ETI
ELECTRONICS TODAY INTERNATIONAL

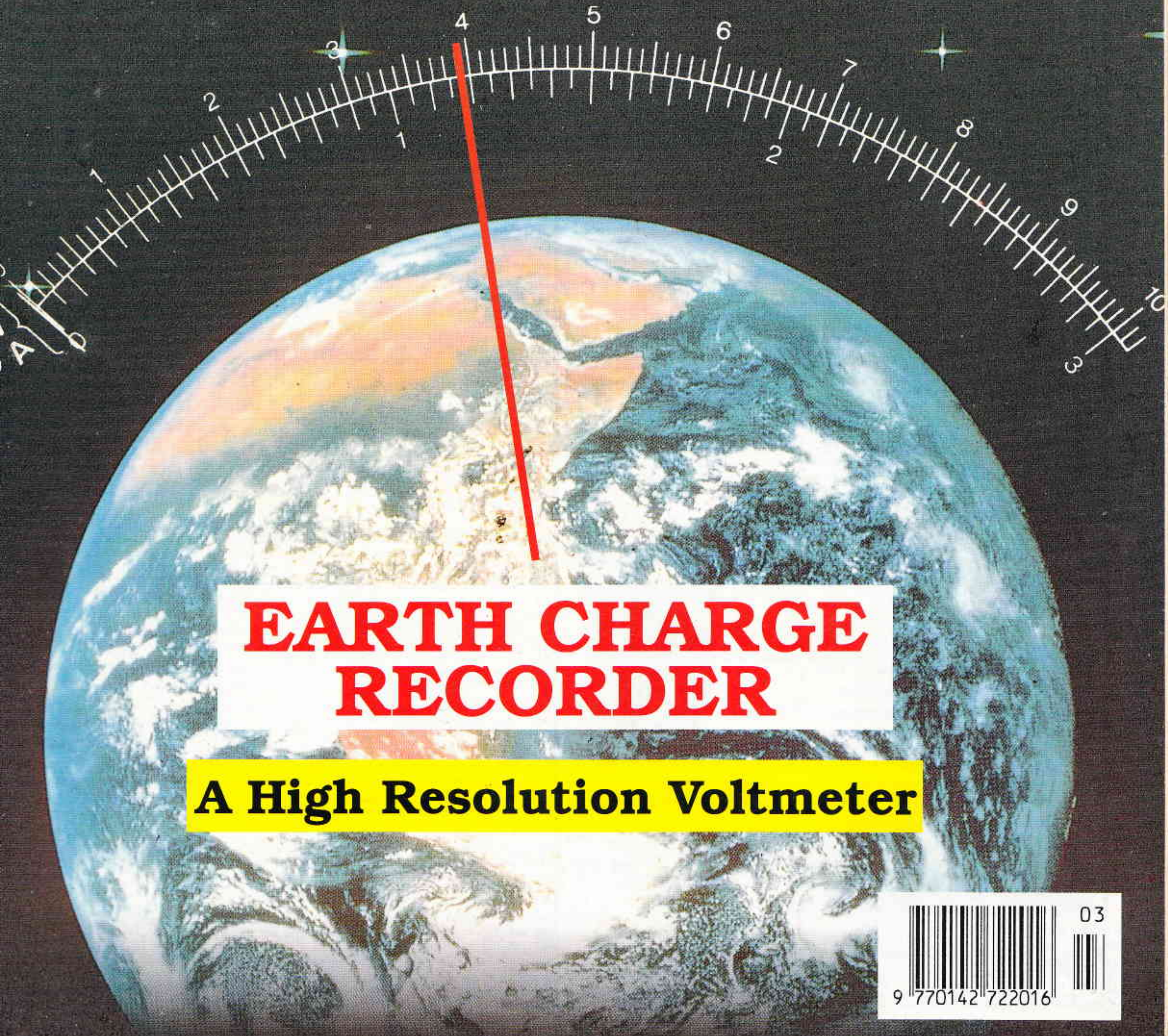
THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY
MARCH 1992 £1.60

MIDI SWITCH
Easier routing for musical instruments

VOLTAGE CONTROLLED OSCILLATOR
Another surface mount project

HIGH ENERGY DISCHARGE

UV RADIATION
Essential or harmful?



EARTH CHARGE RECORDER

A High Resolution Voltmeter

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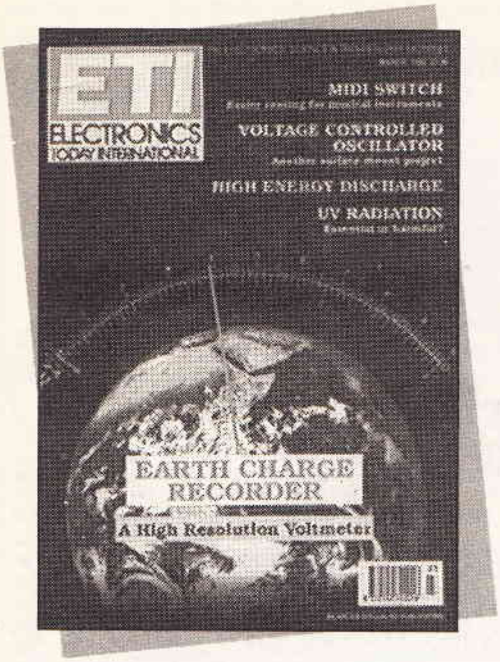
AN ARGUS SPECIALIST PUBLICATION



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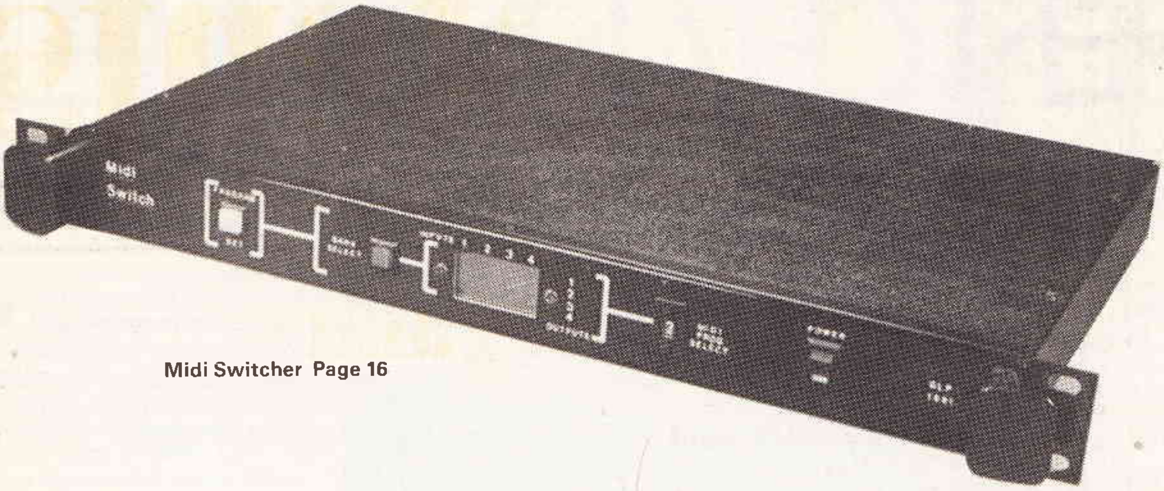

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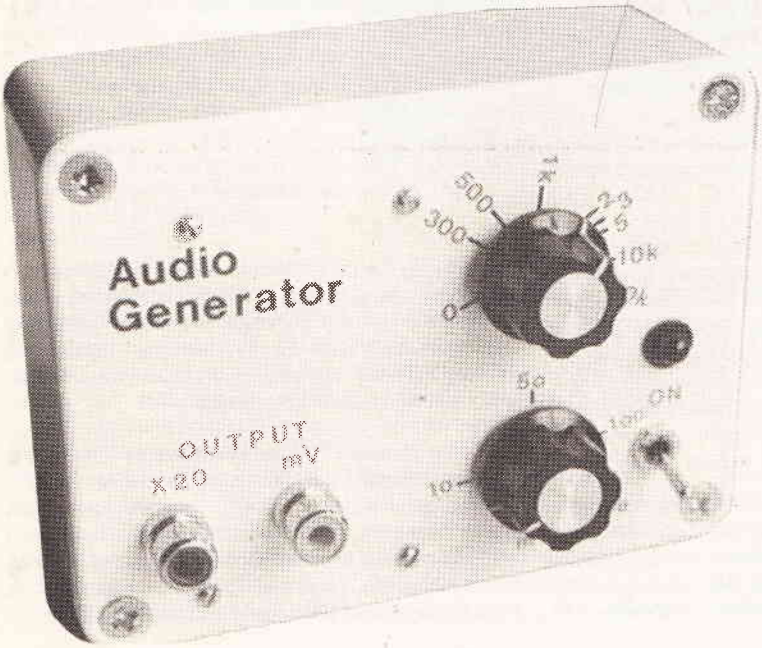

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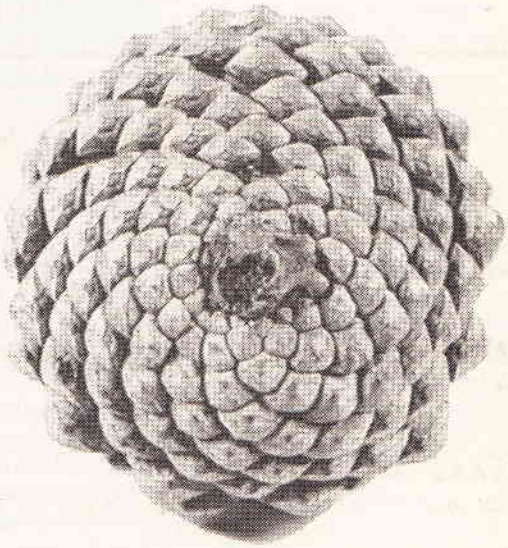

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Editorial

By Paul Freeman

It is my estimate that digital radio broadcasting could if the conditions are right,be in our homes within five years. It would make sense judging by the speed of technological change. If it can overcome the problems inherent in FM and provide high quality reception from a simple box placed in any direction just about anywhere with easy tuning, the public will go for it. They will not be sold on reception quality alone.

It has taken nearly 40 years for the public to accept the higher quality of FM broadcasts. Most of the blame for that should be due to the lack of media publicity and promotion in not putting FM first.

FM is not without its problems though. Conditions for the best reception have always been more ergonomically critical and as a result FM lacks the flexibility over AM. Mr Average has never really quite worked out the object of having flexible or stiff protrusions from a box on the kitchen shelf or the more delicate process of tuning by numbers. Having to wiggle the telescopic antenna every time to get the best reception has always been a pain for portables to say nothing of being stabbed in the eye, the cat from pulling the radio off the shelf, or junior wrapping the steel around their fingers. Mind you, the back room boffins have tried their hardest at improving reception with different transmitter polarisation techniques, AFC, PLL and minimal noise for stereo reception.

The ideas to emerge from conservative developmnet of FM and its accesories like RDS giving us amongst other things visual readout of station identity should all be combined into our newest method of transmission called DAB.

But if DAB remains the plaything of the technologist in the never ending search for quality sound, it will surely take the backshelf for another 40 years.

OPEN CHANNEL

Computer? What computer?

The future of personal computers is my first topic this month. Generally speaking, they are getting smaller. The rash of notebook computers, with the power and performance only dreamt of in a mini-computer a few years' ago, begs the question; when is it all going to stop? Well, the answer is; not for a while yet.

I have reason to believe that before long, say, the turn of the century if not before, we'll all be walking around with a personal computer the size of a calculator or less in our pockets.

What's led me to prophesy this is the recent agreement made between Motorola, Apple and Sony, with a small company called General Magic (yes, that's right magic) for licence to produce Magic's design of a calculator-sized computer. This is no ordinary computer, mind you. It combines computing power with communications ability, as well as pen-based and touch-screen operation. The idea is that your personal pocket-sized computer doesn't have to be all that potent in its own computing ability, provided it can communicate easily with you, and with a larger host computer elsewhere. In effect it's a go-between, combining you with your desk-based powerful personal computer. If you need simple computer-ability use the pocket computer; if you need anything else (say, information from a database, or high-powered number-crunching) use your pocket computer to access your host computer. Obvious, really, isn't it?

If you think it's all too much of a dream, bear in mind who the licencees are. Motorola currently makes the chips used in all Apple's other computers. Sony currently makes the PowerBook 100 notebook computer for Apple. Apple is simply the one in the middle tying up the loose ends.

If you still think it's a pipedream which, even if it works, will take years to come to fruition; just bear in mind that GM already has a working prototype!

Have You Got An HD — Mac?

You only have to read Open Channel for a couple of months' to realise that HDTV is one of my pet topics. Particularly so when people start telling me it's going to take such-and-such a route, when it's patently obvious that such-and-such a route is, for the sake of a better phrase, blinking ridiculous.

For example, I've argued long and hard for a bit of sense when it comes to the acceptance of an analogue stance for high definition pictures. For years companies like Philips, Thomson, Philips, Thomson and, er, Philips and Thomson have been telling us that high definition television should be a natural progression from their satellite transmission system called MAC (multiplexed analogue component). When this was originally voiced way back in 1984 or thereabouts it looked reasonable. But now, in 1992, it looks stupid.

Let me explain. By upgrading their MAC system (known as D2MAC, because it's the second variation of DMAC, which is the fourth variation — A, B, C... and so on — of MAC itself. Yawn, does this ever end?) to HDMAC, they assume everyone will want to follow and will want HDMAC. After all, it is a high definition system which is compatible with D2MAC systems. So people who have invested in D2MAC systems won't be forgotten. Their D2MAC televisions will be able to receive and display HDMAC signals; albeit just in D2MAC format. This logic is inescapable; it's true; and it makes sense.

What doesn't make sense, though, and what I have been arguing for a long time now, is that D2MAC television systems are unnecessary. Who wants them? Not the consumer, who is happy enough with his cheap and nasty PAL system. Not the broadcaster, who is satisfied with PAL and doesn't like the look of costly high definition equipment, anyway. But, yes you've guessed it, it's just Philips and Thomson, who've invested millions upon millions of pounds' worth of research and development into D2MAC and now HDMAC systems.

Finally, the EC has come to this realisation, too. A recent vote by MEPs at the European Parliament in Strasbourg virtually flattened any idea Philips and Thomson may have had in hurriedly introducing HDMAC through the back door, before anyone with any clout had a chance to notice.

Now instead of all satellite transmissions having to be broadcast in D2MAC alone from 1994 (the EC's original proposal) significant changes have been made. For instance, all existing stations have until 1995 to go over to D2MAC. Non-scrambled stations have until 1996. Even then they can be simulcast in both D2MAC and PAL — not just in D2MAC.

This is, hopefully, just the beginning. By then digital HDTV systems will be up and running — Philips and Thomson must have realised this — which will give a much better service. Current PAL systems then only have one upgrade step to go through, not the two steps proposed in the D2MAC-to-HDMAC upgrade.

In support of this argument, HDTV systems already are being developed, to a fairly late stage. General Instrument has already displayed its digital HDTV system, in which pictures are converted into digital signals, compressed and then transmitted, before being deciphered and produced on-screen. This has not been transmitted over-the-air, but it can only be a short time before it's possible. There are four similar digital HDTV systems in development in the US, all of which could produce equally good results.

I'm usually reticent in giving politicians credit for having much sense. But in this case, I have to say I agree with MEPs in the European Parliament. Philips and Thomson my have to swallow their losses in terms of wasted development, but this is far better than consumers being foisted with something they don't want and being told to take it or leave it.

Keith Brindley

ETI NEWS

LOW COST RADAR RECORDER

The International Maritime Organisation requires all vessels over 300 tonnes to be fitted with at least one radar system. While the value of recording the radar data has been long recognised, most operators have not been able to justify the costs traditionally associated with the technology.

Now Walton Radar Systems, an independent UK-based company, whose military radar recording technology has been used on-board Royal Navy vessels since 1981, has developed a singlechannel recorder for merchant marine applications. The price is about half that of the ruggedized military system.

Designated Hindsight-Witness, the system provides a permanent, objective record of radar and navigation data, invaluable in incident investigation, insurance claims, law enforcement, radar operator training and traffic management; and could be of significant assistance in search and rescue operations.

Utilising helical scan recording techniques similar to those found in conventional Video Cassette Recorders (VCR), Witness provides recording periods of three hours in real-time mode or 150 hours in Walton's time-lapse mode on each cassette.

Technical Specification

The basic unit possesses a single processor board which contains all the electronic systems necessary for the recording and replay of a single radar using ACP azimuth.

The unit provides, as standard, interfaces for all radar trigger, video and antenna bearing signals, together with a heading marker. A number of optional interfaces on plug-in cards are available, or planned, to meet the need for different radar formats, particularly for antenna azimuth, and to allow additional navigation information such as speed and compass bearing to be recorded.

Innovative features

Stemming from its military and Air Traffic Control (ATC) radar recording experience Walton has developed a number of proprietary systems.

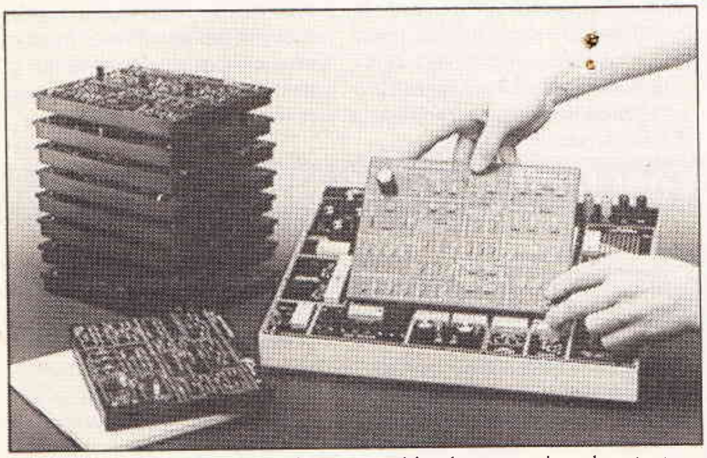
Dynamic System Quality Monitoring (DSQM™) continuously monitors the essential radar signals and circuitry within the recording and replay system, including the coded signal sent to the cassette recorder. The results of DSQM are displayed on record and replay 'health' indicators mounted on the front panel.

Time-Lapse recording extends a standard three hour cassette to provide 150 hours recording capacity. When Time-Lapse recordings are replayed using Fastplay the scenario is speeded up, condensing the replay time and facilitating rapid review.

Walton is optimistic about the market potential of Witness. Mike Jones, Chief Executive of Walton Radar said, "the easy understanding of the important aspects of radar information, and the impact in seeing a situation unfold in realtime gives radar recordings an immediacy which makes it a powerful presentation tool to any audience."

Contact: Mike Jones, Walton Radar Systems Ltd, Tel: 0252 812800

A NEW CADET



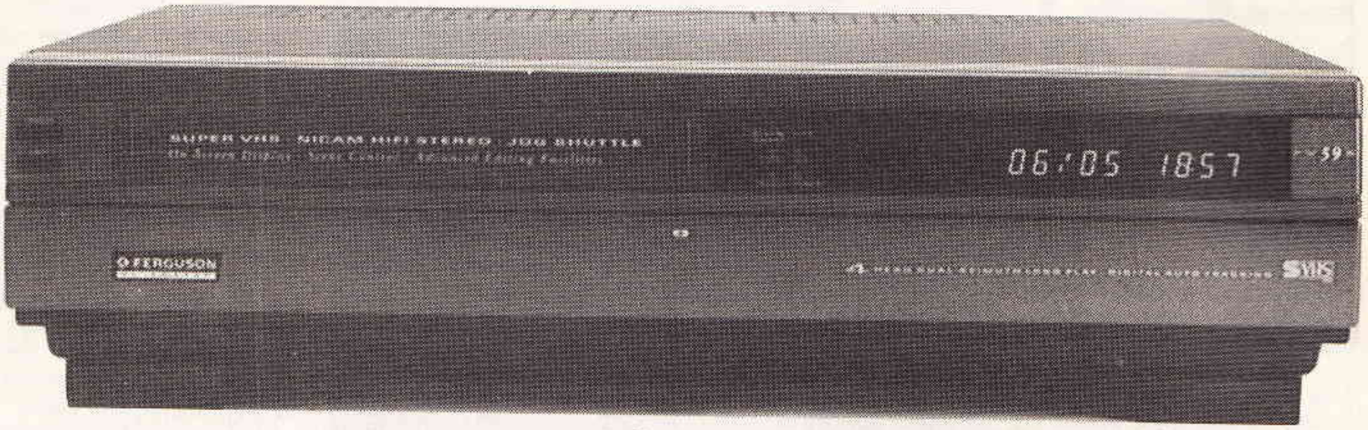
The CADET II is a Complete Analogue and Digital Electronic Trainer for teaching basic AC/DC, linear and digital electronics. With one operation the large central breadboard area, normally used for design work and projects, can be replaced by a number of complete training boards. This eliminates the need for breadboard circuits and component packs until they are once more required. Full supporting course books and instructor's guide are supplied.

The basic CADET trainer is a heavy duty rugged unit with built in features that include: a multi waveform Function Generator — 3 DC voltages and one low voltage AC supply — a Logic Probe with pulse capture — BCD to 2 x 7 segment decoder/display — an 8 channel Logic Monitor — logic switches — Debounced push buttons — SPDT switches and Speaker O/P. 3300 uncommitted tie-points are available on the large breadboard which can accommodate 32 ICs and offers unlimited design and project possibilities. Due to the high quality and reliability, the breadboarding area carries a lifelong guarantee.

Dedicated trainer boards which simply replace the breadboard areas at present include an AC/DC trainer that uses 7 boards to give 100 hours of training in basic electronics with 59 laboratory experiments and the correct use of test equipment. Five boards in a digital trainer give 150 hours of training and cover TTL and CMOS logic families with 45 hands-on experiments. A linear version uses 6 boards and teaches Op-Amp circuit design during 40 hours of training. Other boards are already being developed by E & L Instruments to expand this trainer, which is designed by educators for the education market.

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

FERGUSON LAUNCHES WIDESCREEN SUPER VHS RECORDER



Ferguson is to launch in December a top of the range Super VHS VCR capable of recording and playback in 16 by 9 'widescreen' mode. Priced at around £799.99, the Ferguson Videostar FV59S is a fully specified, state-of-the-art Super VHS machine with NICAM hi-fi stereo, 8-hour long play and a sophisticated 'Jog Shuttle' control on its remote handset providing the precise frame control of a video editing machine.

Widescreen capability

A principal benefit of the FV59S's widescreen capability is its ability to play back pre-recorded 16 by 9 format tapes. As it senses a 'widescreen' tape, the VCR will also automatically send a code to switch a widescreen compatible TV to 16 by 9 mode. Ferguson is working closely with a number of major software companies to ensure that a comprehensive supply of video titles will be available in widescreen format in the near future.

In addition to playback of widescreen tapes, the FV59S is also fully capable of recording and playback from 16 by 9 broadcasts when they commence.

Other key features on the FV59S include 4-head dual azimuth operation, an automatic head cleaner to maintain optimum picture quality, on-screen timer programming, real time tape counter, comprehensive indexing facilities and Fastext programming compatibility with an optional adaptor.

Editing facilities

The jog shuttle remote unit simplifies cueing and invisible editing by providing variable tape speed control for editing purposes. In addition, a 'Retake' function which shuttles videotape backwards or forwards whilst in record pause mode can also be accessed from the jog shuttle, allowing editing without having to return to tape playback search modes. An assemble edit control allows accurate tape editing when re-recording or assembling footage from a camcorder or perhaps another VCR, and is useful when editing out commercials whilst recording a film.

The provision of front camcorder connection sockets also makes the FV49S an ideal camorder editing deck.

On-screen programming

With the increase in programme choice available, the 8-event over 1 year timer is an asset, as is the ability to program over a long period. Programming could not be simpler, with timer information input directly into the VCR from the remote handset, a full on-screen display guides the user with the screen colour changing to green when programming has been completed correctly.

Advanced Indexing and Search Facilities

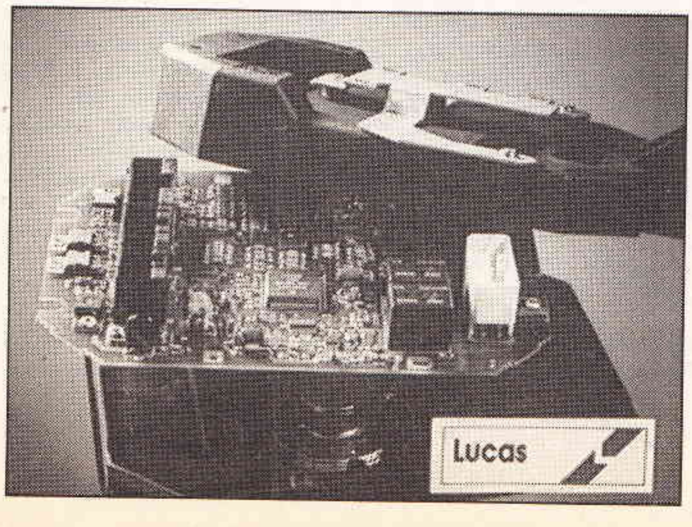
The Videostar FV59S has an indexing capability with mark and erase for fast access to indexed points on any given tape — the index marks effectively allowing the user to bookmark the tape wherever desired. The marks are automatically inserted on the tape when a recording is made or can be manually added or removed by remote control. Indexing facilities also include repeat index playback, a useful feature that, by marking the start and end points of a particular section of a recording, allows the user to programme that section (perhaps a favourite music track) to play back repeatedly up to five times.

