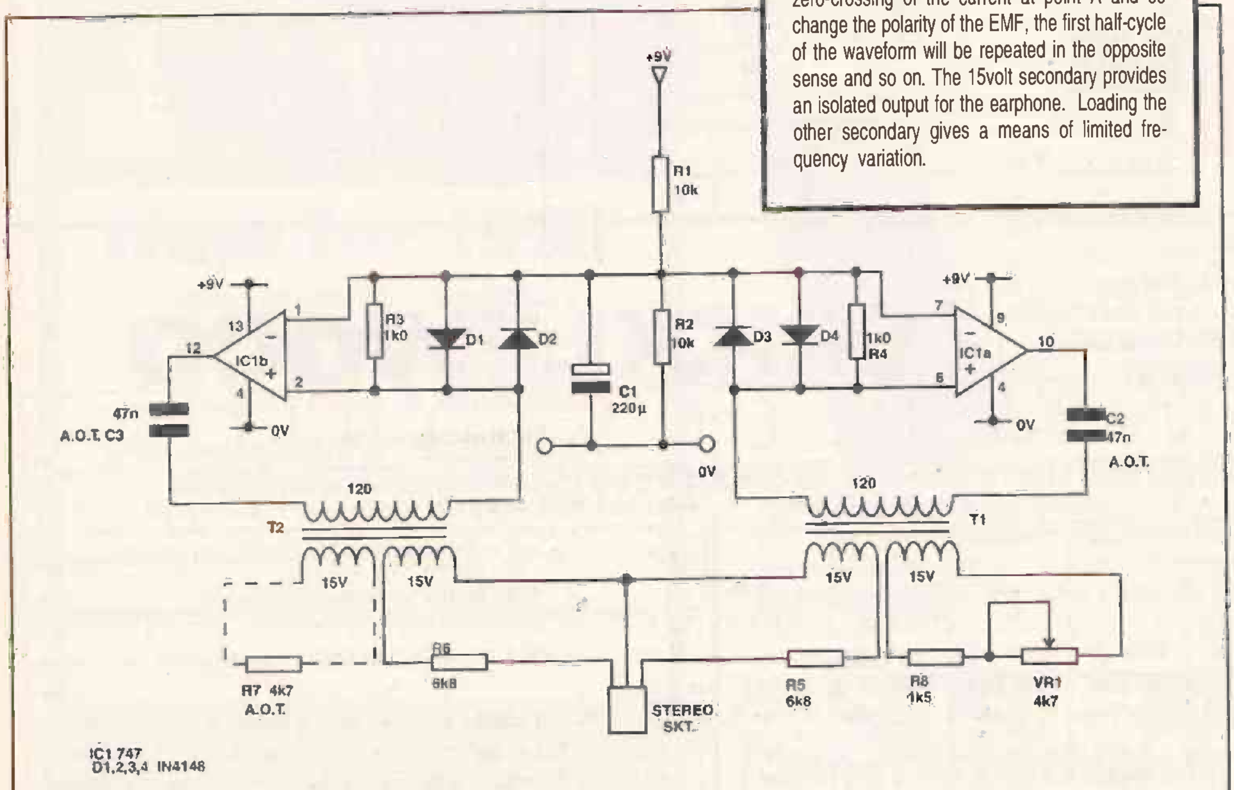


Fig.2 Circuit diagram

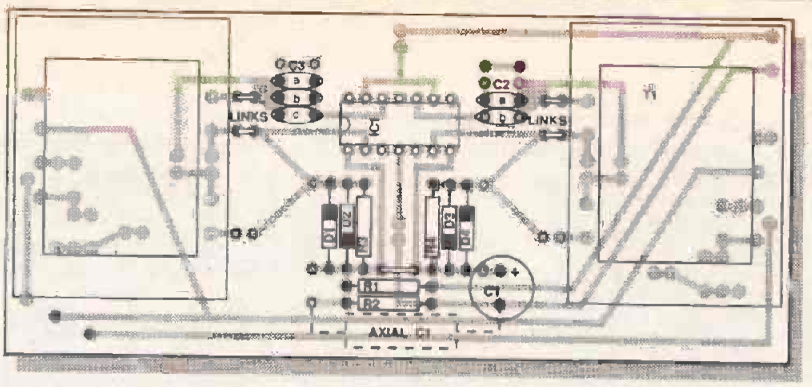


Fig.3a Component Overlay topside

Conclusion

Although the sound level may seem low, it seems to increase inside one's head and the 'beat' sensation comes and goes. It put me to sleep for half an hour, although I thought that I had closed my eyes only for a moment. Anyway, it interests me enough to want to pursue the idea.

PARTS LIST

RESISTORS (All 1/4w 5%)

R1,2	10k
R3,4	1k0
R5,6	6k8
R7	Adjust on test
R8	1k8
RV1	4k7 horiz. preset

CAPACITORS

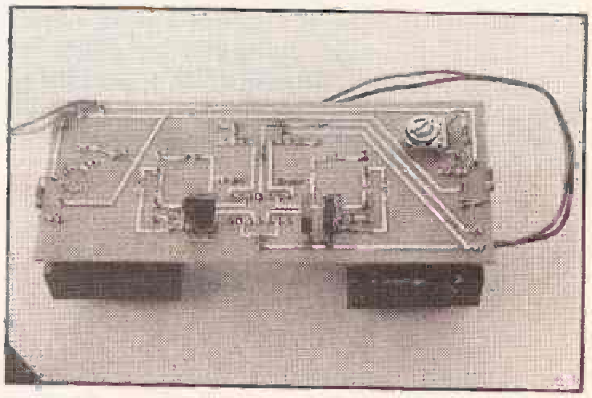
C1	220µ elect
C2,C3	47n AOT

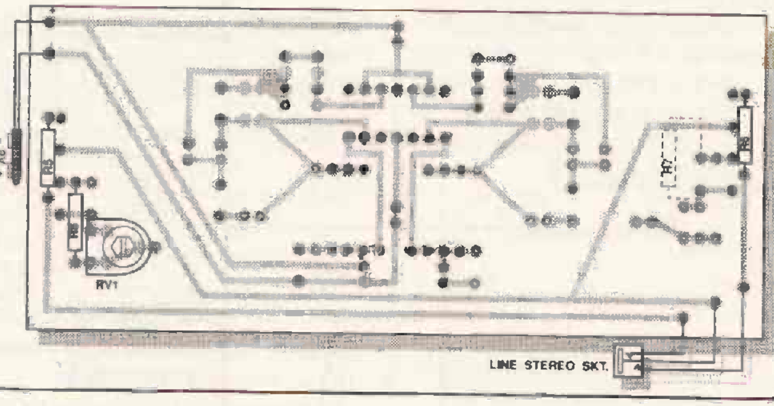
SEMICONDUCTORS

IC1	747
D1,2,3,4	1N4148

MISCELLANEOUS

T1,2 RS 207-598 2x120:2x15v or 12V PCB type
9V battery
Connectors,phones - 32R, Line socket





3b Component Overlay bottomside

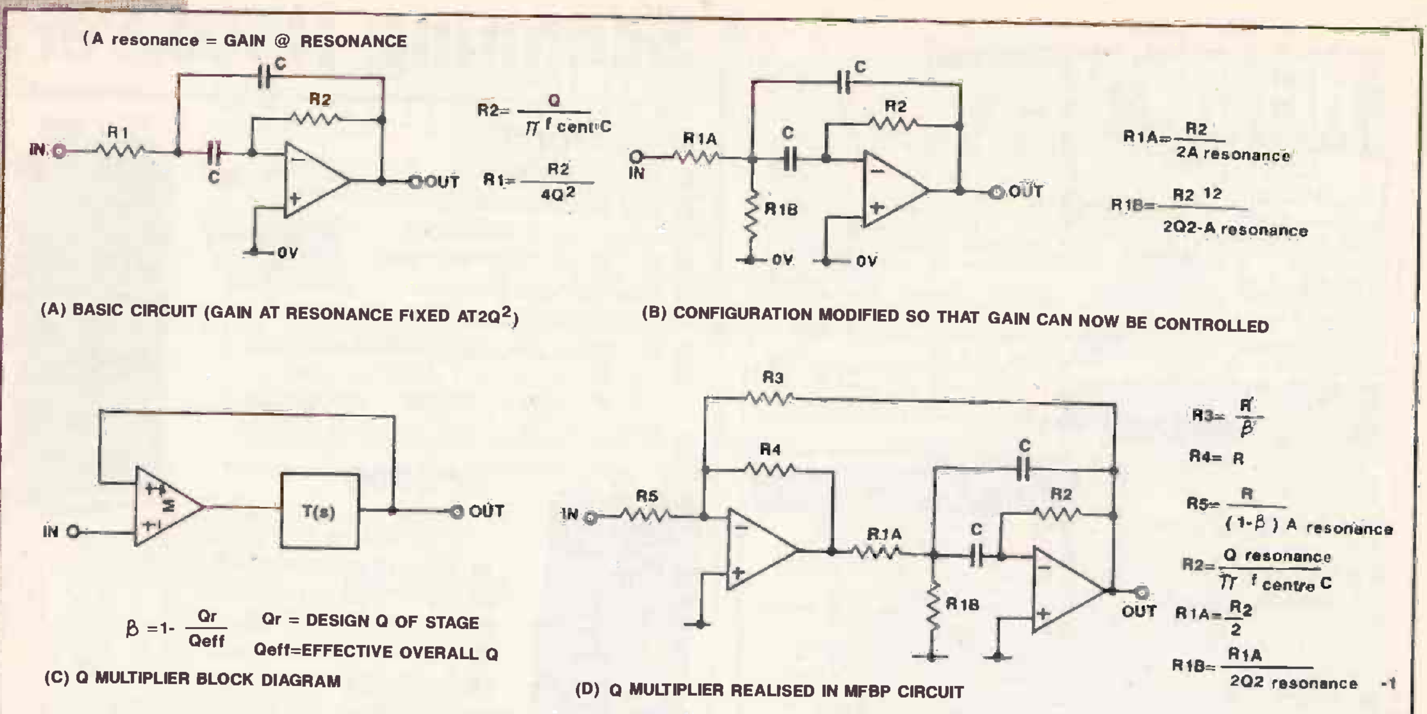


Fig.1 Multiple Feedback Bandpass Filter (MFBP)

AutoMate Anniversary Mixer

7b

Mike Meechan continues to look at everything you ever wanted to know about EQ

Last month, we looked at some of the more common and simple filter sections to be found lurking at the extremes of the audio range. This month, we move on to expand this theme and take a closer look at some of the more complex filters which are to be found inside audio mixing desks.

The very last filter on last months agenda was the Multiple Feedback Bandpass type. A brief recap and rapid vivisection of this type will serve us well as an appetiser for later fare. The MFBP is sometimes known also as the bandpass pole pair and features a a minimum of components and a low sensitivity to component tolerances. Circuit gain at the resonant frequency f is given by:

$Av = 2Q^2$

Because of this, open loop gain of the op-amp at f_{res} needs to be well in excess of $2Q^2$ so that circuit performance is controlled mainly by the passive elements. This factor restricts Q sizes to below 20 - very high by normal audio standards - but also depends on the amplifier type and the frequency range of the audio signal in question.

This equation, shows that extremely high gains occur for even moderate Q values because of the Q1 gain proportionality. In fact, even quite small input signal levels can cause the circuit to clip. A further limitation which restricts flexibility of this configuration is the link between Q and gain.

A refinement of the basic form is shown in Figure 1b. The

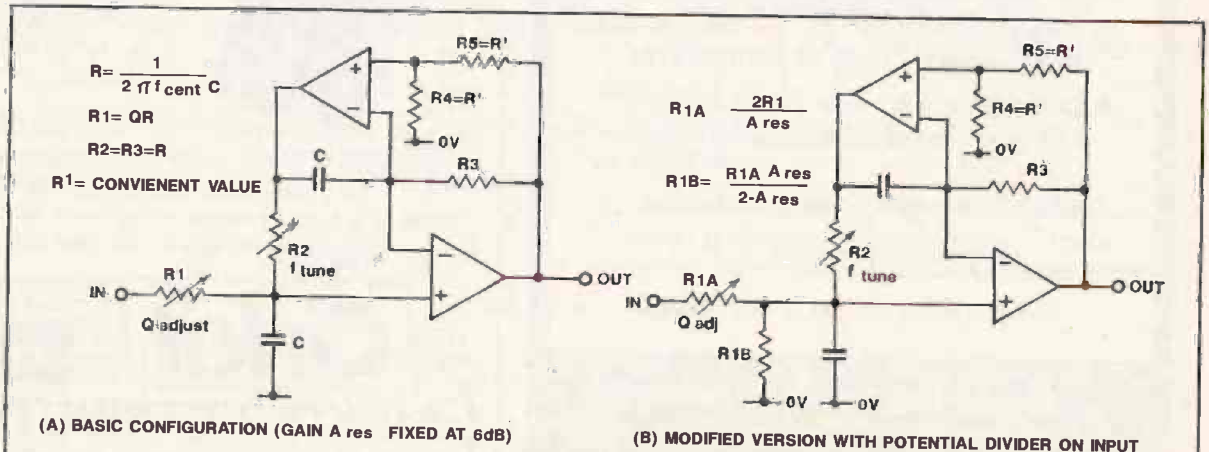


Fig.2 Dual Amplifier Bandpass (DABP)

PROJECT

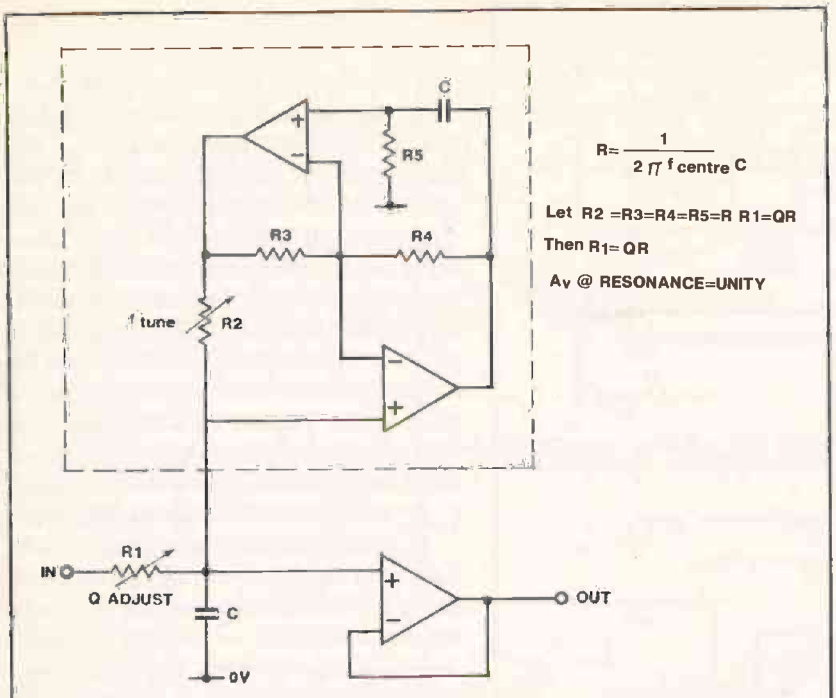


Fig.3 Low sensitivity three amplifier Bandpass

input resistor is now split to form a potential divider so that gain of the network can now be controlled, the parallel combination of the two resistors being made equal to R1 to retain the original resonant frequency.

One way to realise larger Q's with the simple MFBP is to use the Q multiplier approach. Contrary to popular beleif, this is not the same mechanism employed by post offices, banks and DIY stores during their busiest periods. Rather, a low Q bandpass is enclosed within a Q-multiplier structure which increases Q to the desisred vàlue. Figure 1c shows the basic idea. This configuration is not restricted to the MFBP and may be used with other types such as the state variable (which we'll discuss later). The only rudimentary requirements are that the filter should have an overall inverting characteristic and must have a gain of unity at $f_{resonance}$ since the positive feedback nature of the network means that small gain errors cause large Q variation when B is close to unity.

Somewhere in there we mentioned 'sensitivity'. What is it and how does it relate to filter design? It is a very important factor in the choice of filter since it places the burden of both cost and complexity constraints upon the designer. The definition is given as, 'the amount of change of a dependent variable resulting from the variation of an independent variable'. Quite simply, it is used as a figure of merit to measure the change in a particular filter parameter, resonant frequency, say, for a given change in a component value. This is of some importance because of the way in which components can deviate in value from their nominal values because of changes in temperature, humidity or perhaps because of ageing effects. This can cause changes in Q or centre frequency or gain. Sensitivity is a mathematical concept which can be related to many other aspects of electronics, not just those of filter design.

In addition to the effects of component value sensitivity, the active elements too play a part since both Q and be a function of amplifier open loop gain and phase shift. All of these factors ultimately determine whether or not a particular filter is relevant for use in certain applications. The most singularly important and often-quoted sensitivity parameter is Q-related since this is a good measure of circuit stability. Frequency sensitivity is also important because it determines whether or not the circuit will require resistive trimming.

Continuing in this vein of thought, a very interesting bandpass filter arrangement is shown in Figure 2. It was first introduced by Sedra and Espinoza and despite its apparent simplicity, it performs quite remarkably in terms of available Q, low sensitivity and flexibility when compared to similar two-amplifier types. An interesting result of sensitivity studies has shown that if the bandwidths of both op-amps are nearly equivalent, extremely small deviations of Q from the design value will occur. This is especially advantageous at HF where the amplifier poles have to be taken into account.

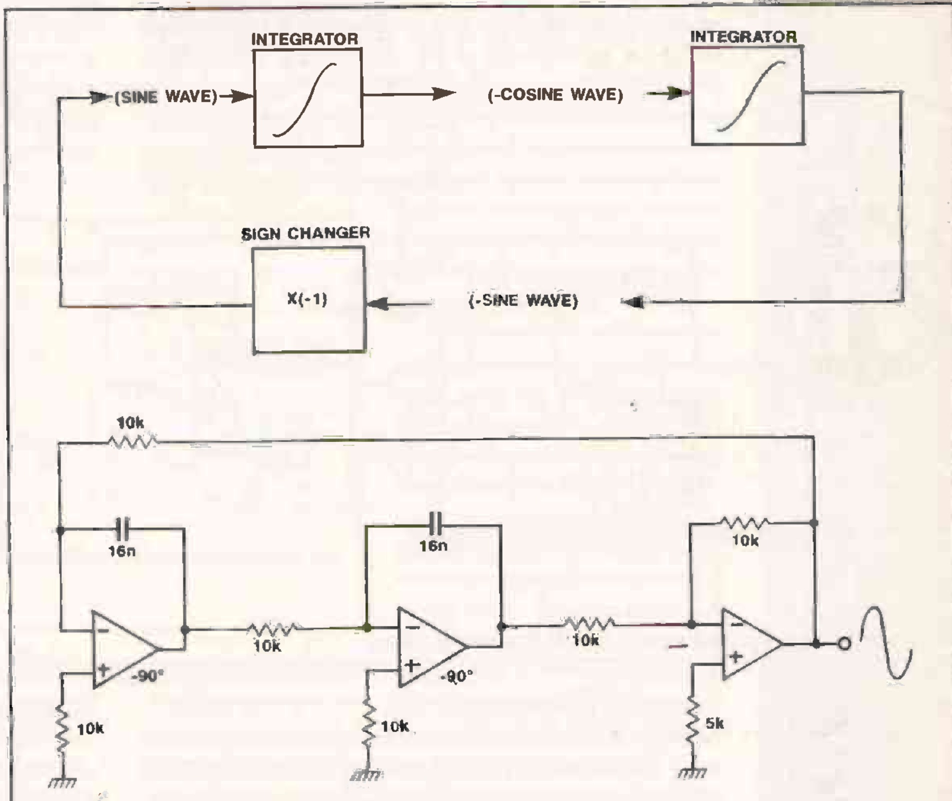


Fig.4 Building a sine wave oscillator pendulum analogue with two integrators and an invertor

A dual op-amp package lends itself readily to the task since there will be close matching of both amplifier halves. The DABP is useful from our point of view because resonant frequency and Q can be independently adjusted. R2 is adjusted for resonant frequency while R1 alters the Q with-

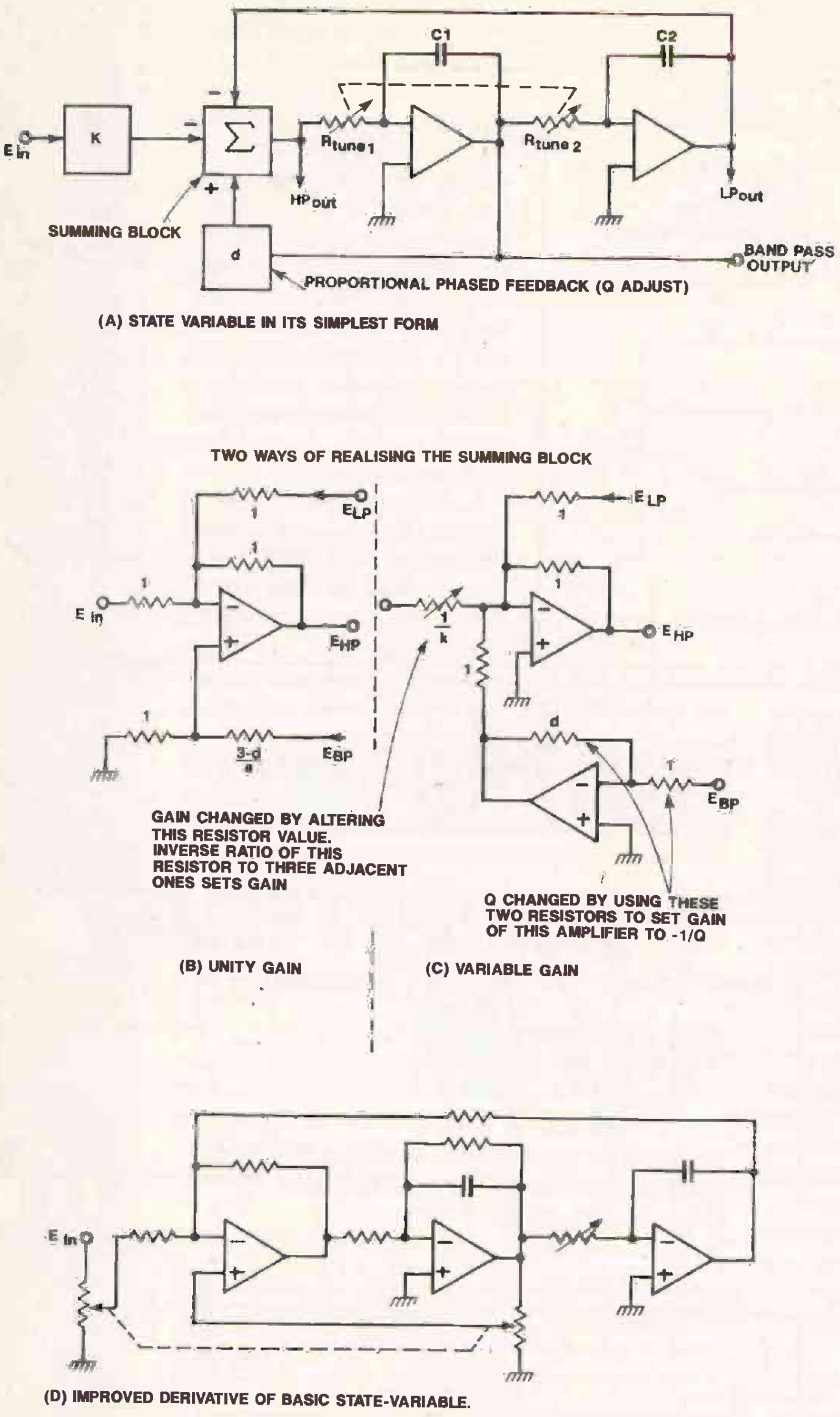


Fig.5 Modifying the oscillator to realise the state variable

out altering this frequency.

We need to look towards a more complicated fully tunable type. The following is a list of attributes which require filters of more complexity than the single or two op-amp circuit.

Any filter which is required to be tuned electronically or controlled with voltage over a wide frequency range.

Applications which require extremely low damping values without upsetting network stability (Damping is the inverse of Q, remember).

The passband requires to be altered from high pass to bandpass or vice-versa.

Variable gain is required within the filter

We can see that the parametric equaliser demands more than one of these listed 'enhancements' The next logical step in the progression is the 'low sensitivity three amp configuration'. This is a slightly modified version of the DABP, which although useful in general purpose applications, suffers markedly in yielding good all-round performance, particularly at HF.Referring to Figure 3, we can see that the section inside the dashed line is actually a gyrator which realises a shunt impedance. The third op-amp serves as a buffer to provide low output impedance and as in the DABP example, $f_{resonance}$ and Q can be independently adjusted.

Further progression in a different direction is shown in Figure 5. A cursory examination of the various filter circuits in the diagram reveals that the arrangement of the different circuit elements bears more than a passing resemblance to an oscillator constructed from similar elements. Having already established that the gyrator tuned circuit is not quite the way forward as far as an easily implemented and tunable design of bandpass filter is concerned, we must find a suitable substitute. A universal filter module known as the 'state-variable' presents itself as a possible answer. Despite the ostentatious name, it is nothing more than an electrical analogue of a mechanical pendulum.

As a related aside, a simple sine-wave oscillator can be built from identical constituent parts-see Figure 4. Let us suppose that we start with a sine-wave from some unspecified source. The sine-wave is, oddly enough, of the right frequency and amplitude. If it is now integrated with the correct time-constant, a new sine-wave is created - it's actually a cosine wave shifted in phase by 90° but we shall conveniently forget that for the moment. Further, an inversion is caused because the signal is connected to the inverting input.

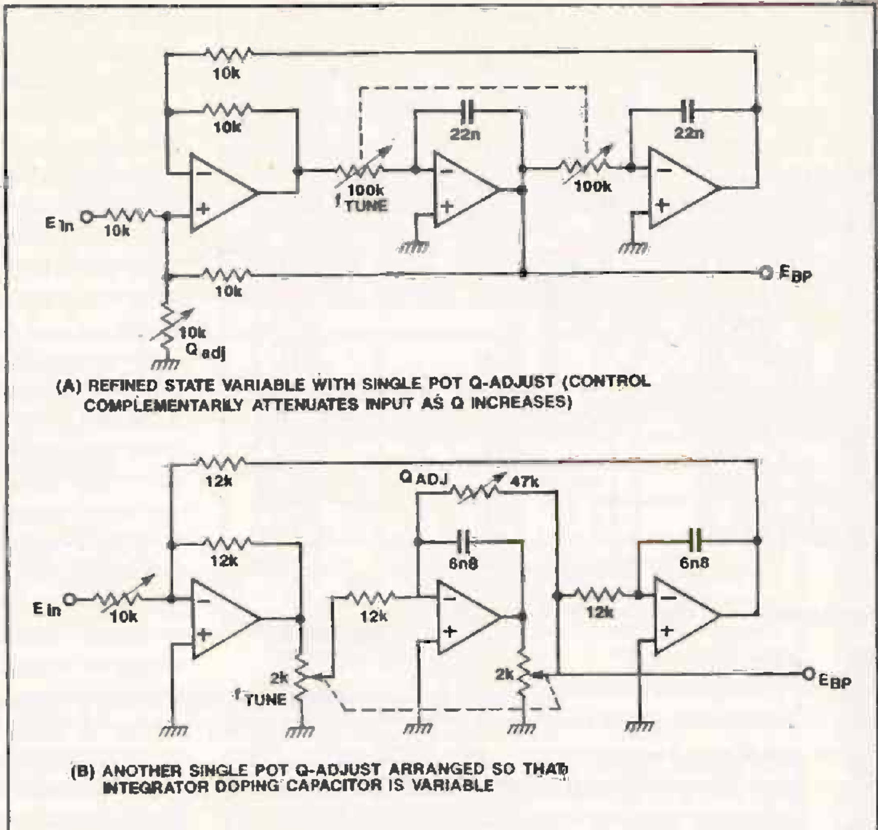
If we integrate again with the correct time constant, another 90° phase shift is yielded giving two inversions and a total phase shift of 180°. Inversions cancel so we finish with an inverted replica of the input waveform. We then route this inverse back to the input via an amplifier of gain -1 and the result is an output which is identical in all aspects to the input. Oscillation results if we connect the output to the input. This is an electrical analogue of a lossless pendulum.

But how does this relate to the parametric equaliser? To yield this function, again we connect two op-amps as inverting integrators in cascade. The output of the second op-amp is inverted and returned to the input of the first integrator. This, as we have already demonstrated, solves the equation for an undamped pendulum or sine-wave oscillator. Additional feedback from the first integrator is also returned to its own input. This is analogous to adding 'rust' or 'air resistance' to the hinge or pendulum since it provides a selected amount of damping.

Finally, an input signal is also routed to the input of the summing stage in front of the first integrating amplifier. This provides us with the necessary electronic input or driving force for the 'pendulum'. The input summing stage combines damping oscillatory feedback and input signals. Proper design of this summer yields a network where independent adjustment of circuit gain, frequency and damping is possible.

Several possible options for the summing block are present. A single op-amp type can mix feedback, input and damping signals in almost any ratio but as the damping signal is not inverted, we cannot independently adjust the gain and the damping with a single pot.

Again, Figure 5 shows a typical configuration. It pays dividends to keep $f_{resistor}$ and $f_{capacitor}$ identical in value. Varying both resistors simultaneously varies frequency inversely, with the lower frequencies associated with the larger RC products. Input, feedback and summing resistors are kept at 1:1:1 ratio for a gain of unity and a DC return path for the input through the source circuit must be provided. The ratio of the resistors on the non-inverting input of the summing amplifier sets the overall gain from the bandpass output to through the mix amp to the high pass filtered output at a gain value of 'd'. Resistors on the non-inverting inputs are non-critical with values chosen to minimise DC offset and they may be replaced with short circuits in many instances.



(A) REFINED STATE VARIABLE WITH SINGLE POT Q-ADJUST (CONTROL COMPLEMENTARILY ATTENUATES INPUT AS Q INCREASES)

(B) ANOTHER SINGLE POT Q-ADJUST ARRANGED SO THAT INTEGRATOR DOPING CAPACITOR IS VARIABLE

Fig.6 Further modifications to the basic state variable

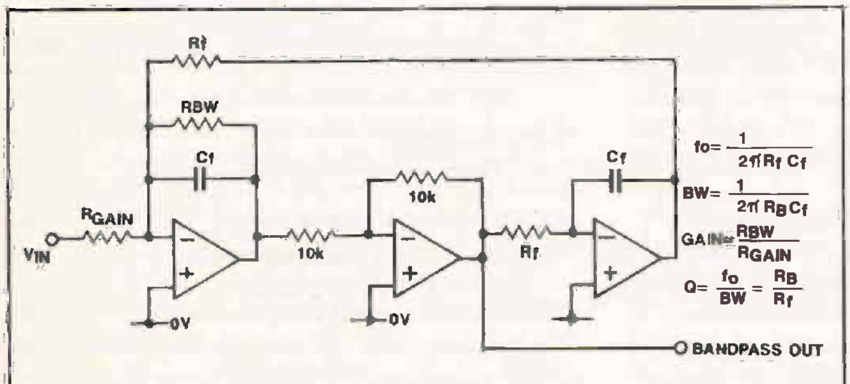


Fig.7 Broad active filter

Further Expansion of the State Variable

The simplest way to make gain and damping completely independent is to invert the damping signal with a fourth op-amp of -d gain and then to sum the input, feedback and damping signals independently on the inverting input. Figure 6 shows the basic idea.

Basically, what we have done is to cascade two variable, passive, first order filter sections with tracking and coincident break frequencies. Performance of this configuration is further enhanced by separating the two filter sections with an intervening inverter op-amp. In this way, each of the filters is isolated from the other and this results in an improved response from the circuit.

The downside is that it can only yield - for audio, virtually unusable and impractically low Q values. (This is a somewhat simplistic view and we shall see at a later stage that there are devious ways of improving performance of this type as regards Q and the size of it). Further improvements result if we apply a controlled amount of positive feedback from output to inverting input. It is this arrangement which now begins to look more like an oscillator than a filter.

Resonators and oscillators are very much related circuits, especially with the parametric type. One might only be a very small margin away from the other by virtue of small changes in component values and as such, the separation of stability and instability in filters and oscillators respectively is very small. That this is so leads us on to the two different approaches predominant within the field of active filter design. We can start either with an oscillator configuration and alter component values in such away that the network loop becomes stable and the desired filter response is yielded. (The state-variable, bi-quad and other integrator loop filters are realised using just such methods). Conversely, we can start with an inert, passive filter network and create gradual instability by introducing carefully measured amounts of positive feedback. This approach yields a circuit which is tediously critical in respect of feedback. (The term 'push or retard' has been coined to succinctly describe the two different approaches to filter design).

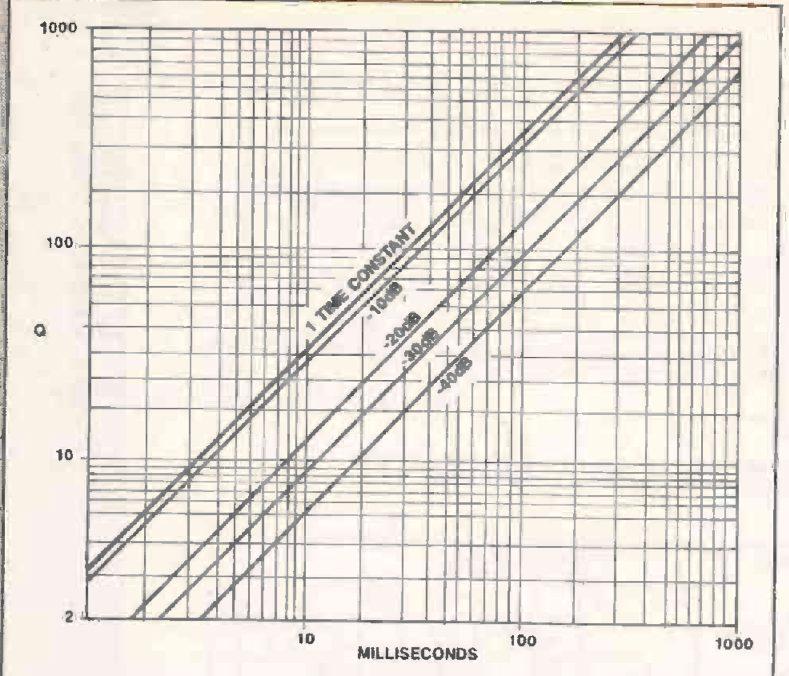


Fig.8 Ringing or exponential decay of a 1kHz pole

The Bi-quad

We can now move on to another related type of loop filter called. the Biquad. It's a distant cousin of the state-variable, is similar only in appearance. See Figure 7.It consists of two integrators and an inverter with loss introduced into one of the integrators with a damping and Q-setting resistor. The gain of the circuit is -Q for a unity input resistor but can be anything else if this value is altered.

Conventionally, the circuit is tuned by varying the tuning resistors although altering the capacitor values achieves a similar effect. In contrast to the state-variable, the bi-quad is a constant bandwidth filter (as frequency changes, bandwidth remains constant), therefore the f/Q term remains constant while the frequency or Q parameters are altered. High frequencies yield high Q's and low frequencies, low Q's. It is absolute bandwidth, NOT percentage bandwidth, so as Q rises in value, the percentage bandwidth decreases with f and vice-versa. For this reason, the bi-quad is sometimes known by this description ie 'constant bandwidth'.

Never Mind The P's, Mind Your Q's

Since Q is an important parameter, musically, within the field of audio active filters, we'll examine that topic next. As previously noted, a filter known as the 'constant-bandwidth' type exists.

This is of little practical use from a console EQ designers' point of view. (The only practical use in an audio environment might be in the splitting of a telephone circuit into discrete frequency bands of identical size for use in a telecommunications or data transfer application). For the filter to be of any creative or corrective use in an audio environment, Q must remain constant - unless deliberately altered by the user -irrespective of changes in frequency. The fact that this should be so evolves from psycho-accoustics - ie the way that the human being responds to sound - and the way that sound occurs in nature.

Consequently, choice of user-variable Q range - and the value of Q set by the operator of such a control - is important if the filter is to sound 'natural' and not harsh and artificial in use since high values of Q (high being relative to audio in this context and referring to values in the region of 5 to 10) can cause ringing at the filter centre frequency when a transient hits the circuitry. This is not what any audio filter is intended to do. What is intended is that it has an audible effect upon any frequency input within its range but it must not generate sound of its own when applied with the correct stimulii ie a transient. Returning to the earlier pendulum analogy, we can see that if we hit it with an impulsive hammer blow, it will oscilllate for some time, the oscillations only dying when the non-perfect Q of the device removes all of the energy of the impulse. Exactly the same happens to an electronic band-pass filter. Narrower bandwidths (or higher Q's) mean that the decay period - or the time that the

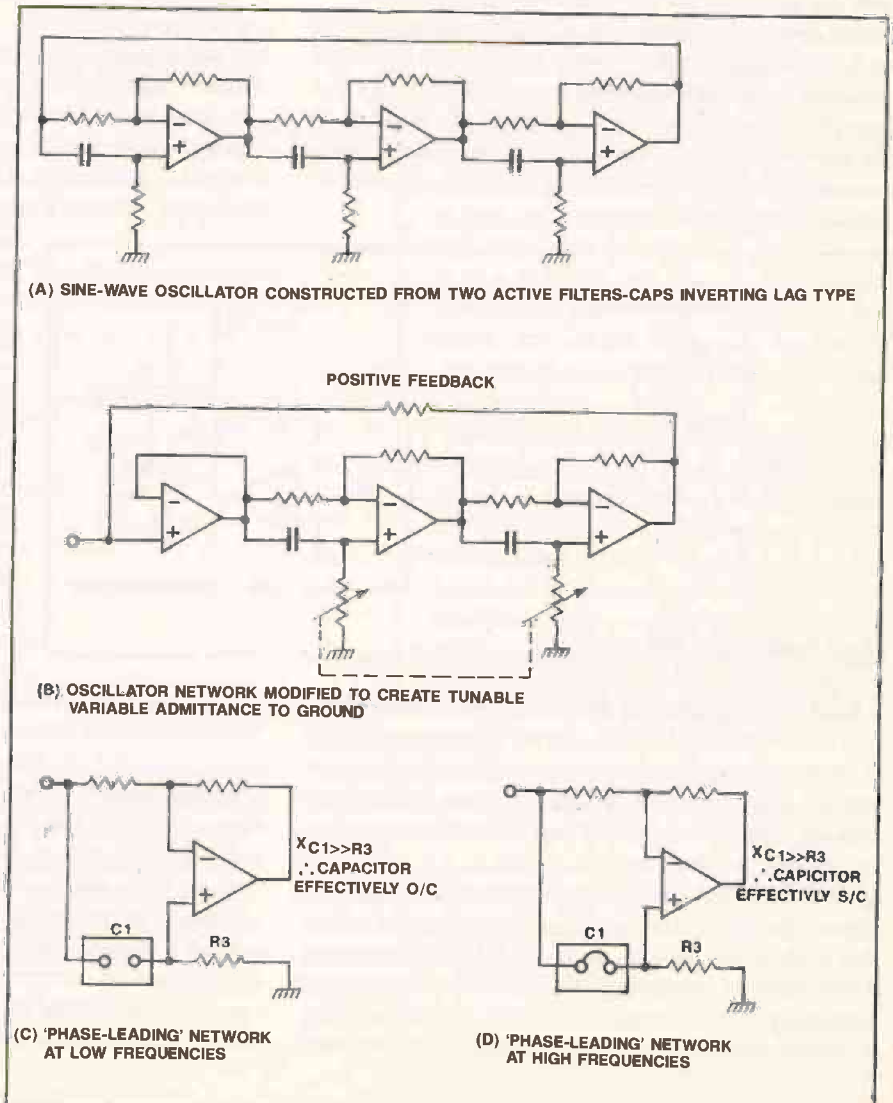


Fig.9 Creating a bandpass filter from delay equaliser (Caps) elements

oscillation takes to die out - is longer. This is known as the transient response of the pole and Figure 8 shows the ringing or exponential decay of a lkHz pole. (Scaling up or down makes the graph applicable for other frequencies).

An unwanted transient effect such as this is therefore akin to the bell (another mechanical equivalent of an electrical filter) ringing of its own accord. Some restraint is therefore in order in this aspect of the design and a usable range of Q's evolved through empirical means seems to be in the region of 0.2 - 0.5 to about 4 or 5.

known as the 'two integrator-loop' seems in the main, and for a variety of the reasons to be the type adopted by many commercial console designers in their realisation of the parametric EQ function. Looking back at what we have already discussed about the creation of complex filters from simple constituent parts, we can now approach it from a slightly different tack. By using three inverters in a closed loop, the resultant 540° phase shift (180° + 180° +180°) means that the loop is completely stable since the input the first op-amp is 180° out of phase with respect to the output.

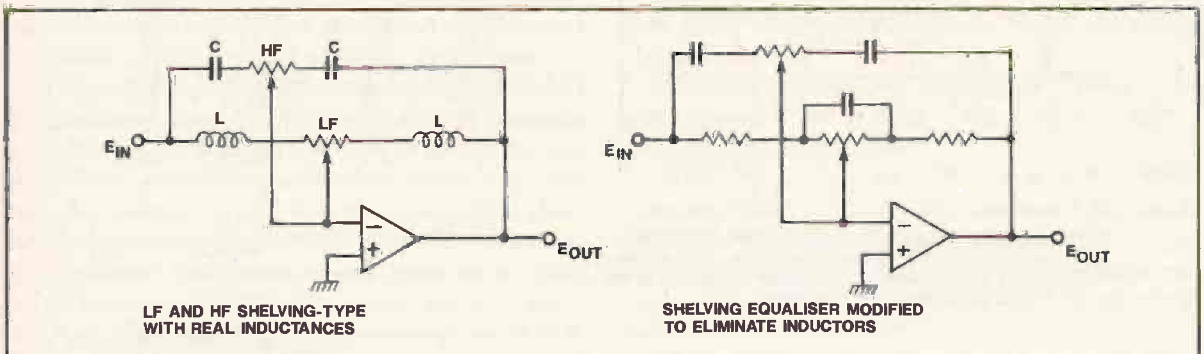


Fig.10 Methods of creating frequency selective elements for a Baxandall-style stage

Control of Q

The Q of the filter is normally related and more usually numerically proportional to the gain of the filter at resonance ie a network with a Q of 2 will have a gain at resonance of 6dB. High values of gain - and of Q - quickly erode operating headroom and just where its needed most. A Q of 5 (which is not unreasonably large from an audio point of view) equates to a voltage gain at resonance of 14dB. One way around the problem is to arrange for Q and circuit gain to be complementarily and simultaneously controlled, ie as Q is increased, the input signal is attenuated by a corresponding amount. With many filters, this would prove to be problematic since most aren't quite obliging in easily providing simultaneous and easy control of both Q and gain. Not so with the state variable. It is provident that with this filter, an arrangement such as this can easily be implemented. Two possible configurations are shown in Figure 5d and 6a. That in Figure 5d uses a dual-gang pot with one half altering the Q by varying attenuation in the retard part of the network while the other half is placed in front of the input summing block and so attenuates the input signal. Equalising the resistor values while keeping capacitor size manageable can prove difficult. A much simpler and more elegant solution to the problem is shown in Figure 6a. Here, a single gang pot - more attractive in terms of cost and without the tracking problems asssociated with the dual-gang variety - is used. The signal is applied to the non-inverting input and a pot between that and ground controls both input signal magnitude and Q.

Where the filter type is such that a similar arrangement is impossible (perhaps because it would mean altering two different resistor values simulataneeously), Q is often variable only in discrete steps, with a multi-gang switch altering both Q-determining and attenuator resistors. In many instances, this is a more than acceptable arrangement.

Stability Or Instability?

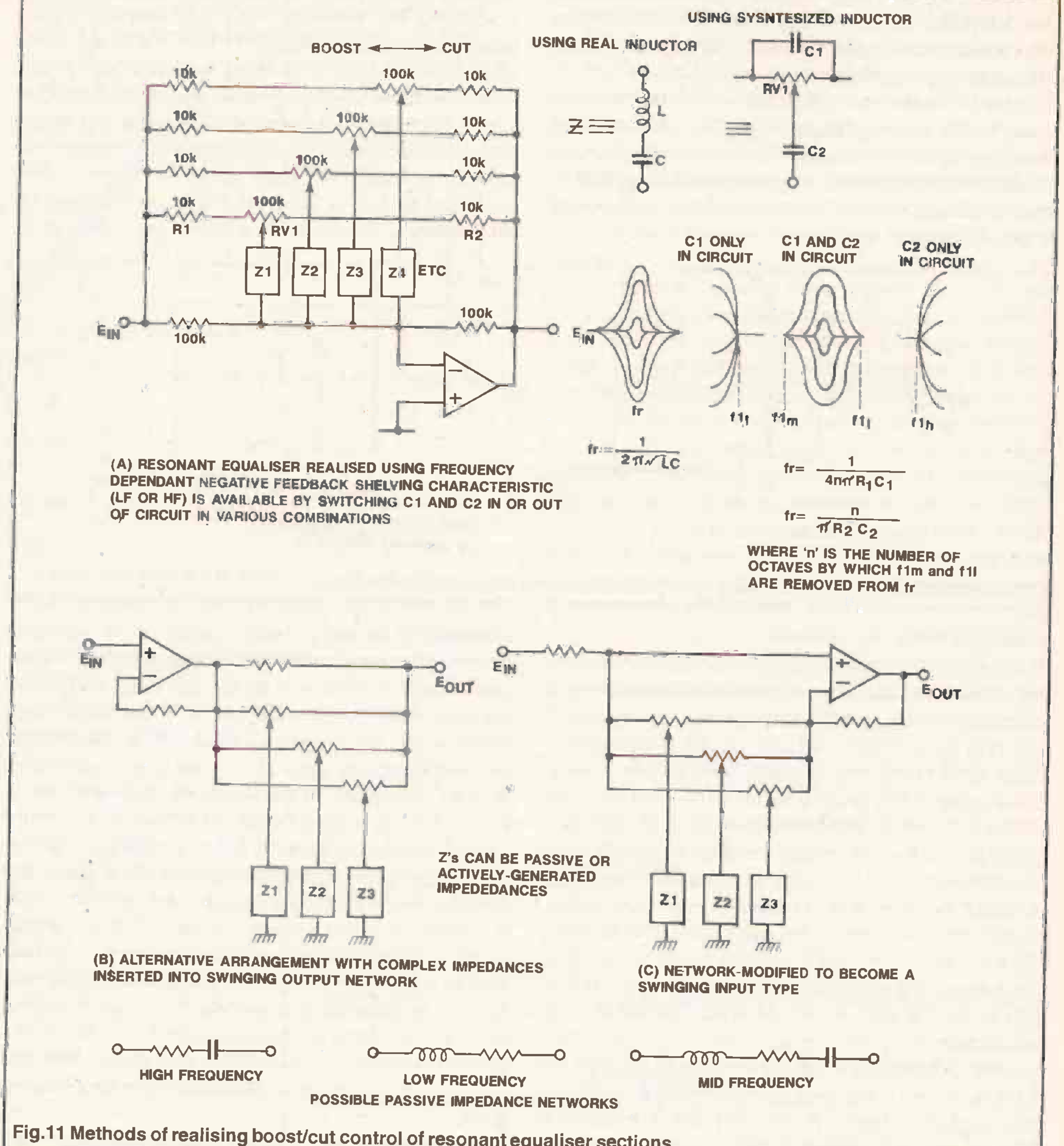
The bi-quad or state-variable topology is by far and away the most frequently-adopted. The arrangement of elements

Arranging for the loop to become unstable at one particular frequency (ie controlled oscillation) using to op-amp integrators - which, in addition to having first order, 6dB/octave response, also causes the relevant 90° phase shifts - then creates a total 180° phase loss. Oscillation is controlled, as previously explained, either by trimming the gain of the third inverter, doping one of the integration capacitors with a resistor or by using phased negative feedback. See Figure 9.