Other features include skip search and blank search. Skip Search allows set periods of picture search in up to four multiples of 30 seconds, thereby allowing the user to quickly skip through, for example, a recorded commercial break. 'Blank Search', is a helpful index facility which can be used to automatically locate the end of a recorded section on a partially recorded tape. Even when a fully recorded cassette is used for re-recording new material, this system can be used to locate the end of the latest recording.

Audio features

A major benefit of the FV59S is its ability to decode and record NICAM digital stereo transmissions, as well as being able to record up to eight hours of hi-fi stereo sound. 'Audiophile' features include a hi-fi stereo record level indicator with level and balance adjustment controls, an audio-dubbing facility with mono microphone input and level control for mixing, and stereo headphone socket with volume control.

BODY COMPUTER FOR NEW ROVER 800 BY LUCAS



Lucas Automotive Electronics are providing Rover cars with an innovative computer that controls many of the features on the new Rover 800.

These include familiar items, such as intermittent wiper control, programmed wash wipe and headlamp delay control. A novel feature is the automatic electronic control of the high intensity fog lights which will help reduce accidental use in good weather.

Lucas's commitment to helping vehicle manufacturers improve their security systems is demonstrated through the Body Computer which has overall control of the Rover security system, bringing together control of central locking, auto window and sunroof closing, full alarm protection and remote control.

With the launch of the new R800, Rover have introduced a new system for minimising stock and providing a rapid build to order service for customers. Their order service for customers. The Body Computer supplied by Lucas helps make this possible. The unit is supplied to Rover as a standard item and Rover are able to use their ROSCO (ROver Serial Communications) system to programme the Body Computer with all their various market/trim/body requirement on their production line in seconds.

Lucas are also supplying other equipment which includes braking systems, switches, wiring harness, battery and leads.

For further information please contact: Don Hiett at Lucas Tel: 021-627 3939

SOLDER STATION OFFER

Ungar, the soldering and de-soldering specialist has announced a special offer based on its ESD-safe, electronically-controlled 2110 solder station.

Not content with simply providing a value-for-money package (normally at just under £80.00) for a high performance station (tip leakage below 2mV, ceramic 60W 24V heater for rapid heat-up and recovery, adjustable temperature, soft, cool-grip handle, etc), Ungar has decided to make their 2110 available on a three-for-the price-of-two-basis, for a limited period only.

Ungar will send you three. Write to Ungar first for full details but act quickly, the offer will not last for ever.

Enquiries about Ungar's 2110 Solder Station Special Offer to: Eldon Industries (UK) Ltd, Clifton Pond, Shefford Beds SG17 5AB Tel: 0462 814914

EDUCATIONAL EPA SOFTWARE SUITE

Pentica Systems has announced the Tango/e suite of electronic design software, aimed at introducing university and college students to real-world electronic design tools.

Tango/e is a complete suite of electronic design software developed for educational course work, labs and individual study. The five programs are specially modified educational versions of the Tango professional design programs. They are priced at about one-eighth of the retail price of their professional equivalents, to allow greater opportunity for students to be exposed to tools of professional standard.

The Tango/e programs offer the functionality of their professional equivalents, with some limitations on the size and complexity of the projects they can handle. They include Tango Schematic/e, the schematic capture tool, for loading, creating, plotting and postprocessing, and working with component libraries. Tango-PLD/e the programmable logic designer supports popular 16V8 GAL and 16L8 and 16R4 PAL devices. TangoPCB Plus/e, for PCB layout, can create and plot multi-layer boards of any size, and includes complete through-hole and SMT pattern libraries. The high performance Tango-Route PLUS/e auto-router can auto-route any size of board up to 30 sq inches, and the Susie Digilab II logic simulator includes a library of PLDs, memory, microprocessor and TTL components.

At £80 per module, the Tango/e series is priced for the education market.

For further information, contact Sarah Westley, Pentica Systems Limited, Tel: (0734) 792101.

FIRST 64 MEGABIT MEMORY

Following an agreement between Siemens and IBM 12 months ago to develop jointly the 64 Megabit generation of memory devices, the two companies have now unveiled the first silicon for their 64 Mbit DRAM chips.

With over 137 million components, the memories are capable of storing 67,108,864 bits of information — equivalent to more than 3000 A4 typewritten pages. Mass production is expected to begin in the mid 1990s.

The pilot line for the 64 Mbit DRAM is in IBM's Advanced Semiconductor Technology Centre in East Fishkill, New York. The joint development team utilised research resources from Siemens' Munich facilities and IBM's Essex Junction plant, with development, testing and housing carried out at Essex Junction.

Commented Juergen Knorr, president of Siemens AG's Semiconductor Group and a member of the company's management board: "The chip technology derived from this joint effort will be made available to Europe, thus strengthening its competitive position in the world of microelectronics."

Today, DRAM devices account for some 25% of the $55 billion market for semiconductor devices.

EVENTIDE HARMONIZER

Harmonizers are being increasingly used to enhance recordings.

The Eventide H3000SE Studio Enhanced Ultra Harmonizer has become an invaluable tool for top US producer Bob Clearmountain, owner of three H3000SEs. He has recently been using them while recording a new album by Californian-band Altered State at London's Mayfair Studios, and for enhancing Paul McCartney's vocal performance on his Tripping the Live Fantastic live album.

Gil Griffith, Sales Manager of Eventide says: "Some of Bob's signature effects and sounds wouldn't be possible today without the H3000SE."

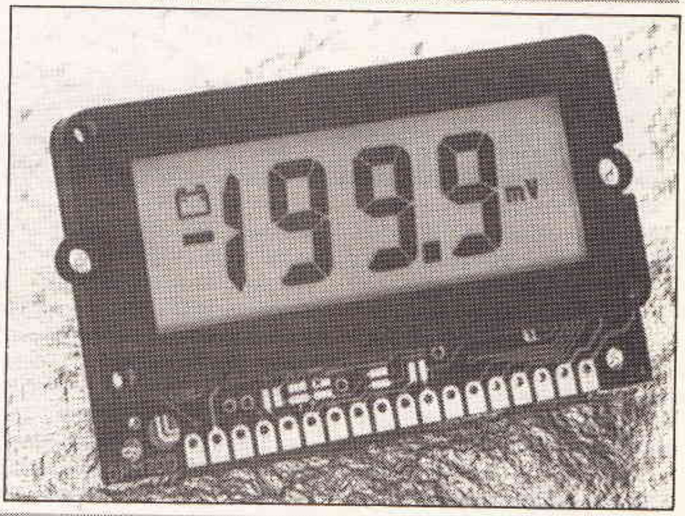
The Harmonizer has also found favour with top UK producers. Mutt Lange, who owns two, has been using them on the new Def Leppard album, while Rupert Hine used them on the new Roll the Bones album by Rush.

Meanwhile Queen's Brian May, choosing to record his latest album in home comfort, has upgraded his studio by adding an Eventide H3000SE along with BSS and Summit units from HHB.

The Eventide H3000SE is not only restricted to studio use; Dire Straits engineer, Robert Collins has taken one on their 21 month tour. Mick Hughes, Metallica's sound engineer was using two H3000SEs on the Monsters of Rock tour and is now on their world tour for the next 15 months. Lastly, Robbie McGrath will be using three H3000SEs on the forthcoming Simply Red world tour.

3½ DIGIT LCD DPM 700

Lascar Electronics have introduced an LED backlit version of their most popular meter. The new DPM 700 gives a clear display in all lighting conditions with an extremely low current consumption. Features include Auto-zero, Auto-polarity, Low battery indication, 200mV FSR, 12.7mm digit height and programmable decimal points. On-card pads for essential interconnections make selection of Operating modes a quick and convenient operation. Calibration is by a 20-turn potentiometer allowing sensitive adjustment of the instrument. A version with negative rail generator (DPM 700S) is also available allowing single rail power supply operation Input low can then be connected to system ground. With its high accuracy and simple connections this meter is particularly suited to high volume applications. The DPM 700 is supplied with a mounting bezel incorporating a clear moulded window.



DS0-DMM

The combining of a top Digital Multimeter and an easy to operate Digital Storage oscilloscope has resulted in the Scopemeter. Now available from Alpha Electronics, this new instrument will have applications in a wide range of disciplines and industries. It is battery operated and contained within a rugged, sealed package.

Ease of operation has been given priority in a unit which will capture, display, store and print out hard copy at a later date for detailed examination, measurement, analysis or comparison. Parameters viewed simultaneously on the 84 x 84mm super twist liquid crystal display as a waveform or alphanumeric function include: Noise — Waveform Distortion - Int. Failure -Signal Quality — Pre and Post Trigger — single Shots - Transients — Power Spikes — Glitches — Low Speed Phenomena - Autoranging — Auto Set Up — Touch and Hold — Min/Max Average and Audible continuity. In fact, all of the problems which elude conventional 'scopes and with many invisible to just a multimeter.

Built to survive, the Scopemeter is helped by being sealed against water, dust and contamination and EMI shielded. Internal rechargeable NiGad batteries or standard C-cells give up to 4 hours' test time away from an AC or DC power supply.

Further information contact Fred Hutchinson of Quiswood Ltd on (0756) 799737.

ETI NEWS stateside

'Intelligent' battery charger

A new single-chip, battery-charging subsystem promises to bring a significant savings in cost, space and effort in charging NiCd or Ni-hydride batteries. The chip is designed to fit between a 50-60-Hz AC source and a battery, and to provide all the control and intelligence necessary for the safe quick-charging and maintenance of the cells.

Reversible chemical reaction driven by the conventional charging current undergoes a fundamental change when the cells are over- charged. Once all the cadmium in the cell has been reduced to its metallic state, further charging begins to work on the electrolyte, thus releasing oxygen gas, with potentially hazardous results.

To prevent this, designers of rechargeable equipment and of standalone battery chargers have resorted to trickle-charging, in which the battery is charged at about one-tenth of the full one-hour charge current. Or they have monitored the battery temperature, looking for the tell-tale release of heat that indicates a full charge.

The trickle-charge approach is relatively safe, but it can take from 12 to 14 hours. Quick-charging takes only about an hour, but you have to stop in time. That means monitoring the temperature.

One complexity in temperature sensing is that it is not enough to just sense the battery temperature. You need to sense the difference between the battery temperature and the ambient. In addition, there are upper and lower ambient temperature bounds beyond which the battery should not be charged in the first place.

The new chip, from Teledyne Corp. of Mountain View, California, provides two charging current levels, so batteries of two different sizes can be handled safely in the same charger. When the chip decides that the battery is charged, either by temperature rise or by expiration of a $1\frac{1}{2}$ hour fail-safe timer, it switches to a trickle-charge mode. This prevents the battery from discharging before it is used. There are two versions of the chip, the TC675 and TC676. On the 676 version, an input pin can force the chip to restart the quick-charge cycle even if the failsafe timer has expired.

The Teledyne charges have a rather elaborate network of control logic for detecting the presence of a battery in the charger, working around the protection diode that is present in many batteries, and compensating for the time it takes a temperature sensor outside the battery to accurately reflect the cell temperature.

Basis for new type of solar cell

Researchers at Oak Ridge National Laboratory are building nanometer scale optoelectronic devices that could form the basis for a new type of solar fuel cell. The new solar cells would produce hydrogen directly from sunlight and water.

At the heart of the photosynthetic process is a molecular optical device that turns photons into electrons. Molecular biologists have also mapped out the electron-driven molecular machinery that extracts hydrogen from water and carbon to build the hydrocarbon chains the fuel plants use to grow. A way has been found to deposit platinum electrodes onto membranes that contain the light-conversion molecules and research is now being concentrated on ways to wire many membranes in parallel to build solar-activated fuel cells.

Helping tumour detection

Results from a picosecond imaging system developed at the City University of New York indicate that ultrafast optoelectronics could dramatically affect the detection rate of tumours in future.

The major source of noise in laser-transmission images is scattered light, but it can be easily eliminated with a picosecond shutter because the scattered light takes longer to arrive at the image plane. The elimination of that noise source has made it possible to detect objects less than 200 microns in diameter. Laser-imaging systems can detect objects down to 1 centimetre in diameter in human tissue.

Current laser-imaging systems were introduced because X-ray techniques cannot find tumours at the early stages of formation. While laser-based imaging has improved the early detection rate of tumours, pushing the resolution down to 1 millimetre diameters could raise the cure rate for breast cancer to 80%.

The experimental system uses a neodymium-glass laser as an optical source and a Kerr optical gate as a shutter. Images were captured with a charge-coupled-device camera connected to a personal computer with videoprocessing capability. Eight picosecond pulses were fired through test systems consisting of polystyrene spheres floating in water, verifying the ability of the fast shutter to screen out most of the light scattered by the water.

New form of carbon

Buckminsterfullerene, a new form of carbon, may play a crucial role in future electronic devices. With proven semiconducting and superconducting properties, new data reveals fullerene compounds as likely candidates for epitaxial growth, a necessary process for VLSI integration.

Recent work with fullerene epitaxy is producing highly uniform films on semiconductor substrates. The next step will be intricately layered circuits built from a host of new compounds. "A whole range of fullerene structures are emerging, and right now the biggest task is simply trying to determine how broad the field is," said Richard Smalley, a chemist at Rice University of Houston.

Fullerenes are large spherical aggregates of carbon molecules, the carbon bonds connecting in a network of a shape first described by engineering visionary R. Buckminster Fuller. A carbon atom sits at each vertex of a buckyball, bonding with three of its neighbours. The resulting molecules, containing 60 or more atoms, are turning out to be versatile building blocks for a new class of materials. The most stable form, C60, are uniform spheres that stack like billiard balls to form a semiconducting crystal that has a direct band gap, like gallium arsenide.

Under normal conditions, carbon atoms tend to form planar hexagonal structures that link together to form planar hexagonal sheets, the structure underlying graphite. The bonds between these horizontal sheets are not strong, which explains why graphite is a soft, structurally weak material. But at high temperature and pressure, carbon atoms are forced into a threedimensional structure that is very hard, resulting in diamond. Smalley expects buckyball bonding to follow the same pattern. "When compressed to 70% of its volume, the carbon-carbon bonding between C60 molecules should take over, producing a material harder than diamond," Smalley explained.

The current task for fullerene researchers is to clarify basic issues such as chemical bonding and fundamental physical properties.

READ\WRITE

ETI LETTERS

RIAA Adjustment

Another new year and another very interesting project 'The Bridge Amplifier'(Feb '92) and to this I refer. Having a general interest in RIAA equalisation, it is somewhat surprising to find in the text R5 is chosen at 1.8k to give a −3dB point of 40Hz as part of the RIAA recommended pick-up playback response.

There are many myths about the RIAA requirements and much correspondence last year as to what they do or do not include in which I have no wish to join. Lest any reader gets a wrong impression, 40Hz has no place in the RIAA recommendations.

It appears to me that John Dix has used the non-standard R6/R7/C5 network hopefully to balance the R5/C3 pair but the result unfortunately is a reduction in response between 100Hz down to 30Hz of up to 3dB at least. However, if anyone feels this is unacceptable, it can be generally remedied by using two 2µ capacitors in parallel for C3. I realise that the pre-amp is but a minor part of the whole unit but it seems a shame to ignore this point.

W Harms,
Bexhill,
East Sussex

Longer Lasting Freeze Alarm

In the Dave Bradshaw article on a Freeze Alarm (Oct '91), the circuit needs to be powered for long periods of time, in fact for all the cold months of the year and the only practical solution is to use a mains powered unit.

There is another solution where the measured variable changes slowly, and does not justify continuous monitoring and that is to sample it breifly at long intervals. A micro power timer can be used to power up the circuit for say, 1 second every 15 minutes. This would add up to 2¼ hours over 3 months. A battery that could supply 10mA for 2 hours continuously would suffice, because a carbon-zinc cell works best on intermittent discharge.

Several years ago there was an article on micro power CMOS circuits and this included examples of 'sleeping' power supplies.

Is there some unwritten rule about not using another author's ideas? After all, one can always give an acknowledgment to the originator of the idea.

H Hodgson,
South Wirral.

EPROM Service Required

Is there any company or person that you know of that can program EPROMs, or give me the information on how to program it using the Hex dump?

C Graham, Liverpool.

We have had several letters on this point of programming EPROMs. Very often, if projects contained programmed EPROMs, the author would offer the service, but for a limited period of time from the publication of the project.

If you want to do it yourself, there are companies selling EPROM programmers with all the information on how to enter a Hex dump. We featured one in the sept '91 news pages. Ohterwise if there is anybody out there offering programming services, let us know at the ETI office and we will publish a listing -Ed.

64 Page EPROM

Regarding the publication of my Test-card/Test Pattern generator project, unfortunately I have had to withdraw the offer of sending constructors a copy of the Hex listings of the EPROMs since these listings extend to 64 pages of A4, which is rather costly to photocopy, impractical to post and would take somebody a ridiculous amount of time to type in!

The offers of supplied EPROMs programmed for £5 or an Intel Hex dump on a supplied disc for free still stand, and will continue to do so indefinitely.

I would like to apologize for withdrawing this offer, unfortunately I didn't realize what was involved when I made it.

P Stenning,
Hereford.

Acute Problem

With reference to the article in Jan '92 issue on making PCBs at home, may I point out two essential rules when designing PCBs:

Never have corners of less than 90 degrees because they act as acid traps.

Keep lines straight where possible.

On a different subject, here is a suggested project. Convert radio/cassette player so that it can be used like a video recorder, recording pre-programmed broadcasts for playback at a later date. It must be possible with servo controlled decks.

P Ward,
Haywards Heath.

Those Without Loudness

I have seen numerous amplifier projects published in your magazine and others, but not one it seems was designed with a loudness facility. Perhaps this facility is aimed at the commercial market only. It does enhance the overall sound of the amplifier! Please editor, I hope a feature on this will appear in your magazine.

G Daniels,
Johannesburg, SA.

I have always considered the loudness control as a 'bass boost' at low volume — handy for those of us who prefer a heavier bass without necessarily upsetting the neighbours. In which case a switched filter or change of tone control will do much the same thing. It may be that the apparent avoidance of the use of a loudness control in project designs is that the 'purist' would not want to introduce any further irregularties to an otherwise flat reponse. They would say listening must always be at a decent level thus making the loudness control ineffective — Ed.

An Apology

The article entitled 'Introduction to Audio Mixers' published in the January isssue of ETI contained a number of similar drawings first published in Electronics World + Wireless World, April 1991 as part of an article entitled 'Inside Mixers' by Douglas Self. We wish to apologise to the author and publisher of 'Inside Mixers' for any possible breach of copyright.

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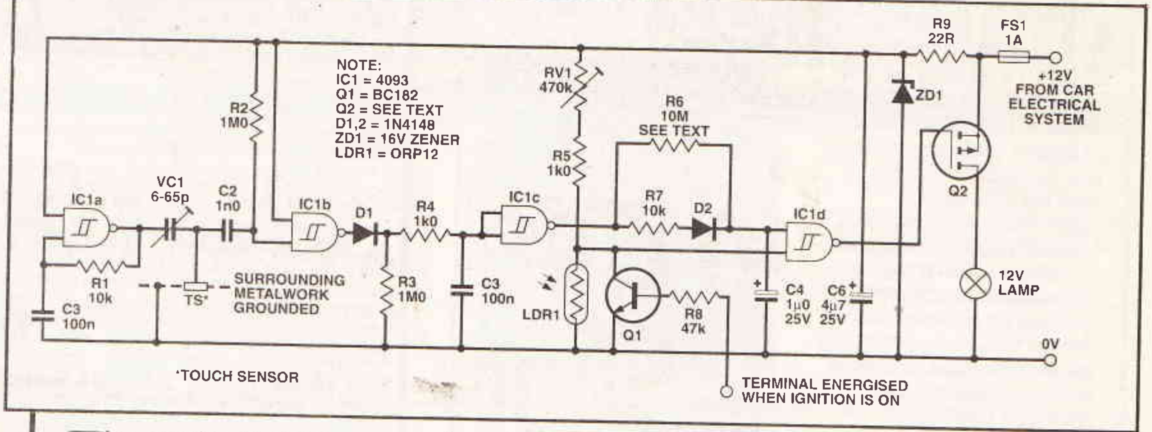
BLUEPRINT

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



This month's Blueprint query is from Lindsey Sutherland, who asks: "Can anyone help me to design a circuit that will sense a small current leakage to ground and respond by lighting an LED for a preset time. This would help me to find the keyhole of my front door or my car late at night.

The circuit of Figure 1 is a design suitable for use with a car electrical system. Certain parts may be left out if it is to be used in a domestic location. It works by detecting when a high-frequency signal is shorted to earth by hand-capacitance.

IC1a forms a high-frequency squarewave oscillator whose frequency is set by the values of R1 and C1. With the component values given, the frequency of oscillation will be approximately 1MHz. Normally, the 1MHz signal will cause IC1b to produce a squarewave which will keep C4 charged close to the positive supply. This switches the output of IC1c to logic 0, forcing the output of IC1d to logic 1, which switches off the P channel power MOSFET controlling the lamp.

If anybody touches the touch sensor most of the signal will be capacitively shorted to ground. With little or no signal appearing on the input of IC1b via C3, the voltage on this input is pulled up to logic 1 by R2. This switches the output of IC1b to logic 0, allowing C4 to discharge. This switches the output of IC1c to logic 1.

If the other input of IC1d is close to the positive supply voltage, then its output will switch to logic 0, turning on the lamp. There are two mechanisms by which this input of IC1d can be pulled to logic 0 (or at least below the lower switching level of the Schmitt trigger). A light level detector is provided to prevent the lamp from switching on in daylight, and an inhibit circuit prevents the lamp from operating when the ignition is on. This part of the circuit, comprising R8 and Q1, is only required for automotive applications.

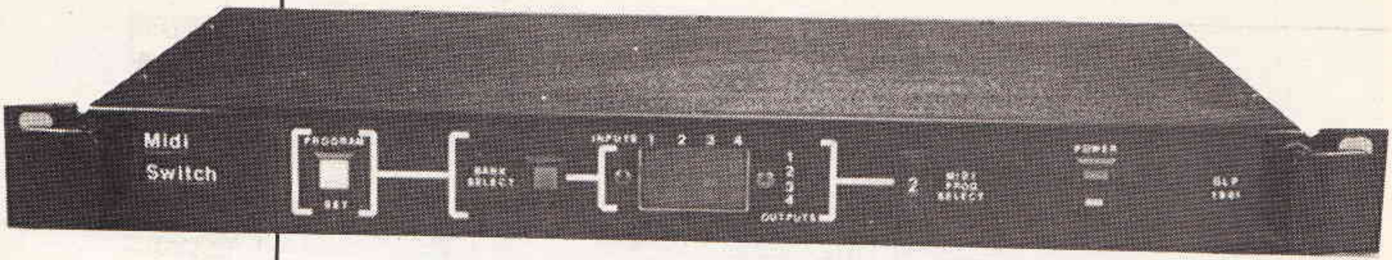
The light level detector comprising LDR1, RV1, and R5 should be adjusted to prevent operation of the lamp in normal daylight. This part of the circuit is optional, but may be of value. If it is not required, then LDR1 and RV1 should be omitted, and the top end of R5 should be connected to the positive supply. In these circumstances, a more suitable value for R5 would be 10k.

If neither the light level detector or the inhibit circuit are required, then the two inputs of IC1d may be joined together, or one of them may be connected to the positive supply.

If the unit is to be powered by a mains power supply rather than by a car electrical system, FS1, R9 and D2 may be omitted. R9 and D2 are there to protect the circuit (which will be connected to the supply all the time) from high voltage spikes on the car electrical system. FS1 is there to prevent the wiring from melting if the lamp is short circuited, but this should not be needed if a mains power supply incorporating a voltage regulator and a mains input fuse is used.

The time for which the lamp remains illuminated is set by the values of R6 and C5. The period will be approximately 1 second per megohm if C5 is a 1µ capacitor as shown on the circuit diagram. The exact value required should be found by experiment, but a suggested starting value would be 5M6.

Andrew Armstrong



MIDI Switcher

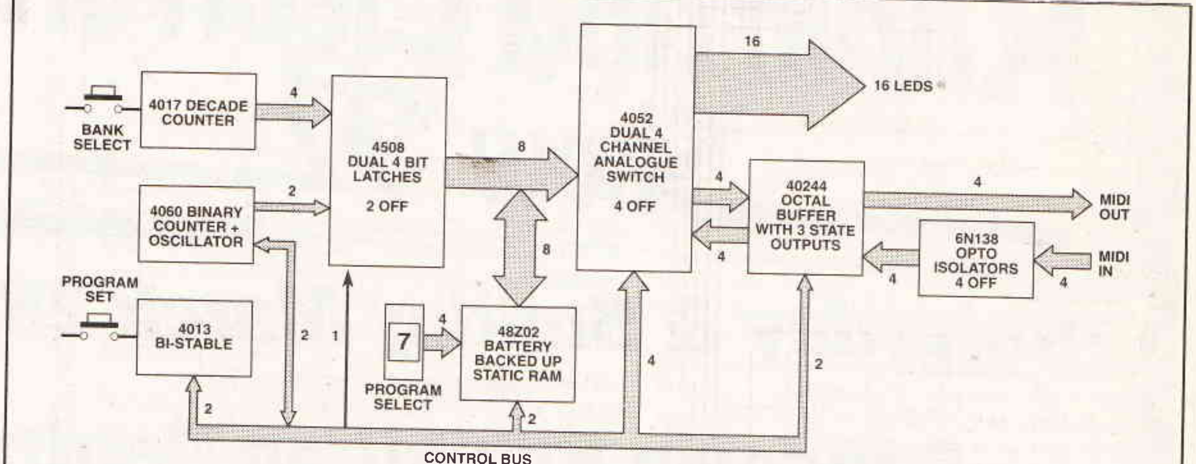


Fig.1 Block Diagram

PROJECT

A four by four MIDI router by G. Parris.