Each method has its merits and shortcomings. The first is unduly critical as regards the determination of Q while the second is fine as long as the frequency remains fixed. This is because Q is largely dependant on the ratio of Xc : parallel R and so varies proportionately with frequency. The third method is especially interesting. The feedback is not truly negative in nature but is taken from the output of the first integrator, providing an easily alterable Q which is completely independent of frequency. This phased feedback arrangement is inherent in the design of modern mixing desks.

Although popular, it is not without problems. The integrating capacitors create time delays which in turn affect open loop bandwidths around the amplifiers because of significant phase shifts in the megaHertz region. The phase shifts can be large enough to cause instability at these frequencies and though applied compensation can tame this instability, this corrective measure is detrimental to good response at the HF end of the audio spectrum. (See Part 6).

To properly understand the nature of the problems, we must first analyse the network at very high and very low frequencies within the audio bandwidth, conditions which mean that circuit impedances are virtually short or open-circuit respectively. At HF, when a virtual short-circuit path exists between output and inverting input, we have a voltage follower configuration with all of the previously-documented attendant stability problems. Similarly, when an open-circuit condition persists at extreme LF, any external resistor noise, input-applied LF, shot noise and internally generated Johnson noise are subjected to horrendously large amounts of amplification. This is in addition to any other low frequency



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

$$fr = \frac{1}{4n\pi R_1 C_1}$$

$$fr = \frac{n}{\pi R_2 C_2}$$

Fig.11 Methods of realising boost/cut control of resonant equaliser sections

noise already riding on top of the input signal.

The other problems which manifest themselves are inherent in any op-amp circuitry. We have discussed the problems associated with real and finite op-amp output impedance and its detrimental effect upon phase margin - in the context of the filter, it affects usefulness at HF. Other problems are also output stage-related - is the op-amp output stage meaty enough to cope with the transient current demands of any capacitor connected as a load, and even if this is so, can it charge it in the short time available at HF. Again, the response in this region of the spectrum is badly affected if slew-rate limiting is allowed to happen. Further, high-pass filtering, by the very nature of its action, is a much noisier process than its low pass counterpart since the LPF removes much of the frequency spectrum where noise is usually present.

We can see that we are torn between two conflicting interests. On one hand we must strive to reduce external resistor values as much as possible in order to minimise noise whilst on the other, these very values will mean that any in-circuit op-amps will be struggling to cope with the current demands placed upon them. This is because the capacitors must be necessarily large in value to realise the same RC product with smaller resitors.

Okay, so we have at last a network which is conditionally stable and one where we are able to alter two of the parameters of interest - Q and break frequency - completely independently. At this stage, though, we have no control over how much the peaking or notching effect of the filter shape is in or out of circuit -it is a binary situation with the equaliser either hard IN or hard OUT with no subtleness whatsoever. As such, it is of little creative use to man nor beast since we have already discussed that any EQ must be applied in a subtle and deliberate manner with some notion of the effect to be achieved if it is to sound natural.

How then do we realise the third parameter of a true parametric equaliser, that of a continuously variable cut and boost facility? Actually, the rudimentary circuit elements used to achieve this function were outlined in Part 5 although the circuits were touted purely for 'overall gain control and not frequency conscious cut and boost. The most popular is the Baxandall-style arrangement where a frequency conscious network - either real or synthetically generated - is enclosed in the feedback loop of an op-amp. See Figure 10. As noted in the previous reference, it is usual for a fixed gain-determining leg to be introduced with the frequency conscious leg made variable. The feedback:attenuation ratio sets the overall boost or cut of the network at a frequency determined by the complex components. A normal shelving bass-lift (as found on many domestic hi-fi amplifiers) which levels off and continues at a raised level down to the bottom end of the frequency range will tend to exaggerate any hum or rumble or mic-handling noise present at the input. Similarly, HF shelving lift will emphasise noises from close-mic'd source or mic amp hiss. The maxim of restraint both in provided and implemented levels of boost and cut is one which holds true at all frequencies and with all types of equaliser. Often +/- 6dB is more than enough although most commercial examples seem to have settled on an accepted median in the range +/-10 to +/-15dB. Some designers offer assymetrical boost and cut with more cut than boost available to the user. It has as much to do with sounding natural as it has of not wishing to provide an instrument to rob the channel of more headroom than is necesssary.

Other possibilties include swinging input and swinging output type arrangements - again, see Part 6 for a fuller explanation of these types - where the filter section is configured as a variable admittance to ground. There will be further discusion on this subject when we analyse the AutoMate EQ section.

In true AutoMate style, we're going to keep all of you in tenterhooks for another month when we'll then publish - promise, promise - the AutoMate EQ circuitry. After EQ, the topic next in line for examination will be switching.

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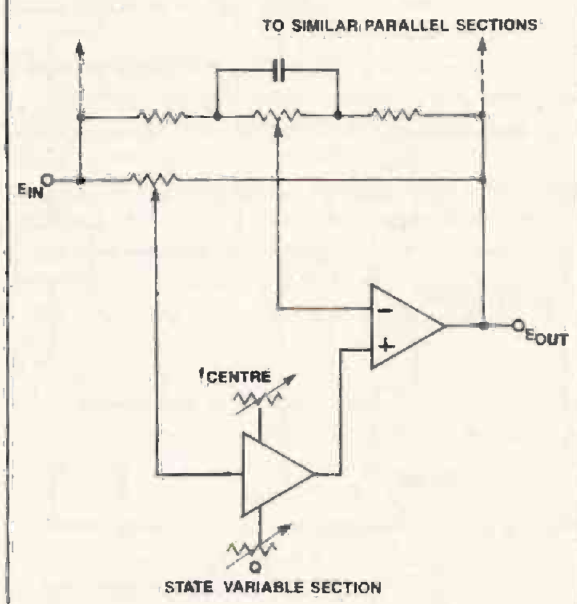
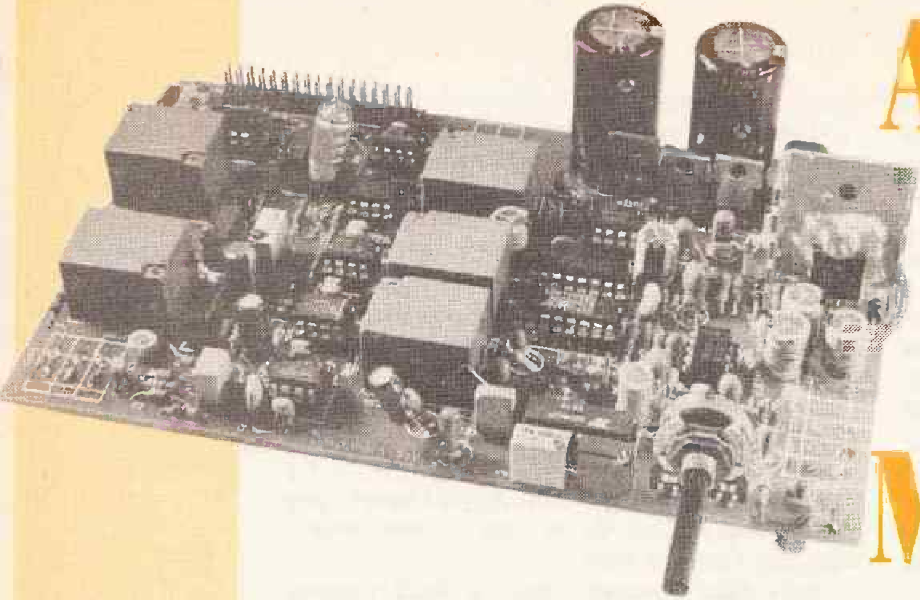


Fig.12 Incorporating the state-variable into a baxandall layout



Automatic Audio Response Measuring System

Ralph Mantel reports from Germany on a convenient way to check the response from a loudspeaker.

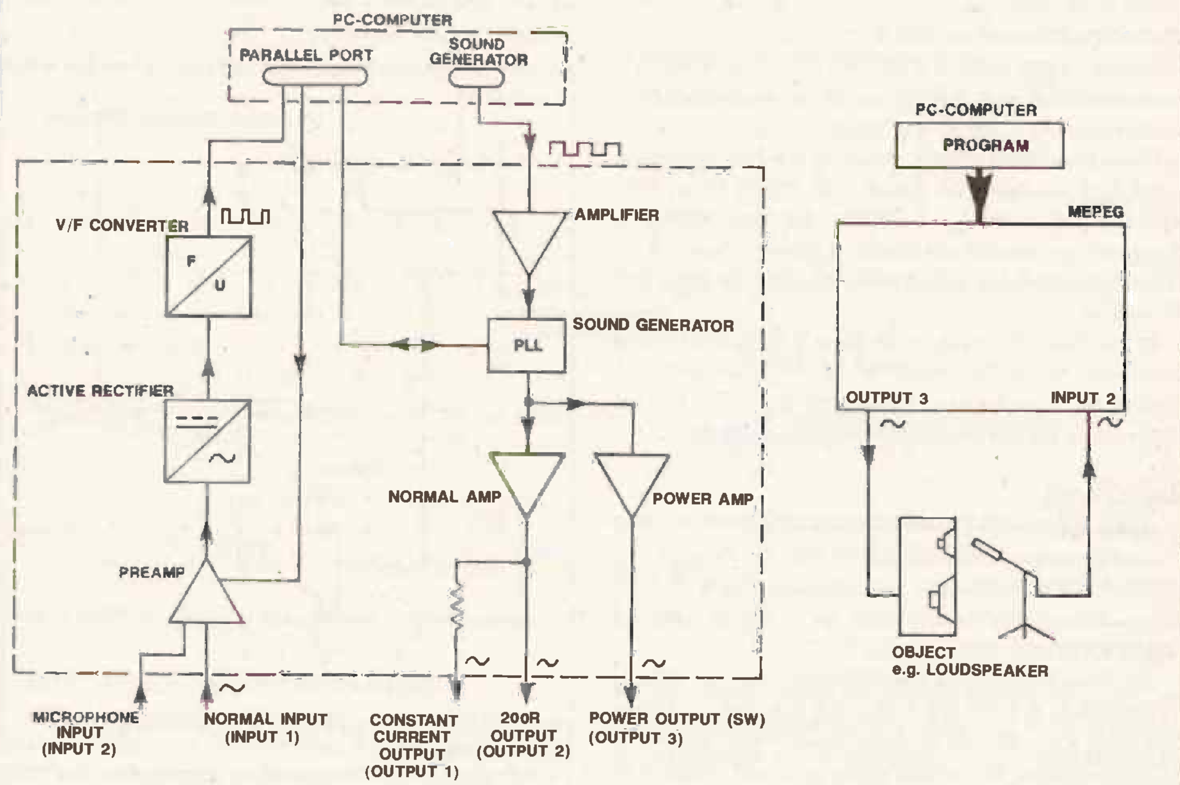


Fig.1a & 1b Block diagram of audio response measuring system

PROJECT

Without the use of response measuring equipment the serious construction of loudspeakers or indeed any audio equipment is very difficult. Most attempts usually fail due to the high cost of commercially available equipment and the developer often has to fall back on the old 'Trial and Error' method.

The following NF-Audio measuring system (MEPEG), in conjunction with an IBM compatible PC is a low cost alternative to the commercially available systems currently on the market. By using a PC to carry out the measuring functions the system is able to offer a far more extensive range of possibilities in the areas of data evaluation and storage than is usually available on similar systems. Thanks to the comprehensive software the user has numerous possibilities for comparing, displaying, saving or printing his response curves and associated data. The ability to draw several response curves on one diagram is also available as is the 'digital' analysis of the data within the Program.

MEPEG provides an answer to numerous acoustical measuring problems. The system has been designed primarily around the problems associated with measuring loudspeakers and several of the program functions specifically address this area. Loudspeakers can been driven directly via a 5 watt internal amplifier. Measurement of signal to noise ratios, channel separation and frequency response curves on other audio equipment is also possible. The overriding consideration during the development of MEPEG was ease of operation combined with a wide range of measuring and evaluation possibilities. The system is self calibrating and runs fully automatically i.e. all control functions are carried out by the computer,(program). This enables complex functions such as automatically measuring and calculating Thiele/ Small parameters. In fact, the only adjustment to be made by hand is setting the level of the measuring signal by means of a potentiometer on the front panel. Another important consideration in the development was to keep the hardware requirements to a minimum without compromising on accuracy and features. There is no need to use an expensive laboratory microphone for measuring sound pressure levels. In fact a simple electret microphone is used in conjunction with a compensation file. Using this method the large tolerances often found with electret capsules are eliminated thus preventing the microphone from influencing the measured values. Every microphone comes supplied with its own individual compensation file.

The Hardware

Block Diagram

To gain an initial appreciation of the functions of the system let us concentrate on the details shown in the block diagram (Figure 1a). MEPEG can be divided into two basic sections, firstly signal evaluation and secondly signal generation. Signal evaluation is achieved by passing the input signal (sine wave) through a pre-amplifier then on to a zero loss rectifier, thereby converting the signal to DC. This DC level is therefore proportional to the effective level of the input signal. This DC signal is then passed to voltage/ frequency converter and converted into a proportional frequency (serial A/D conversion). The period of the frequency is then measured using a software controlled period measurement routine.

Signal generation is achieved by using the computers internal sound generator. This generator is controlled by the program and supplies a square wave signal in the range 20 to 20000Hz. The signal is then passed to a Phase Locked Loop (PLL) which then generates the actual signal used for measuring. The functions of the PLL are controlled by the program via the parallel port. The output signal (sine wave) can be sent to the 5 watt power amp, a constant current output or a 200 Ohm output. All outputs are of course short circuit protected.

Every individual measurement and generator function is checked by the program to reduce the possibility of evaluating 'false' values.

Diagram 1b shows a typical layout for measuring a loudspeakers response curve. In this example the power amp output is used. The remaining inputs and outputs of the measuring system are used when taking other measurements, more on which later.

MEPEGs' technical specifications are shown in Table 1. These results were obtained from our test system and can easily be obtained if the system is constructed carefully.

Table 1 Technical Data

1.Measuring circuit	
Range	0.5-7000 mV (82.9 dB) , = ca. 13.8 Bit
Resolution	0.5mV
Frequeny range	20-20000Hz
Input inpedance	1M0
2.Generator circuit	
Frequency range	20-20000Hz
Resolution	0.1Hz (range 20-150Hz) 1Hz (Range 150-20000Hz)
Distortion	<1%
Voltage range	0-15 Volt pp on all outputs
Output loading	3.5 Watt/into2R, short circuit protected
3.Total System	
Linearity	+ - 0.2dB(20 -20000Hz)
Frequeny raster	1/30 or. 1/6 octave, user determined
Amplitude plotting scale ***selectable***	+20 to -100dB +10 to -50dB +5 to -25dB +2 to -10dB
Maximum plotable amplitude resolution	0.04dB
4.Measuring microphone	
Type	Electret,omni directional
Linearity (Free field)	+-0.2 dB with compensation file

Measurement Functions

MEPEG works with fixed measuring points within the frequency range. The audio range (20-20000)Hz is divided into 60 or 300 discreet frequencies (according to the resolution chosen). The Program sets the frequencies in ascending order and measures the associated amplitudes. Different scales are possible when plotting the amplitude values, the maximum resolution being 0.04 dB per screen pixel.

The following measuring functions are possible using MEPEG:

-level measurement
-sound pressure level measurement
-near field sound pressure measurement with automatic calculation of sound level relative to 1m distance.
-impedance measurement.
-Thiele/Small parameter measurement of loudspeakers including automatic calculation.
-1/3 Octave output.
-difference and average calculation of various curves.
-audio frequency voltmeter.
-computer controlled sine wave generator.

With the exception of the impedance curve, the amplitude of all curves are shown in decibels. The 0 decibel line on the diagrams represents a reference value which is established before each measuring session. The value of this reference value can be obtained from the individual diagrams. Let us now look at an example of level measurement to demonstrate this more clearly.

Level Measurement

Plot 2a is a hard copy of the results of a level measurement on a simple amplifier. The amplitude level is shown in decibel per volt (Y axis) with a scale of 60db (+10db to -50db), this being infact the default setting. In addition to this setting, three other scales are available (see Table 1). Under

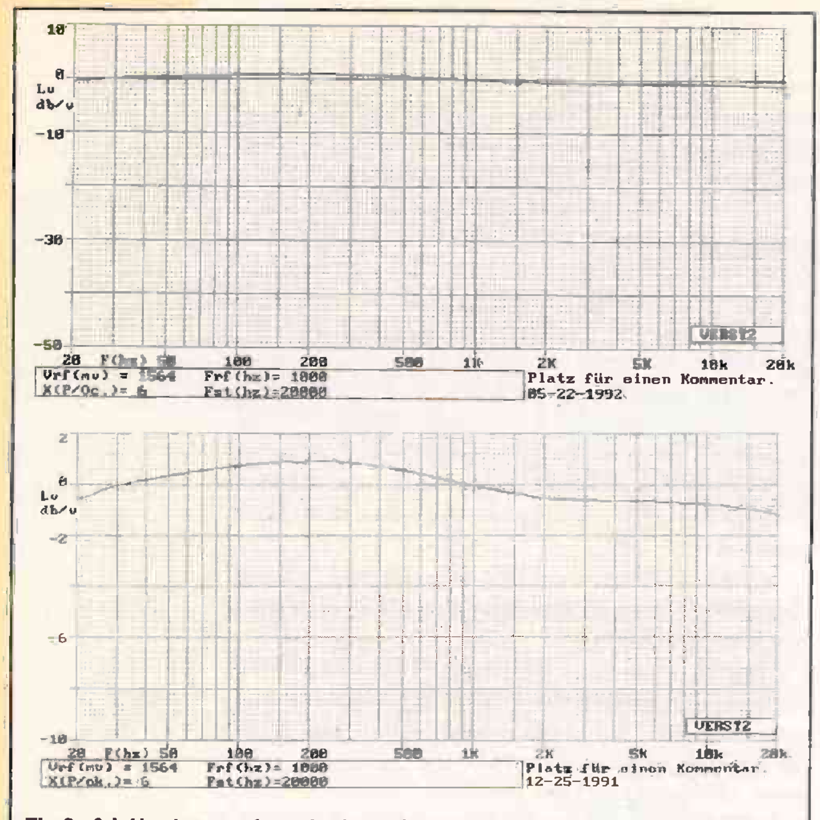


Fig.2a & b Hard copy of results for a simple amplifier

the co-ordinates is a box showing details of the parameters used during the measurement; Vrf is the reference value (0 decibel line) in millivolts, Frf is the frequency at which this value was measured. The value X(P/ok) is the resolution chosen in the frequency range. The user can choose 6 or 30 (High res mode) measurements per octave. The higher resolution is essential for certain MEPEG functions. In this particular example 6 measuring points per octave have been selected. This gives 10 octaves in the range 20-20000Hz, a total or 60 measuring points. The value Fst is the stop frequency selected by the user at which MEPEG stops measuring. In addition, the name of the curve (VERST2) and the date when the hard copy was printed are also shown; the user can also add a short commentary if needed.

Plot 2b shows the same curve but with a different scale namely 12db, resulting in a resolution of only 0.04dB/screen pixel. The shortcomings of this particular amplifier are now clearly shown.

Near and Far-field sound pressure level measurement

The function sound level measurement is principally the same as the above mentioned level measurement. Here too the user has the possibility to choose between 6 or 30 measuring points per octave in the frequency range and various scales in the amplitude range.

One difference is that the reference value is shown as Srf and not Vrf and the reference sound level is relative to the hearing threshold of 0.00002N/m^2.

Plot 3a and b shows the results of a sound level measurement of a quality 2 way loudspeaker system measured in a low reflection room. The measurement was taken using an output voltage of 2.83V at 1 metre from the baffle. Plot 3a shows the amplitude response using the normal scale measured with 30 frequency-measurements/octave. Plot 3b shows the output of the same loudspeaker system measured under the same conditions but with a resolution of 6 measurements/octave. Both diagrams show clearly a number of peaks below 200Hz. These can be attributed to insufficient absorption of the measuring room. Also, the high res mode shows up much more clearly the narrow banded amplitude peaks and troughs for example at 53Hz. With the exception of these narrow banded anomalies the two curves are identical. For most measurements the lower resolution will be used which has the additional bonus of a considerable time saving.

An extension of the 'normal' sound level measurement (by normal we refer to far-field measurement) is sound level measurement in the loudspeakers 'near-field'. A description of the different properties of near and far field measurement cannot be given in a brief article like this; sufficient to say that up to a certain frequency the response of a loudspeaker is identical in near or far-field. In addition to the frequency, the maximum measuring distance from the speaker membrane is also critical to avoid falsifying the results [1]. Measuring distance and max frequency are dependent on the diameter of the speaker and can be calculated. The max frequency can be calculated as follows;

$F_{max}=c/(2\pi r)$

Where

F_{max} Highest frequency (Hz)

c Sound velocity (344m/s)

r Membrane diameter (m)

The Frequency range up to this frequency is known as the Piston Range.