A flexible way of connecting together a number of musical instruments and a computer for playing and recording purposes was required for the studio.The MIDI standard for this type of data transfer has been explained in a number of magazines and books but the following is a short description for those not familiar with it now follows.

MIDI stands for Musical Instrument Digital Interface. Every action of an electronic instrument may be converted into a digital form consisting of 1's and 0's. This signal is then converted to a serial format enabling it to be sent along a coaxial cable. The opposite takes place for receiving which means an instrument can respond to this MIDI data. Each instrument can both transmit and receive MIDI data and so MIDI OUTPUT and MIDI INPUT sockets of the 5-pin DIN type are found on virtually all modern electronic musical instruments. Not only can electronic instruments respond but computers as well. Although sometimes the MIDI serial converters are built into them, as in the ATARI ST or fitted as an extra as in the IBM computers.

Design Solution

This 4×4 MIDI switcher unit is one method of connecting the MIDI in and MIDI out of up to 4 devices, one of which can be the computer. With a small number of devices ordinary switches are suitable but if the combination of connections differ by more than 3 or 4 then these switches become complex and expensive.This unit has the facility to switch up to 10 such combinations but if the constructor so wishes this may be increased.The combinations can be programmed while the unit is in use and these are stored even when it is switched off. It was also required that the IN/OUT routing was clear and visible at the front panel as some of these types of units even commercially only indicate the program number.

To further simplify the project it was decided to keep away from a computer based approach even though a computer memory was used.

Construction

Main PCB

The PCB diagram shown in Figure 5 requires careful production as some of the tracks are very narrow. The board was etched in a Ferric Chloride bubble etch unit after being exposed under a UV lamp and developed. Any shorted tracks were then separated using a scalpel. Correct size holes are required for the various components and the medium sized pads shown in Figure 4 are for terminal pins. The three largest are support locations. The IC holders to be used must not be so large as to obstruct the fitting of other components. The SIL (Single In Line) resistor R28 should be

HOW IT WORKS

The circuit is based around the 4052 dual 4 channel analogue switch shown in Figure 3. Note that sub circuits A and B in Figure 3 containing the output and input interface details are shown in Figure 4. The main board supply connections are also shown in Figure 4.

The circuit diagram in Figure 2 shows the control and memory. The block diagram is shown in Figure 1 with a computer layout flavour. Note the use of an 8-bit bus system for connecting the 4052 switches, 48Z02 memory and 4508 latches. A control bus is shown containing the connections for operating each portion of the circuit.

The 4 MIDI inputs are taken to 6N138 opto isolators Figure 4A for isolation and conversion to 5 volt digital levels as is normal practice for MIDI. It will be observed that IC15 Figure 4 is used to isolate the MIDI in and out terminals at digital level so that the external devices connected are not affected by the changes in the 4052 switches whilst they are being set up. Each 4052 IC contains two switches which are controlled by 2 inputs at pin 9 and 10 Figure 3 and both switches will be identical. One switch in each IC is used for the LED's and the other for the MIDI. As there are 4 inputs and outputs there are 4 analogue switch IC's each requiring 2

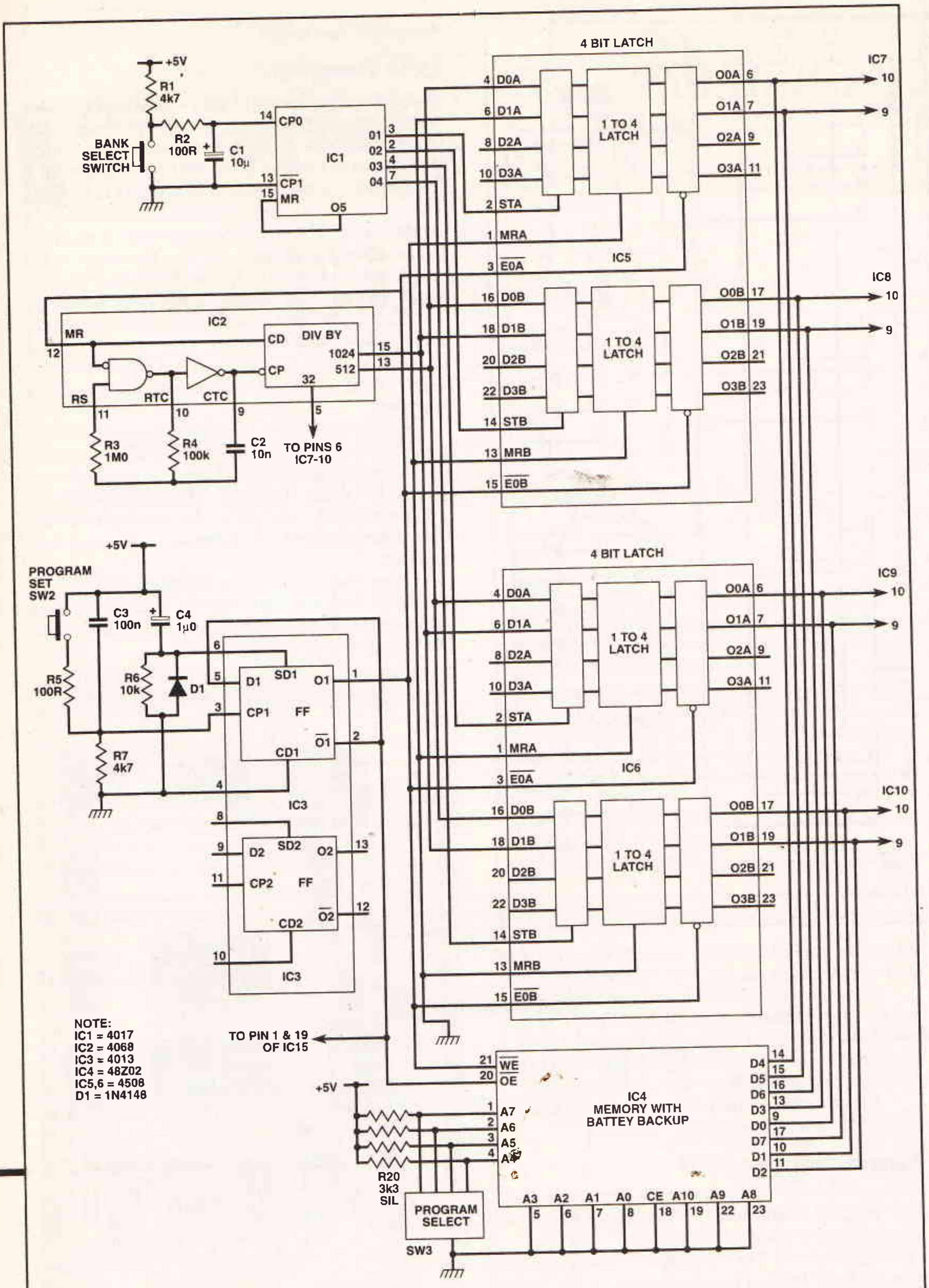


Fig.2 Control and memory

binary inputs for switch selection so 8 binary inputs are used in 4 pairs.They are connected as an 8-bit bus system to the RAM IC4 and LATCHES IC5-6 Figure 2. Only 2 bits of each half of IC5-6 are used and the store latch STa and STb and the output isolation $\overline{EOa}$ and $\overline{EOb}$ are connected for switching.

The memory chip IC4 is a 2K 8-bit CMOS static RAM with built in battery backup facilities. This means that the memory data is stored even when no 5 volt supply is connected. Its internal battery is charged when the external 5 volts is applied.

Only 4 address lines are switched by the PROGRAM SELECT thumbwheel on the memory and data combinations are fed from the 8-bit data bus.

The PROGRAM SET circuit is built around IC3 Figure 2, a 4013 dual bi-stable but only one half is used. The three components D1-C4-R6 makes sure the bi-stable starts at power up in the read condition. For bounce free operation R5-R7-C3 produce a clean input to the clock pulse connection. The circuit IC1 is used to count up pulses in binary by means of the push SW1 and shaping components C1-R1 and R2.

Circuit IC2 is an oscillator and divider combination. The oscillator is set to 434 Hz by means of R3-R4 and C2. Pins 13 and 16 feed each of the 4 halves of IC5 and 6. When mains is applied the circuit is in the READ condition so the latches IC5 and 6 are isolated by pin 1 of IC3 being at 5 volt. The memory IC4 is set to output data D0 to D7 and IC7-8-9-10 switches respond. The buffers IC15 (Figure 4a-b) are switched on from pin 2 of IC3 being at 0 volt so MIDI data is routed through according to the switch combination as is also the LED supply.

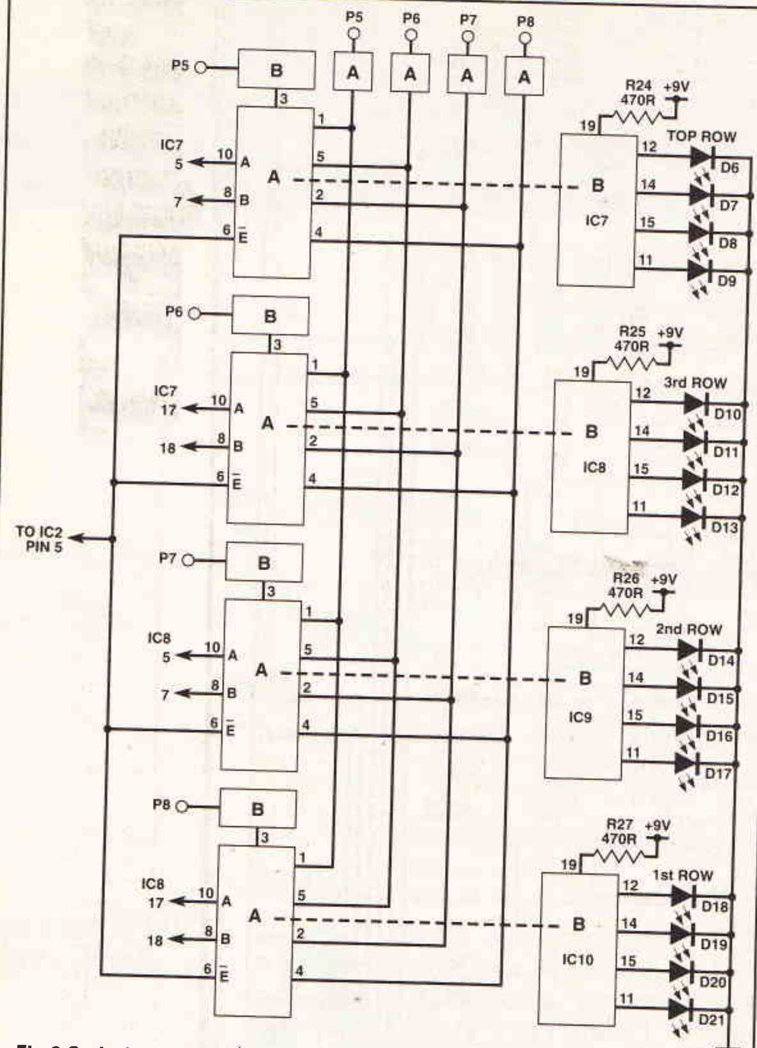


Fig.3 Switch and MIDI interface

a 4 resistor unit but a 5 resistor one with the pin farthest from the common pin cut short, was used.

If you use a type greater than 4 make sure you cut the excess pins from the end that is NOT the common connection and when fitting it the common pin must be nearest the link. Also the thumbwheel switch has its common or earth pin farthest away from the link.

It is advisable to use 1/4 watt miniature resistors as space is at a premium.

Power Supply PCB

Any type of power supply is adequate providing it gives +5v and +9v. If dirty mains is a problem then a more sophisticated one would be required.

For adequate LED brilliance a higher voltage than the 5 volt for the logic was required. In this case 9 volts was obtained unregulated directly from the output of the bridge rectifier as shown in Figure 10.

This meant that the power supply has three output connections with terminal pins (Figure 6). The PCB was constructed in the same way as the main board with two terminal pins for the 240 volt mains supply connections. If required the DIL bridge rectifier could be mounted directly to the board and not in the 8 pin DIL socket but watch both the position and rotation for correct operation. If the DIL bridge type is not available the equivalent is shown in the 'BUYLINES' section.

The transformer was a FARNELL 149-975 type but CIRKIT do a version P0309 which means that pins not locating in a hole must be bent flat. Those needing connection should be linked with insulated wire. Everything else should be straight forward.

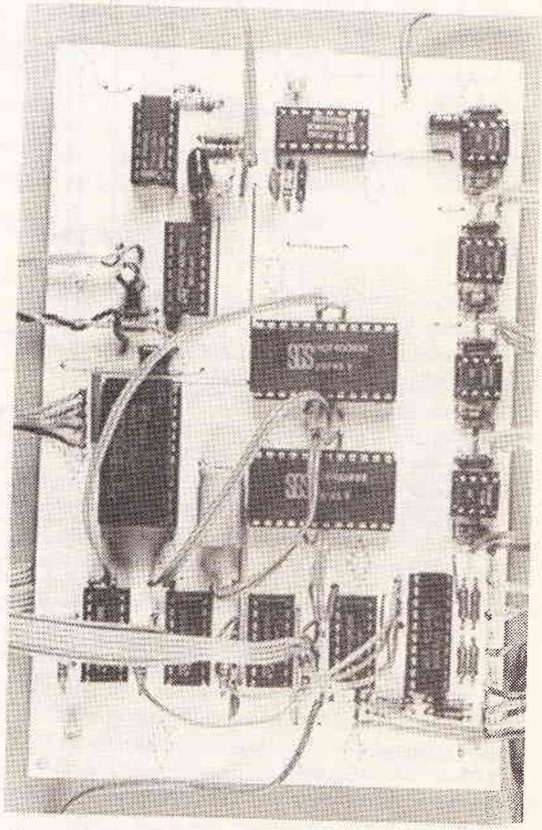
LED Readout

The LED matrix consists of 4 red and 12 green wedged shaped types mounted on 0.1 inch stripboard. The wedge shape was the nearest to arrows that could be obtained and it will be noted that where the input is routed to the same devices output a red LED is used. This connection is possible and can be handy but is not regularly used.The MATRIX construction is shown in Figure 7 and it must be noted that the height of the stripboard assembly must not prevent the top and bottom covers of the cabinet from being slid into place.

The appropriate holes for each LED are drilled through the matt black sheet as are the two M2.5 screw holes. The copper strip runs vertical which is used to short all the cathode connections of the LEDs together.

A shorting link is soldered from each of these vertical strips to a common point which is taken to 0 volts on the power supply board. These cathode leads can now be cut short. The anode connections which are the longest wires on the LEDs need to be isolated from each other by means of a stripboard cutter and then soldered.

They must be cut to 5 mm length to ease the connection of the 4 way cable from the main board. Note that these wires are interchanged in a particular way at the main board for correct operation.



Internal Wiring.

The switcher is mounted in a 19 inch 1U high rack cabinet and the layout for the PCB's and other components are shown in Figure 8.Front panel design is not critical except to note that it may well be worthwhile to use a safer switch for PROGRAM SET (SW2) such as a biased off short toggle type rather than the push variety used. This is because accidental operation would result in resetting the program that the unit was switched to.

Markings on the front and back panels are white rub on transfers coated with a transparent spray lacquer. The front panel is shown in Figure 9 and the rear

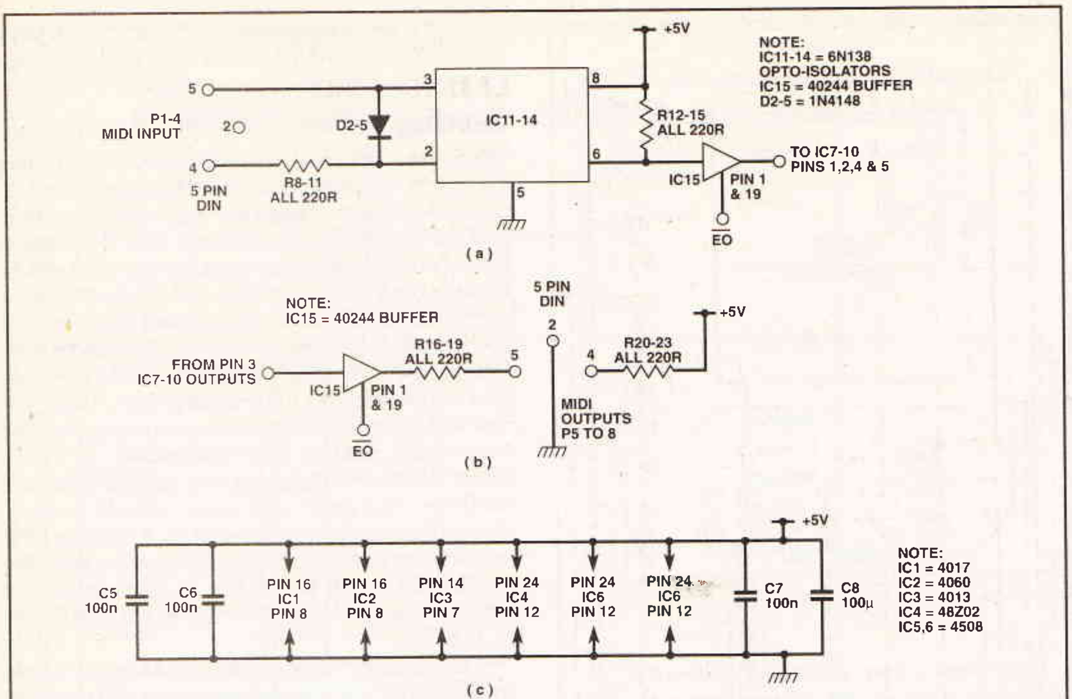


Fig.4 Sub circuits

panel is shown in mirror image in Figure 8 as it is so simple.

No measurements are given for the position of the panel components as they are not critical.

Operation

To set up a program for memory storage the PROGRAM SET push is activated. This toggles IC3 so pins 1 and 2 reverse state which makes IC15 isolate the MIDI sockets from the external devices and puts the memory IC4 to the write condition. Also IC5-6 outputs are enabled by the $\overline{EO}$ pin going to 0 volt connecting it to the 8-bit bus and the circuit IC2 is switched on as pin 12 MR goes to 0 volt. The counter IC1 stays at a particular setting activating one latch of IC5-6 but as IC2 is continuously counting from pins 13 and 16 the 2 bit input to one of IC7-8-9-10 is making one bank of switches to switch on and off from left to right. This is indicated by the LEDs as one row will light up left to right.

The left to right switching of the LEDs is slow enough so that at the point when the chosen one lights, the BANK SELECT push SW1 can be activated

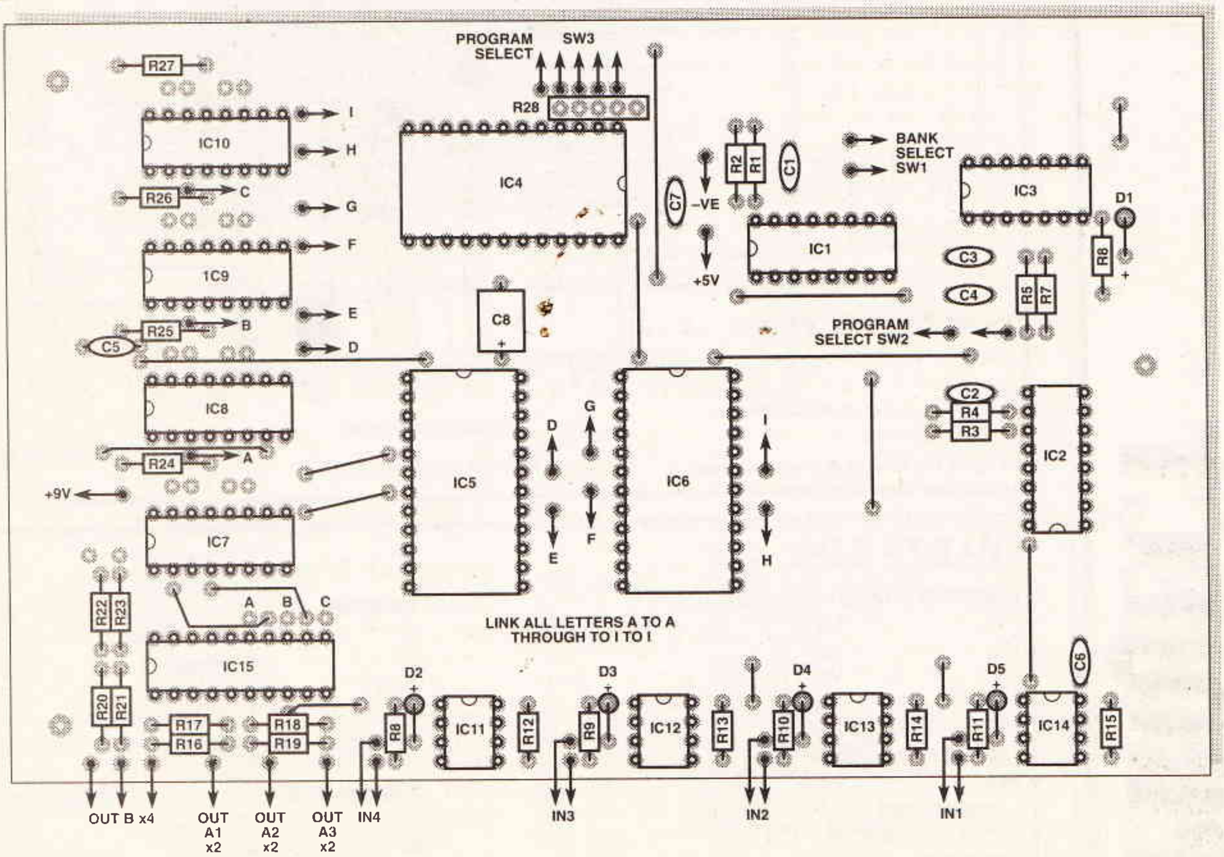


Fig.5 Component Overlay of main board

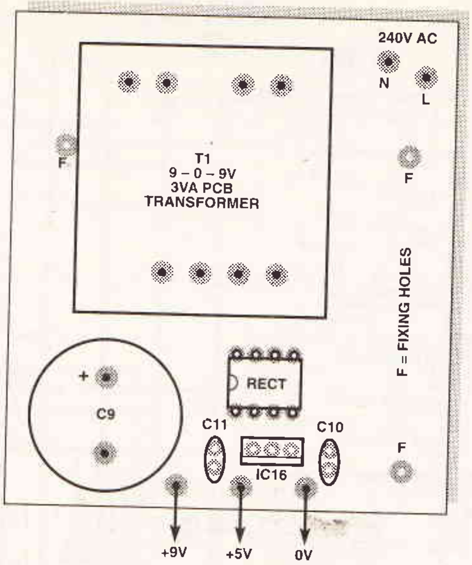


Fig.6 Power supply component overlay

thus stepping to the next row of switches and LEDs. The next row will be stepping left to right and again at the appropriate moment the BANK SELECT push is activated. This is done until no LED stepping is observed. The chosen combination of switch settings can now be stored by operating the PROGRAM SET push SW2. Bi-stable IC3 toggles causing IC2 to reset, the memory IC4 to output data, the latches IC5-6 to be isolated and the buffers IC15 to reconnect the MIDI sockets. The complete LED MATRIX flashes on and off at 13Hz with a signal from pin 5 of IC2 which feeds pin 6 of IC7-8-9 and 10. This is done to indicate that the circuit is in the programming mode.

Testing

The power supply may be tested first by disconnecting the output connections and switching on the mains. Check the correct voltages are supplied. Connect the front panel 9 volt lamp feeds and test. They should light. Use an ohmmeter to check for any short circuits between the 5 and 9 volt feeds and 0 volts. Now connect them to the power supply board and when the mains is switched on the front panel LEDs should light. Operating the thumbwheel switch should now produce a change in the LED readout pattern. These patterns will depend on the stored memory data. Note the thumbwheel position and combination of LEDs. Switch off the mains, wait a few seconds and then switch on. The same LED pattern should be seen. Change the thumbwheel position for a different LED combination and again switch off the mains. Alter the thumbwheel switch to the first position noted and switch on the mains. The combination of LEDs should be as before.

Go through the operating procedure for setting up and storing a program combination and carry out the above tests. The unit is ready for a MIDI test. Connect the MIDI OUT of a keyboard or MIDI producing device to the No. 1 MIDI INPUT socket. Next take the No. 1 MIDI OUT socket to a MIDI device like a computer with indication or a sound module.