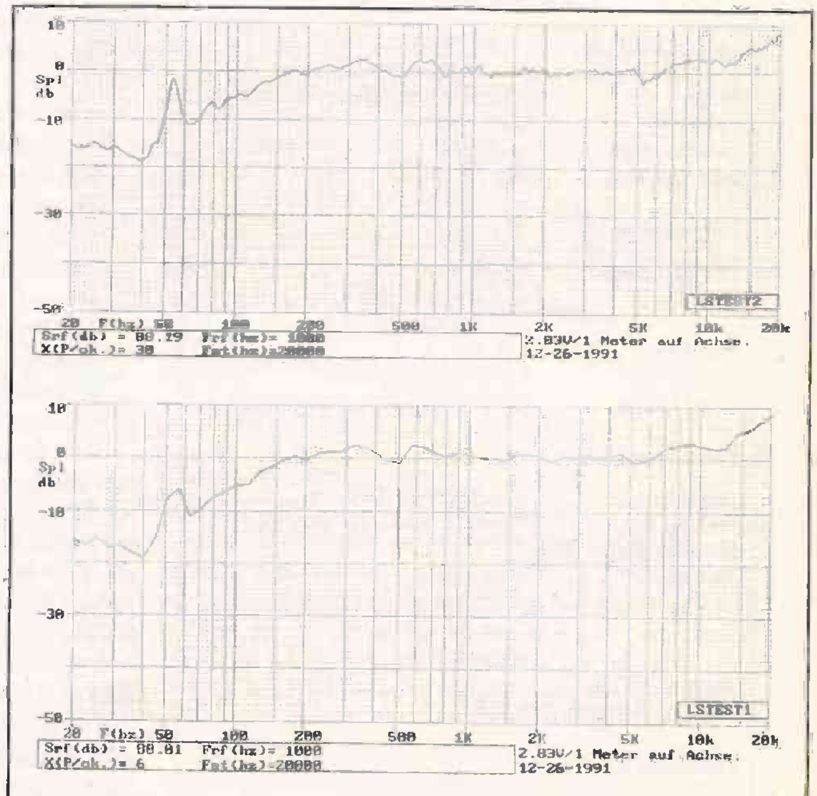


Fig.3 a & b Plot of quality two-way loudspeaker system measured in a low reflection room

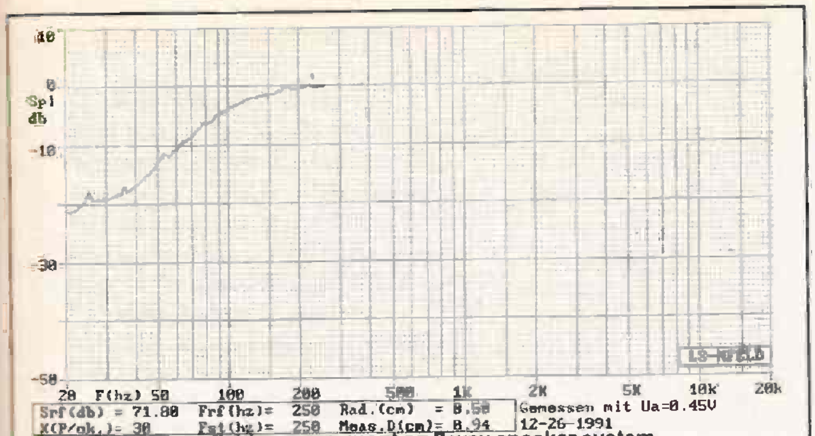


Fig.4 Plot of near-field measurement on 2 way speaker system

MEPEG has a function Near-field measurement which calculates the maximum measuring distance for the current loudspeaker which enables the microphone to be accurately positioned before the measuring session begins. The maximum frequency can be calculated using the above formula. The resulting near-field sound pressure level curve will then be automatically converted into far-field sound pressure level curve at 1metre measuring distance. This helps considerably in the final evaluation of the curve.

Plot 4 shows the result of a near-field measurement on our 2 way speaker system. The measuring distance was 10mm from the membrane of the bass/mid speaker. (see value Meas.D in the info box). Rad gives the loudspeaker radius. The output voltage was only 0.45 V as using a higher voltage resulted in too high a level in the near-field measurement causing the microphone to distort. Srf shows the reference sound pressure at 1 metre measuring distance. With an output voltage of 2.83V the resulting sound pressure level would be:

$$Srf = 71.8dB + 20\log_{10}(2.83V/0.45V)$$
$$= 87.8dB$$

which is exactly the reference sound pressure (see plot 3) of this speaker at 1 metre.

Average-value and Difference curves

MEPEG works with a a Temporary Store. With this it is possible to work with up to 30 measured curves at any one time. This has the advantage that a new measurement does not automatically overwrite the previous one and also that it is possible to show several curves on one diagram and establish average and different curves. Plot 5a shows curves measured at different angles to the membrane of our 2 way speaker system. The troughs in the 30 and 60 degree curves can be clearly seen. These troughs are caused by firstly the directional properties of the individual loudspeakers in the higher frequencies and secondly due to the cut off frequency of the crossover network. In other words, every loudspeaker has a certain directional characteristic. In order to fully evaluate a loudspeakers quality it may be useful to evaluate the strength of this directional characteristic. This can be done with so called average curves. The average is formed by evaluating several curves measured at different angles as follows:

Eqn.3

$$Sp_{Average} = 20\log_{10}\left(\sum_{n=1}^{N} 10^{Spm/20}\right) \times 1/N$$

$S_{pAverage}$ = Spl of Average

N= Number of curves for evaluation

Plot 5b shows the average curve calculated by MEPEG from the 3 curves shown in plot 5a. To gain a realistic estimation of the directional characteristics of the speaker it would be necessary to obtain many more readings at various angles than we are using here for our example.

MEPEG also has a function to calculate the difference between curves. Plot 5c shows the level difference of the 0 degree curve (on axis) and the 15 degree curve from Plot 5a. Difference is calculated using the following method:

Eqn.4

$$Sp_{difference} = 20\log_{10}\left(10^{(Spn/20)} - \left(\sum_{n=2}^{N} 10^{(Spn/20)}\right)\right)$$

Difference curves are particularly useful when selecting a matching pair of speakers. Using this method differences in response can be shown which may not normally be immediately evident using a normal level response curve.

1/3 Octave Output

A further feature of MEPEG is the calculation of a 1/3

Fig.5a Curves at different angles to the membrane of the 2 way system
5b) Average curve of the three shown in 5a.
5c) Level difference of the 0 degree curve

octave frequency response curve from a normal sound pressure or level curve. This feature may astound some readers as it is not normally possible to make such readings without considerable effort usually using 'pink noise' and band filters.(Terzfilters)

Firstly, what is a 1/3 octave measurement? A loudspeaker or amplifier etc. is initially fed with 'pink noise'. Pink noise statistically contains the entire audio frequency range in similar quantities i.e. the unit being measured is fed the entire audio frequency spectrum at the same time. With the help of a band-filter a particular frequency spectrum with a particular band width (1/3 octave) is filtered out and the energy content of this frequency spectrum measured.

The range 20-20000Hz covers 10 octaves ie 30 1/3 octaves (Bands). If we carry out the above method for every band in the specified frequency range we will obtain the 1/3 octave output curve. This method is at least carried out on loudspeakers.

As already mentioned, MEPEG does not use this method but instead calculates the 1/3 octave response from the measured amplitude response using the following formula.

Eqn.5

$$Sp_{octave} = 20\log_{10}\left(\sum_{n=1}^{10} 10^{(Spn/20)}\right) \times 1/10$$

$$Sp_{octave} = \text{Spl of 1/3 Octave}$$

During this method the high resolution mode from MEPEG finally is used to good effect. From a typical high resolution curve with 30 measuring points per octave the average of the ten 1/3 octave bands are calculated. This mathamatical method has the same effect as a normal measurement, assuming the basic curve was measured using a sufficently high resolution in the frequency range. MEPEG in high resolution mode easily satisfies this requirement.[2].

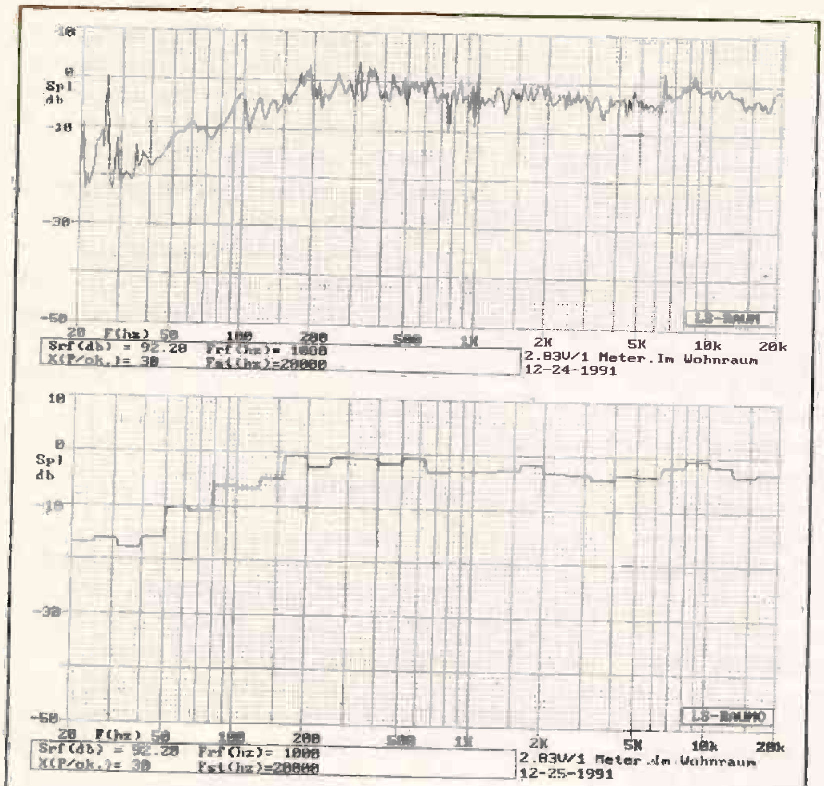


Fig.6 Plot of an amplitude curve with 2 way speaker system at 30 degrees
Fig.6b 1/3rd Octave curve

The advantage (or disadvantage) of this measuring method in relation to loudspeakers is, among others, that interference effects (advantage) and narrow banded resonances (disadvantage) in the amplitude frequency curve are not evident. An example to demonstrate this is as follows. Plot 6a shows an amplitude curve from our 2 way speaker system measured at 30 degrees to the right in a normal living room. The wavy nature of the curve shows the room effects/interference quite clearly. With this type of curve it is very difficult to make any sort of accurate analysis of the speaker. Plot 6a is the 1/3 octave curve calculated as shown above. If this curve is now compared with Plot 5a which was measured in a low reflection chamber it can be seen that the two curves are very nearly identical. In other words the interferences are calculated out.

Thiele/Small Parameter measurement

Thiele/Small Parameters are obtained using the impedance curve of a particular loudspeaker and assist in accessing the quality of the driver. Using these parameters it is also possible to accurately calculate the enclosure details for the driver [3,4].

MEPEG has a function which automatically calculates these parameters using the constant current method. It is only necessary for the user to enter the value of the DC resistance of the driver coil in question. The parameters are calculated by MEPEG using the method described in [5] and not using the '3-point method' as is often recommended. By this method all the values obtained in the range + one octave of the resonant frequency are include in the calculation. This has the advantage that the unavoidable measuring error is, expressed as a percentage, far less than would be the case using the 3 point method. There is a marked difference whether one value in three or one value in thirty is incorrectly measured. The measurement and calculation therefore are far more accurate and reliable using this method rather than the 3 point method.

Plot 7a shows the result of a Thiele/Small parameter measuring session. Because the amplitude representation is an absolute value (ohm) there are no values for 'reference-value' and 'reference-frequency' shown in the boxes.. Thiele/Small parameters are measured in High resolution Mode (30 P/oct.). The value Rad is the membrane radius of the loudspeaker being measured.

The values in TH/SM parameter field have the following meaning:

qe	Electrical Q value
qm	Mechanical Q value
qt	Total Q
vas	Equivalent air volume of driver
fs	Resonant frequency
re	DC resistance of coil

The value mm is the mass of the additional weight used in obtaining the value for vas. As an alternative to using this

PROJECT

weight a closed box enclosure (infinite baffle) can be used. In this case the volume of the enclosure vb is shown instead of mm.

The remaining value co.fac. gives information on the accuracy of the measurements and therefore the accuracy of the Thiele/Small-Parameters. This value should ideally be one although in reality this value is virtually impossible to obtain. A result in the range 0.95 to 1.005 indicates a very accurate result.

Of course MEPEG will also carry out a 'normal' impedance measurement. (Plot 7b).

Nf-Voltmeter/Sinewave generator

As already mentioned MEPEG can be used as a Nf-Voltmeter and as a computer controlled sine wave generator. The voltmeter range is 0-7000mV, with a resolution of 0.5mV in the range 20-20000Hz.

The sine wave generator also has a range from 20-20000Hz and a resolution of 1Hz.

In the Voltmeter mode a 1kHz test signal is generated to assist in the construction and functional testing of the circuitry. The voltmeter mode is also used to test the microphone output voltage and for calibrating the output voltage of the signal generator before a measurement commences.

Next month we look at circuit construction and software.

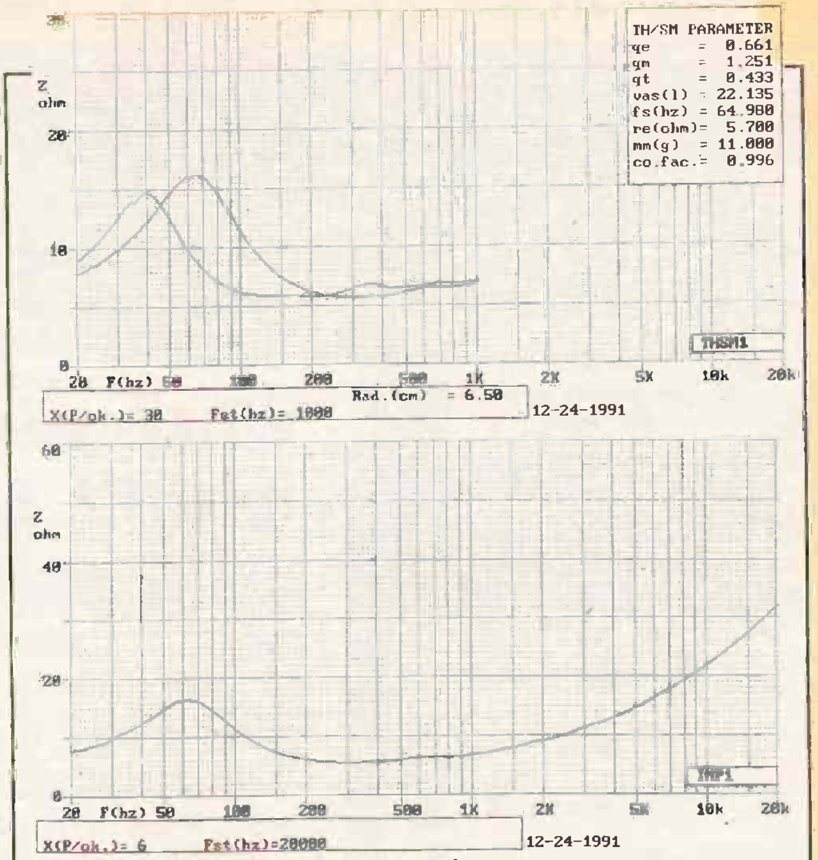


Fig.7a Theile/Small parameter measurements
7b) Normal impedance measurement

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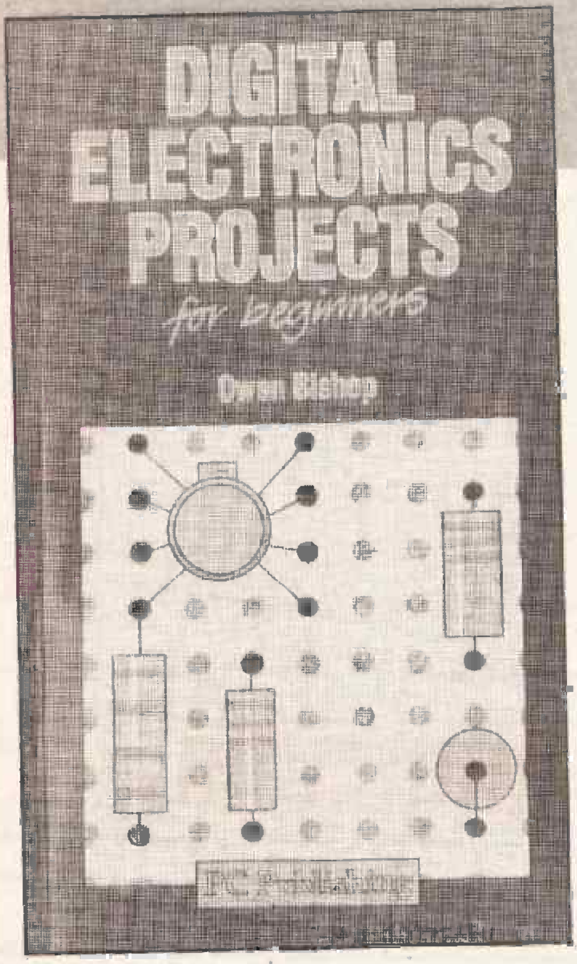

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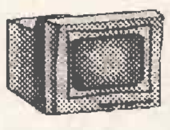

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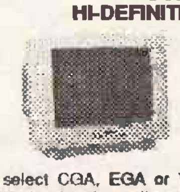

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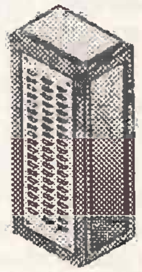

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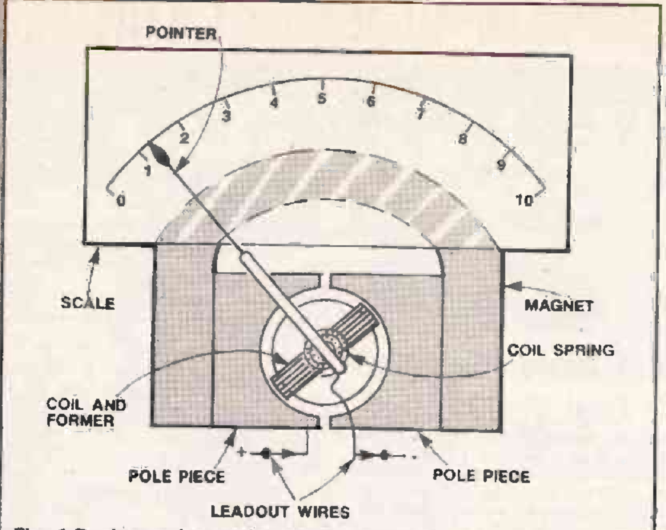

Fig. 1 Basic moving-coil meter movement.

Basic Meter & Multimeter Circuits

Ray Marston continues his 'test gear' series with an in-depth look at moving-coil meter circuts.

Three major classes of meter are in general use in the electronics world. The oldest of these is the simple electromechanical 'analogue' type, which draws energy from the signal under test and uses it to move a pointer a proportionate (analogue) amount across a calibrated indicator scale; this class of meter is the main subject matter of this and next month's episode of this 'test gear' series. The two other classes of meter are the electronic analogue and digital types, which are internally powered and absorb negligible energy from the test signal.

Moving-coil Meter Basics

A variety of electromechanical moving-pointer meters have been developed over the years, but the most important one in modern use is the moving-coil type. This draws its energising current from the signal under test and passes it through a coil of fine copper wire, which is carried on an aluminium bobbin that also carries the meter's pointer and is supported on low-friction bearings. This assembly is mounted within the field of a powerful magnet, as shown in Figure 1, and the signal currents are fed to each end of the coil via a pair of contra-wound springs which are fitted in such a way that their tensions balance out when the meter's pointer is in the 'zero' position. These signal currents generate a magnetic field around the coil, and this interacts with that of the magnet; the resulting torque forces the coil and pointer to rotate until a position is reached where the torque is countered by the force of the two coil springs. The magnitude of this rotational movement is proportional to that of the coil current, and the meter's scale can thus be directly and linearly calibrated in terms of current.

Most meters have the 'zero' current mark on the left of their scale, as shown in the diagram, but a few (known as 'centre zero' types) have the zero in the centre of the scale, with negative numbers to its left and positive ones to its right. The pointer's 'zero' position is usually trimmable via a screw-headed control on the t of the meter.

All moving-coil meters have their movements or coil units supported on a bearing assembly. If the bearings are of the jewelled type a degree of friction inevitably occurs between the coil pivots and the bearings, and may cause the meter to suffer from a characteristic known as 'stiction', which makes the pointer slow or inaccurate in following current variations, and may even make it jam completely. Some of the more-expensive meters have their movements supported on a taut-band or rod, which acts rather like a torsion bar and gives friction-free suspension. These 'taut-band suspension' meters do not suffer from stiction problems.

The most important parameter of any moving-coil meter is its BASIC full-scale deflection (FSD) current value, which is usually referred to simple as its 'sensitivity'; most practical meters have a basic sensitivity in the range 50µA to 10mA.

A moving-coil meter is quite a versatile device; it can be made to act as a high-current DC meter by wiring a shunt resistor across (in parallel with) its terminals, or as a DC voltmeter by wiring a 'multiplier' resistor in series with its terminals, or as an AC voltmeter by connecting it into a bridge rectifier that is fed via a suitable multiplier resistor.

Meter FSD (indicated)	Coil Resistance (typical), ohms	Volt Drop at FSD	Sensitivity, ohms/volt
50 A	2700-4300	135-215mV	20k/v
50-0-50 A	1300-3000	65-150mV	20k/v
100 A	1300-3750	130-375mV	10k/v
100-0-100 A	1100	110mV	10k/v
200 A	750	150mV	5k/v
1mA	75-200	75-200mV	1k0/v
100mA	0.5-0.8‰	50-80mV	N.A.
1A	0.05-0.1‰	50-100mV	N.A.
5A	0.01‰	50mV	N.A.
10A	0.005‰	50mV	N.A.
5v, 10v, 15v, 100v, 300v at 1k0/v	75-200‰	75-200mV	1k0/v

Fig. 2. Typical ranges and performance details of some popular fixed-value moving-coil meters.

Practical moving-coil meters are not guaranteed to have perfect linearity, or to have precisely the indicated value of FSD current sensitivity. Instead, their accuracy is expressed in terms of 'percentage of FSD value' error over the 'effective range' of the instrument. The 'effective range' is defined as 'from 10% to 100% of FSD value' in DC-indicating meters. Typically, meter accuracies vary from about ±3% of FSD in cheap models, to 2% of FSD in medium-quality ones, to 1% of FSD in high-quality ones. Thus, a medium-quality meter can be expected to be accurate to within ±2% at full-scale, or ±4% at half-scale, or ±20% at 1/10th-scale, etc.

The meter's coil has a finite resistance, r, and this causes a proportionate voltage to be generated or 'lost' across the meter's terminals when it is in use. This loss voltage is typically in the range 50mV to 400mV at FSD Figure 2 list typical performance details of some popular and readily-available 'fixed value' moving-coil meters.

Measuring The Coil Resistance

The most useful moving-coil meter is the multi-range type, which can be made from any meter with an FSD sensitivity of 1mA or less if its coil resistance value (r) is known. This value can be measured via the Figure 3 circuit, in which R1 and RV1 have a series value equal to V_{IN} multiplied by 'y', the meter's 'ohms per volt' or 1/I sensitivity value, and Rx

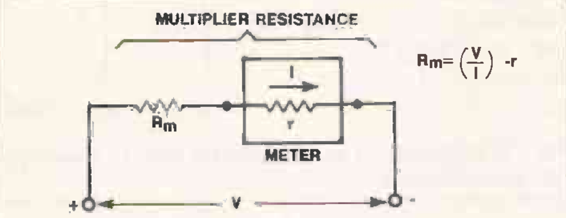

Fig. 4 Basic DC voltmeter circuit.

is either a calibrated variable resistor or a fixed-value precision type roughly equal to the estimated 'r' value. In use, RV_1 is first adjusted, with SW_1 open, to set the meter reading at precisely FSD. If a high impedance (at least 1M0) digital voltmeter is available, the r value can then be found by measuring the meter's volt drop, v, and calculating r from 'r - v/I'. Alternatively, if Rx is a calibrated variable type, r can be found by closing SW_1 and adjusting Rx to set the meter reading at precisely half-scale value, at which point the Rx value equals r. Alternatively, if Rx is a fixed precision type, simply close SW_1, note the change in the meter's current reading, and deduce the 'r' value from:

$r = Rx\,(I - i)/i$

where I is the meter's FSD rating, and i is the meter's new reading.

Manufacturers often quote the nominal value of a

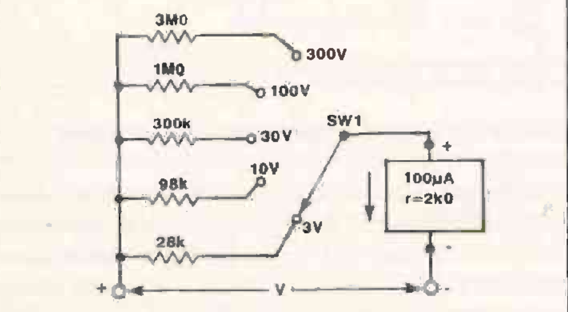

Fig. 5 5-range DC voltmeter using individual multiplier resistors.

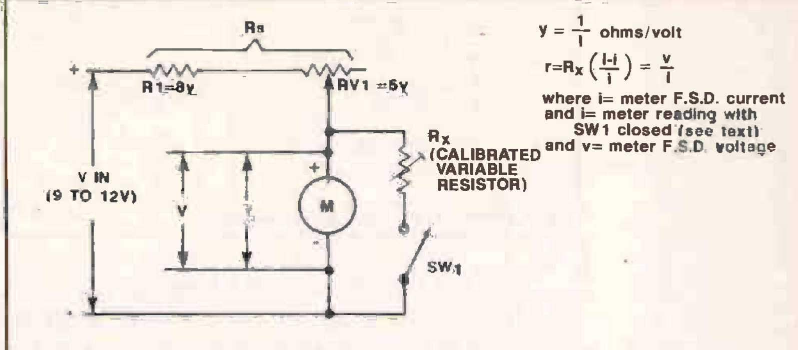

Fig 3 Circuit for measuring the meter's internal coil resistance, r.

meter's coil resistance in the instruments specification sheet, or mark it on the meter's dial; note, however, that these quoted values usually have a precision in the range ±5% to ±15%, and (since the coil is made of copper wire) have a temperature coefficient of +0.4%/°C at temperatures in the region of +20°C. Thus, the resistance of a coil that measures 1000ohms at 20°C rises to about 1040ohms at 30°C, etc.

Designing DC Voltmeters

A moving-coil meter can be made to indicate values of DC voltages by feeding them to it via a series 'multiplier' resistor, as in Figure 4, so that the meter current is proportional to the applied voltage. The appropriate multiplier

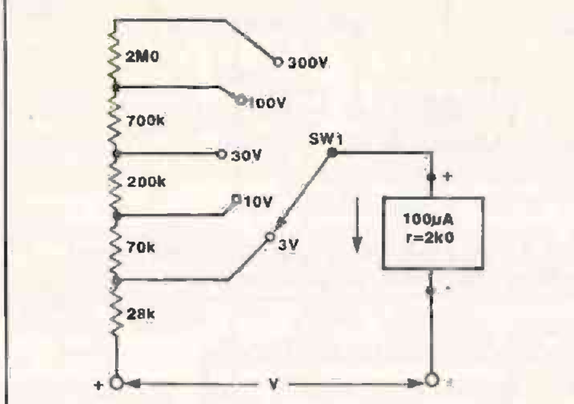

Fig. 6 5-range DC voltmeter using series-wired multiplier resistors.

resistance value equals V/I, where V is the desired FSD voltage reading and I is the meter's FSD current value. Meter sensitivity is often expressed in terms of 'ohms per volt', where the 'ohms' value equals 1/I, so a 1mA meter has a sensitivity of 1k0/volt and can be used to read 10V FSD by using 10k of multiplier resistance, and a 100µA meter has a sensitivity of 10k/volt and can read 10V FSD by using a 100k multiplier, etc. Note, however, that multiplier values include r, the meter's coil resistance, and the actual value of external multiplier resistance, Rm, needed to give a desired FSD voltage value is thus given by:

$Rm = (V/I) - r.$

To take two examples in the use of this formula, assume that a 100µA meter has an 'r' value of 2k0 and is to be used to measure (a) 3V and (b) 30V FSD

The following results are obtained:

(a). Rm = 30k – 2k0 = 28k.

(b). Rm = 300k – 2k0 = 298k.

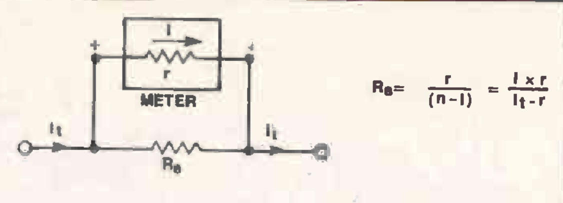

Fig.7 Basic DC current meter circuit.

Note that the exclusion of r from the calculation would result in a final error of 6.6% in the case of (a), but of only 0.66% in the case of (b). In practice, r can usually be ignored in cases where Rm is at least 100 times greater than r.

Figures 5 and 6 show two alternative ways of using the above 100µA meter to give FSD voltage ranges of (a) 3V, (b) 10V, (c) 30V, (d) 100V and (e) 300V. In each circuit, the total multiplier resistance needed on each range is (a) 30k, (b) 100k, (c) 300k, (d) 1M0, and (e) 3M0. The effect of 'r' has to be allowed for on both of the lower ranges in Figure 5 and that if any range resistor develops a short circuit the meter may burn out when it is switched to that range. In the Figure 6 circuit the effect of 'r' needs to be allowed for on the lowest range only, and (except in the case of the lowest range) the meter is unlikely to burn out if any resistor develops a short circuit. The Figure 6 type of circuit is widely used in good-quality multimeters.

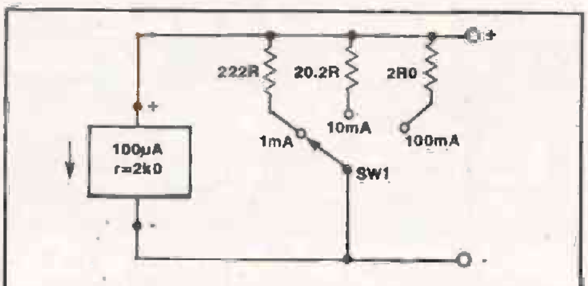

Fig. 8 Classic example of how NOT to use shunt switching in a multi-range current meter.

Extending Current Ranges

The effective current range of a basic meter can be extended by connecting a 'shunt' resistor across the basic meter, as in Figure 7, so that a known fraction of the total current passes through the shunt and the remainder passes through the meter, which can be calibrated in terms of 'total' current. The relative values of shunt and meter currents is set by the relative values of the coil and shunt resistances, and the value of shunt resistor, Rs, needed to give a particular FSD current reading (It) is given by:

Rs = r/(n - 1) or (I,r)/(It – I)

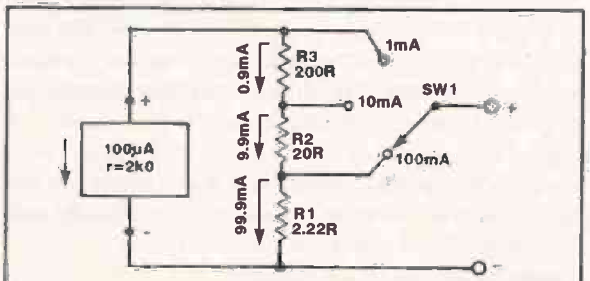

Fig. 9 Worked example of a 3-range universal shunt circuit.

where n= It/I, the number of times by which the desired meter range is greater than the basic range.

Thus, to convert the 100µA, 2k0 meter to read 100mA FSD, Rs needs a value of 2000/((1000 – 1) = 2.0 ohms.

In a practical extended – or multiple-range current meter the shunt resistors should be either permanently wired or screwed into place, and should NEVER be switched into position using a circuit of the type shown in Figure 8, because if this switch accidentally goes open-circuit the entire test current will flow through the meter and possible burn it out. If the meter is to be used as a switched multi-range current meter its circuitry must be designed around a so-called 'universal' shunt network.

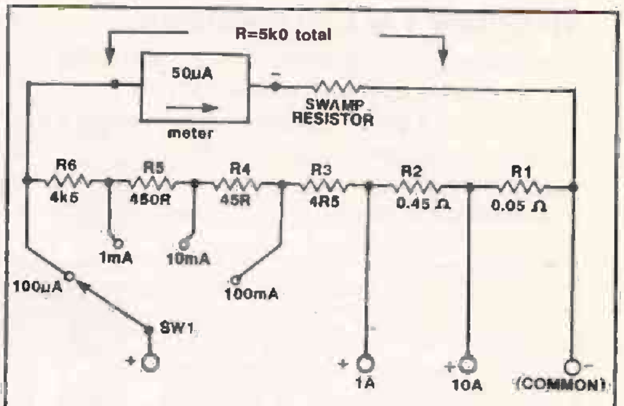

Fig. 10 Example of a swamp resistor used in a 6-range DC current meter.

The Universal Shunt Circuit

Figure 9 shows the practical circuit of a 100µA, 2k0 meter fitted with a universal shunt that gives DC current ranges of 1mA, 10mA and 100mA. The three series-connected range resistors are permanently wired across the meter, and range changing is achieved by switching the test current into the appropriate part of the series chain; the meter's accuracy is thus not influenced by variations in SW1's contact resistances. Note that, since the meter is shunted on all ranges, the lowest effective current range is greater than that of the basic meter.

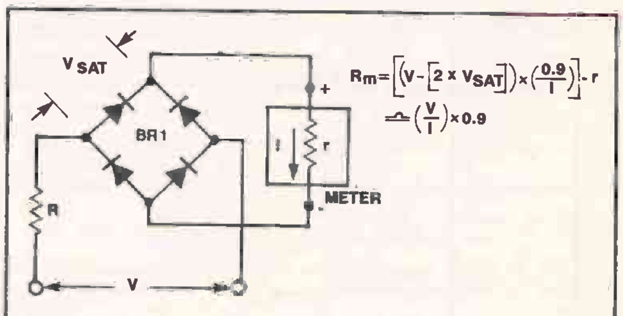

Fig. 11 Basic AC voltmeter using a bridge rectifier.

The procedure for designing a universal shunt follows a logical sequence. The first step is to determine the TOTAL resistance (Rt) of the R1-R2-R3 shunt chain, which sets the FSD value of the lowest (1mA) current range, using the formula:

Rt = r/(n – 1)

where r is the meter's coil resistance and n is the current

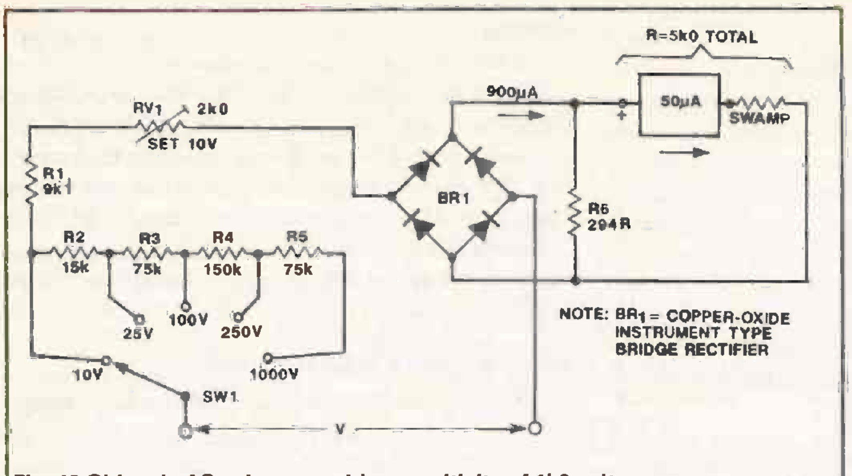

Fig. 12 Old-style AC voltmeter with a sensitivity of 1k0 volt.

multiplication factor. In the example shown
Rt = 2000/9 = 222.2 ohms.

The next design step is to find the value of the HIGHEST current shunt (R1), using the formula:
Rs = (r + Rt)/n
which in this case gives a value of 2222.2/1000 = 2.22 ohms for R1. The same formula is used to find the values of all other shunts, and on the 10mA range gives 22.22 ohms, but since this shunt comprises R1 and R2 in series, the R2 value =22.2 – 2.2 ohms = 20 ohms. Similarly, the shunt value for the 1mA range is 222.2 ohms, but is made up of R1 and R2 and R3 in series, so R3 needs a value of 200 ohms. That completes the design procedure.

Since the total resistance in series with the meter depends on the shunt range setting, the circuit's FSD voltage sensitivity varies between ranges; in the example shown, the FSD sensitivity is 200mV on the 1mA range, 210mV on the 10mA range, and 211mV on the 100mA range. It is normal practice on commercial instruments to make all current ranges above 1 Amp accessible via screw terminals wired directly into the universal shunt, rather than via a range switch, thus eliminating the need to use switches with very high current ratings.

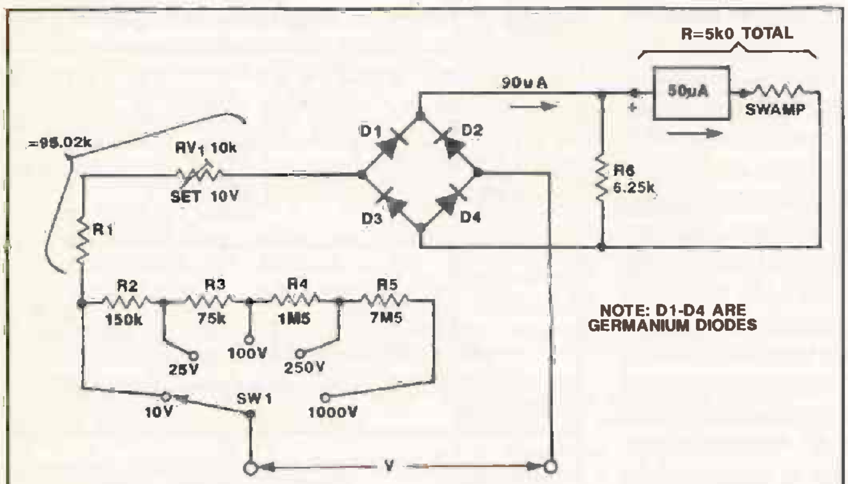

Fig. 14 Basic AC voltmeter using half-wave rectification.

The Swamp Resistor

It has already been noted that the coil resistance (r) values of identical models of meter may vary by as much as ±15% when the meters are new (and even more when they are old) and have a temperature coefficient of +0.4%/°C. Thus, if a brand new meter with a ±15% 'r' value is used in the 3-range circuit of Figure 9, its current reading errors could be as high as 15% at +20°C and 19% at +30°C, and readings may vary by up to 30% between individual meters.

An obvious solution to the above problem, which is used in all commercial multimeters, is to wire a 'swamp' resistor in series with the basic meter and trim its value to give a precise R_{TOTAL} (= r + R_{SWAMP}) value, which is designed to match into a standard universal shunt net-

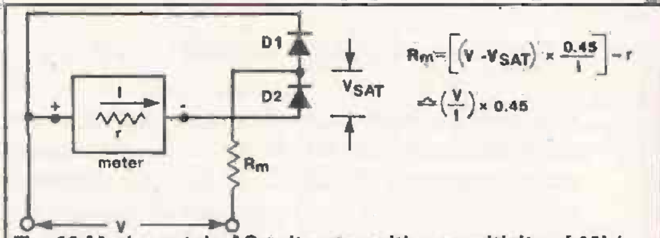

Fig. 13 Modern-style AC voltmeter with a sensitivity of 10k/volt.

work, as shown in the 6-range current meter circuit of Figure 10. If R_{SWAMP} is a carbon film resistor, its temperature coefficient (which has a typical value of -0.25%/°C) will effectively nullify that of the coil; if (for example) r and R_{SWAMP} have similar values at 20°C, their combined temperature coefficient will be only +0.075%/°C, and meter readings will vary by only 0.75% between 20°C and 30°C.

The swamp resistor thus converts the ordinary and troublesome moving-coil meter into a truly useful and semi-precision measuring instrument. Note, the penalty paid for this precision is an increase in the effective FSD voltage value of the meter, i.e. a meter that has a normal FSD sensitivity of 100mV will have one of 200mV if R_{SWAMP} = r, etc. To put this into perspective, Figure 9 circuit has an FSD sensitivity of 100mV on its most sensitive (1mA) range but may have shockingly bad precision, while the Figure 10 circuit has an FSD sensitivity of 250mV on its most sensitive (100µA) range but has excellent precision. Note in Figure 10 that the 1A and 10A ranges are selected via screw terminals, and that the FSD sensitivity rises to 500mV on the 10A range.

AC Voltmeters

A moving-coil meter inherently reads only mean values of DC currents. It can not respond directly to AC, but can be made to act as an AC voltmeter by feeding the voltage to it via a suitable rectifier and voltage multiplier resistor. The rectifier is usually of the full-wave bridge type, in which case the voltmeter is calibrated to read RMS values of a sineware input on the assumption that the resulting meter current is 1.11 times greater than the simple DC equivalent current; such a voltmeter uses the basic circuit and formulae of Figure 11. The Rm value is approximately equal to (V/I) x 0.9, but that the precise design formula is complicated by the fact that the forward volt drop of the bridge rectifier (=2 x V_{SAT}) must be deducted from the effective 'V' value, and that the value of the meter's coil resistance (r) must be deducted from the simplified Rm value.

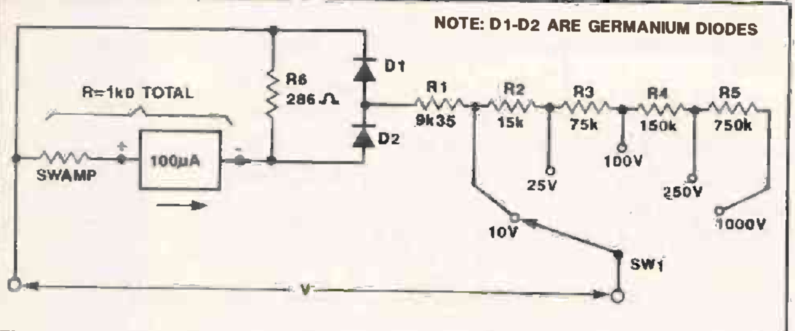

Fig. 15 AC voltmeter using half-wave rectification; sensitivity - 1k0/volt.

The bridge rectifier should ideally give a low forward volt drop, so silicon diodes are not really suitable for this application. Old-style (pre-1970) instruments often used a special copper oxide bridge rectifier to meet this ideal, but these suffered from high reverse leakage currents; to overcome this snag, the meters were usually operated at an FSD current of 900mA (to give a high forward/reverse current ratio), and this resulted in the typical circuit of Figure 12, which has a basic AC sensitivity of 1k0/volt. By contrast, most modern meters use a bridge rectifier made of germanium diodes that are pre-tested for low reverse-leakage currents, and are able to give a sensitivity of up to 10k/volt, as in the case of the circuit of Figure 13.

A minority of AC voltmeter circuits (including the classic old 'Avo Minor' multimeter) use half-wave (rather than full-wave) AC rectifier circuits of the type shown in Figure 14, in which the 'V_{SAT}' voltage losses are only half as great as in the bridge type, but in which AC sensitivity is unfortunately also halved. Figure 15 shows an example of a multi-range AC voltmeter using this technique; here, the meter is shunted (by R6) to give an effective FSD sensitivity of 450µA, enabling the multiplier resistor (R1 to R5) values to be chosen on the basis of 1k0/volt.

Rectifier-type AC voltmeters inevitably become rather non-linear when measuring low voltage values, and for this reason commercial multimeters are rarely provided with FSD AC ranges lower than 10 volts. A few models (including the famous Avo 8) use a step-up autotransformer to boost the voltage from a 2.5V AC range to a higher voltage that is fed to the meter via the rectifier network, thus overcoming the non-linearity problem. A better solution is to use an electronic meter for low-voltage measurements.

When considering the construction of the Figure 11 to 15 circuits, note that most resistors have maximum voltage breakdown values of about 200 volts, so the multiplier resistances on the 100V and greater ranges should be made of several resistors wired in series, to give even voltage distribution. Also note (particularly in the case of Figure 13) that the multiplier networks are not frequency compensated, and (except on the 10V ranges) are accurate at low frequencies only.

AC Current Measurement

Alternating current is difficult to measure with a moving-coil meter, and few commercial multimeters have provision for such measurements. One exception is the Avo 8, which has AC current ranges of 100mA, 1A, 2.5A, and 10A, and uses an autotransformer to couple the 'transformed' (voltage-boosted and current-divided) AC signals to the rectifier and meter network; Figure 16 shows its basic circuit on the 100mA range.

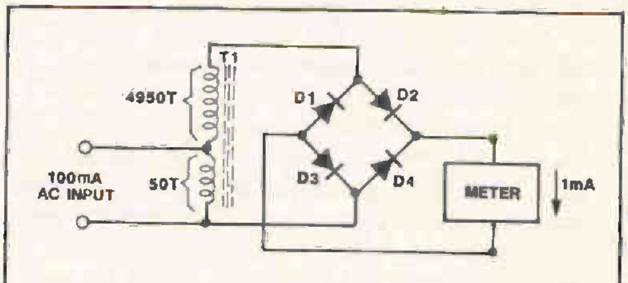

Fig. 16 A step-up autotransformer circuit used to give a linear AC current reading.

Figure 17 shows an alternative AC current meter circuit. Here, the shunt resistor values (R1 to R3) ensure that 500mV is generated across each set of input terminals at its designated FSD current value, and this voltage is fed to the meter circuitry via R4. The meter circuitry is configured as a half-wave AC voltmeter (as in Figure 14) with an FSD sensitivity of 500mV (set via RV1). Meter readings are not perfectly purposes; if perfect accuracy is important, the scale can be hand calibrated. To initially calibrate this circuit, simply feed an accurate 100mA AC current into the '100mA' terminals and trim RV1 for a full-scale reading (the meter has an effective FSD sensitivity of about 180µA under this condition).

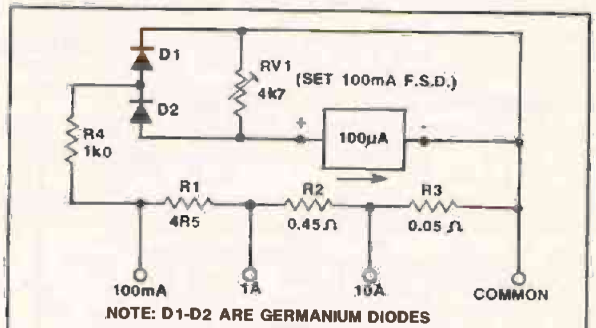

Fig. 17 3-range AC current meter using half-wave rectification.

TO BE CONTINUED

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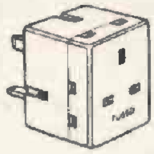

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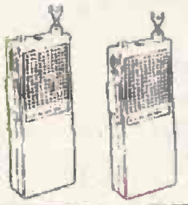

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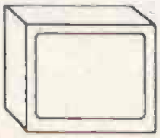

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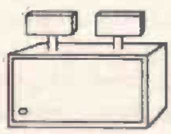

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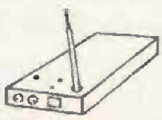

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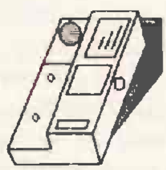

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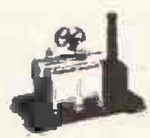

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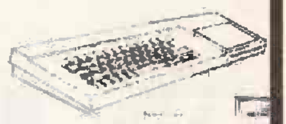

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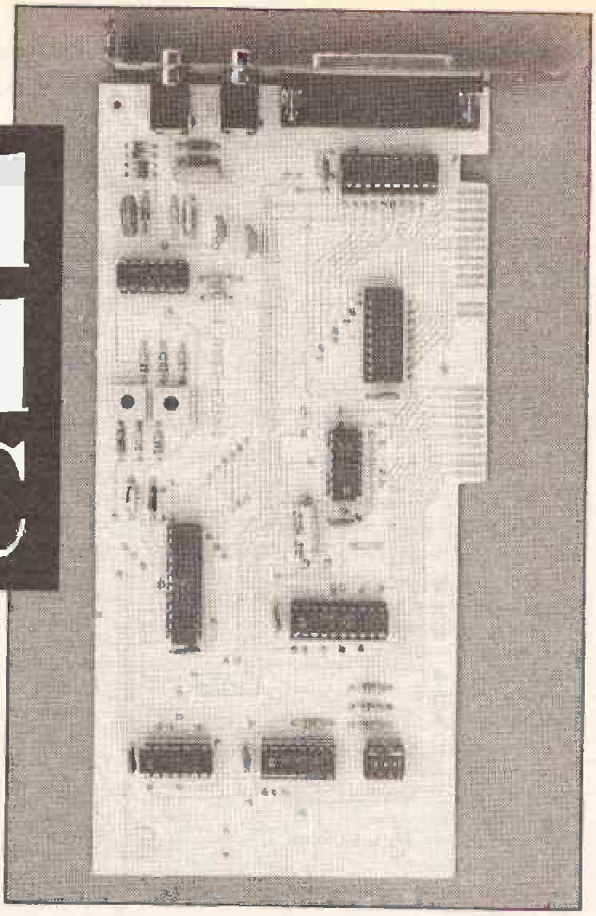

2

Design & Development by Neil Johnson

In the first part of this project the hardware design and construction was described, together with a specification for this interface card (InterCard for short). This month we shall move on to the programming side of this project, in both BASIC and C, together with a few example programs and finish off with some suggestions and ideas for the future.