Either switch to a program with the thumbwheel that has the top left RED LED illuminated or set up a program to produce this result. Play the keyboard and there should be response from the output device. Each IN to OUT combination can be checked this way and if working you are in business.

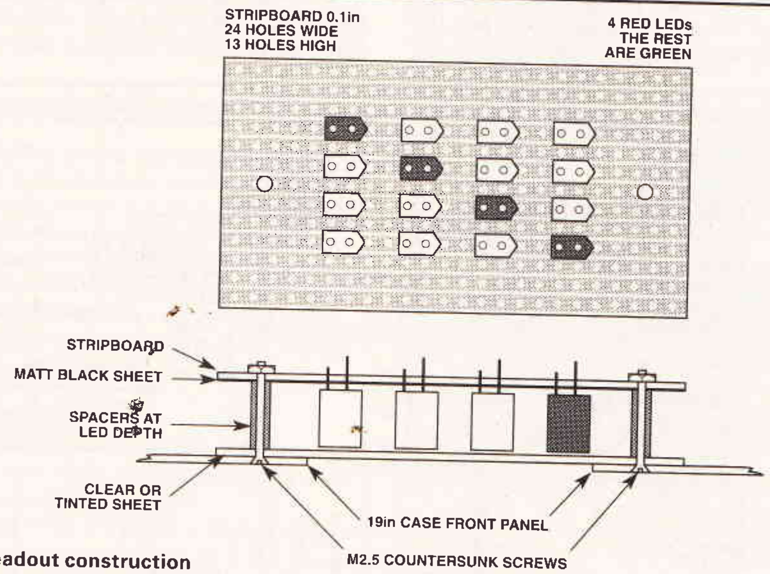


Fig.7 LED Readout construction

PARTS LIST

RESISTORS (all ¼watt 5% unless stated)

R1	4.7k
R2	100R
R3	1M
R4	100k
R5	100R
R6	10k
R7	4.7k
R8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23	220R
R24,25,26,27	470R
R28	3.3k SIL (see note)

CAPACITORS

C1	10µ 16V electrolytic
C2	10n polyester
C3,5,6,7	100n polyester
C4	1µ 16V electrolytic
C8	100µ 16V electrolytic

SEMICONDUCTORS

IC1	4017
IC2	4060

PROJECT

PROJECT

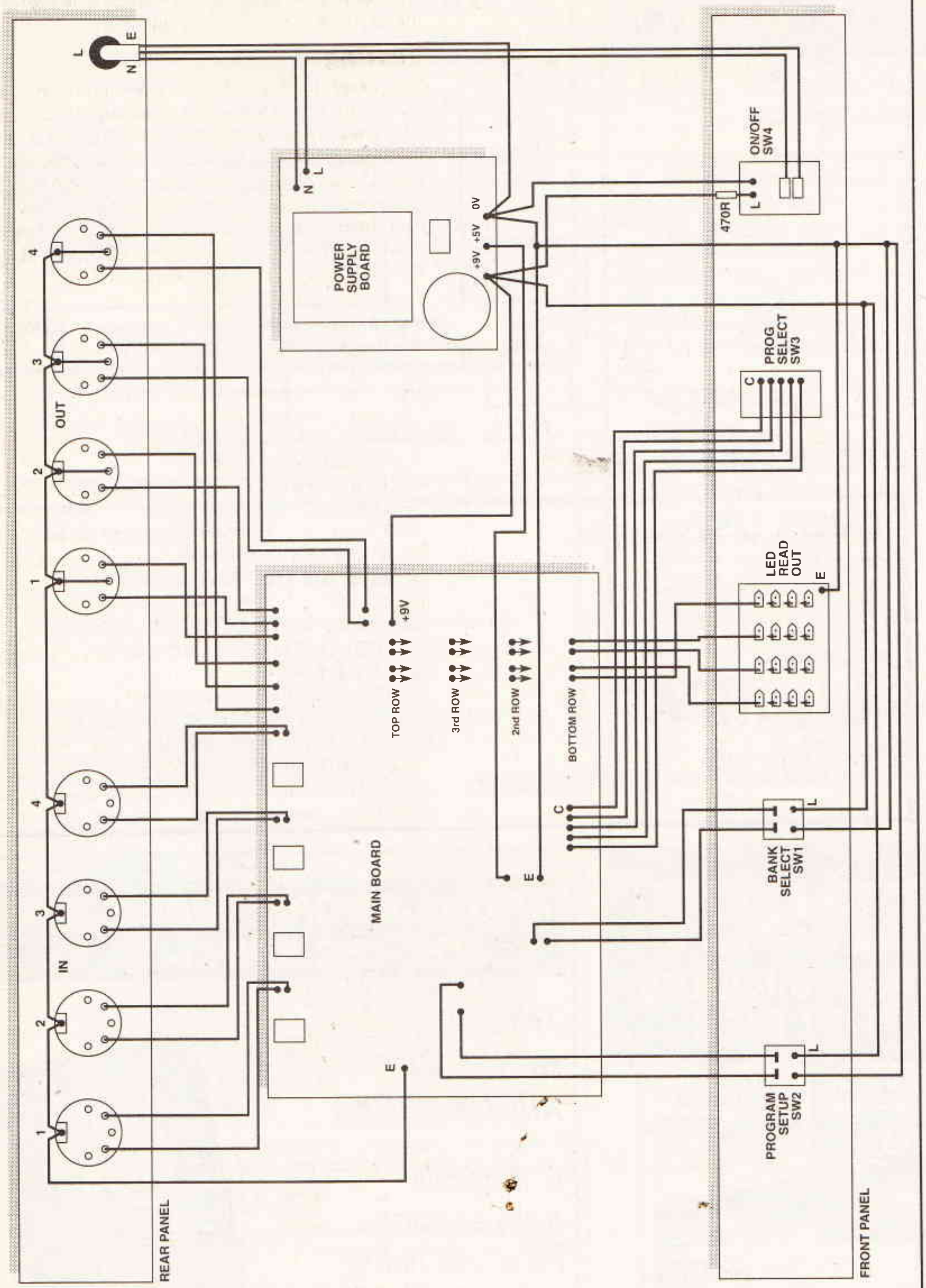


Fig.8 Cabinet wiring

IC3	4013
IC4	48Z02 RAM
IC5,6	4508
IC7-10	4052
IC11-14	6N138 Opto isolator
IC15	40244
D1-5	1N4148
D6-21	Wedge shaped red and green LEDs
MISCELLANEOUS	
SW1,2	1-pole momentary-action normally open illuminated push
SW3	Thumbwheel 0 to 9 BCD switch
4	8-pin IC sockets
1	14-pin IC socket
6	16-pin IC sockets
1	20-pin IC socket
3	24-pin IC sockets
8	5-pin DIN 180deg sockets
1	19-inch 1U high rack mount case
23	0.04 inch terminal pins
3	Adhesive backed supports

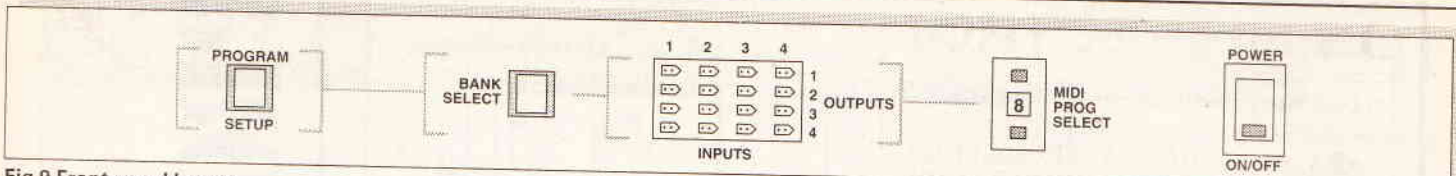


Fig.9 Front panel layout

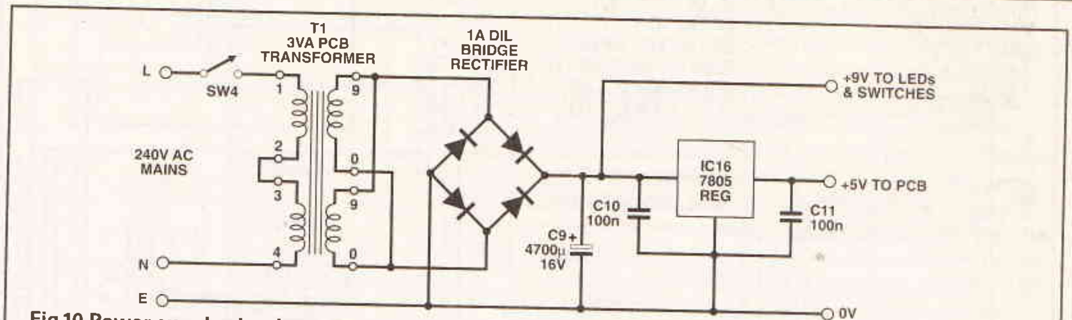


Fig.10 Power supply circuit

PARTS LIST POWER SUPPLY

CAPACITORS

C9	4700µ 16V electrolytic
C10,11	100n polyester

SEMICONDUCTORS

RECT	1A DIL bridge rectifier
IC16	7805 regulator

MISCELLANEOUS

T1	9-0-9volt 3va PCB mounted transformer (see note)
SW4	1-pole ON/OFF illuminated mains switch
1	8-pin IC socket
5	0.04 inch terminal pins
3	adhesive backed supports

BUYLINES

Most of the components are readily available. The 3k3 SIL resistor R28 may be a MAPLIN type 4k7 8 way is (RA29G). IC4 memory is available from ELECTROMAIL type MK48Z02B-25 (301-016). Wedge shaped leds are from MAPLIN and the DIL 1.0 amp bridge rectifier is from RS. MAPLIN type W005.

High Energy Discharge Systems

Average versus Peak Power

by A. P. Stephenson.

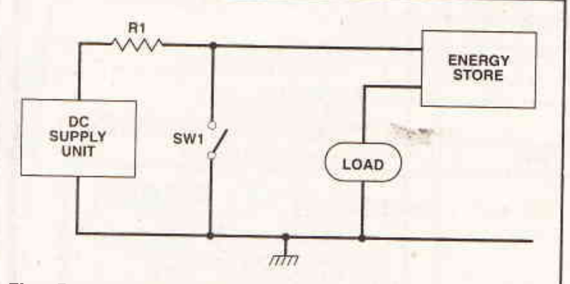


Fig.1 Basic energy discharge system

A power unit for a system which operates continuously at some fixed high power level is costly, massive in weight and may need water or forced air cooling. For example, a device operating at 40 kilovolts and demanding a continuous current of 50 amps requires a unit capable of supplying at least 2 megawatts average power. Design of such a brute force power unit is conventional and mainly concerned with choosing components of sufficiently high power rating.

In contrast, supplying 2 megawatts to a system which only operates at intermittent intervals deserves, in the name of efficiency, a more sophisticated design approach. For example, if a one megawatt device is switched on for one microsecond and switched off for one millisecond, the average power required is reduced by a factor of one thousand. These figures suggest that the unit need only be powerful enough to supply an average power of one kilowatt.

Energy Discharge Systems

The power supply, instead of being directly connected to the load, can be used to charge a capacitor or some alternative form of energy storage system. After a time, sufficient to ensure the system is fully charged, the stored energy can then be released into the load.

Figure 1 shows the essential components of such a system. The action is best explained in terms of charge and discharge cycles:

The Charging Cycle

With the switch (SW1) open, the DC power supply is free to charge the energy storage device via the high resistor (R) and the load (RL) It can be assumed that the load cannot operate during this cycle because the voltage across it is too low and of an incorrect DC polarity.

The Discharge Cycle

When SW1 is suddenly closed, the stored energy is discharged rapidly into the load.

A Homely Analogy

The essential advantage of the system is based on the difference between the power delivered from the primary DC supply during the slow charging cycle, and the much higher power delivered to the load from the energy store during the rapid discharge cycle.

An almost perfect analogy, although not in the best of tastes, is provided by the traditional lavatory flushing system shown in Figure 2. Assuming that the ornamental knob on the chain has just been pulled, the cistern will begin to fill slowly from the water mains via the small bore pipe. This is the low power 'charging cycle'.

At any time later, providing sufficient time has elapsed for the cistern to refill again, a sudden pull on the chain will allow the cistern contents to discharge rapidly via the relatively wide-bore outlet pipe. This is the high power 'discharge cycle'.

Provisional Calculations

For simplicity, assume in the first instance that the energy storage device is a single 0.01µ capacitor (C), the voltage (V) of the DC charging source is 20 kilovolts and R is a resistor of 100k.

Average power during discharge

The stored energy (W) in a capacitor is given by $W = (CV^2)/2$ Joules. With the above values for C and V, this works out to 2 Joules. The relation between energy (W), power (P) and time (t) is $P = W/t$ so if we assume that the 2 Joules are discharged into the load in, say, 1 microsecond, the power turns out to be 2 megawatts!

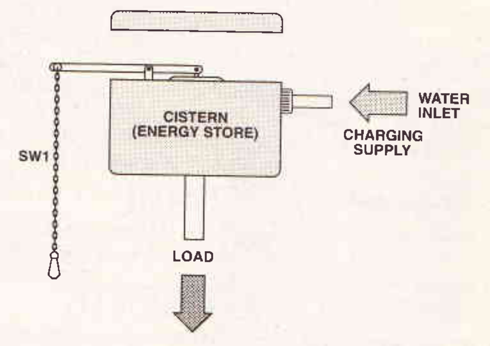


Fig.2 Flushing system analogy

Peak current delivered by DC supply

The capacitor is charged via the 100k resistor, so although the initial current will be 20kV/100k = 0.2 amps, it will fall exponentially towards zero as the charge proceeds.

Time taken to charge

The time taken to fully charge a capacitor via a resistor is usually taken to be 5CR seconds which, since C = 0.01µ and R = 100k, works out at 5 milliseconds. This suggests there must be at least a 5 millisecond gap between discharge actions which, in frequency terms, means that the pulse repetition frequency must be greater than 200Hz.

ENERGY

Pulse Forming Networks

An energy storage system employing a single capacitor suffers from a major disadvantage – the exponential nature of the discharge curve. An ideal storage system should deliver its energy at a constant power level for a finite time. In other words, the discharge pulse should be straight sided and flat topped rather than falling off exponentially. Figure 3 shows a popular pulse forming network. It is sometimes called an Artificial Delay Line because it is has properties similar to a length of coaxial transmission line except that the L and C values are in the form of 'lumped constants'. Depending on the number of individual sections, the network is capable of delivering a pulse of reasonable shape.

Such a network is an improvement on simple capacitor storage because of the cascading action from one capacitor to the next along the chain. At the beginning, all capacitors are charged to the same voltage but as soon as the first one starts to loose voltage, the one behind it is then free to discharge into it. This topping-up action, which trickles down the network from capacitor to capacitor, is the mechanism by which the voltage across the output terminals tends to hold onto its original level. The action, of course, ends abruptly when the stored energy is finally exhausted.

The inductors in between each capacitor cause a slight delay between each topping-up action during the discharge cycle. During the slow charging cycle, their inductive reactance is negligable so all capacitors are effectively in parallel.

In a real transmission line, such as coaxial cable, the L and C values are uniformly distributed along its length.

In theory, a real line could be used but would be of prohibitive length because the line would discharge at the speed of light (c) = 3×10^8 metres/second. For example, if the discharge time is to be 1 microsecond the line, and air spaced, it would have to be 300 metres long? If the line was polyethylene filled, which has a permittivity constant (Kr) of 2.26, the discharge speed would be reduced by a factor of $\sqrt{Kr}$ and so the line would only have to be 200 metres long – still too long for comfort!

Action: Assume the input terminals have been connected to a charging source for a time sufficient to ensure that all capacitors are fully charged to a voltage (V). During this relatively slow charging action, the inductors have little effect and can be ignored so all the capacitors can be treated as if they were in parallel with each other.

If the terminals are now connected to a 'matched' load, the energy will be released in the form of a reasonably straight-sided flat-topped pulse for a time depending on the L and C values on the network and the number of sections. The quality of the pulse improves as the number (N) of L, C sections is increased.

Pulse Width

The time (T) taken for complete discharge (the pulse width) is given by:

$T = 2N\sqrt{LC}$ seconds .... Equation 1

Note that if, for pulse quality reasons, N is to be large, then the LC values must be correspondingly small to maintain a given pulse width.

Characteristic Impedance

Because the pulse forming network is simulating a real transmission line, it should not come as a surprise to learn that it also has its own 'characteristic impedance' (Zo), given by: $Zo = \sqrt{L/C}$ ohms .... Equation 2

The ideal pulse shape is only guaranteed if the Zo of the network is matched to the impedance of the load.

Example: According to the above equations, a network with ten sections, each of L = 10μH and C = 1n would have the following properties:

Pulse width = 2 microsecond

Characteristic impedance = 100R

Applications in RADAR

A pulse modulated Radar employs the principles of high energy discharge for supplying power to the transmitting device. After delivering a short burst of microwave power, the transmitter is switched off and the receiver is activated, ready for detecting any echoes which return from the 'target'. Because the velocity of electromagnetic waves is a known constant (c), the time which elapses between the transmitter pulse and the returned echo is proportional to the range of the target.

The Radar Mile

The velocity (c) is 186,000 miles per second so a pulse to travel one mile takes 1/186,000 seconds = 5.38μs. But before the echo returns back to the receiver it has travelled twice this distance, so a useful term, the so-called 'radar mile' is defined as follows:

One Radar Mile = 10.7μs

Minimum Radar Range

The pulse width of a radar system represents the time the transmitter is operating. Since the receiver is inoperative during the transmitter pulse, the pulse width indirectly determines the MINIMUM target range. Example. If the pulse width is 1μs, the minimum detectable range is about 1/10th of a mile.

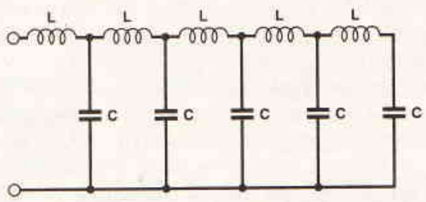


Fig.3 Pulse forming network

Maximum Expected Radar Range

The absolute range of a radar is dependent on the transmitter pulse power, the receiver sensitivity and, to some extent, the reflecting properties of a target. Apart from these considerations, the time allowed between transmitter pulses sets the limit on the maximum range. Time must be allowed for an echo to return from the maximum expected range before the next transmitter pulse. If, for example, the time allowed between pulses is 1 millisecond, the maximum range is:

1 ms/10.7 μs = 93 miles approx.

Transmitter Requirements

Good discrimination between adjacent targets is only possible with a high directivity aerial system, that is to say, one with a narrow beam width. To achieve this, a large antenna 'mirror' is necessary but how large depends on the wavelength of the transmitted pulse. There is a useful empirical formula for beam width (ø) in terms of scanner diameter (D) and wavelength λ: = 70λ/D (degrees). Note that, for a given diameter mirror, the shorter the wavelength the narrower the beam. This calls for a transmitting device which combines very high power with very short wavelength. The resonant cavity magnetron is capable of powers approaching a megawatt at centimetre wavelengths and so is admirably qualified for the job.

Basic Radar Pulse Modulator

Figure 4 shows the bare essentials of an energy discharge system suitable for pulse modulating a magnetron. The individual components function as follows:

The DC Charging Supply

Although required to deliver many kilovolts, the average current requirement is low so half wave rectification is normally adequate.

The Pulse Forming Network (PFN)

As explained above, this must be designed to deliver a high power pulse of a width determined by the minimum expected radar range. It must also have a known characteristic impedance (Zo).

The Pulse Transformer

The primary purpose for its inclusion is to match the impedance of the PFN to the input impedance presented by the input terminals of the magnetron. Maximum power transfer between the PFN and the magnetron, and also the quality of the pulse, depend crucially on correct matching.

An important, but less obvious, reason for having the transformer is to provide a DC path for the charging current — the magnetron is open circuit in between pulses!

The design of a transformer capable of passing a narrow, steep-sided pulse with negligable distortion was not an easy task way back in the pioneering days of the art.

The Magnetron

The intimate details of the magnetron appeared in the October '91 issue of ETI. For our present purposes, it can be treated simply as a pulse operated diode which happens to require several kilovolts between its anode and cathode and is capable of passing an anode current of several amps. In return, the magnetron responds by disgorging extremely high power centimetric waves into the scanner via the waveguide plumbing system for as long as the energy store in the PFN lasts.

The Discharge Switch

This is the end-component of what is best described as the 'Master Control Unit'.

In the non-conducting state, the PFN is free to charge up slowly via the DC power unit.

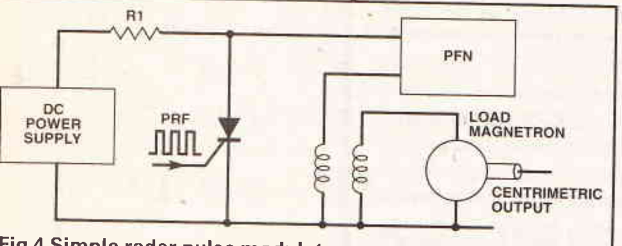


Fig.4 Simple radar pulse modulator

When it is triggered to conduction, it behaves as a virtual short circuit. This places the output of the PFN in parallel with the primary of the pulse transformer and so energises the magnetron.

The time (T) between conduction trigger pulses is arranged in accordance with the maximum expected range. The pulse recurrence frequency (PRF) is simply 1/T.

A high voltage, high current thyristor is shown as the discharge switch and is triggered by a low level pulse waveform generated by a 'master oscillator'. Modern thyristors with truly impressive credentials are now freely available — state-of-the-art specimens think nothing of handling 5,000 volts and currents of 2,000 amps.

Range Switching

Long range working requires a high energy pulse. Since energy = power × time, it follows that the pulse width (T) should be long. However, as mentioned earlier, the pulse recurrence frequency (PRF) must be low in order for the longest range echoes to return in time.

Short range working demands a narrow pulse width but the PRF can be increased in order to gain the advantage of reduced flicker.

So, for long range working, extra LC sections are switched in to increase the pulse width and an extra charging resistor can be added in series to allow for the longer time between pulses.

Average Power Equation

The average power in a pulse operated system is:
Average power = Peak Power × Pulse width × PRF

Example: Let Peak power = 100kW
Pulse width = 2µs
PRF = 1kHz
Then average power = 200 watts.

(The product of PRF and Pulse width is sometimes called the 'Duty Cycle').

When designing range switching, it is advisable to arrange the values such that the average power remains the same during long or short range working. If the pulse width is increased by, say, a factor of ten and the PRF is reduced by ten, the average power remains the same.

Design Example:

The following attempt to design a simple radar pulse modulator based on Figure 4 may help to consolidate much of the previous material. To avoid filling the pages with tedious arithmetical steps, rounded figures are used and the use of a calculator has been assumed.

The radar is to have a minimum range of about 1/10 mile and a maximum range of 10 miles. The magnetron in use requires an EHT voltage of 30kV and presents an input impedance of (Zin) of 900R.

Calculations:

Design of PFN

1 radar mile is 10.7µs so, for 1/10 mile, the pulse width must exceed 1.07µs — which rounds to 1µs.

The Zo of the PFN can be chosed arbitrarily because the turns ratio of the pulse transformer can be calculated to provide the correct matching between the PFN and the magnetron. Letting Zo = 100R would be a convenient choice. From Equation 2 above,

$Zo = \sqrt{L/C}$, so $10^2 = \sqrt{L/C}$
or $L = 10^4C$ .... Equation 3

The number of sections (N) is arbitrary so we shall use the value, N = 5

Pulse width is to be 1µs, so substituting in Equation 1 above gives:

$10^{-6} = 2 \times 5 \sqrt{(10^4C)C} = 10 \times 10^2C = 10^3C$

which gives the value of C as 10^{-9} = 1n.

Since $L = 10^4C$, then $L = 10^{-5}$ = 10µH.

Pulse Transformer

To match Zo of the line to the magnetron Zin, the turns ratio of the transformer (Tr) must obey the equation, $Tr = \sqrt{Zin/Zo}$ so, $Tr = \sqrt{900/100}$ = 3:1

The magnetron requires 30kV but the transformer ratio will step up the voltage by a factor of 3 so the primary voltage must be 10kV. The voltage across the PFN drops by half when feeding a matched load, so it must be charged to twice the primary voltage so the power supply must provide 20kV.

The Charging Resistor

The maximum range is to be 10 miles so the interval between pulses must be 10 × 10.7µs = 107µs or longer. The inductors in the PFN can be ignored during the slow charge so the total capacitance (Ct) is N × C = 5 × 1n = 5n.

It will take 5R seconds to charge up the PFN and this time (T) must equaL 110µs so,

$T = 5 \times Ct \times R$ $\quad R = T/(5 \times Ct)$

Plugging in the figures,

$R = (100 \times 10^{-6})/(5 \times 10^{-9}) = (110/5) \times 10^3) = 22k$

(In practice, instead of the simple resistor shown, a more sophisticated charging system using resonant choke techniques would probably be used).

Summarizing:

Pulse forming Network: N = 5, L = 10µH, C = 1n
Pulse Transformer: 3:1 voltage step-up
DC Power Supply: 20kV
Charging Resistor: 22k

ENERGY

Attenuator Circuit Design

Ray Marston continues his 'test gear' mini-series by looking at the design of 'L'-type attenuators.

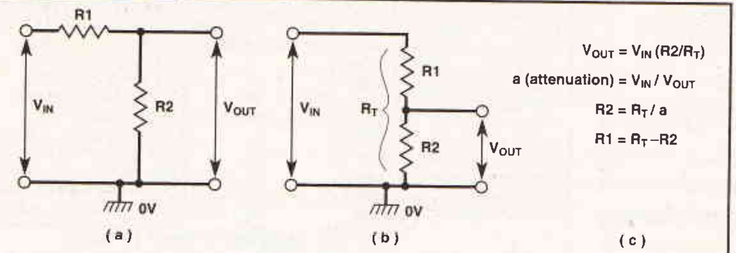
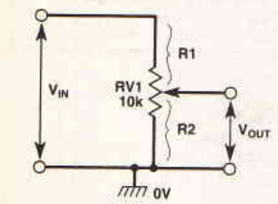


Fig.1 The basic 'L'-type attenuator (a) is really a simple potential divider (b); its design is controlled by the formulae in (c)



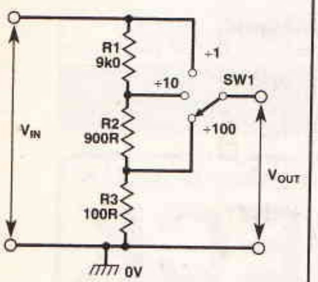


Fig.2 This 'pot' attenuator is a fully-variable version of the 'L'-type attenuator
Fig.3 The design of this switched attenuator is fully described in the text

Attenuators are widely used in modern instrumentation and test gear circuits to correctly condition or adjust the amplitude or quality of signals reaching the inputs of indicating instruments or coming from the outputs of generators. This and next month's article looks at practical versions of these basic circuit elements.

Attenuator Basics

Attenuators are used to reduce an awkward value of input signal to a lower and more convenient output level. The simplest attenuator is the 'L'-type (so named because of its diagram's resemblance to that letter), which (as shown in Figure 1) is really a simple potential divider and consists of two resistors (R1 and R2) wired in series. The degree of attenuation (a) is set by the ratio of R2/(R1 + R2), as shown. Note that the output of this type of attenuator must be fed to an impedance that is very large relative to the R2 value, so that the load does not significantly shunt R2 and thereby increase the overall attenuation of the circuit. Also note that the attenuator's input impedance equals R1 + R2 (=R_T).

The method of designing an 'L'-type attenuator with desired values of attenuation 'a' and total resistance R_T is to first work out the value of R2, and then the value of R1, on the basis of:- (i) $R2 = R_T/a$, and (ii) $R1 = R_T - R2$. Thus, to design a basic 'L' attenuator that has an R_T value of 10k and an 'a' value of 10 (= 20 dB), R2 needs a value of 10k/10 = 1k0, and R1 needs a value of 10k-1k0 = 9k0.

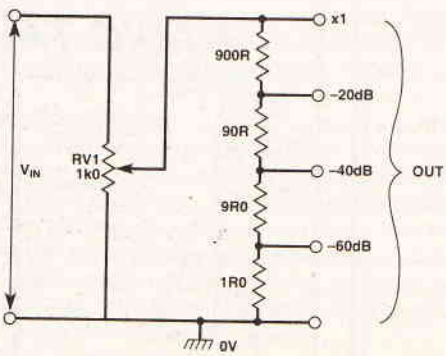
The simplest type of variable attenuator is the variable 'pot' type shown in Figure 2, which may be used as a volume control in an audio system or as an output level control in a simple audio generator, etc. Note that this pot has upper and lower arms, and is merely a variation of the 'L'-type attenuator.

Another variation of the 'L' attenuator is the switched variable type shown in Figure 3, which can provide a selection of values of attenuation. The procedure for designing this type of circuit is similar to that already described (using obvious variations of the (i) and (ii) formulae), except that a separate calculation is made for each attenuation position, starting with the greatest. Thus, the Figure 3 attenuator has an R_T value of 10k, so the first step in the design is to work out the R3 value needed to give '÷100' attenuation, which works out at 10k/100 = 100R. Similarly, the 'lower arm' (i.e., R2+R3) value needed in the '÷10' attenuation position equals 1k0, but 100R of this is already provided by R3, so R2 needs a value of 1k0-100R = 900R. R1 needs a value of 10k-1k0 = 9k0, as shown. This basic design procedure can be expanded up to give as many attenuator steps as are needed in any particular application.

Figure 4 shows how modified versions of the Figure 2 and 3 circuits (with greatly reduced resistance values) can be combined to make a fully-variable wide-range attenuator that can serve as the output of an audio sinewave generator, etc; RV1 should be provided with a hand-calibrated scale.

Voltage Ranging

One popular application of the multi-step 'L' attenuator is as a 'voltage ranger' at the input of an electronic voltmeter, as shown in Figure 5. Here, the actual voltmeter has a fixed FSD value of 1 volt, but the instrument is 'ranged' to indicate other FSD voltage values by feeding them to the voltmeter via a suitably scaled switched 'L' attenuator. The attenuation ratios (V_{IN}/V_{OUT}) are chosen on the basis of:- 'a' = Desired FSD/Actual FSD. Thus, the Figure 4 attenuator is designed to give output ranging of 1-10-100 volts, which in this case correspond to attenuation values of 1, 10 and 100. Note in the diagram that the meter's range is extended to 1000 volts FSD by connecting the high



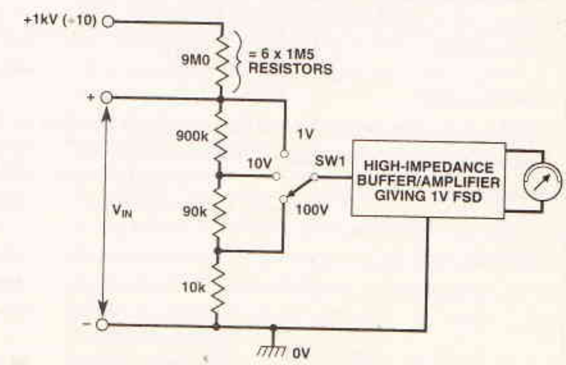


Fig.4 This fully-variable wide-range attenuator can be used in the output of a simple sinewave generator, etc
Fig.5 This attenuator is used for 'ranging' an electronic voltmeter

ATTENUATOR

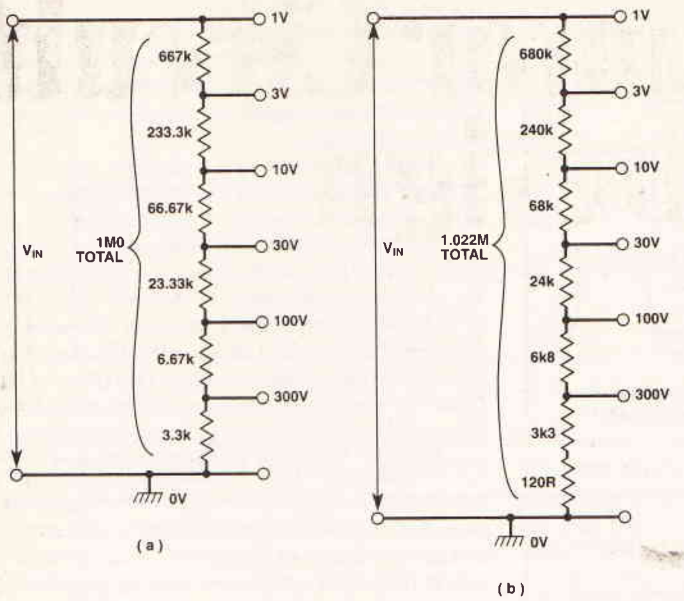


Fig.6 These attenuators give 1-3-10, etc., voltage ranging; the one in (a) uses 'odd-ball' resistor values, which total 1M0; the one in (b) uses standard values, which total 1,022 M

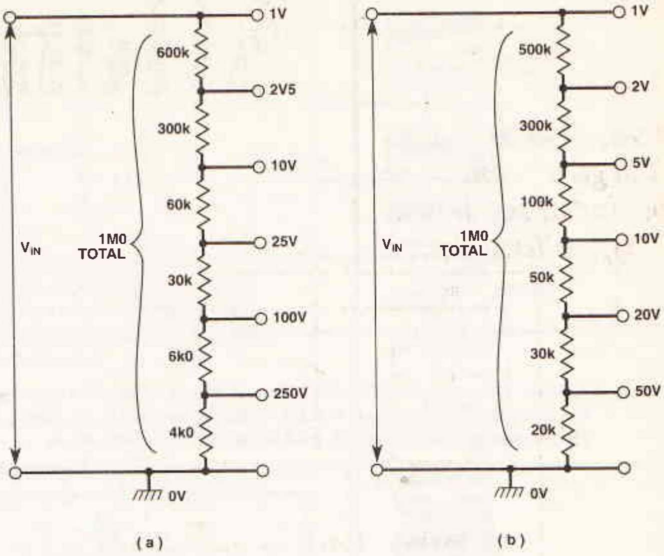


Fig.7 These 1M0 attenuators give (a) 1-2.5-10, etc., and (b) 1-2-5-10, etc., voltage ranging. For alternative total resistance values, simply multiply or divide all resistors by a proportionate amount (e.g., divide by 100 for 10k total)

voltage via a separate input terminal (marked '1kV' and '÷10') and a 9M0 resistance chain made up of six series-wired 1M5 resistors, thus ensuring that (at FSD) a maximum of only 150 volts appears across any resistor or pair of switch contact; when inputs are connected to this terminal, the meter's sensitivity is effectively reduced by a factor of ten on all ranges.

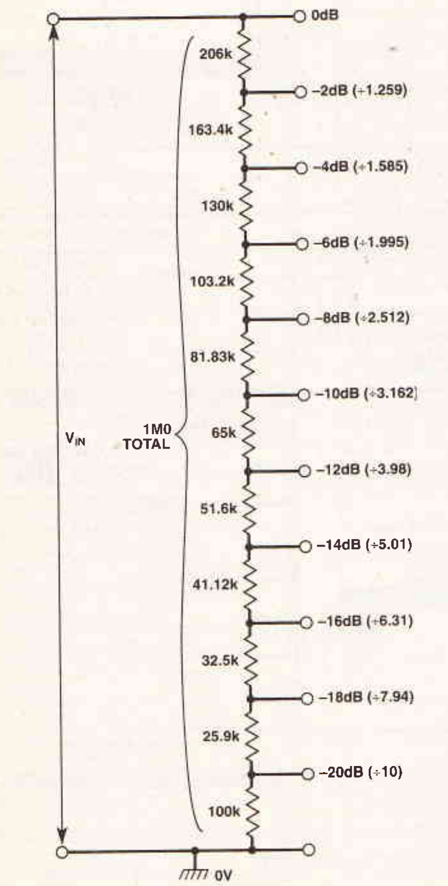


Fig.8 The output of this 1M0 attenuator is variable in 2 dB steps

Figures 6 to 8 show some useful variations of 'L'-type voltage— ranging attenuators. Figure 6 shows two versions of an attenuator designed to feed a 1V FSD meter with 1-3-10-30-100-300 volt ranging. The version shown in (a) has a total resistance of 1M0 and calls of odd-ball values of resistance; the version shown in (b) uses standard resistors and generates maximum ranging errors of less than 0.4%, but has a total resistance of 1.022 Megohms.

Figure 7 shows two more 1M0 attenuators designed to give 1 volt FSD outputs; that in (a) gives 1-2.5-10-25-100-250 volt ranging, and that in (b) gives 1-2-5-10-20-50 volt ranging. Finally, Figure 8 shows a 1M0 attenuator that gives an output that is variable from 0dB to −20dB in 2dB steps.

Note that all the attenuators shown in Figures 3 to Figure 8 can be made with alternative total resistance (R_T) values by simply multiplying or dividing all resistor values by a proportionate amount. Thus, any of the '1M0' designs can be adapted to give an R_T value of 10k by dividing all resistor values by 100, etc. Odd-ball values of resistance can be created by wiring two or more standard resistors in series or parallel.

Frequency Compensation

'L'-type attenuators of the types shown in Figures 1 to 8 are accurate only at DC or low frequencies or when made up of low— value resistors. Stray capacitances invariably shunt all resistors and make their impedance decrease as frequency increases, and in the case of the 'L' attenuator this may affect its attenuation ratios. This effect is particularly acute when high-value resistors are used; a mere 2p of stray capacitance represents a reactance of about 800k at 100kHz and can thus have a significant effect on any resistor value greater than 10k or so. This problem can be overcome by deliberately shunting all resistors with correctly chosen values of capacitance, as shown in Figure 9.

Here, each resistor of the chain is shunted by a capacitor, and these have reactance values that are in the same ratios as the attenuator's resistive arms. The smallest capacitor (largest reactance) is wired across the largest resistor and typically has a value in the range 15 to 50p, which is large enough to swamp strays but small enough to present an acceptably high impedance to input signals. The attenuator's frequency compensation is set up by feeding a good square wave

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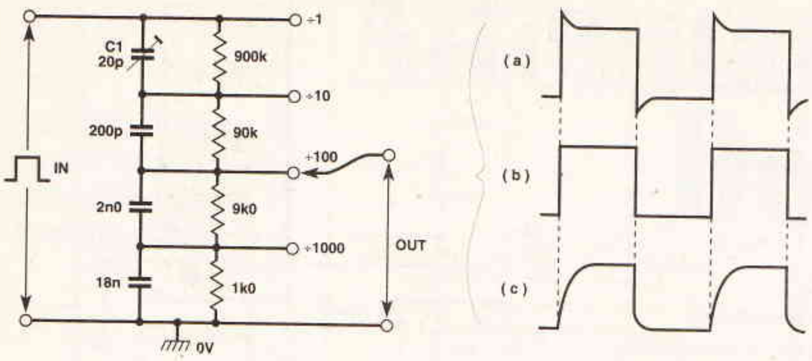


Fig.9 A basic 'compensated' wide-range 'L'-type attenuator, showing square wave output waveforms when the C1 trimmer setting is (a) over compensated, (b) correctly compensated, and (c) under compensated

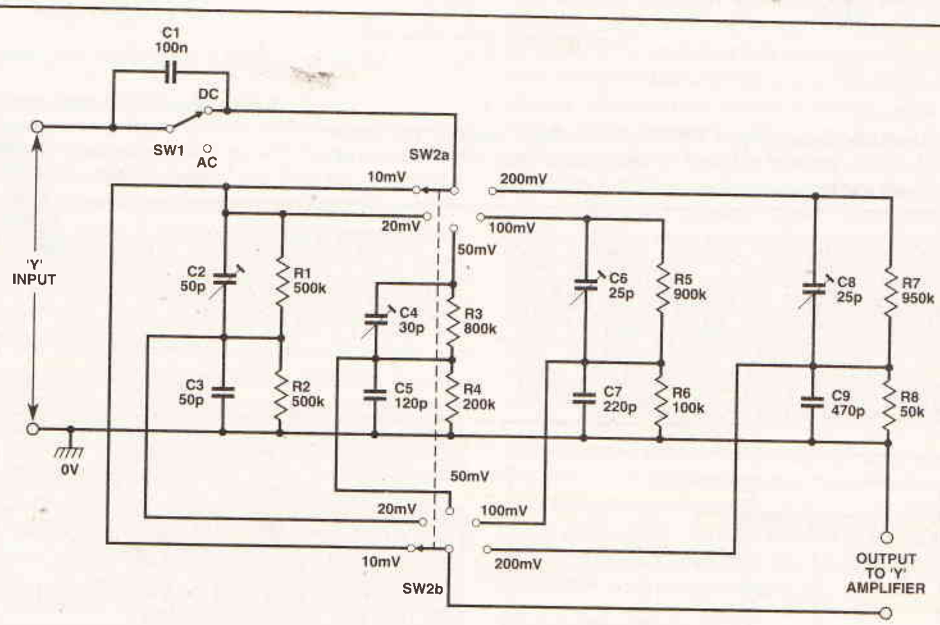


Fig.10 Part of a typical 'scope 'Y' amplifier attenuator

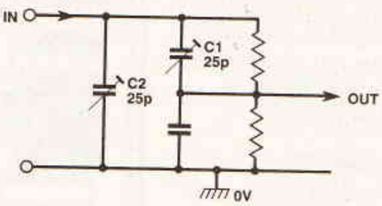


Fig.11 Alternative type of 'Y' amplifier attenuator section; C1 sets frequency compensation; C2 sets input capacitance

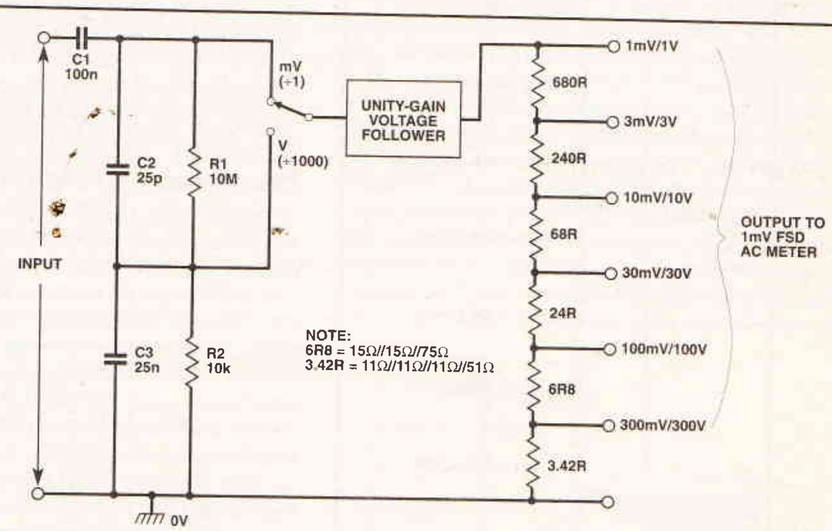


Fig.12 Use of primary and secondary attenuators in an A.C. millivoltmeter

to its input, taking its ÷100 or ÷1000 output to the input of a 'scope, and then trimming C1 to obtain a good square wave picture, as shown in (b) in the diagram.

Oscilloscopes invariably use compensated 'L'-type attenuators at the input of their 'Y' amplifiers. Figure 10 shows part of a typical example, in which an individually trimmed 1M0 attenuator sections is used on each range. Figure 11 shows a variation of one of these sections; in this case C1 is used to set the section's frequency compensation, and C2 is used to adjust the section's input capacitance so that the 'Y'-channel attenuator presents a constant imput impedance on all ranges.

Figure 12 shows how a 2-range compensated 'primary' attenuator and a low-impedance uncompensated 6-range 'secondary' attenuator can be used together to help make an AC millivoltmeter that spans 1mV to 300V FSD in 12 ranges. The primary attenuator gives zero attenuation in the 'mV' position and ÷1000 attenuation in the 'V' position. The secondary attenuator is a modified version of that shows in Figure 6b, with all resistor values reduced by a factor of 1000. Note that if readily-available metal film resistors with values greater than 10R are to be used throughout the construction, the 6.8R and 3.42R resistors can be made by wiring three or four resistors in parallel, as indicated in the diagram.

An 'L'-Type Ladder Attenuator

One snag with the basic 'L'-type attenuator of Figure 1 is that it needs two greatly different resistance values if used to give a large amount of attenuation, for example, for 60dB attenuation R1 must be 900 times grea-

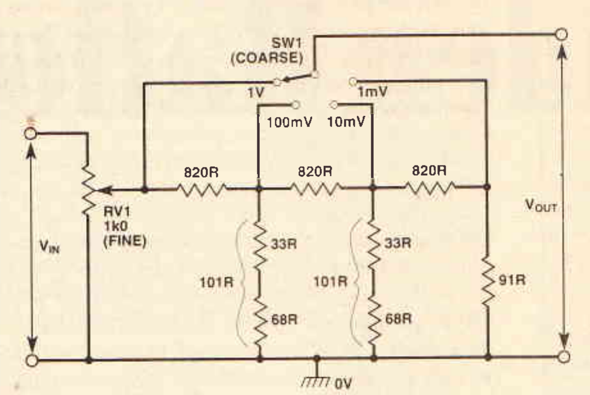


Fig.13 This fully-variable attenuator uses an 'L'-type ladder network and makes an excellent wide-band output section for audio and pulse generators, etc.

ter than R2. In this example, if R2 has a value of 10R minimum, R1 nees a value of 9k0 or greater, and must be frequency compensated if used above 20kHz or so. An easy way round this snag is to build the attenuator by cascading several lower-value attenuator stages, with sensibly restricted resistor values, as shown in the practical circuit of Figure 13. Such a circuit is known as a ladder attenuator.

The Figure 13 ladder attenuator consists of three cascaded 20dB attenuator stages, each with a maximum resistance value of 820R and with a useful uncompensated bandwidth extending to hundreds of kHz. Note that the right-hand (1mV) stage has 'R1-R2' (see Figure 1) values of 820R and 91R, and that these shunt the lower 'R2' 101R leg of the middle (10mV) attenuator and reduce its effective value to 91R. Similarly, the middle attenuator shunts the lower leg of the first (100mV) attenuator and reduces its effective value to 91R. Thus, each stage effectively consists of an 820R/91R 20dB attenuator that is accurate within +0.2%. The odd-ball 101R resistors are made by series-wiring 33R and 68R resistors.

The Figure 13 attenuator is an excellent design that can be used as the output section of a variety of audio and pulse generator circuits. Its output is fully variable via RV1. The attenuator's output impedance, on all but the '1V' range, is less than 90R, so its output voltage is virtually uninfluenced by load impedances greater than a few kilohms.

The series will continue next month with an in-depth look at matched resistance attenuators.

The Golden Ratio

Geoff Martin relates to a simple but pleasing proportion found in nature.

Isn't Mathematics wonderful! Used as a tool, it attempts to model nature and predict the aesthetically pleasing proportions of evolution be they within the shapes of animals, plants or by artifacts created by the human hand. Natural shapes appear to be exceedingly complex at first sight but under closer examination we often find that nature reveals a replication of a simple shape and so time conscious formulae can produce examples which are a close approximation of the truth. Increasingly, beautifully simple formulae emerge as the most likely representation of natural events.

$$\frac{AB}{BC} = \frac{BC}{AC} = 0.618034$$

OR 1.618:1

Fig.1 The Golden Ratio created on a line in mean and extreme ratio

Historically, the invention of numerical symbols to represent size or incremental moves in angular or linear fashion was the first step to giving us a link with nature. Since then, Arabic numerals have almost universally been used to get closer to nature.

Take a chap like Fibonacci, an Italien mathematician of the thirteenth century, he produced a simple series of numbers that relates closer to nature than perhaps he had initially thought. Here is part of the series:

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, . . .

It is part of, because it can go on and on forming an infinite series. But how do these successive terms relate?

The next term in the series is the sum of the preceeding two terms. It is a very simple series.

If we gaze at these numbers for a moment and take pairs of numbers in sequence, an interesting convergent decimal appears out of the two groups of fractions. Here they are:

1/1=1.00	1/2=0.5
2/3=0.6666	3/5=0.6000
5/8=0.625	8/13=0.615385
13/21=0.619048	21/34=0.617647
34/55=0.618182	55/89=0.617978
89/144=0.618056	144/233=0.618026

Now you can go on doing this as much as you like, but the significant point is the decimal on either side is converging to 0.618034 to the first six significant figures. The left hand column decreases from one and the right hand column increases from a half of one.

This figure or ratio if divided into one, is classically called the Golden ratio, a term first used by Leonardo da Vinci. The ratio was also known to the ancient Greek geometers. Although no documentaary evidence exists, it seems it was used to proportion their buildings. Here is the ratio.