Programming

Assuming that your board seems to be working OK, i.e. no wisps of smoke from any of the chips and your PC functions normally, you should be ready to try it out. For simplicity, I will assume that you have selected a base address of $300. The term 'address offset', which I will use quite a lot, is simply added on to the base address to find the actual address. I have also used this system in the C program examples. The converter data is accessible at address offset 0 and to start the A-to-D converter a write must be done to address offset 1, the actual data that is written being unimportant. External 8 bit port A is located at address offset 2 and port B is at address offset 3 (this is summarised in Figure 11 last month). This is about all of the address information needed to program this board, so let's get on with it.

To start with, I'll explain about using the external 8 bit digital ports and then go on to explain how to take audio samples, store them and then play them back through the InterCard. In case programming is not quite your forte I have written a few simple programs, which will be used as examples. Even better, if you send for the disk (available from the author - see buylines) you not only get the example programs already typed in and tested but also the fully working programs, as well as a few other programs that might be of interest to you. So, without further delay, let's start with the digital ports.

Both external 8 bit ports can be read from and written to. Program 1 is an example C function to write a value to port A, address offset 2. The specific code to access the I/O ports is usually compiler specific (this is Microsoft QuickC) so read your compiler manuals before compiling this code, unless you use QuickC. For those of you unfamiliar with C, Program 2 is a GWBASIC equivalent. Personally I don't like BASIC simply because it's too slow to be of any real use for interfacing, although for this project there will be BASIC equivalents for the digital interface programs. Looking at Program 1, the first line of the main() function declares outvalue to be of type char, which is only one byte in size. The next line assigns the value 100 (decimal) to this variable. This is going to be the value sent to the port. The third line is where the actual data is sent to the output port. BASEPORT is a constant whose value is that of the base address as set by the DIL switches on the InterCard, and 2 is the address offset for port A. With the BASIC version you should be able to see how it works from the C program.

Program 3 is a C function to read a value from port B and display it on the screen. Again the main() function is used, this being the actual function that gets executed by the computer. This time the variable in-value is declared to be of type int (2 bytes) since this is the type returned by the inp() function. Although some of you who know C will say that I could have cast the return value of inp() to be of type char, at this stage I'm keeping things simple. Finally, the printf() function displays the result on the screen, much like BASIC's PRINT command. Again, Program 4 is a GWBASIC equivalent. That's about it as far is the digital ports are concerned. The rest is more a programming exercise, which I leave up to you, unless you want to get a copy of my programs and see one way of doing it. Programing with the analog ports is a little bit more involved. The main programming task is to move data, namely the sample, at a suitably fast enough rate to achieve the desired sample record/playback speed. For this reason it is impossible to use BASIC for this work. Some versions of PASCAL can just about get up to speed; C is fast enough to record and playback samples with a little headroom, but if you intend to do some real-time processing you'll have to learn assembler, just like I've had to. To illustrate this point, I wrote a simple program that gets a sample file from my hard disk and plays it through the analog output port to my hi-fi. I then coded this program in Pascal, C and Assembler and timed how long it took each version of the program to run. The results are shown in Figure 12. Although the Assembler and C versions both took the same time to execute, the C

PROJECT

program is working flat out whereas I had to put quite a hefty delay into the Assembler version - without this delay you can't really make out what is being played since it sounds much like a 'blip' from the speaker. And finally the Pascal version takes a massive 12 seconds from start to finish, most of this time being taken to read in the file, but again the playback code is working flat out. Now that you can see what sort of speed you need to work at, I think you'll find it worth your while learning to program in C, or better still Assembler. Although the actual code to record and playback samples is not really that difficult, programming the user interface in Assembler is somewhat time consuming and lengthy. A better alternative would be to code the sample handling routines in Assembler and use a C 'front-end' to run the whole program. The two example C programs that I've written are a sample recorder and a sample player (on the available disk is a program which combines both these in a menu driven environment). In both programs the sampling speed can be varied to change length of sample or playback speed. First of all the sample recorder, with the C code shown in Program 5. Apart from the specific C syntax, the operation of the program is fairly self evident. The program asks the user for the number of samples to take and the delay between taking samples. Pressing the RETURN key starts the recording process. After the sample has been taken, the user is given the option of saving the sample to a named file. The file format is raw binary which is compatible with some of the available shareware sound player programs (for example, both Sounder and SoundTool use raw binary sample files). The large number of if(..) statements are there to include a certain amount of error handling, especially with file access. The maximum number of samples that can be taken with this program is 65000 samples, although it is possible to record more samples if the program and memory model are changed to HUGE (or equivalent). Notice the definition BASE-PORT. This is the base address of my InterCard, as set by the DIL switches. The '0x' infront of the 300 is C's way of indicating a hexadecimal number. Obviously you would change this if your card was somewhere else in the I/O map. The second program is a sample player. The C code for this is shown in Program 6. Again its operation can be deduced from the basic C code. The name of the sample file to be played is entered on the command line just after the program name. If a different delay is to be used the new delay value is also placed on the command line after the sample filename. For example, to play the sample hello.sou with a delay value of 30 (mildly slow) the following would be typed in :-

player hello.sou 30 <RETURN>

and viola, my PC says a slow 'Hello' to me !

In both these programs I have tried to introduce some modularity by placing the common sample handling code in a separate file, called INTRCRD1.C (Program 7). This should be included into the source code after the definition of BASE-PORT and outside any functions.

These programs are by no means definitive ways to program with this InterCard, only examples which I have been using for some time now. I must confess here and now that I am not an expert at quality programming. I can write programs which do the main work, and leave it at that. If there any C or Assembler wizards out there who feel they want to write a decent program to drive this board, I would certainly give you my utmost support in this venture. In the meantime, happy sampling !

Program1

```
include <conio.h>

main()
{
char out_value;   /* out_value is the value sent to the port */
out_value=100;    /* for example, out_value is set to 100 */
outp(BASE_PORT + 2, out_value); /* send out_value to port A */
}
```

Program 2

```
10 VALUE = 100
20 OUT (BASE_PORT+2, VALUE)
30 END
```

Program 3

```
include <stdio.h>
include <conio.h>
main()
{
int in_value;  /* variable to hold value of port */
in_value=inp(BASE_PORT+3); /* read data from port B */
printf("Value read from port B is %u",in_value); /* display result */
}
```

Program 4

```
10 VALUE = INP(BASE_PORT + 3)
20 PRINT VALUE
30 END
```

Program 5

```
RECORDER.C
Version : 1.0
Written : 23-04-1992
By : Neil Johnson
For : IBM PC & Compatibles
Language : Microsoft C (written in QuickC 2.5)

Notes :-
1) Compile using atleast the COMPACT memory model.

#include <malloc.h>
#include <io.h>
#include <conio.h>
#include <stdio.h>
#include <fcntl.h>          /* O_ constant definitions */
#include <process.h>
#include <stdlib.h>

#define BASE_PORT 0x300

#include "intrcrd1.c"

main()
{
unsigned int sam_len,del,result;
```

Continued over...

Program - Continued

```
char string[30];
unsigned char *sample_ptr;
int filehandle;

printf("\nRecorder v1.0 - record samples with InterCard 1");
printf("\n————————————————————————————————\n");
printf("Enter No. Of Samples (max 65000):");
gets(string);
sam_len=atoi(string);
printf("Enter delay (0 to 255):");
gets(string);
del=atoi(string);
if (del>255)
{
printf("Sorry, delay too long\n\n");
exit(0);
}

/* now allocate enough memory for the sample */

if ((sample_ptr=(unsigned char*) malloc((size_t)sam_len))==NULL)
{
printf("Sorry, not enough memory.\n\n");
exit(1);
}
/* o.k. got block of memory, now get ready to take sample... */
printf("\nPress RETURN key to start recording...\n\n");
gets(string);

/* o.k. now record the sample*/

if ((result=_GetSample(sample_ptr,sam_len,(unsigned char)del))==-1)
{
printf("Sorry, can't get sample.\n\n");
exit(2);
}
printf("Sample now in memory.\n\n");
printf("Press key to play sample...");
gets(string);
del++;
if ((result=_PlaySample(sample_ptr,sam_len,(unsigned char)del))==-1)
{
printf("Sorry, can't play sample.\n\n");
exit(2);
}

printf("Do you want to save sample to disk ? (y/n)");
gets(string);
if (string[0]==121)
{
printf("\n\nEnter name of file:");
gets(string);

if ((filehandle=open( string,O_CREAT | O_WRONLY)) == -1L)
{
printf("\n Sorry, I cannot open that sound file\n\n");
exit(1);
}
if (write(filehandle,sample_ptr,(unsigned)sam_len) == -1 )
{
printf("Sorry, can't write sound file. \n\n" );
exit(1);
}
}

free(sample_ptr);
}
```

Program 6

```
PLAYER.C
Version : 1.0
Written : 23-04-1992
By : Neil Johnson
For : IBM PC & Compatibles
Language : Microsoft C (written in QuickC 2.5)

Notes :-
1) Compile using atleast the COMPACT memory model.

#include <malloc.h>
#include <io.h>
#include <conio.h>
#include <stdio.h>
#include <fcntl.h>          /* O_ constant definitions */
#include <process.h>
#include <stdlib.h>

#define BASE_PORT 0x300

#include "intrcrd1.c"

/*
Note: this program makes use or errorlevel return codes :
0 = program run o.k.
1 = program aborted due to disk/memory error
2 = program run without command line arguments.
*/

main( int argc, char *argv[] )
{
int filehandle,delay;
long length,loop;
char *buf;              /* pointer to data buffer    */

printf("\nPlayer - play sound files through InterCard 1 board");
printf("\n————————————————————————————————\n");

if ( (argc==1) || (argc>3) )
{
printf("\nUsage:\n\n    player <sound> [<speed>]\n\n");
printf("\n<sound> = name of sound file to play\n");
printf("<speed> = playback speed : 1 (fast) to 255 (slow)\n");
exit(2);
}

if ( argc==2 ) delay=9; else delay = atoi( argv[2] );
printf("\n\nAccessing sound file...\n");

/* can we open the named sound file ?  */
if ((filehandle=open(argv[1],O_BINARY | O_RDONLY)) == -1L)
{
printf("\n Sorry, I cannot open that sound file\n\n");
exit(1);
}

/* will this file fit inside 64k ? */
```

PROJECT

Program 7

```
INTRCRD1.C

Version : 1.0
Written : 23-04-1992
By : Neil Johnson
For : IBM PC & Compatibles
Language : Microsoft C ( written in QuickC 2.5 )

Notes :-
1) The global definition BASE_PORT must be defined before this code is included - it defines the hardware set base address of the Inter-Card 1

#include <conio.h>

function : _GetSample
return : if successful, the number of samples recorded, otherwise -1.
block_ptr  : a pointer to an allocated block of memory in to which the sample data will be placed.

block_size : size of data block in bytes
delay : number betweem 0 and 255, used to control the sample rate.

unsigned int _GetSample ( unsigned char *block_ptr, unsigned int block_size, unsigned char delay )

{
unsigned char *data_ptr, delay_loop;
unsigned int loop;

data_ptr=block_ptr;

if (block_size)
{
/* start conversion */
outp ( BASE_PORT+1, 0 );
/* begin sample loop */
for (loop=0; loop<block_size; loop++)
{
*data_ptr = ( unsigned char) inp(BASE_PORT);
outp ( BASE_PORT+1, 0 );
data_ptr++;
for ( delay_loop=0; delay_loop<delay; delay_loop++ )
{
/* this is the delay loop */
}
}
/* all done */
return (loop);
}
else
return (-1);
}
function : _PlaySample
return : if successful, the number of samples played, otherwise -1.
block_ptr  : a pointer to an allocated block of memory in to which the sample data is.

block_size : size of data block in bytes

delay : number betweem 0 and 255, used to control the playback speed.

unsigned int _PlaySample ( unsigned char *block_ptr, unsigned int block_size, unsigned char delay )

{
unsigned char *data_ptr, delay_loop;
unsigned int loop;

data_ptr=block_ptr;

if (block_size)
{
/* begin playback loop */
for (loop=0; loop<block_size; loop++)
{
outp(BASE_PORT, *data_ptr);
data_ptr++;
for ( delay_loop=0; delay_loop<delay; delay_loop++ )
{
/* this is the delay loop */
}
}
/* all done */
return (loop);
}
else
return (-1);
}
```

```
if (( length = filelength( filehandle )) > 65535 )
{
printf("Sorry, file is too big to fit in here.\n");
exit(1);
}

/* yes it is, but is there enough memory available to hold it ? */

if( ( buf = (char *)malloc( (size_t)length ) ) == NULL )
{
printf("Sorry, not enough memory to load sound file\n");
exit(1);
}

/* ok, so read in blocks of data if possible */

if( read( filehandle,buf,(unsigned)length ) == -1 )
{
printf("Can't read that sound file. \n\n" );
exit(1);
}

/* now play the sound through the DAC board */
if ( _PlaySample( buf,(unsigned int)length,(char)delay ) == -1 )
{
printf("\nFor some reason the sound file won't play\n\n");
exit(1);
}

printf("Finished.\n\n");

if ( close(filehandle) == -1 )
{
printf("\nFor some reason I can't close the sound file\n\n");
exit(1);
}

free( buf );
}
```

Bibliography

The Art Of Electronics; Horowitz and Hill; Cambridge University Press

MASM Bible; N. Barkakati; The Waite Group (SAMS)

QuickC - The Complete; W. Feibel Reference; Osbourne McGraw-Hill

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The staff of ETI for such a damn good readable magazine.

Toby Martin for introducing me to the wonderful world of C.

Kris Buglear for giving me the impetus to design this project.

And finally The University Of Surrey for both teaching me electronics and for having such wonderfully stocked component trays in the electronics labs.

Buylines

If you want a copy of a disc with the C source code and executable programs, as well as a few other programs for this card, send a cheque or postal order for £5-00 to: Neil Johnson , 2 Chapel Field, Dixter Rd, Northiam, East Sussex, TN31 6PQ. At the moment I can supply 5 1/4" and 3 1/2" discs I both normal and high density (please specify what you want) but after July 1993 I'll only be able to supply 5 1/4" high density discs (1.2MB).

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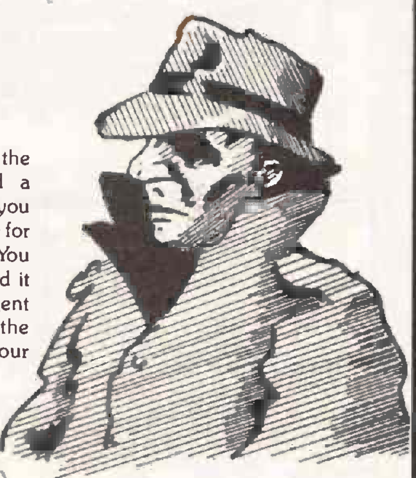

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Electronic Die for Board Games

A pocket-sized device no hardened board-game-player should be without. Shabaz Yousaf reports

The electronic die described here is very compact, It's large, dice-like display is totally unambiguous, it doesn't get misplaced easily, and it doesn't fall off tables either. Operating the die is simplicity itself - it is switched on, and the 'throw' button is pressed. The buzzer beeps, and a random number is displayed using seven miniature LEDs arranged as a face on a die.

The Circuit

As can be seen from the circuit diagram in Figure 1, the circuit is based around two logic IC's and a handful of other components. It was decided that the design should use CMOS logic rather than 74-series TTL for two main reasons; CMOS circuitry uses less current (essential for battery-powered equipment), and it's power supply requirenents are very tolerant. This means that no voltage regulating circuitry is rerquired and the hole circuit can operate from a PP3 9V battery.

Current consumption is about 30mA maximum, so the battery will last quite a while unless you are in the habit of playing board games every minute of the day, which could result in a trivial pursuit after a fresh battery...

HOW IT WORKS

IC1a is a Schmitt-trigger invertor used as an oscillator running at a few hundred Hertz. Switch SW1 gates the output from the oscillator to the input of the binary counter IC2 and the piezo buzzer element.

The counter is wired such that the three outputs (pins 6,11,14) go logic '1' in a sequence (binary) of 100, 010, 110, 001, 101, 011. The three sets of LEDs are arranged so that faces of a die are represented. Invertors IC1c,d,e are used to buffer the outputs to drive the LEDs. Individual current limiting resistors are not required for the LEDs because resister R3 provides a voltage drop to the whole circuit, and the voltage across each LED is reduced to around 2 volts.

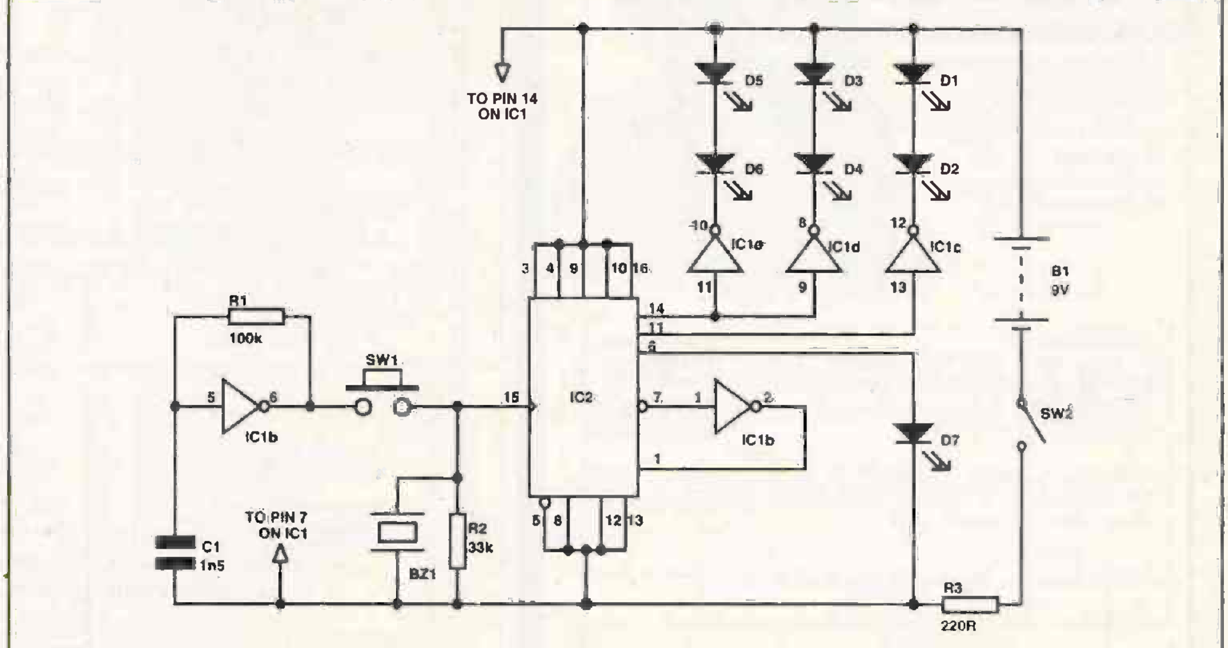


Fig.1 Circuit diagram of Electronic Die

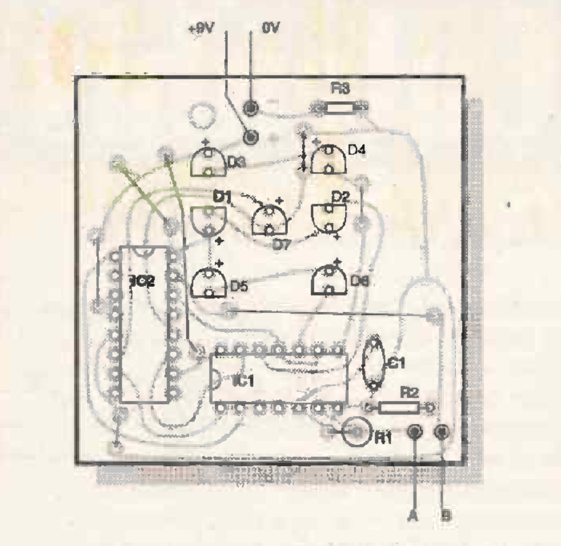


Fig.2 Component overlay

Circuit Assembly

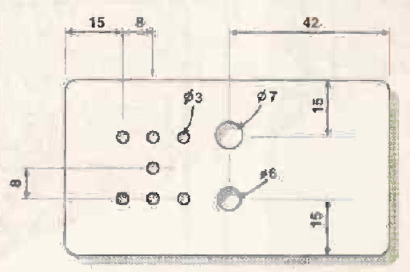
The prototype was constructed on a single-sided fibre-glass PCB. Figure 2 shows the printed circuit board layout. Note that there are seven wired links, and these should be soldered first. Next, solder the three resistors and the capacitor, and then the two integrated circuits, They are both static-sensitive, so the usual precautions should be taken while soldering. IC sockets could be used, but as the ICs are both very inexpensive, it was not considered necessary on the prototype.

The LEDs are next, but unlike the previous components the LEDs are soldered on the solder-side of the board. It is important that all the LEDs project the same height from the board, so trim all the leads first to about half an inch.

Take care to orientate the LEDs correctly as shown in the component layout (Figure2). After soldering, if any LED is not in line with the others, the solder can be re-melted and the LED adjusted.

The buzzer, battery clip and the two switches can now be wired to the board as shown in Figure 3. Holes are then drilled in the case to accomodate the LEDs using a 3mm drill bit. Two larger holes are drilled for the switches. If you are using the recomended case, drilling positions are indicated in Figure 4.

Taking care not to buckle any LEDs, the PCB is carefully pushed into position until the LEDs protrude slightly, from the other side of the case. The switches are screwed into position. The piezo buzzer element is glued into place, using a good quality impact adhesive such as UHU. The battery and PCB are held in position by two pieces of sponge or foam glued on the inside of the lid to the case. When screwed down, this provides firm pressure. Most types of foam will be suitable but do not try to use the black stuff in which integrated circuits are supplied, as this is conductive and could cause all sorts of odd effects and would eventually run the battery down. The battery is now clipped into place and the cover is screwed on. All that remains now is to design a logo for the top panel and glue it just below the switches.



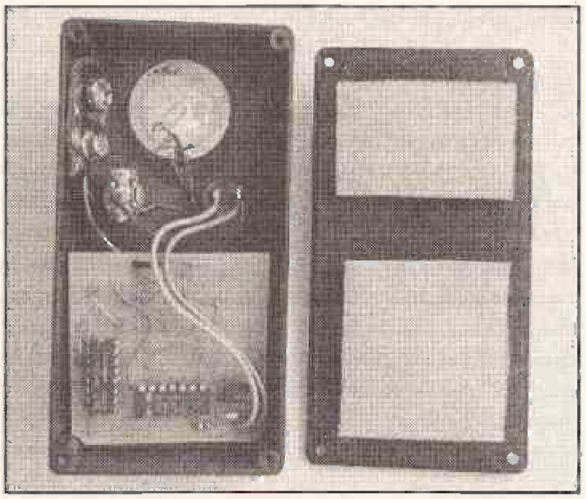
ALL DIMENSIONS IN MILLIMETRES

Fig.4 Dimensions for drilling case

Testing

With the battery inserted, switch the toggle switch on. Depending on the state of the counter IC (IC2), some LEDs may be lit. Push the 'throw' switch, If all is well, you will be greeted with an inviting 'beep' and on release of the button a random number will be displayed. If this doesn't happen, switch off immediately. If the battery is not flat, something is definitely wrong and you will have to fetch the multimeter.