1:0.618034 or 1.618:1

Turning this into a ratio on a line, we can see from Figure 1 where this dividing point appears spacially. The golden section is described as a ratio of lengths:

AB/BC = BC/AC

It has a numerical value of $(\sqrt{5}-1)/2$ or 0.618034

The Shape To Stand The Test Of Time

Turning the ratio into a Golden rectangle is simple as shown in Figure 2. The ratio of the width to the length is 0.618034. This particular rectangle is said to have the most pleasing proportions to the eye and consequently

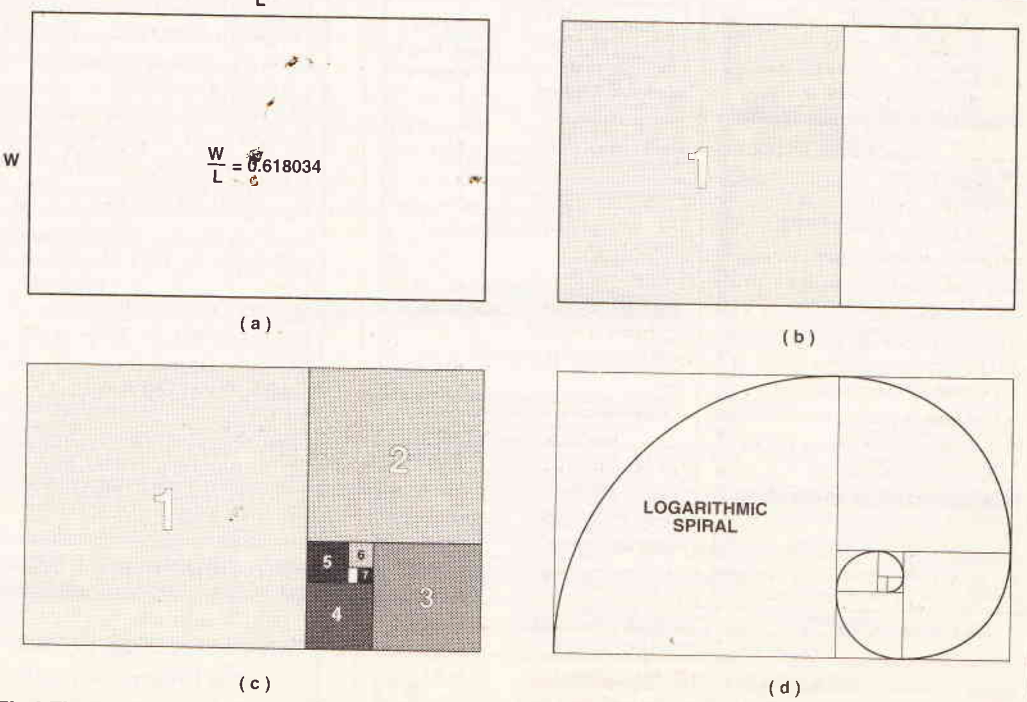


Fig.2 The Golden Rectangle and subsequent divisions to form a logarithmic spiral

has been used by many painters and artchitects thoughout history for the outline of a landscape picture, within the picture itself, or to proportion buildings. The technique of using 'dynamic symmetry' within many paintings, sculpture, pottery and buildings must have had a profound affect upon local communities because the architectural and artistic merit of such a geometrical arrangement has ensured their partial preservation throughout wars and the ravages of pollution. This is exemplified within some Grecian monuments, for the Greeks must have known all about the ratio as the Golden rectangle is incorporated into The Parthenon and also into the Grecian way of life.

Another shape of symbolic significance is the pentagram seen in Figure 3. An archaic symbol of health, and now an important national symbol of the USA, this regular 'star' has golden proportions.

For AB/BC=1.618034 and BE is cut into the same ratio BD/DE=1.618034 by the chords of the regular pentagon.

Returning to the rectangle, an interesting development can be seen if we now divide this shape up into a square and rectangle shown in Figure 2b. The resulting rectangle is also 'golden'. Continued further as in Figure 2c until no more rectangles can be produced a shape called a logarithmic spiral can be drawn within the squares and rectangles (Figure 2d). Nature has produced logarithmic spirals in 'snail-type' creatures in the sea and on land.

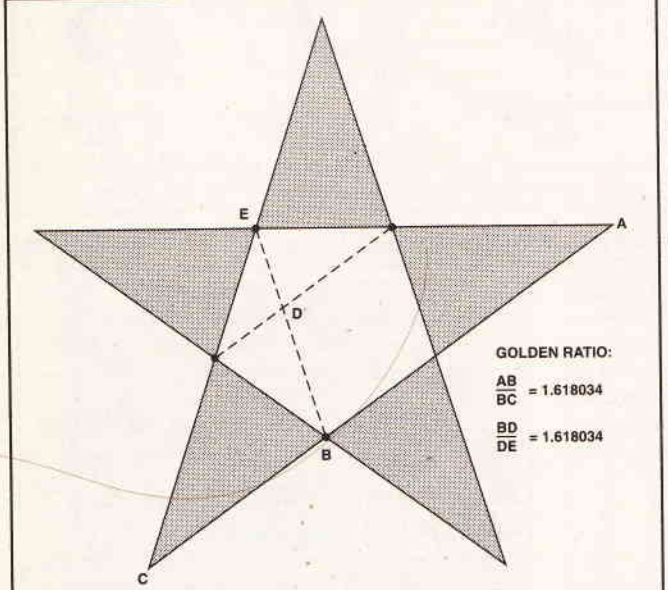


Fig.3 The regular five-pointed star and pentagon with golden proportions

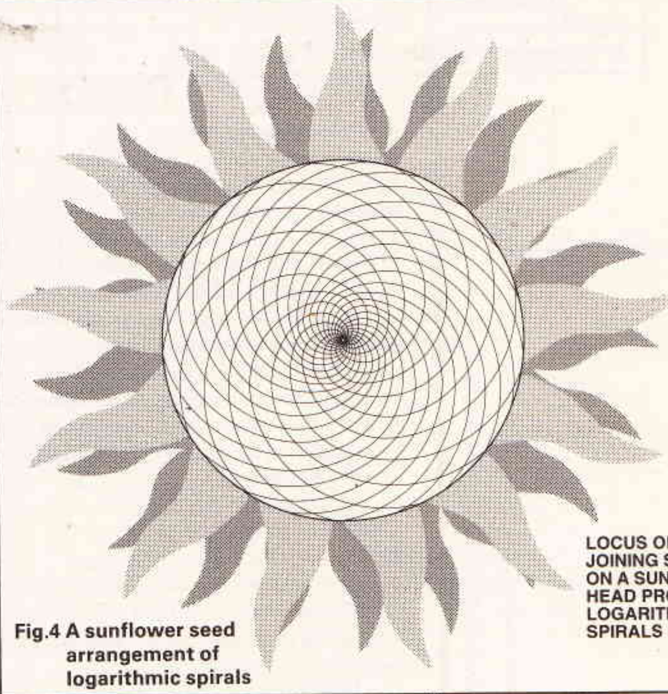


Fig.4 A sunflower seed arrangement of logarithmic spirals

The most striking occurence of this is within the head of the sunflower (Figure 4). The seed head arrangenent follows logarithmic spiral patterns and the number of clockwise spirals to the number of anticlockwise spirals are two successive terms of the Fibonacci series. One might have expected from a symmetry in nature that the number of spirals would be equal in either direction!

Is there a consistency in nature to produce the higher Fibonacci number of spirals in one direction?

The same effect occurs in a pine cone and is somewhat easier to count. Examination of the base should verify this (see Figure 5) and the photograph.

Returning to the original Fibonacci series of numbers, there is the same curious mathematical connecton within plant growth. A shoot will twist as it grows, producing leaves on the stem. The twisting and number of leaves produced relates to this series. Figure 6 shows some possible arrangements. Looking from the top, 6a has half a turn anticlockwise to the next leaf up the stem. Figure 6b shows 3/5 of a turn to the next leaf and finally in 6c 5/8 of a rotation is taken up to the next leaf. These are simplified diagrams, but it shows a trend. Why do plants twist as they grow up anyway and do all plants twist the same way? Could it be affected by the rotation of the earth and rather like the spiralling of water down the plughole, whether the plant is twist direction sensitive in the northern or southern hemisphere. What an intriguing thought! While on the subject of bean shoots and seeds, we digress here – which ever way one plants a runner bean seed (remember from your school days), the root always knows which way to grow. Has the seed an in-built gravity detector?

The Shape of Things To Come

Back to pleasing proportions, today's world has a host of rectangular ratios ranging from A4 paper (1.41:1), Laptop LCD screens (1.58:1) and TV screens (1.33:1). Whether these shapes provide us with a degree of subconscious satisfaction within our brains remains debatable.

Regarding the latter, discussions have taken place over the aspect ratio of future TV screens. Present screens use 4:3 and the proposed wide-screen TV looks as if it is settling around 16:9. Based on cinema pictures it is in fact a wider rectangle compared to the Golden rectangle (14.56:9). Given the choice, most subjects when asked opted for a picture ratio of 15:9 as the most pleasing but 16:9 has been chosen to keep the film industry happy.

In conclusion, it would be interesting to know whether the Golden ratio through creations crafted by man has been and will be 'a timeless shape'. If it does remain, will it be because we like to mimic some natural shape with golden proportions not discovered yet, a shape that came before us, perhaps an evolutary guide for us to hanker after our roots?

Afterthoughts

What about all the other similar series where the next number is the summation of the previous two terms, like:

0,2,2,4,6,10,16,26,42 i
0,3,3,6,9,15,24,39,63,102,165 ii
0,4,4,8,12,20,32,52,84..iii
0,5,5,10,15,25,40,65,105,.....................................iv
2,5,7,12,19,31,50,81,131,212 v
1,3,4,7,11,18,29,47,76,123,199............................vi

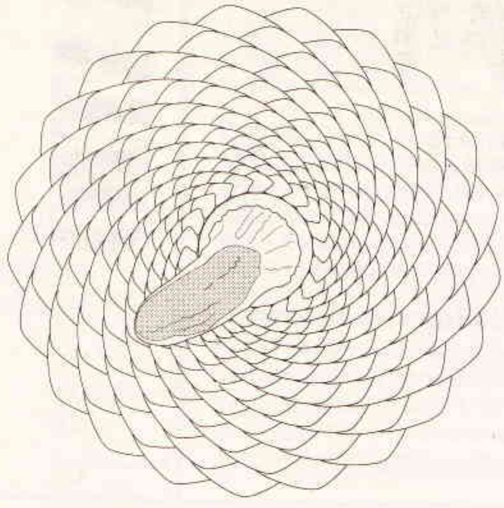


Fig.5 A Pine cone arrangement of spirals

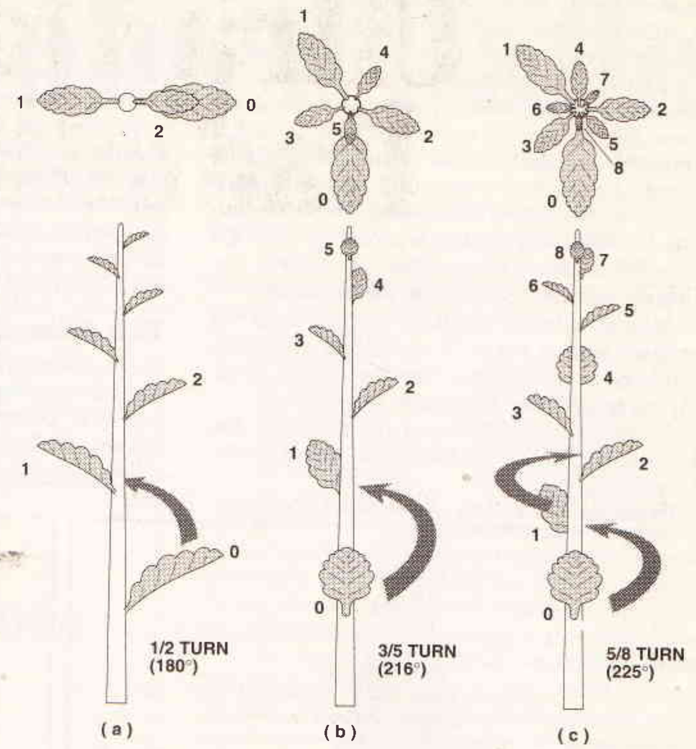


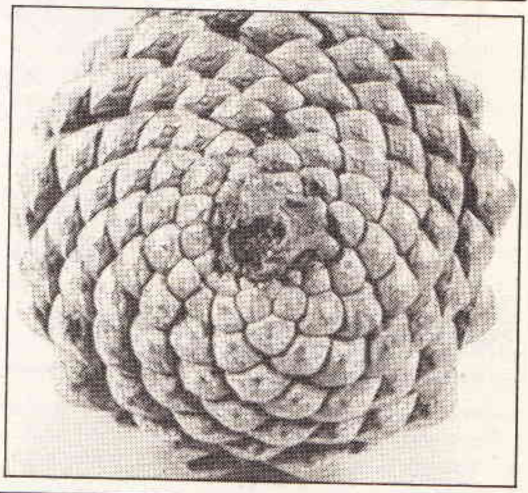
Fig.6 Shoot growth in relation to the Fibonacci series

We can forget series i and iii as they are double and quadruple the Fibonacci series respectively. But if we take the other series and find the series of fractions as before, we find the same decimal (0.618034) arises from the converging pairs. Which makes you think, why did Fibonacci pick the series he did, instead of the others? Is this Fibonacci series unique to nature or do the other series of numbers have any significance? Further, we might consider the beginings of these sequences. One might ask the question: what about any numbers before zero like

. . . −16,9,−5,4,−1,3,2,5,7,12, . . .
. . . −24,15,−9,6,−3,3,0,3,3,6,9, . . .
. . . 25,−15,10,−5,5,0,5,5,10 . . .
. . . 7,−4,3,−1,2,1,3,4,7,11,18 . . .

You'll notice that some have numerical symmetry but all have alternating signs and are again infinite in length. Are these just creations of the mind or are do they relate to the real world?

Why not do some investigations yourself to find out some of the answers?



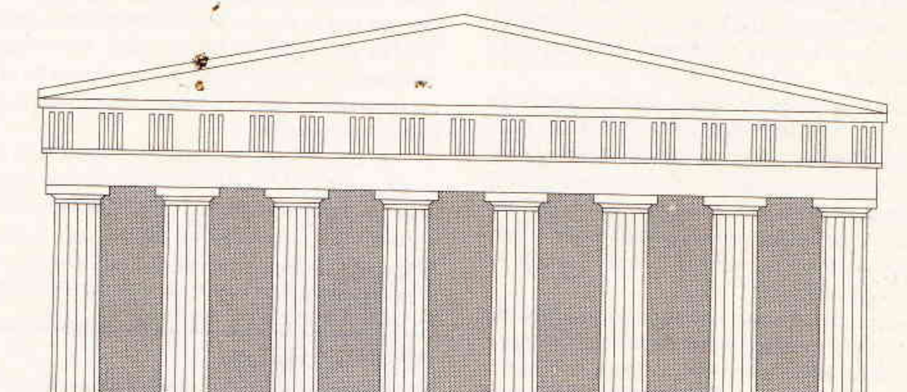


Fig.7 The Parthenon designed with the Golden Ratio in mind

Ultra Violet Radiation

by Douglas Clarkson

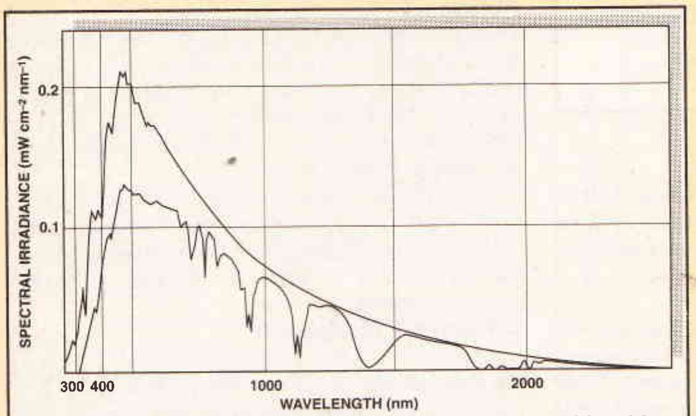


Fig.1 Spectral irradience produced by the sun at the earth's orbit (upper curve outside atmosphere: lower curve at sea level)

The sun is a source of a broad range of electromagnetic radiation. Figure 1 shows the distribution of radiation from the sun in terms of spectral irradiance in units of mW per square centimetre of power per nm step in wavelength. The higher the value of this term then the greater the amount of radiation at the corresponding wavelength. Two graphs are in fact shown. The upper curve is that outside the earth's atmosphere while the lower one is that relating to radiation at sea level.

The shape of the curve is basically derived from the so called 'black body' radiation emitted by the sun. For a surface at a specific temperature, there is a corresponding spread or distribution of wavelengths or emitted radiation. Figure 2 shows the distribution of radiation for surfaces at a range of temperatures. The hotter the surface the more radiation of shorter wavelengths is emitted.

For surfaces below 1000 K, no ultraviolet radiation is produced, while a surface at 2000 K will produce a small amount of radiation down to 200 nm. The shape of the upper curve of Figure 1 is characteristic of a surface at 6000 K. If the sun's temperature was considerably higher, therefore, there would be a higher proportion of energy emitted in the ultraviolet range of wavelengths. This 'temperature of a surface' is also described as the colour temperature of a light source. An ordinary tungsten light bulb has a colour temperature of 2600 K.

While there are specific 'dips' in the lower curve of figure 1, in the visible and infra red wavelengths, ozone in the atmosphere acts to block out the shorter Ultra Violet wavelengths below about 290nm. Thus although there may be significant amounts of this radiation present in space around the earth, it is not allowed to penetrate to ground level.

Ultraviolet radiation is conveniently broken down into convenient wavelength extents, being described as either UVA, UVB or UVC in increasing order of photon energy. Table 1 outlines the wavelength bands corresponding to the regions of radiation.

UVA and UVB are present in normal sunlight and UVA is typically produced by artificial sun tan equipment. UVC radiation is only generally encountered from artificial lamps since it is totally absorbed by the earth's atmosphere. UVA and UVB tend to interact with the skin in different ways. UVA is more penetrating than UVB though UVB is more damaging to the skin in terms of response per unit of absorbed energy. On a clear summer's day the maximum intensity of UVA will be about 5 mW/cm^2 while the corresponding figure for UVB will only be 0.2 mW/cm^2.

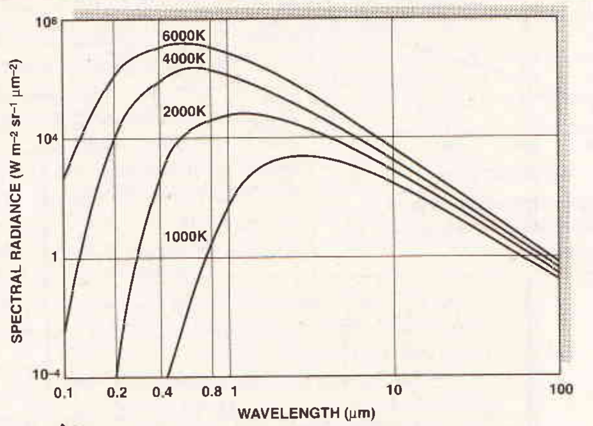


Fig.2 Spectral irradience produced by a black body radiation of a specific temperature. With increasing temperature, more energy is generated towards shorter wavelengths

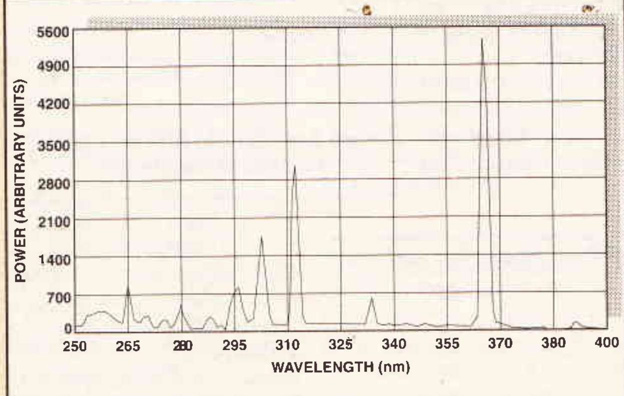


Fig.3 Relative spectral power of UV treatment lamp with UVA and UVB contributions

Region	Wavelength Limits
UVA	400-320nm
UVB	320-280nm
UVC	280-200nm

Table 1: World Health Organisation Classification of Ultra violet regions.

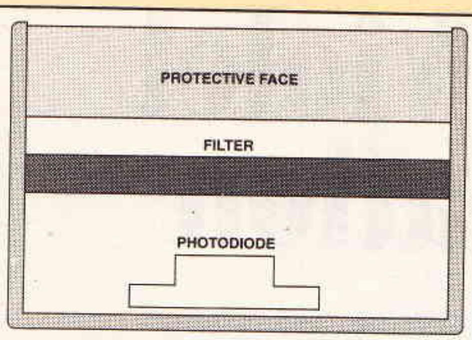


Fig.4 Main elements of a UV detector incorporating a photodiode

Uses of UV Radiation

Ultra violet radiation is used in a broad range of medical, industrial and leisure activities. Where artificial sources are used, these should be used with appropriate caution.

Medical

In the medical sphere, the main activity is that of whole body UVA therapy for Psoriasis. This is a distressing condition where skin the normal mechanisms of skin metabolism become disturbed and large areas of the body become covered in unsightly skin scales. A therapy introduced in the 1970's called the PUVA treatment involves the sensitisation of the patient's skin to UVA radiation by means of the drug such as 8-methoxypsoralin (8-MOP) either by oral tablets or body immersion in a bath or application of creams. This particular drug was initially mainly extracted from papyrus reeds grown in the region of the Nile Delta, though subsequently other sources of supply have been obtained. New types of photosensitising drugs are constantly being investigated to try and find a more effective treatment.

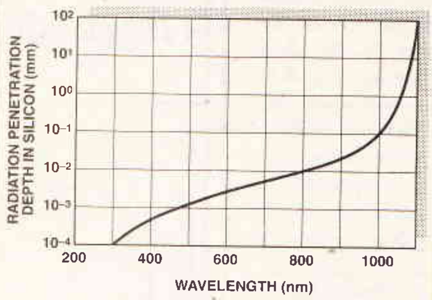


Fig.5 Radiation penetration depth in a Silicon photodiode as a function of incident wavelength

After the skin has become sensitive, the patient stands in a whole body cabinet termed a PUVA cabinet (Psoralen plus UVA) for a specified treatment period. A series of such treatments usually on a twice weekly basis typically leads to a control of the condition in two or three months. Patients are treated on the basis of a specific dose of energy for a specific treatment.

Table 2 shows the values of absorbed dose for specific treatment times for a range of typical UVA intensity values. Tubes have to be replaced so that treatment times do not become to long.

Energy Dose (J)	Treatment mW/cm²	Time to deliver dose (mins)
11	5	3.3
1	10	1.7
2	5	6.7
2	10	3.3
5	5	16.7
5	10	8.3
10	5	16.7
10	10	33.3

Table 2: Treatment times for specific values of Energy Dose and treatment intensities.

Use is also made of UVB treatment lamps for treating various skin conditions. Figure 3 shows the typical relative spectral output of such equipment, in this case a low pressure mercury vapour lamp.

UVC radiation has been used as a germicidal lamp to kill bacteria. While the use of such radiation will act to decrease numbers of bacteria, it is not a trusted method where absolute sterilisation is required. Preferred methods would in this eventuality be heat, Ethylene Oxide or exposure to high levels of Gamma radiation.

Industrial

The use of ultra violet radiation in industry is primarily for acceleration of chemical reactions such as in the curing of epoxy adhesives. UVB radiation is mainly used and this is often passed down optical fibres to produce a high intensity of radiation at the site where the reaction is being accelerated.

Ultra violet radiation is also used in etching processes such as in the manufacture of printed circuit boards. A range of other photochemical processes utilise the property of ultraviolet radiation to trigger photolithographic processes.

Laboratory Equipment

Extensive use is made of the measurement of the relative absorption of visible and ultraviolet radiation as it passes through samples being analysed. Specific types of analysis utilise ultraviolet radiation where optical wavelengths cannot provide the required level of selectivity.

Detection of Art Frauds

Ultraviolet light has been extensively used to detect art forgeries. The mechanism used is that of fluorescence where photons of ultraviolet light 'excite' atoms on a picture surface to emit visible photons of light. The distribution and colour of the photons observed is characteristic of the age and composition of the paint and varnish layers of the picture.

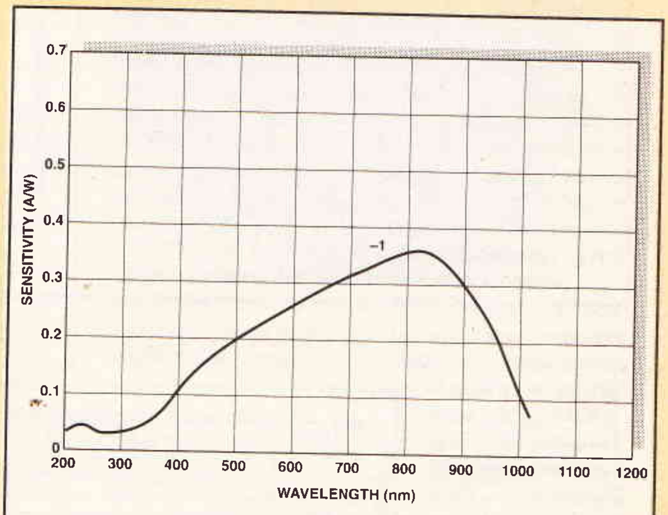


Fig.6 Sensitivity in A/W for a Silicon diffused photodiode as a function of wavelength

An old marble surface such as that of an ancient Greek statue will tend to fluoresce a yellowish-green colour while a more modern cut surface will yield a bright violet colour.

Leisure

Everyone will be familiar with the use of sun beds for skin 'tanning' utilising the UVA region. While it is unlikely that skin with normal sensitivity will experience an adverse reaction with such treatment, skin specialists remain cautious about extensive exposure to such radiation. Extensive work has been undertaken to try and assess the possible benefits and hazards associated with this type of therapy. Details of the effect of ultraviolet radiation on the skin will be given in a later section.

Detecting Ultra Violet Radiation

Figure 4 indicates the main elements of an ultraviolet radiation detector element. There is initially some element of protective cover required. In addition a filter response element is used to select a specific wavelength band. The actual sensing element, such as a silicon or Ga-As detector will also have its own wavelength sensitivity. The principal used in such semiconductors is that of the photoelectric effect where an incident photon raises electrons to the conduction band of the semiconductor, resulting in net flow of current. The actual response of the detector with wavelength will be influenced by all three components of the system. Usually, the main factor is the wavelength response of the filter element. Silicon based detectors tend to have a response which extends into the infra red though Ga -As devices have the advantage of being much less sensitive in this region.