All that remains is to get that old Monopoly board out...



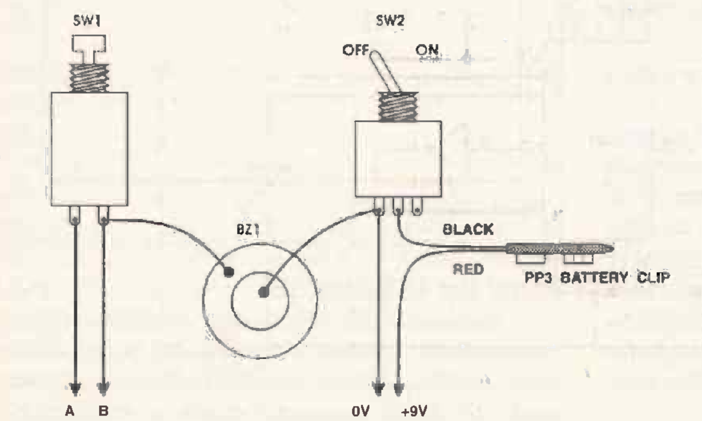


Fig.3 Wiring Diagram

RESISTORS
R1 100k
R2 33k
R3 220R

CAPACITORS
C1 1n5 Ceramic or polyester

SEMICONDUCTORS
IC1 40106
IC2 4029 Counter
D1-7 3mm Red high brightness LEDs

MISCELLANEOUS
SW1 Push-to-make switch
SW2 SPDT toggle switch
BZ1 Piezo element
B1 9v PP3
Case, impact adhesive, PCB,wire, foam (45x30x5mm and 45x40x5mm)

All components except the piezo element were purchased from Electrovalue Ltd., Tel:0784 433603. The catalogue number for the case is B520.

The piezo element is available from Maplin, order code YU87U or from Tandy, Cat No. 273-073. The Tandy version is enclosed in a plastic surround, but this can he easily removed.

Differential Calculus

Zeno's Arrow and Achilles' Tortoise

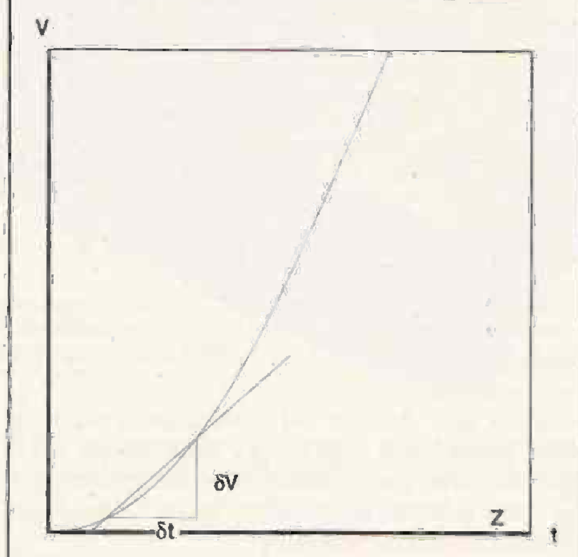


Fig. 1 Crude Tangent

ETI and A P Stephenson show that maths is not all π in the sky

According to classical historians, the ancient Greek intelligentsia were great thinkers. This is hardly surprising since they were waited on hand and foot by slaves and so had little else to do but munch grapes and think. Because science had not yet been invented and proven facts were thin on the ground they were fond of entertaining each other with logical puzzles. One such puzzle was the brainchild of Zeno of Elea who founded a philosophical school in the 5th century BC. Apparently, he had a bee in his bonnet about motion. Motion, according to him, was impossible and set out to prove it by the following reasoning:

1. Consider an arrow in flight between point A and B.
2. It cannot reach B until it passes half the distance.
3. But it cannot reach this half distance until it has passed the quarter way point ... and so on.
4. Since there are an infinite number of points on a line it is clear that motion is impossible.

This paradox, which came to be known as Zeno's Arrow, was debated by some philosophers for many centuries to follow. Although common sense and their experience of the physical world told them that motion was certainly possible, they found it difficult to spot the flaw in Zeno's logic.

Another much discussed paradox was the strange case of Achilles and the Tortoise. Achilles, who was the Greek equivalent to our Linford Christie, challenged a tortoise to a race but allowed it a few yards start. But Achilles never managed to overtake the tortoise because:

a) By the time Achilles had reached the spot where the tortoise started from, it had moved on to a second spot.

b) By the time Achilles reached the second spot, it had moved on to the third .... and so on. Because Achilles could never overtake the tortoise, he lost!

These two examples of ancient Greek thinking suggest they had not yet managed to grasp the idea of a space continuum or a rate of change. They considered an object in flight progressed by a series of digital jerks, occupying different fixed points in space at different times.

Newton And Leibnitz

In the latter half of the 17th century, Isaac Newton, apart from mechanising the planets and popularising the humble apple, developed a collection of mathematical concepts which we now refer to as The Calculus. Unfortunately, a German mathematician by the name of Leibnitz protested, with some vehemence, that it was he, and not Newton, who developed the calculus. Insults were exchanged between the two contenders and a full scale academic war raged, the rumblings of which can still be heard in academic circles. The probable truth is that they were both right and that the calculus was developed simultaneously simply because science found it could not progress much further without it. History abounds with simultaneous discoveries due not to coincidence but because there was a need for them at the time and great minds are always ready to respond to a challenge.

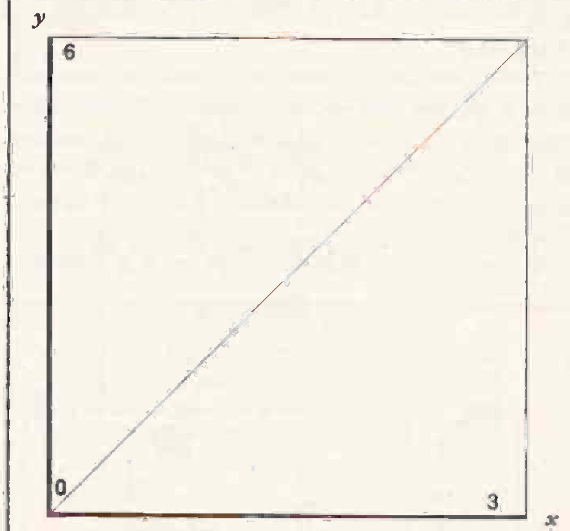


Fig 2a Curve of Y=2x

What use is Calculus?

It has been said that the only thing in the universe that is constant is change! Time is changing, the planets are constantly changing position, biological species evolve, governments rise and fall and money changes in value - usually downwards. Electrons scurry around, electric and magnetic

MATHS

fields constantly change amplitude and even our homely domestic power supply voltage is continually bobbing up and down and reversing its polarity.

Calculus is valuable because it provides a mathematical tool for dealing with change and, more importantly, with the rate at which a change is taking place. The following examples in the electronic's field are sufficient to illustrate the relevance of calculus:

a) The magnitude of an induced emf in a coil is proportional to the inductance (L) and the *rate of change* of current. Likewise, the current flowing into a capacitor is proportional to the *rate of change* of voltage across it. Calculus is of value in both these cases.

b) Calculus can be used to choose circuit values which either maximise performance or minimise unwanted features. In other words, it can find maxima and minima points on a performance curve.

c) Calculus can find the area beneath a curve which is the intermediate step in finding the average value of a varying voltage.

d) The behaviour of systems in all branches of physics, including electronics, can nearly always be analyzed from first principles by the use of differential equations expressed in calculus notation. The numerous formulae which grace the pages of a/c theory text books have been derived in the first instance from differential equations.

Extolling the virtues of calculus is all very well from the academic viewpoint but there will be many readers, already possessing considerable knowledge and expertise in electronics who may respond with: "I have managed very well

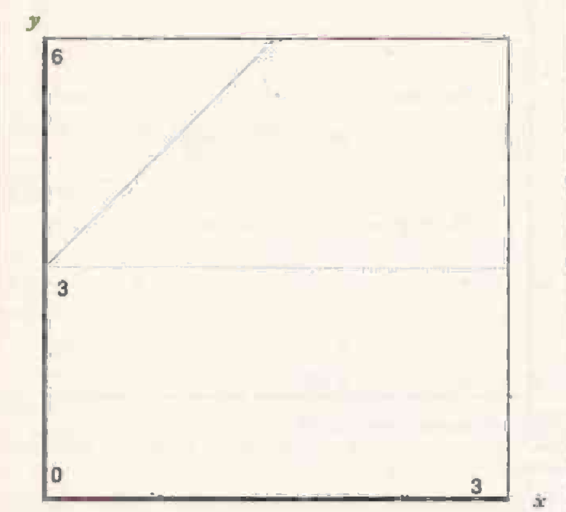


Fig 2b Curve of Y=2x+3

without calculus up to now so why should I bother? I have heard it is such a difficult subject and I already know enough maths to get me by."

The first part of the argument is difficult to combat because a dedicated electronic hobbyist can diagnose equipment faults, test and even design complex circuitry and, at the same time, have a good understanding of the underlying theory - all this without even knowing what a differential coefficient is! All that can be said in defense of this argument is that additional knowledge tends to breed additional interest and does wonders for the ego. It will be possible to derive from first principles many of the commonly used equations instead of taking them at face value and will therefore increase self confidence. Whether calculus is a "difficult subject" or not will depend on the way it is approached. To understand calculus with all its tortuous ramifications requires time, gallons of coffee and several bottles of aspirin. An alternative approach is to learn just enough for it to be used as a tool and leave the understanding bit until later.

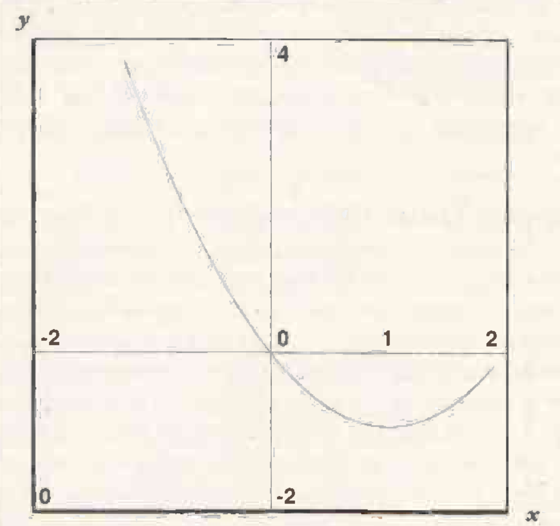


Fig. 3 Curve of $Y=x^2-4x$

The Two Branches of Calculus

Given the equation of any curve, calculus can find a corresponding equation which represents a rate of change. The process of finding this rate of change is called *differentiation* or, sometimes, the differential coefficient.

Conversely, given the rate of change, integral calculus can find the original equation - well usually, anyway! The process of finding this original equation is called integration.

Differentiation The term 'rate of change' suggests that two variables are concerned, such as voltage and time, current and charge, or power and resistance.

Suppose the original equation is $V = t^3$, then the rate of change of V with respect to t turns out to be $3t^2$. (This result is not intended to be obvious but follows from a rule to be given later.)

The Leibnitz Notation

The following notation for expressing a differential coefficient (a rate of change) is attributed to Leibnitz:

dV/dt means 'the rate of change of V with respect to t.'

dI/dt means 'the rate of change of I with respect to t.'

dy/dx means 'the rate of change of Y with respect to x.'

It is important to understand that these ratios must not be considered as normal algebra. Just because d is in the numerator as well as in the denominator, it does not mean they can be cancelled out. The symbol (d) just means a very small change in the variable which follows it. In other words, dV/dt means the ratio of a small change in V which results from a small change in t. With regard to the question, how small is small, the answer is vanishingly small! In other words, however small you think it is, it still ain't small enough! The reason for the emphasis on smallness can be seen by studying the curve of $V = t^2$ in figure 1. Since the curve is not linear, it follows that the rate of change, or slope of the curve, will vary for different values of t. Geometrically, this rate of change could be found by drawing the tangent to the curve at a given value of t, but it is difficult, if not impossible, to draw a perfect tangent by hand since it must only touch the curve at one point. The "tangent" shown in figure 1 crosses the curve at two widely separated points so labelling the horizontal and vertical of the small triangle as dt and dV respectively would be patently wrong. This is why they are labelled δV and δt (read as 'delta V' and 'delta t'). The symbol δ means a small but finite change in the variable which follows it. However, if the two sides of the triangle are made smaller and smaller, the hypotenuse coincides nearer and nearer to the true tangent until, when δV and δt are vanishly small, it is permissable to replace them by dV and dt.

Higher Order Differentiation

Velocity (V) is the rate of change of distance (S), so can be written as $V = dS/dt$. But acceleration (a) is the rate of change of velocity and is written as $a = dV/dt$. This example indicates that we need a notation to cover the case when differentiation has to be performed twice on the same variable. Thus, the equation for acceleration can be written in one go: $a = d(dS/dt)/dt$, or in the alternative form, $a = d^2S/dt^2$. There is no denying that Leibnitz's notation is ugly and difficult when it comes to second order differentials. Fortunately, a more concise method is given in the paragraph which follows.

Functional Notation

A rigid definition of a function can be quite tricky because it involves things called "domains" and "codomains" but it is sufficient for our present purpose to refer to the right hand side of an equation as a function. Thus if $Y = abx^2$ then, if x is the variable in question, we refer to the term abx^2 as a function of x.

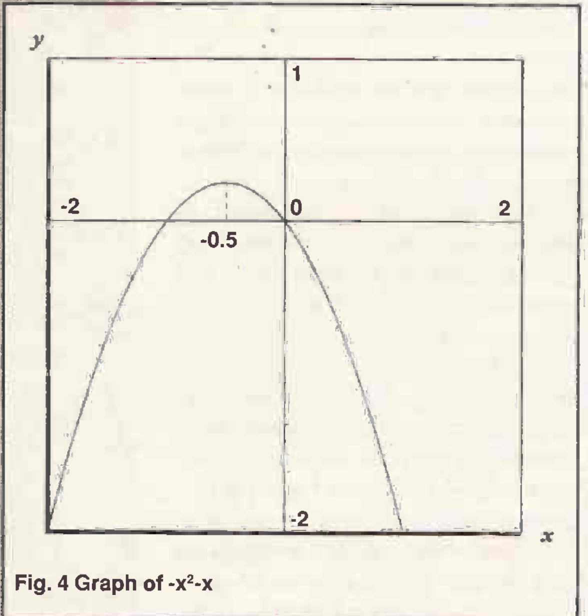


Fig. 4 Graph of $-x^2-x$

Functional notation is an alternative to the dy/dx method of Leibnitz and in some applications is less cumbersome. Assuming x is the variable, a function of x means any expression containing x. If we write $Y = f(x)$, we mean that Y is some function of X without having to state the particular function. It also allows us to fix some particular value for x when the function is evaluated. Thus, if $Y = f(x)$ and we write f(3) it means the value of x is to be taken as 3 when evaluating the function. The notation also provides a more concise alternative to the dy/dx method of expressing differential coefficients. Thus, if the original function is written f(x), the differential coefficient is written $f'(x)$ and the second differential coefficient is written $f'(x)$.

Variables and Constants

It is important to distinguish between a constant (any term in an equation which, for the particular operation in question, is presumed to remain fixed in value) and the particular variable of interest.

For example, the equation for power in a resistive circuit is $P = I^2R$ so if we want to indicate that I is to be the variable, the function would be written as f(I) and the differential coefficient as $f'(I)$. However, if I is to be treated as constant and R designated the variable, the function would be written as f(R) and the differential coefficient $f'(R)$

Standard Differential Coefficients

It is all very well knowing what a differential coefficient is but there still remains the vital question - how do we differentiate? Fortunately, it's quite simple because other people have already done the work for us so all we have to do is look up a table of differential coefficients! Serious students of calculus would be able to prove them from first principles but there is no harm in taking them for granted in order to get started. In the old days, the poor souls sitting examinations were expected to commit them to memory but because modern educationalists place more emphasis on reasoning and less on memory, they are now often given out with exam papers. The full list of differential coefficients is quite lengthy but the following three (expressed in general terms

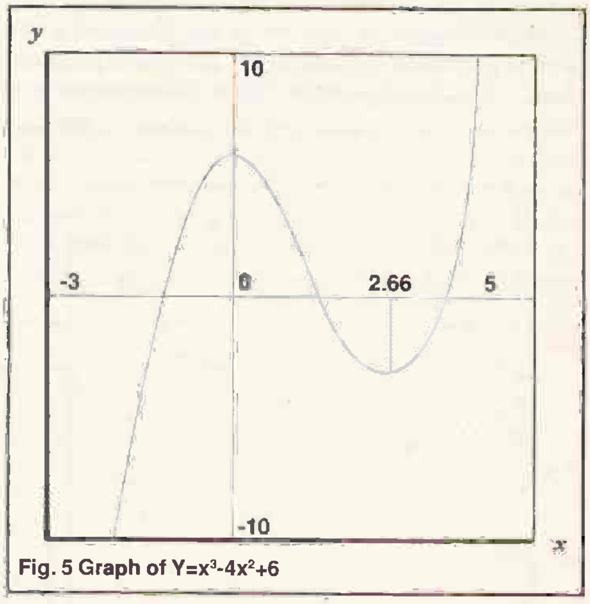


Fig. 5 Graph of $Y=x^3-4x^2+6$

of Y,X and constant a) are particularly applicable to electronics and quite sufficient for a preliminary feel of the subject. It is the form, in which the following rules are expressed, which matters, not the choice of variables.

Rule for differentiating powers of X

If $f(x) = ax^n$ then $f'(x) = nax^{n-1}$

Examples:

If $f(x) = 3X^3$, then $f'(x) = 9X^2$

If $f(x) = 4X^5$, then $f'(x) = 20X^4$

If $f(I) = I^2R$, then $f'(I) = 2IR$

If $f(x) = X$, then $f'(x) = 1$ (Because x is actually x^1 and $x^0 = 1$)

Rules for differentiating trig functions.

If $f(x) = \sin x$, then $f'(x) = \cos x$

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If $f(x) = \cos x$, then $f'(x) = -\sin x$

If $f(x) = \tan x$, then $f'(x) = \sec^2 x$

(Note: x represents the angle in radians not degrees.)

Examples:

If $f(x) = 4 \sin x$, then $f'(x) = 4 \cos x$

If $f(t) = V \sin t$, then $f'(t) = V \cos t$

If $f(t) = P \cos t$, then $f'(t) = -P \sin t$

If $f(t) = R \tan t$, then $f'(t) = R \sec^2 t$

Rule for differentiating the exponential function (e)

If $f(x) = ae^x$, then $f'(x) = aex$

Examples:

If $f(x) = e^x$, then $f'(x) = e^x$

If $f(t) = e^t$, then $f'(t) = e^t$

If $f(t) = Ve^t$, then $f'(t) = Ve^t$

Notice the exponential function e^x is unique in the sense that it remains unchanged after differentiation.

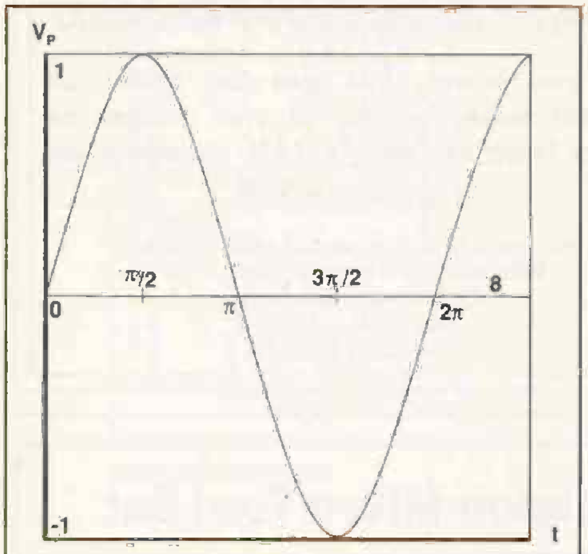


Fig. 6 Curve of $Y=V_p \sin \varpi t$

Added Constants

Figure 2a shows the curve of 2x and figure 2b shows the curve of 2x + 3. Notice the slope (the differential coefficient) of the curve in both figures are the same. This is an important result which leads to the following general statement:

Added constants vanish when differentiated.

Examples: If $f(x) = x^2 + a$, where a is any constant, then $f'(x) = 2x$

If $f(x) = \sin x - a$, then, $f'(x)$ is $\cos x$

Note from the second example that subtracted constants also vanish because subtraction is merely the addition of a negative.

The Addition rule

A string of functions separated by + or - signs is differentiated term by term.

Examples:

If $f(x) = ax^3 + P \sin x + R \cos x$

then $f'(x) = 3ax^{2+} P \cos x - R \sin x$

The Function of a Function Rule

Suppose $Y = \sin \varpi t$. Then $\sin \varpi t$ is a function of t (the major function) and ϖt is also a function of t (the minor function), so we have an example of a function of a function. The rule is:

Differentiate the major function and multiply by the differential of the minor function.

Examples:

If $f(x) = \sin x^2$, then $f(x) = (\cos x^2)(2x) = 2x \cos x^2$

If $f(t) = V \sin \varpi t$, then $f'(t) = \varpi V \cos \varpi t$

If $f(t) = Ve^{(t/CR)}$, then $f'(t) = V(1/CR)e^{(t/CR)}$

Finding Turning Points

Some equations, when plotted, show turning points in the curve. The curve of $x^2 - 2x$ in Figure 3 shows a minimum in the middle with increasing values either side and is a typical example of a turning point. Notice that the tangent to the curve at the turning point is exactly horizontal so the differential coefficient at any turning point must be zero. This suggests the following rule:

To find the x value at a turning point, first differentiate, then equate the result to zero and solve for x.

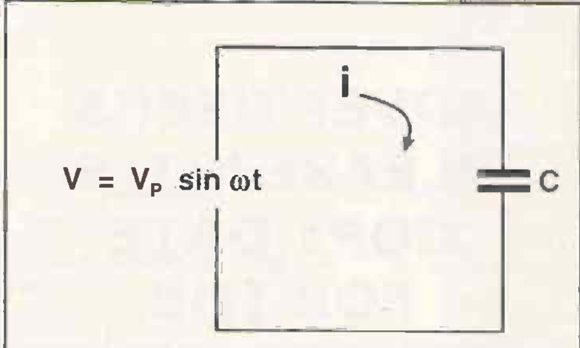


Fig. 7 Current into adaptor

We can try this out on the curve of Figure 3:

$f(x) = x^2 - 2x$, so $f'(x) = 2x - 2$. If $2x-2 = 0$ then $x = 1$ at the turning point. The turning point in the curve of Figure 3 happened to represent a *minima* but some curves show the turning point at a maxima. For example, Figure 4 is a plot of the function $f(x) = -x^2 - x$ and shows a maxima at the turning point. Note that $f'(x) = -2x - 1$ and when this is set to zero, the turning point occurs at $X = 0.5$ which checks with Figure 4.

Figure 5 shows the graph of the function $f(x) = x^3 - 4x^2 + 6$ which happens to be the proud possessor of two turning points, one a maxima and the other a minima. To find the x values of the turning points, we start with the function $f(x) = x^3 - 4x^2 + 6$ and differentiate to produce $f'(x) = 3x^2 - 8x$. Setting this to zero and solving for x, results in the quadratic equation, $3x^2 - 8x = 0$. This has two solutions:

$x = 2.66$ and $x = 0$. (Check the graph of figure 5 to verify these two values of x give the correct turning points.)

Sine And Cosine Curves

The sinusoidal voltage shown in Figure 6 is represented by the equation:

$v = V_p \sin \varpi t$, where V_p = peak voltage and v = the instantaneous voltage at any given time (t) after some arbitrary starting point. By convention, the starting point is taken to be the first zero reached from a rising voltage. In one complete cycle there are two turning points with a maxima at the positive peak voltage (V_p) and a minima at the negative peak voltage ($-V_p$). Although the graph clearly shows a maxima occurs at $\pi/2$ radians and a minima at $3\pi/2$ radians from the starting point, it is worth verifying by some calculus:

Since ϖt is an angle (θ), it is more convenient to write the sine wave in the form, $f(\theta) = V_p \sin \theta$. This is now differentiated to give, $f'(\theta) = V_p \cos \theta$. To find the turning points, we make $V_p \cos \theta$ = zero. From basic trigonometry, $\cos \theta$ first equals zero at $\pi/2$ radians then at $3\pi/2$ radians so the first turning point is a maxima and occurs at $\pi/2$ radians (90°) and the second is a minima which occurs at $3\pi/2$ radians (270°).

Capacitive Reactance

Elementary a/c theory states (usually dogmatically) that the opposition to current flow (X_c) presented by a capacitance (C) is given by $X_c = 1/(\varpi C)$. Calculus will help us to see why. Figure 7 shows a capacitance stuck across a sinusoidal voltage generator. It is evident that the voltage across C and the instantaneous voltage (v) delivered by the sine wave generator must at all times be equal - because Mr Khirchoff said so!. The voltage across the capacitance (V_c) is given by $V_c = q/C$ so we may write:

V_p sine $\varpi t = q/C$ which, on rearranging, gives $q = CV_p \sin \varpi t$. To find how much current flows, we recall that current is the rate of change of charge which, in calculus terms, can be written as dq/dt or as f′(t).

So, to find the current, we must differentiate the equation for q:

$q = CV_p \sin \varpi t$

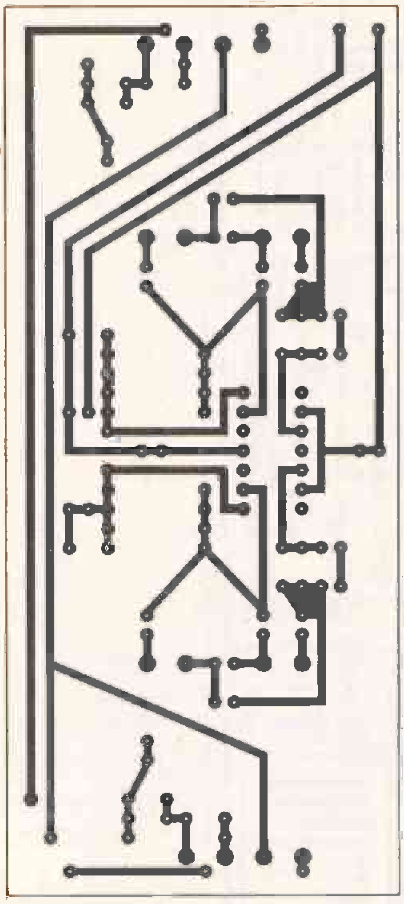
$i = dq/dt = \varpi CV_p \cos \varpi t$. This can be written in sine form as:

$i = \varpi CV_p \sin (\varpi t + \pi/2)$ .... Equation 1

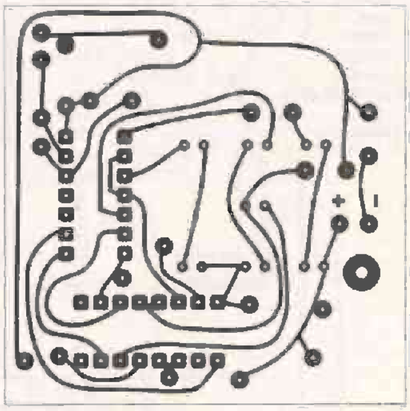
Note that the current is proportional to the input voltage generator - which should have been obvious anyway - but it is also proportional to ϖC - which was not so obvious! So ϖC represents the capacitive susceptance (B_c) and its reciprocal $1/\varpi C$ must be the capacitive reactance (X_c). Apart from deriving the formula for X_c, our excursion into calculus has also proved, by Equation 1, that the supply current *leads* the supply voltage by $\pi/2$ radians (90°).

PCB Foils

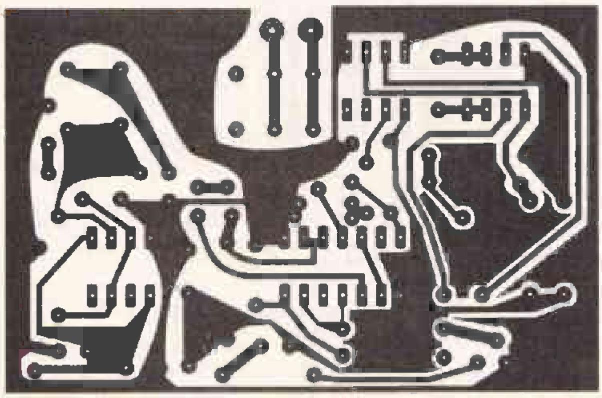
The PCB foil patterns presented here are intended as a guide only. They can be used as a template when using tape and transfer for the creation of a foil.



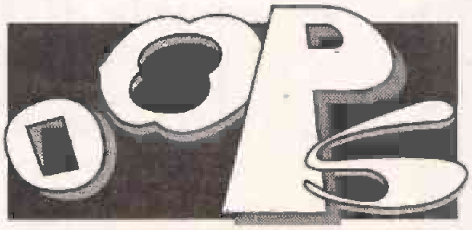
Quick-Build Hemisync



Electronic Die



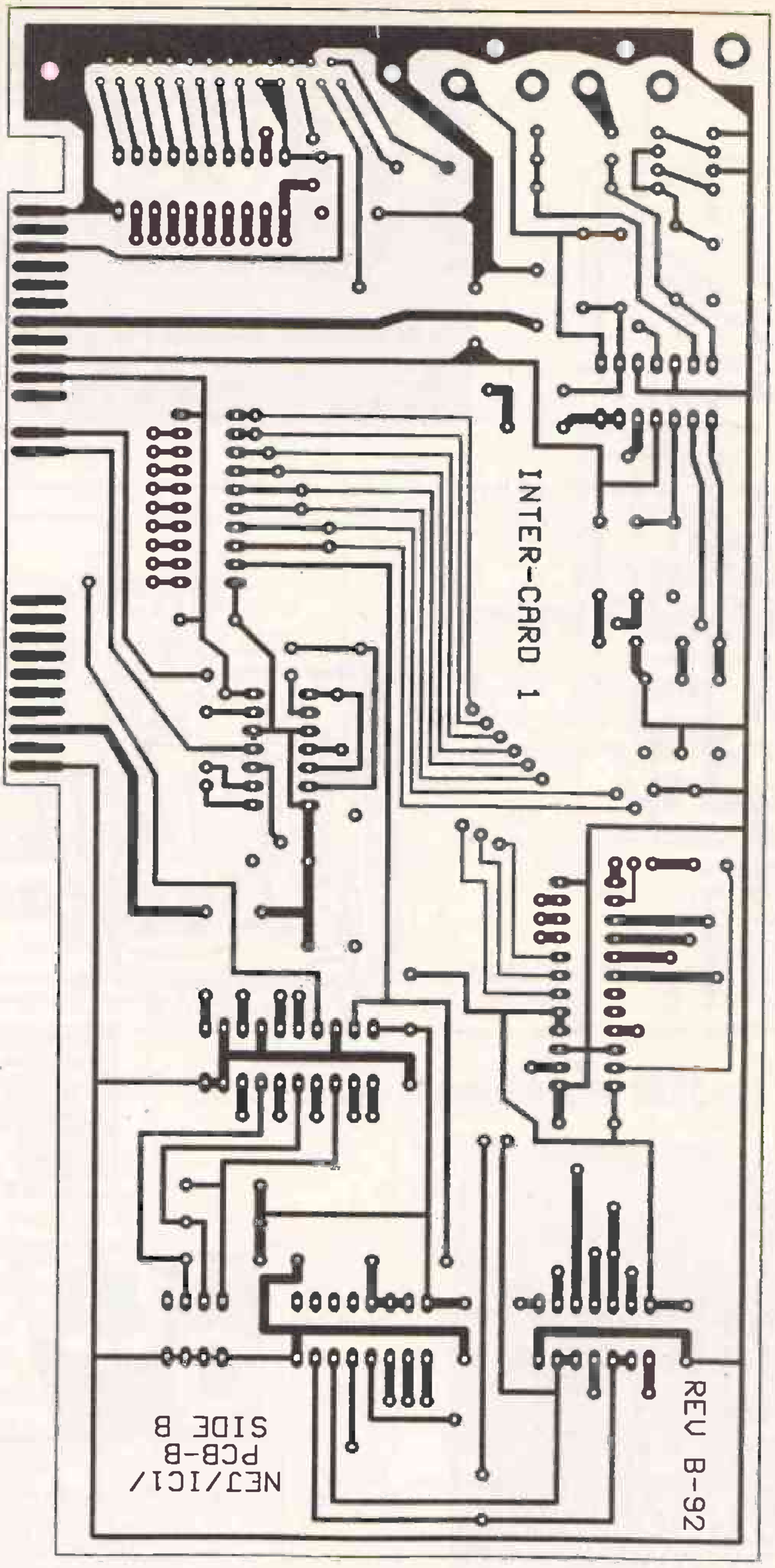
Auto Protection Car Alarm



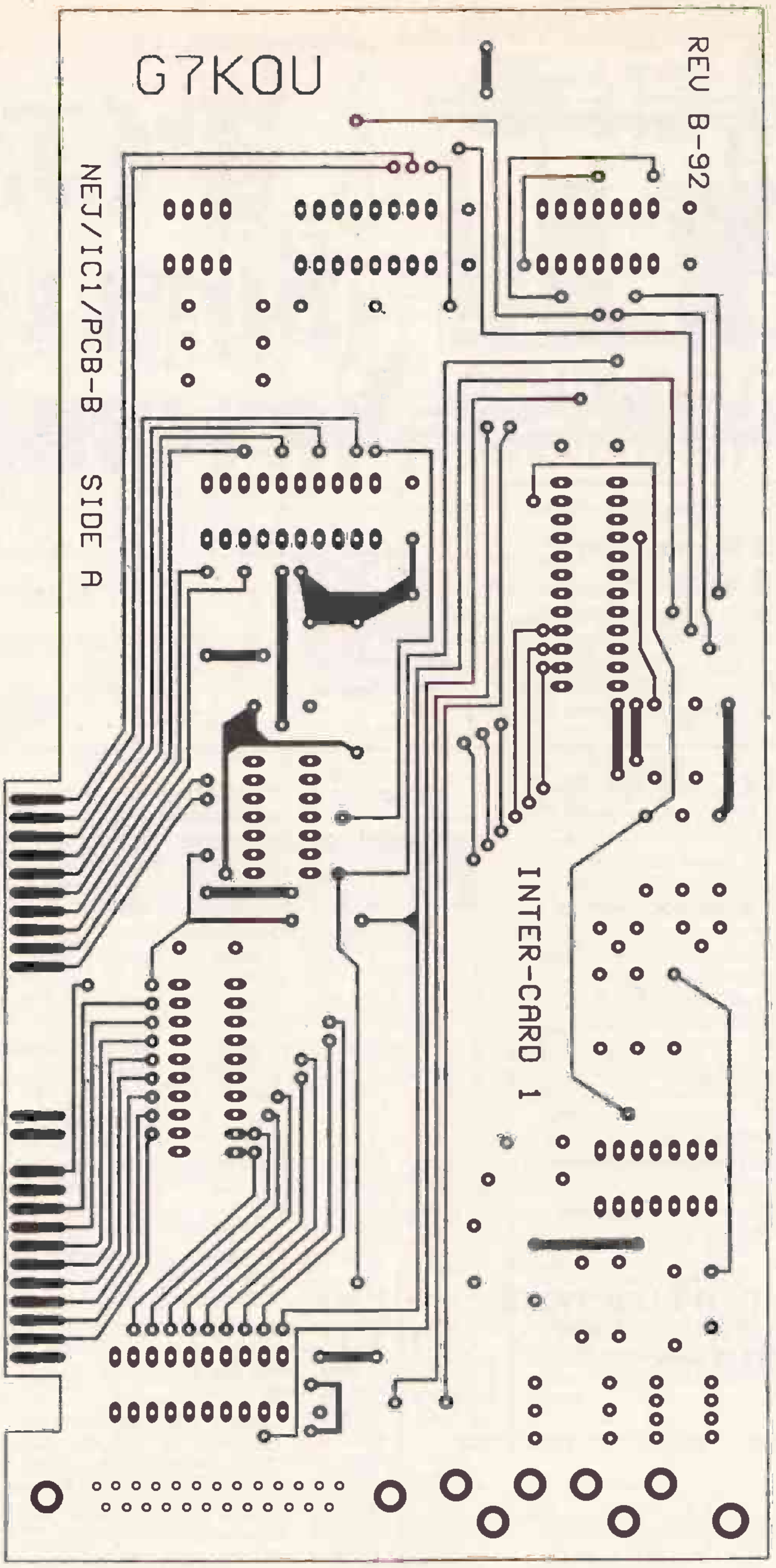
45watt Hybrid Power Amp Sept '92

C3 in Figure 2 and the parts list shows a voltage of 63V, this should be a 400µ/450V capacitor. C4 should be 220µ/630V. In Figure 2 the transistors should be labelled MPSA 92. Figure 5 should have a connection from the centre tag to the tag immediatley to the left thus connecting the live to T2. The valve heaters can be connected in series pairs across 12V if so wished. In Figure 6, the componant overlay, D5-8 should be labelled D1-4, also Q1, 1 and Q1a, 2a should be rotated 180°

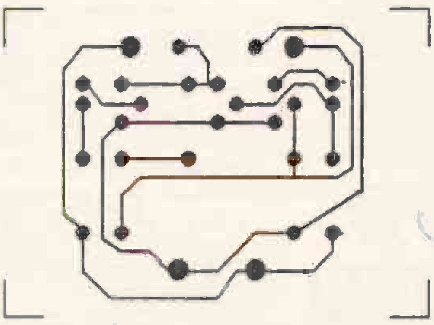
FOILS



Universal I/O Interface for PC (solder side)



Universal I/O Interface for PC (topside)



Rapid Fuse Checker
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E9107-3	Temperature Controller- Probe PCB	F
E9107-3	The Foot Tapper- Volume Control (2 Sided)	J
E9107-4	The Consort Loudspeaker	H
E9108-1	Pulsed Width Train Controller	E
E9108-2	Model Speed Controller-Main Board	F
E9108-3	Model Speed Controller-Power Supply	F
E9109-1	Geiger Counter	E
E9109-2	Hemisync Waveform Generator Board	G
E9109-3	Hemisync Pulse Generator Board	F
E9109-4	Hemisync Power Supply Board	C
E9109-5	Nighfighter Main Processor Board	O
E9110-1	Freeze Alarm	E
E9110-2	Document Saver	E
E9110-3	Prototype Designer	J
E9110-4	Nightfighter - Sound to Light (2 sided)	L
E9110-5	Nightfighter - Ramp Generator Board	F
E9110-6	Nightfighter - Cyclic Crossfade (2 sided)	M
E9110-7	Nightfighter- Strobe Board (2 sided)	J
E9110-8	Nightfighter - 8 Channel Triac Board	N
E9111-1	Digital Code Lock	L
E9111-2	Switched Mode Power Supply	E
E9111-3	Nightfighter Mode Selection (2 sided)	J
E9111-4	Nightfighter- Display Board (2 sided)	M
E9111-5	Nightfighter - Bass Beat Trigger (2 sided)	L
E9111-6	Nightfighter- Sequence Select (2 sided)	H
E9111-7	Nightfighter - Master Controller PSU	K
E9111-8	Nightfighter- Output Switch (2 sided)	M
E9112-1	Nightfighter Sensor Switch Master Control (2 sided)	L
E9112-2	Nightfighter Sensor Switch Channel Control (2 sided)	L
E9112-3	Nightfighter Sensor Switch Sound Trigger	H
E9112-4	Nightfighter Connector Board	F
E9112-5	Nightfighter Sensor Switch PSU	K
E9112-6	Nightfighter 8-Channel Input Interface (2 sided)	P
E9112-7	Power On and Overload Regulator	P
E9201-1	Laboratory Power Supply	F
E9201-2	Test Card Generator Board	M
E9201-3	LED Star (2 sided)	L
E9201-4	Enlarger Timer Main PCB (2 sided)	N
E9201-5	Enlarger Timer Selector Board (2 sided)	K
E9201-6	Enlarger Timer Switch PCB	E
E9203-1	MIDI Switcher- Main Board	L
E9203-2	MIDI Switcher- Power Suply	E
E9203-3	Sine Wave Generator (surface mount)	F
E9204-1	Auto Car Lights	F
E9205-1	Bat Detector	E
E9205-2	Pond Controller	F
E9206-FC	Stereo amplifier	G
E9206-2	Xenon flash trigger Main Board	J
E9206-3	Xenon flash trigger Flash Board	F
E9206-4	Scanner for audio generator	D
E9207-1	Improved Rear Bike Lamp	D
E9207-2	Mini Baby Bug Monitor	C
E9207-3	Ultrasonic Audio Sender (2 boards)	H
E9207-4	Camera Add-on unit (4 boards)	O
E9207-5	AutoMate 5V/48V Mixer power supply	J
E9207-6	AutoMate Precision 17V power supply	J
E9207-FC	Surround Sound Decoder	F
E9208-1	Dynamic Noise Limiter	F
E9208-2	Touch Controlled Intercom (2 boards)	H
E9208-3	MIDI Keyboard	K
E9208-FC	Battery charger	F
E9209-1	Intercom for light aircraft	H
E9209-2	Alarm protector	C
E9209-3	Temperature controller	M
E9209-FC	45W Hybrid power amp	F
E9210-1	Universal I/O Interface for PC (2 Sided)	N
E2910-2	Rapid Fuse Checker	E
E9210-3	Heartbeat/Audio Listener	E
E9210-FC	Wizards Hat	E

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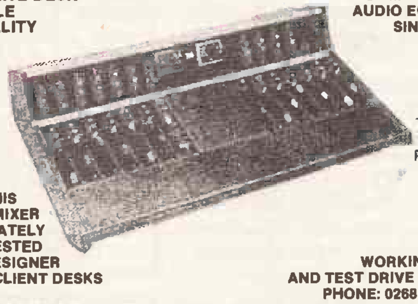

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Next Month

There may be times out in the field, when you've wished a low power mains supply was to hand. Next month **ETI** may be able to help out, for we include a project with our cover PCB which could satisfy your requirements - A 50W mains inverter.

Also in the December issue for test equipment enthusiasts, there is a digital circuit tester to see what the state of your digits are at. We continue with the constructional element of our Automatic audio response system for testing loudspeakers and for the valve enthusiasts we present a Hybrid Line amp.

We mustn't forget to include an RS232 interface for computers and we feature a subject of topical interest about the 'Green car'.

These are just some of the items of interest which may just cause you to go out and buy a copy of **ETI**. At your newsagents on **Friday 6th November**.

The above articles are in preparation but circumstances may prevent publication

Last Month

Our October issue featured:

Rapid Fuse Checker
Flashy Wizards Hat
Universal I/O Interface for the PC
Coping With Radiation
Heartbeat Monitor
AutoMate Pt7
Aerial Tuner Unit
Digital TV Pt5

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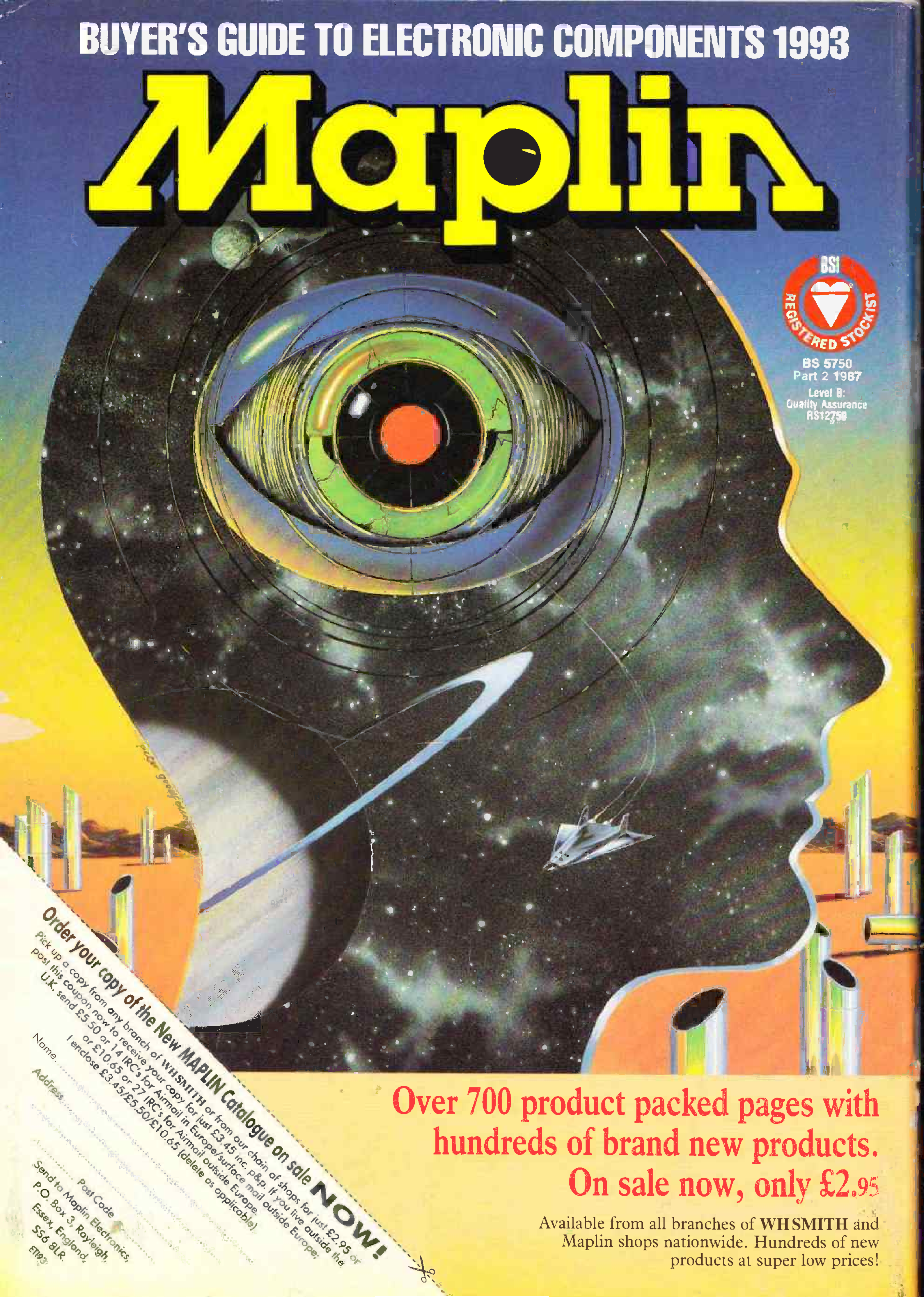

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