The short wavelength limit of ultraviolet sensitivity of silicon is determined to a large extent by the radiation penetration of ultra violet photons in silicon. UV radiation tends to be absorbed in the first 0.1 micron thickness of the detector and often due to surface deposits on the semiconductor surface, the response to UV radiation is correspondingly degraded.

The radiation penetration depth of silicon as a function of wavelength is shown in Figure 5.

Figure 6 shows the response of a typical 'UV-blue' silicon photodiode. Such wavelength responses are specific to particular manufacturing processes. The 'window' on such devices is usually made of fused silica since a standard glass window would absorb wavelengths shorter than about 300 nm.

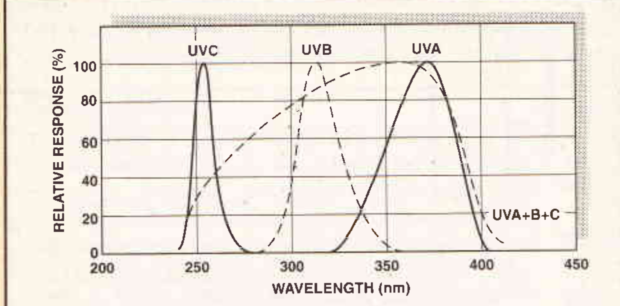


Fig.7 Spectral response in UVA, UVB and UVC ranges for a typical commercial UV measurement unit

As indicated previously, it is essentially the filter element used with a specific detector that determines the wavelength response of the detection system. Figure 7 shows the specific set of filter responses used for UVA, UVB and UVC. Table 3 indicates the corresponding peak response wavelength and bandwidth (FWHM) for a specific commercial unit.

Response	Peak Wavelength	FWHM
UVA	365nm	37nm
UVB	310nm	34nm
UVC	254nm	10nm

Table 3: Data for UVA, UVB and UVC filters uses in a specific commercial UV meter.

The filters used for this 'building block' approach to UV sensor construction are in fact a subset of a much more extensive set of commercially available interference filters covering the ultraviolet, visible and infra red ranges of radiation. The cost of such filters can often be considerably more than that of the silicon or GaAs photodiode used to convert incident photons into current.

The recent development of semiconductor technology has favoured the use of Ga-As devices for detection of UVA and UVB radiation. Figure 8 shows the spectral response of two devices produced by Hamamatsu which include a Ga-As photodiode and a separate filter element. One device, the G3614 is primarily a UVA device while the G3614-01 senses mainly in the UVB. The active area of the device is only 0.8 by 0.8 mm while the filter element is approximately 3.6 x 3.6 mm in size. The UVA detector has some sensitivity in the UVB range, through this would not be a problem for measuring UVA in sunlight or from UVA tubes since the UVB contribution would normally be relatively small. Figure 9 shows a typical circuit used with the photodiode sensor to measure UV radiation. It is important when using such photodiodes to shield the sides of the sensor since the photodiode itself will be sensitive to optical wavelengths.

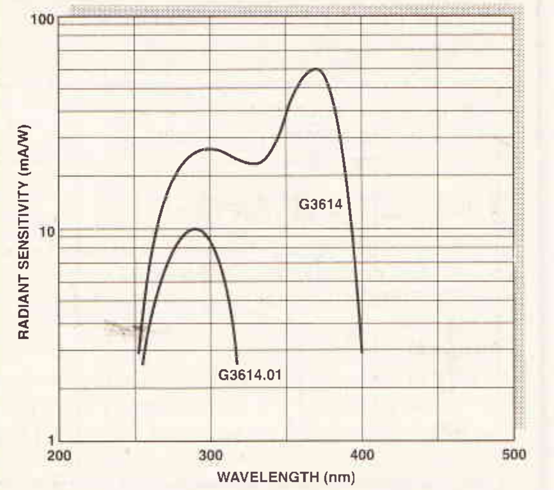


Fig.8 Spectral response of Hamamatsu G3614 (UVA) and G3614-01 (UVB) photodiodes

Figure 10 shows also a UV radiation to frequency conversion circuit using the G3614 type devices where the output frequency is modulated by the input UV level. In order to structure a circuit where the output frequency was proportional to the input level of UV radiation, a specific V/F chip such as the Teledyne TC9400 series would be more appropriate.

These types of sensor are designed for high volume applications, such as personal ultra violet dose meters or for educational science equipment. Where a more specific wavelength response is required, other combinations of semiconductor detector and filter outlined previously would be selected. This solution would certainly be more expensive than the Hamamatsu devices which cost only about £8.00 (+ VAT) each.

The circuit of Figure 10 is acting as a simple current to voltage generator where current flowing from the photodiode to ground passes through the resistor R1, raising the potential at the output of the operational amplifier accordingly.

Part of the problem of using such devices is the need to provide physical protection to the specific sensor in the housing of the sensor probe. The problem has typically been in relation to UVB detection. Recent developments in materials science, such as the Schott product Ultran 30, whose absorbtion spectrum is compared in Figure 11 with material BK7, provides a convenient new material to shield UVB sensors. The figure shows the absorbtion for a 5 mm thickness of material. At 300 nm, the mid point of the UVB range, the Ultran 30 absorbtion is only about 4%, while it is at least 50% for the BK7.

The sensitivity of UV detectors is often described in terms of values of Amps per Watt of incident radiation. Typical values for photodiodes are in the region of 0.5 A/W. In the case of a small photodiode with a 0.5 mm square active area and an incident radiation level of 5 mW/cm^2 (the upper range for natural UVA) , the current flowing will be approximately 6 micro amps.

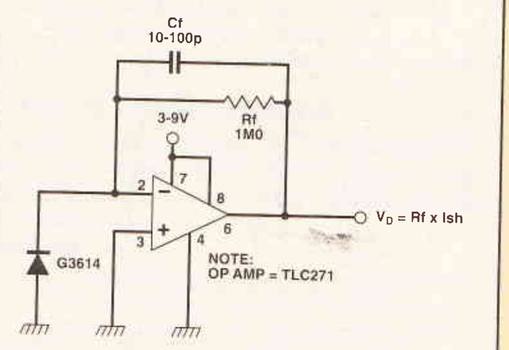


Fig.9 Simple photovoltaic circuit used with G3614 photodiodes to measure levels of UVA/UVB

Other Detection Methods

A photomultiplier tube with an appropriate window for UV radiation is typically used for detecting low levels of UV radiation. Sensitivity of such devices usually ranges between 20 and 200A/W of incident energy-typically a factor of 400 greater than a photodiode detector. Devices can also be obtained with sensitivities considerably in excess of this value. Photons which pass through the window of the photomultiplier tube strike a photocathode which ejects electrons which are then cascaded down through a series of voltage steps, multiplying the pulse of current by a given factor.

While such devices can detect very low level of UV radiation, their spectral response is not flat across the UV range. Photomultiplier detectors have the disadvantage of requiring a high voltage stabilised power supply. Their delicate vacuum tube design is also relatively fragile.

The main disadvantage of the previous detectors described is that their sensitivity is wavelength dependent. It is possible to absorb the incident UV radiation and use thermal detectors such as miniature thermocouples to measure it. One commercial design uses a front absorbing disc which is bonded to a ring of discrete thermocouples which in turn are bonded to a large copper heat block. Under steady state conditions, a given incident power level will generate a stable temperature difference across the array of thermocouples. This in turn generates an output voltage which can be measured and displayed.

The manufacturing costs of such detectors, however, are relatively high and photodiode detectors, with all their problems of wavelength sensitivity are more economical and practical.

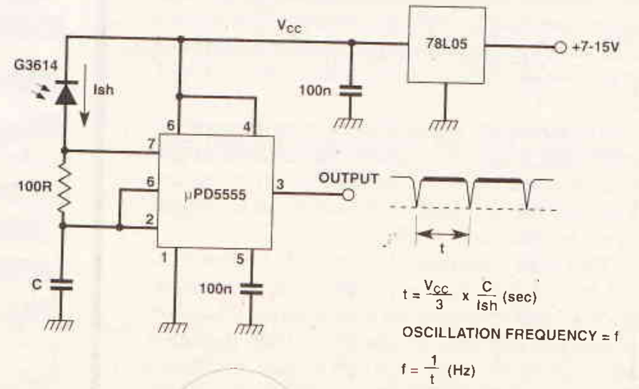


Fig.10 Simple circuit for demonstrating V to F characteristics using the Hamamatsu photodiode

Interaction of UV Radiation

Production of Vitamin D

Ultraviolet light, particularly the component around 280 nm, acts as an agent to synthesise Vitamin D in the body. A daily intake of 400 International Units (IUs) per day is recommended and clinical symptoms are evident when daily intake fall below 70 International Units. Chronic lack of vitamin D results in the disease known as rickets. Exposure to UVB radiation over a yearly cycle acts to top up the body's reserves of the vitamin.

Individuals particularly at risk from vitamin D deficiency are for example the elderly confined at home or in a hospital/nursing home environment. It has been shown that the addition of a component of UVB to the normal lighting of such an environment results in an improvement in vitamin D status of such individuals.

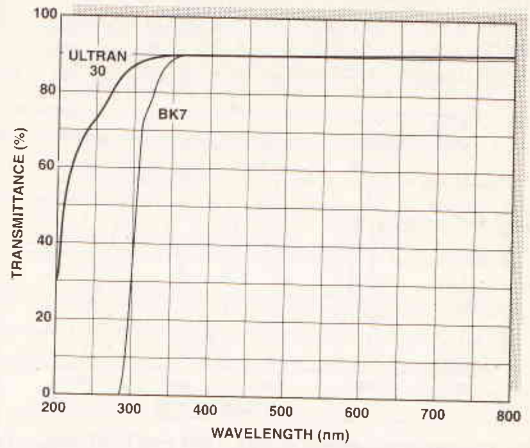


Fig.11 Diagram of transmittance of Ultran 30 as a function of wavelength

Skin Interaction

There are basically two elements to understanding the interaction between the UV radiation and the skin. One is to separate out the effect of the basic sensitivity of the skin to UV radiation as a function of incident wavelength. The other is to consider what constitutes a safe exposure of either natural solar radiation or artificially produced UV radiation. Table 4 shows how the variation of the so called action spectra, given by 1/D where D = the minimal ertherma dose (MED — that level which will just cause skin reddening on exposure of white skin) as a function of wavelength. It can be seen that significantly more UVA radiation than UVB has to be given to achieve the same element of skin reddening. In numerical terms, this factor is between 2000 and 3000.

When dealing with natural sunlight spread over the solar spectrum wavelengths, the MED is approximately 1 Joule per square centimetre. This level of reddening is therefore the summed contribution of a range of wavelengths with a wide variation in resulting skin sensitivity.

Action Spectra m2/J	Wavelength nm
0.00009	400
0.0001	320
0.001	350
0.05	300
0.03	280

Table 4: Values of action spectra as a function of wavelength. The peak of skin sensitivity occurs at around 300nm.

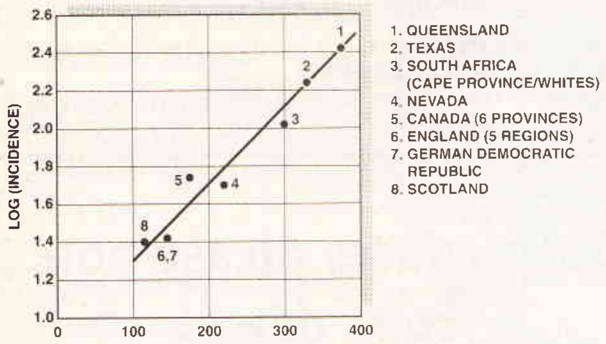


Fig.12 Graph on log scale of incidence of (male) non-melanoma skin cancer as a function of annual UV irradience

The tanning of the skin can be produced by UVA exposure without 'burning' of the skin which is characteristic of UVB exposure. This is why it is possible to safely receive a given energy dose to the skin from UVA sun tan tubes but experience serious burning from an equivalent dose from solar radiation which has significant UVB contributions.

UVB is, however, some 600 times more effective in producing tanning effects than UVA.

Skin Cancer

A wide range of clinical studies have investigated the link between skin cancer and Ultra Violet radiation. Figure 12 indicates the incidence of male non -melanoma skin cancer as a function of annual ultraviolet exposure. Studies have also been undertaken of the incidence of the more serious malignant melanoma as a function of sunspot activity. Figure 13 shows there is a steady increase in the observed incidence with time but this seems also to be influenced by the level of sunspot activity. This cancer link is associated with UVB type radiation and current medical advice is therefore to minimise exposure to UVB radiations. The increased incidence of skin cancer is associated with increasing social trends for 'sun and sea' foreign holidays where very large doses of UV with harmful UVB components are accumulated in a short time scale. It is suspected that the'short sharp tan' may add an additional degree of risk compared with the accumulation of the same dose over a longer time interval.

Minimising Exposure

The key element to minimising exposure is naturally enough not to expose too much skin or use adequate sun screen preparations. The so called sun protection factor (SPR) is the ratio of exposure time to produce a given skin reaction to that of unprotected skin. Thus the higher the number, the more effective the level of protection. A value of 10, for example, would allow someone to remain in the sun a factor of 10 times longer without burning compared with the time taken with no protection. The protection level against UVB is the most important element of the sun screen's formulation.

Articles of clothing would be expected to have a high equivalent protection factor. While articles such as cotton tops can have a value greater than 1000, values for materials such as polyester can be as low as 4. Perhaps summer beach wear should also have its UV protection factor indicated.

The Nature of Ozone and the Link with Levels of UVB Radiation

It is the key crucial link between atmospheric ozone concentrations and levels of ground based UVB which is at present under intense scientific scrutiny. Most atmospheric oxygen is present as O_2 — two atoms bonded together. Ozone exists as O_3 — three atoms bonded together. Ozone is thought to form in the atmosphere due to upwards diffusing O_2 molecules encountering downwards diffusing singly ionised oxygen atoms. At ground level ozone released in car fumes converts hydrocarbons from vehicle exhausts into irritating smog. Ozone is light blue in colour and very irritating to the lining of the lung. Levels in excess of 1 part per million are hazardous to health.

The valuable role of ozone of absorbing the shorter wavelengths of UV radiation, is in fact achieved by a remarkably small amount of the gas-equivalent to a layer at normal temperature and pressure of only 3mm. The ozone exists mainly in the stratosphere between approximately 10 and 50km. The maximum concentration tends to occur at around 25km.

Normal diatomic oxygen tends to absorb UV radiation of less than 242nm. The ozone molecule tends to absorb radiation less than 320nm. Thus ozone 'mops up' initially in the UVB range of radiation while diatomic oxygen absorbs into the UVC range.

Figure 14 shows the relative absorbtion of radiation by ozone in the atmosphere as a function of wavelength and compared with conventional Rayleigh scattering. Ozone is therefore more absorbing in the UVB range.

The depletion of ozone was first discovered by British Scientists in the Antarctic. While this is described as a 'hole' in the ozone layer, it is probably more apt to describe it as a depleted area. In October 1990 NASA reported that the level of depletion observed matched the lowest levels observed during 1987 and 1989, so there is anxiety that the trend of

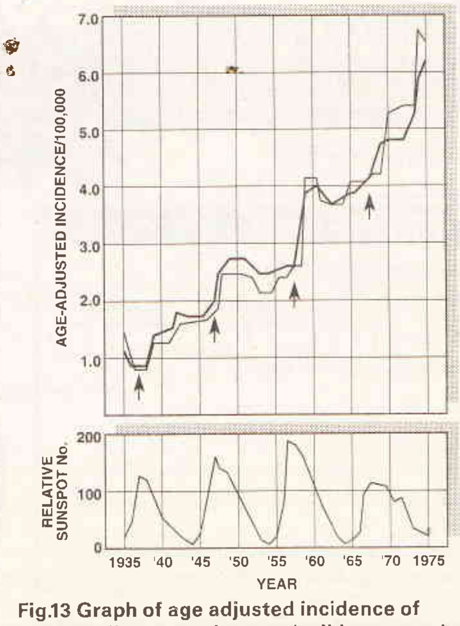


Fig.13 Graph of age adjusted incidence of malignant melanoma (solid curve males broken curve females) as a function of sunspot activity

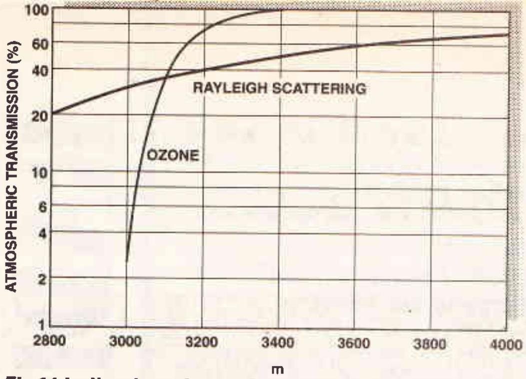


Fig.14 Indication of the effect of ozone and Rayleigh scattering on incident ultraviolet radiation

depletion has not yet been reversed. The level of depletion of ozone on a global scale is considered to be between 5 and 20% from a diverse range of sources, the principal one being halogenated hydrocarbons.

The areas around the poles tend to become depleted of ozone and periodically become refreshed from the supplies from less extreme latitudes.

While the effects of increased levels of UV radiation on the human population is one factor, scientists in a broad range of earth sciences are investigating the effects of raised levels of UVB radiation on plant and marine life in general. There are indications, for example, that plants exposed to increased levels of UVB radiation become more susceptible to disease. This is stimulating research into creating strains of plants with 'immunity' to increased levels of UVB radiation. Research, however, into determining the influence of increased levels of UVB on the ecosphere is only in its infancy and it is impossible at this juncture to assess the full environmental impact caused by the erosion of atmospheric ozone.

Further Reading:

Non ionising radiation, Microwaves, Ultraviolet and laser radiation by H. Moseley, Adam Hilger, 1988.

1

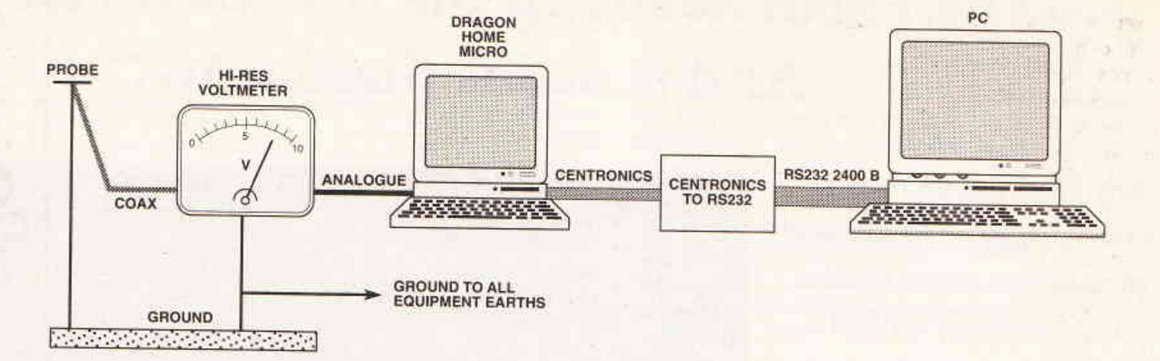


Fig.1

Earth Charge Recorder

Kevin Garwell measures the voltage between heaven and earth.

By way of introduction I am the technical director of Newchapel Observatory & Natural Sciences Centre (Ref.1). The observatory was built about 25 years ago, by two brothers and houses an 18 inch Newtonian reflector. Later they added a planitarium. All this was done as a hobby ie. they had no financial support.

About 6 years ago the site was expanded, in compass not size, to become the Natural Sciences Centre Ltd, and this is when I came on the scene as one of the directors. Its objective was to try to bring to the public an understanding of science, particularly the sciences associated with natural phenomena. This is still an unpaid exercise (although we do now charge visitors an entrance fee).

Having designed and built a more elegant equatorial drive for the main telescope I am just completing a fully automatic recording weather station. It was during the early work on this that I came across an article (Ref.2) which suggested that it might be possible to detect meteors (shooting stars) by their effect upon the upper layers of the atmosphere.

The ionised layers of the atmosphere which extend from about 40-200 km (25-125 miles) upwards are positively charged with respect to the earth. Much nearer the earth, just a few hundred feet up, are the clouds which often have a negative charge at the bottom and a corresponding positive charge at the top. To measure these voltages a voltmeter with extremely high input resistance is needed.

I saw this as a double interest to us at Newchapel. First some more information about the weather and its effects and second, possibly some more astronomical information. As a consequence I have built the first Earth Charge Recorder at my home intending later to install one at Newchapel. I suppose this name really is a complete misnomer, it should be Atmospheric Charge Recorder. However Earth Charge Recorder was the name used in the first mention of the project and it's stuck so I will continue to use it.

The system is shown in outline in Figure 1 and I shall discuss it now in general terms. Later I shall describe each item in detail. The system consists of a very high input resistance voltmeter coupled to a probe mounted a few metres above ground. The output from the voltmeter (although these very high resistance voltmeters are more often called electrometers) is monitored via the analogue input port of a small home computer. A Dragon 32. Every hour when running this machine dumps the data onto disc. Then when required the data from the Dragon disc can be passed to an IBM PC look-alike for processing. Of course the PC has to be called George!

The theory behind the detection of meteors goes something like this. The earths atmosphere in proportion to the earth is rather like the skin of an orange, the earth being nearly 13000 km in diameter whilst the atmosphere is only some 300 km thick. A meteor entering the earths atmosphere leaves a strongly ionised path which can be likened to sticking a needle just a little way through the skin of the orange. The

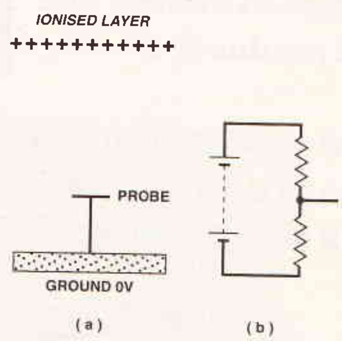


Fig.2

ionised meteor trail effectively lowers the ionised layer thus increasing the potential gradient and hence the voltage detected at the probe. Looking at it another way the potential of the ionosphere establishes a potential gradient between the ionosphere and the earth. At the point of entry of the meteor this potential is extended down to the bottom of the ionised trail consequently the same potential difference is applied over a much smaller distance. I believe that this effect will be local ie. only detectable below the meteor trail and extending only a few kilometres either side. Probably in proportion to the height of the bottom of the trail. For example if the bottom of the trail were 40 km above ground then the effect would only be detected within a circle of radius 40 km below.

Results from radar detection of meteors seem to suggest that the ionisation caused by the meteor is rapid followed by a slow decay (relatively). The whole

PROJECT

exercise taking only a few seconds. The exercise therefore consists of looking for blips of this order in the atmospheric voltage. Of course the difficult bit is trying to convince oneself that the blips detected are due to meteors! According to my theory, and again this is my theory and consequently open to question, the incidence of meteors penetrating the earths atmosphere should be greatest during the hours between midnight and midday (sun time, not BST, GMT or any other variety). This is the period during which the observation point is facing the direction of earths travel. Common sense suggests one is more likely to run into something in the direction one is travelling, especially when the speed is about 100,000 km/hour (67,000 miles/hour) which is the earths orbital velocity.

The records so far taken over a few days don't seem to be biased in this way, although there are a fair number of blips. They don't seem to show any daily pattern either which suggests they are not man-made. This is why we intend to install two of these devices about 5 miles apart so that the two sets of readings can be compared. Any blips which coincide are likely to be natural phenomena. Man made noise is unlikely to be identical in time and amplitude at that distance.

The Dragon micro spends most of its time whirling round in a loop measuring the voltage and comparing it with the previous reading ie. looking for short term differences (the blips). The maximum difference

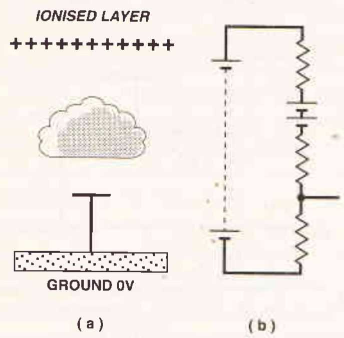


Fig.3

for each minute is saved as well as maximum and minimum values. The date and time (daynumber, hour, minute) is added to the record. Each entry thus consisting of six values day, hour, minute, maximum value, minimum value, maximum difference. Hourly the entries are consigned to a file the name of which is derived from the current date eg. T0610.ECR the T indicates 1991 then the month and day. The suffix identifies the source of the data, the earth charge recorder. Each file starts at midnight.

The Dragon has no RS232 capability but it does have a printer port which is standard Centronics parallel. A special PCB converts from Centronics to RS232 at 2400 Baud for transmission to an Amstrad PC lookalike for processing. The transfers are performed as and when convenient (Figure 1).

The PCB in question is one which I designed some time ago and several of them are in use both here at my home and at Newchapel. One interface is RS232 at 1200 Baud and the others are 8 bit input and 8 bit output with strobe and ready respectively. The board requires plus and minus 12v and 5v.

There is no reason why the job should not be done by a PC fitted with an analogue input board except that it then becomes a dedicated processor and is not available for anything else eg. analysing the data!

References

1. Newchapel Observatory & Natural Sciences Centre. Newchapel, Stoke on Trent ST7 4PT. 2. "A new meteor logging technique" Anthony Hopwood Electronics & Wireless World June 1989.

High Resistance Meter Theory

So far I have talked about the ionosphere being positive and the earth being negative, clouds being negative at the bottom and positive at the top. It's time to tighten up the terminology. I shall therefore adopt the common practice of using the earth as the reference point and consider it as 'ground' or 0 volts.

The device to be described when connected to a suitable probe allows the potential gradient above the earth to be measured and compared with actual physical conditions. For instance although the earth-ionosphere voltage is positive many clouds carry a negative charge below and a corresponding positive charge above. Because of their proximity compared with the ionised layers this negative charge is far more appar-

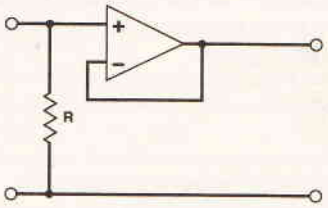


Fig.4

ent. The voltage at the probe thus wanders between positive and negative values depending upon weather conditions. Figure 2a suggests the cloudless situation with Figure 2b as the suggested equivalent circuit. With a charged cloud present the corresponding figures are 3a and 3b. To detect these voltages at all is not easy as the input resistance of the voltmeter used must be very high indeed. After all, the resistors in figures 2b and 3b are the atmosphere. The effective resistance of which is dependant among other things on the amount of water vapour present.

The input resistance of the device to be described was measured as 25,000 Megohm. How this was measured will be discussed later. The input voltage allowed is +10 to −12 volts.

Now to consider the the basic circuit and its operation, the input stage is derived from a simple op-amp buffer (Figure 4). The input resistance is that of the op-amp in parallel with the input resistor R. Since my catalogue shows the input resistance of a typical FET input op-amp to be 1.5 T ohms (1.5×10^{12}) we can forget the op-amp resistance as it is more than an order of magnitude greater than the figure being aimed at. Which simplifies everything and just leaves R as the effective input resistance. However 10,000 Meg resistors are not readily available! The best one can easily do is 10 Megs. 10 of which bundled in series gives 100 Megs and still leaves us a long way short of the target. Fear not help is at hand!

Suppose that instead of connecting the input resistor down to 0v it was connected to the op-amp output as in Figure 5. Since the negative terminal of the op-amp is within a few millivolts of the positive terminal there would only be these few millivolts across R and so it would look to the outside world like a very large resistor. Unfortunately any voltage at the input sufficient to establish this current would cause the op-amp to switch completely to the supply rail either positive or negative depending on the sense of the input. Another way of looking at this arrangement is that there would be posi-

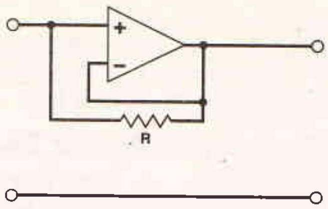


Fig.5

tive feedback between output and input and with a gain of 1 the op-amp would behave as a trigger.

Since Figure 4 and Figure 5 are two unacceptable extremes how about trying a compromise? Figure 6 shows this compromise with the input resistor R tapped between the output of IC1 and 0v by resistors R1 and R2.

Now to see what the effect is. I will use standard computer symbols for the arithmetic to avoid possible ambiguity through using a typewriter. For those not immediately familiar with BASIC or other computer languages, an asterisk indicates multiply. Expressions inside brackets are worked out first, otherwise * and / are worked out first followed by + and –.

Consider Figure 6.

Let the input voltage be E

Voltage across R1+R2 = E because the gain of IC1 is 1

Let the input current be I which is also the current through R Let the voltage across R2 be V

Let the input resistance be Ri

Then:

I=R/(E-V)
Ri=E/I
V=E*(R2/(R1+R2))
I=(E-V)/R
I=(E-(E*R2/(R1+R2))/R
I=E*(1-(R2/(R1+R2)))/R
I=E*(R1/(R1+R2))/R
Ri=E/(E*(R1/(R1+R2))/R)
Ri=R/(R1/(R1+R2))
Ri=R*(R1+R2)/R1

If R2 is large compared with R1 (which it is) this becomes Ri=R*R2/R1

Putting this simply into words, the input resistance is equal to the value of the resistor R, multiplied by the ratio between R2 and R1, always with the proviso that R2 is large compared with R1.

The Reality

Figure 7 shows the circuit with practical values added. R is a 100M and consists of 10 off 10M resistors. R1 is a 10k preset and R2 a 1M variable. The 10k preset enables the maximum value of R1 to be set, if this is zero then the circuit will be unstable, in practice I have set the preset to its mid position corresponding to 5k. This according to the formula derived previously would give an input resistance of:

Ri = R * R2 / R1
= 108 * 106 / 5*103
= 2*1010 ie. 20,000 Megohm

Figure 8 shows the circuit finally adopted. Both ICs are FET input and the portion of the figure to the left of the broken line is the primary part of the circuit. The portion to the right, IC2 is concerned with changing the gain of the system, shifting the ground reference and buffering the output for input to the Dragon. A conventional meter can be connected to the output of IC2 if required.

Associated with IC1 components R, R1 and R2 have already been discussed.

R3 and C1 perform two functions. They form a simple low-pass filter to reduce 50 Hz AC, and there's always plenty of that arround! Secondly they provide protection for the input to IC1 from high DC voltages. The IC has input protection in the form of internal diodes and these in conjuntion with R3 prevent any large currents from flowing through the IC.

Before discussing the rest of the circuit a few words about surface leakage. It must be appreciated that this can be significant when considering the high resistance of this device. Notice that the input connection is shown as a socket, in fact a standard TV coax chassis mounted socket, but the outer connection is not connected to earth but to the output of IC1. This is part of a general technique for measuring very high resistances first developed many years ago when measuring the insulation resistance of cables. To prevent leakage across the surface of the insulation between the cable conductors and the cable sheath, which in those days was invariably lead, a piece of wire was wrapped round the insulation and connected to the voltage source being used to measure the resistance. The piece of wire became known as a 'guard-ring' and the same technique is used here. Coaxial cable is used to connect the device to the probe when used for atmospheric measurements and the outer screen is connected via the socket to IC1 output. Since the output voltage of IC1 is the same as its input voltage there is no voltage difference between the cable screen and its centre conductor and hence no leakage current between them.

C2 bypasses any AC components on the screen to earth to prevent high frequency interference reaching the probe via the screen, whilst R4 provides a bit of

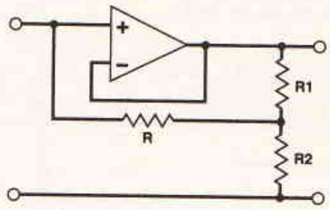


Fig.6

safety buffering for the IC. The low pass filter action of R4 and C2 also attenuates 50 Hz to reduce the input resistance to this frequency by not allowing the screen to operate as guard-ring at 50Hz.

The second part of the figure containing IC2 enables gain adjustment, level shifting and buffering. In my particular case the analogue input to the monitoring microprocessor only accepts inputs from 0 to +5 volts whereas the output from IC1 varies from −12 to +10V. R5 and R6 convert this from 0 to +11. A further division by 2 occurrs between the output resistors R9 and R10. R7 and R8 allow the gain to be increased from 1 to 6. This is convenient for observations where the probe voltage is close to zero.

Construction

There are no problems with component layout. Everything is happening so slowly components can be put where convenient! The precautions required in construction are twofold. To prevent leakage, particularly surface leakage, from affecting the input and to shield the device from stray electric fields. The latter is easily achieved by mounting the device within a metal case. The former by mounting IC1 on an insulated platform which is connected to IC1 output. A repeat of the guard-ring technique in interposing a metallic barrier at the same voltage as the input between the input connections and the rest. This is suggested in Figure 9 which shows the layout I have adopted.

All insulation associated with the input should be plastic rather than paxolin/Veroboard as is more usual.

In the prototype I found that the easiest construction was to make a two part aluminium case. The bottom flat with two turn-ups at the end, coax input socket isolated on paxolin (OK here) in turn mounted at one end of the base. The output, power connectors, and controls at the other. Figure 9. Fastened to the base of the case a small breadboard of the sort where components just push in. These are made usually of nylon, polyester or ABS which are more suitable because they are moisture-proof. The secondary advantage of these is that circuit changes are easily made. I have found this a considerable advantage particularly in making changes to the scaling done by IC2.

Failing a breadboard of this nature Veroboard or something similar can be used for all IC2 connections and for the earthed ends of the IC1 components and

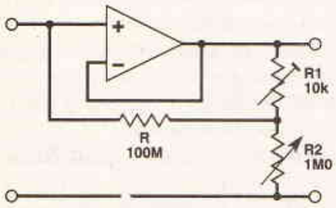


Fig.7

the output connections to IC1. However the input connections will have to be birds-nested in this case. Evo-stick or similar will stick IC1 to its platform. Resistor R is worth a mention. It should be constructed from ten, 10 Meg resistors mounted on a piece of plastic sheet. A washing up liquid bottle with parallel sides can be cut up for this. Solder the ten resistors together in a zig-zag then support them by pushing the soldered ends through holes made in the plastic. Make a hole to fasten the plastic or leave it to be self supporting. The arrangement is shown in Figure 10.

The last important item is C1. Preferably it should be air-spaced and use ceramic insulation. Concentric trimmers of about 100p are most suitable.

analogue input ports 0—3. A peculiarity of the machine is that all four inputs are digitised when, and only when, port 0 is read. The value is a 6 bit number. The ports were intended to be used for joysticks. In my case port 0 is connected to a source of one second pulses and port 2 is connected to the output from IC2. As the permitted input to the ports is 0 to 5 volts the connection is via a potential divider, R9 and R10 in Figure. 8. The 1 second pulses are obtained from a 32.768kHz crystal and a 15 bit divider consisting of a 4060 oscillator and divider followed by a 4024 divider.

The Program Synopsis

Put heading and copyright on screen
Reset values max, min and difference
Input date from user and write to file 'T=1991, U=1992, etc using date as filename
Input comment from user and write to file
Input time hour, minute and second
Put legends on screen
Get in sync with clock input
Read "previous value" of input Do
Wait for negative edge of clock
Set internal timer to 0
Update time
If seconds = 0 then
Save data on the minute
Write to file on the hour
Start new file at midnight
End if
Read input port 1 (requires dummy read of port 0)
Update max, min and maxdifference
Put values on screen
If jobs have taken longer than 1 second then
Update seconds count
Keep in sync with 1 second clock
Loop

The program which follows is identified by the line numbers. The discussion and comments are not part of the program. I should add perhaps that this early version of Microsoft Basic doesn't care about spaces except when they are necessary to avoid ambiguity. Using other machines may require the addition of

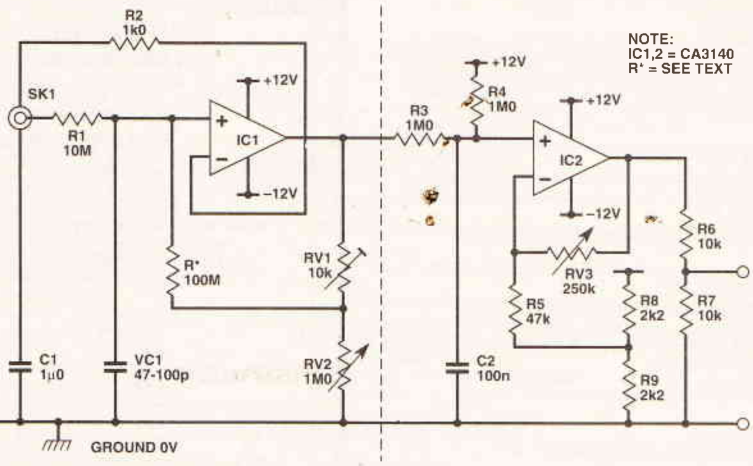


Fig.8 Circuit of high resistance voltmeter

The Dragon Program

Fire and Brimstone?

The object is to repeatedly read the value at the input port, comparing it with the previous value and logging the difference. In this way sudden changes in value become apparent, while slow changes will not be logged. This occurs every second. The maximum value of these differences is retained in an array and similarly the maximum and minimum values read at the port. Hourly the data is written to disk. The Dragon has four

spaces. For instance GOTO2000 is quite legal in Dragon Basic and saves space. Other machines may expect GOTO 2000. Dragon Basic only allows two characters to identify variables.

Program identity, copyright declaration, clear string space and declare array for data.

```
5 DATA EARTH CHARGE RECORDER V3.02
8 DATA COPYRIGHT K GARWELL 1991
20 PCLEAR1:CLEAR5000:DIMEC$(300)
```

Set initial values for max, min and line number on the screen for data. The Dragon only knows the screen position as character positions 0 to 511. Giving 16 lines of 32 characters.

30 MX=0:MN=70:LN=320

Constants to identify months and month numbers.

40 MI$="JANFEBMARAPRMAYJUNJULAUGSEPOCTNOVDEC"

50 MN$="01X02X03X04X05X06X07X08X09X10X11X12X"

To skip all the subroutines and go to the start of the program. 90 GOTO1000

SR converts day number DA to a string of two characters eg. 03 or 11 for March and November.

200 DA$=STR$(DA)

210 IFDA<10THENMID$(DA$,1,1)="0"ELSEDA$=RIGHT$(DA$,2)

220 RETURN

SR writes DN$ which is the file name to the file as an identity. Remember these files are going to be transmitted to another machine and for safety's sake the file name is embedded in the file. The file name is in the form T0905.ECR the T indicates year 91, 09 is September followed by day 5. The suffix indicates the data came from the ECR program

310 GOSUB200

320 CLOSE:DN$="T"+MO$+DA$+".ECR"

330 FWRITE DN$;DN$

340 RETURN

Here be treasure ie. the program proper starts here. Read and display heading and copyright.

1000 READPN$:READCR$

1010 CLS:PRINTPN$:PRINTCR$

Input month name and convert month name to month number.

1020 INPUT"MONTH 3 LETTERS";MO$

1030 MP=INSTR(1,MI$,MO$):MO$=MID$(MN$,MP,2)

Write date to file.

1040 INPUT"DAYNUM,HOUR";DA,HR

1050 GOSUB200

1060 GOSUB310

Add any comment to file. eg. weather conditions.

1080 INPUT"COMMENT";CO$

1090 FWRITE DN$;CO$ Input the time information.

1100 INPUT"MINUTE, SECOND";MI,SE

Put up headings and legend for data display.

1105 CLS:PRINTPN$:PRINTCR$

1110 PRINT@160," DAY HOUR MIN SEC

Get into bit sync with the clock.

Read the clock input and wait till it becomes zero.

1120 IFJOYSTK(0)THEN1120

Wait for positive going edge of clock pulse.

1130 IFJOYSTK(0)=0THEN1130

Put up legends

1140 PRINT@224,"MAX MIN CV MAXDIF"

Read Value of port connected to ECR.

1150 PV=JOYSTK(1)

The main loop starts here at line 2000

Wait for negative edge of clock pulse.

2000 IF JOYSTK(0) THEN 2000

Set the Dragon internal timer (50ths of a second) to zero.

2010 TIMER=0

Update and print the time on screen.

Note. £ signs should be hashes.

2020 SE=SE+1:IFSE>59THENMI=MI+1:SE=SE-60

2030 IFMI>59THENHR=HR+1:MI=0

2040 IFHR>23THENDA=DA+1:HR=0

2050 PRINT@192," ";

2060 PRINTUSING"## ## ## ##";DA,HR,MI,SE;

Check to see if a key has been pressed ie. user wishes to make a comment.

2070 IFINKEY$=""THEN2100

Read comment and write to file.

2080 PRINT@96," ";:INPUT"COMMENT";CO$

2090 FWRITE DN$;CO$

Jobs to be done every minute ie. seconds count = 0.

2100 IFSE<>0THEN2200

Print day, hour, minimum value of input, maximum value, maximium difference and make up data string

2110 PRINT@LN,DA;HR;MI;MX;MN;MD;

2120 EC$(EP)=STR$(DA)+STR$(HR)+STR$(MI)+STR$(MX)+STR$(MN)+STR$(MD)

2130 EP=EP+1

Hourly jobs ie. minute count = 0. Write data to file.

2140 IFMI<>0THEN2180

2150 FORI=0TOEP:FWRITE DN$;EC$(I):NEXT:EP=0

Write data to file.

Daily jobs ie. hour count = 0 midnight.

Open new file with new date.

2160 IFHR<>0THEN2180

2170 GOSUB310

Reset max, min, maxdif and increment screen display line number. 2180 MN=70:MX=0:MD=0

2190 LN=LN+32:IFLN>448THENLN=320

Every second.

Read the analogue input.

Z is a dummy to cause all ports to be read.

See note above.

2200 Z=JOYSTK(0):CV=JOYSTK(1)

Update max min and max difference values.

Then previous value is set to current value for next time round. 2210 IFMX<CV THEN MX=CV

2220 IFMN>CV THEN MN=CV

2230 CD=CV-PV:IFCD>MD THENMD=CD

2240 PV=CV Print values on screen. Hash signs again. 2250 PRINT@256," ";

2260 PRINTUSING"## ## ## ##";MX,MN,CV,MD

Now the tricky bit is to allow for the time taken by any of the previous activities. The object is to return to the start of the loop (line 2000) when the 50ths count is between 46 and 48. This to ensure that the loop starts by waiting for the clock pulse. If the timer has counted more than 50 50ths the seconds count is incremented and the timer correction count increased by 50.

2270 IFTIMER-CR>46THENCR=CR+50:SE=SE+1:GOTO2270

2280 IFTIMER-CR<48THEN2280

Finally reset the time correction counter and return to start of loop.

2290 CR=0:GOTO2000

PARTS LIST

Breadboard. Any good quality breadboard. Being mean we use a Euro Breadboard from Maplin (YR83E) and cut it down the middle with a hacksaw so that we have two!

MISCELLANEOUS

SK1	TV socket chassis mounting. If an insulated one is obtained there is no need for the insulation shown in Fig 9.
SK2,3	Connectors of type required to connect to meter or micro. I use a 3.5mm jack socket.

RESISTORS

R	100M resistor see text.
R1	10k trimmer. See note below.
R2	1M variable. See note below.
R3	10M.
R4	1k.
R5,R6	1M.
R7	47k.
R8	250k variable.
R9,R10	10k.
R11,R12	2k2.

CAPACITOR

C1	47-100p. Preferably air spaced trimmer, alternatively fixed polystyrene 47p.
C2	1µ metallised polyester.
C3	100n metallised polyester.

SEMICONDUCTOR

IC1,2	CA3140 FET op-amp.

NOTES

The values given for R1 and R2 allow for experiment. In our "Standard device" the values are 5k fixed for R1 (a pair of 10ks in parallel is most convenient) and 1M fixed for R2.

None of the components are at all special, except if C1 is air-spaced, and are readily obtainable eg. from Maplin.

AMSTRAD PORTABLE PC'S FROM £149 (PPC1512SD). £179 (PPC1512DD). £179 (PPC1640SD). £209 (PPC1640DD). MODEMS £30 EXTRA.NO MANUALS OR PSU.

HIGH POWER CAR SPEAKERS. Stereo pair output 100w each 4ohm impedance and consisting of 6 1/2" woofer 2" mid range and 1" tweeter Ideal to work with the amplifier described above. Price per pair £30.00 Order ref 30P7R

2KV 500 WATT TRANSFORMERS Suitable for high voltage experiments or as a spare for a microwave oven etc. 250v AC input. £10.00 ref 10P93R

MICROWAVE CONTROL PANEL. Mains operated, with touch switches. Complete with 4 digit display, digital clock, and 2 relay outputs one for power and one for pulsed power (programmable). Ideal for all sorts of precision timer applications etc. £6.00 ref 6P18R

FIBRE OPTIC CABLE. Stranded optical fibres sheathed in black PVC. Five metre length £7.00 ref 7P29R

12V SOLAR CELL. 200mA output ideal for trickle charging etc. 300 mm square. Our price £15.00 ref 15P42R

PASSIVE INFRA-RED MOTION SENSOR. Complete with daylight sensor, adjustable lights on timer (8 secs -15 mins), 50' range with a 90 deg coverage. Manual overide facility. Complete with wall brackets, bulb holders etc. Brand new and guaranteed. £25.00 ref 25P24R

Pack of two PAR38 bulbs for above unit £12.00 ref 12P43R

VIDEO SENDER UNIT Transmit both audio and video signals from either a video camera, video recorder or computer to any standard TV set within a 100' range! (tune TV to a spare channel). 12v DC op. £15.00 ref 15P39R Suitable mains adaptor £5.00 ref 5P191R

FM TRANSMITTER housed in a standard working 13A adapter (bug is mains driven). £26.00 ref 26P2R

MINATURE RADIO TRANSCEIVERS A pair of walkie talkies with a range of up to 2 kilometres. Units measure 22x52x155mm. Complete with cases. £30.00 ref 30P12R

FM CORDLESS MICROPHONE. Small hand held unit with a 500' range! 2 transmit power levels reqs PP3 battery. Tuneable to any FM receiver. Our price £15 ref 15P42AR

12 BAND COMMUNICATIONS RECEIVER. 9 short bands, FM, AM and LW DX/local switch, tuning 'eye' mains or battery. Complete with shoulder strap and mains lead NOW ONLY £19.00!! REF 19P14R.

WHISPER 2000 LISTENING AID. Enables you to hear sounds that would otherwise be inaudible! Complete with headphones. Cased. £5.00 ref 5P179R

CAR STEREO AND FM RADIO Low cost stereo system giving 5 watts per channel. Signal to noise ratio better than 45db, wow and flutter less than .35%. Neg earth. £25.00 ref 25P21R

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NICAD BATTERIES. Brand new top quality. 4 x AA's £4.00 ref 4P44R. 2 x C's £4.00 ref 4P73R, 4 x D's £9.00 ref 9P12R, 1 x PP3 £6.00 ref 6P35R

TOWERS INTERNATIONAL TRANSISTOR SELECTOR GUIDE. The ultimate equivalents book. Latest edition £20.00 ref 20P32R

CABLE TIES. 142mm x 3.2mm white nylon pack of 100 £3.00 ref 3P104R. Bumper pack of 1,000 ties £14.00 ref 14P6R

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FM BUG KIT. New design with PCB embedded coil. Transmits to any FM radio. 9v battery req'd. £5.00 ref 5P158R

FM BUG Built and tested superior 9v operation. £14.00 ref 14P3R

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SINCLAIR C5 MOTORS 12v 29A (full load) 3300 rpm 6"x4" 1/4" O/P shaft. New. £20.00 ref 20P22R.
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ACORN DATA RECORDER ALF503 Made for BBC computer but suitable for others. Includes mains adapter, leads and book. £15.00 ref 15P43R

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BARGAIN NICADS AAA SIZE 200MAH 1.2V PACK OF 10 £4.00 REF 4P92R, PACK OF 100 £30.00 REF 30P16R

FRESNEL MAGNIFYING LENS 83 x 52mm £1.00 ref BD827R

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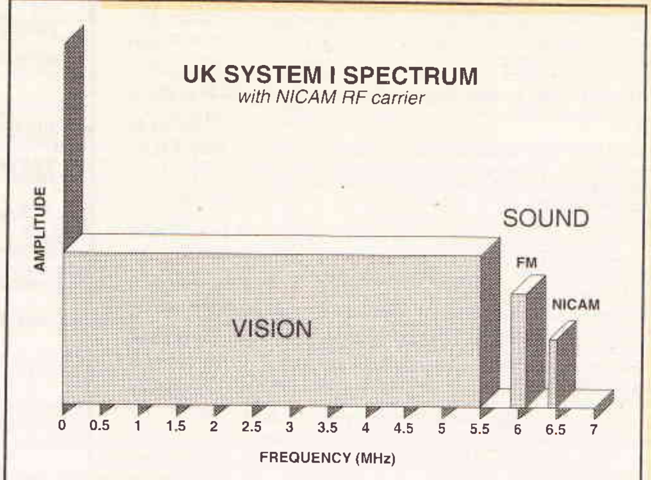


Fig.1 Showing how the NICAM sound signal is added to TV transmissions

RADIO

1

Digital Audio Broa

In the first of two articles, James Archer takes an in-depth look at Digital Radio Broadcasting.

It is not so many years ago that if you wanted the best source of high quality audio you tuned to the VHF/FM services of the BBC, and it was well known that Radio 3 in particular took a great pride in providing the best of classical music at the highest possible technical quality. Only the real hi-fi enthusiast who was prepared to spend hundreds of pounds on the most exotic turntable equipment could ever hope to better the sound quality available from FM radio, and even then it proved very difficult to keep vinyl records in top class condition for more than a few months. All this changed with the introduction of the Compact Disc system, which for the first time brought digital sound recording to any ordinary listener who was prepared to buy a relatively inexpensive CD-player. Compared with vinyl recordings, cassette tapes, or even reel-to-reel recordings, CD gave an immense and immediately noticeable improvement in sound quality, with a total lack of background hiss, due to previously unheard of signal to noise ratios, and a phenomenal dynamic range which could enable you to hear the most pianissimo of sounds as well as the loudest percussion, without distortion — provided that the rest of your system could cope, of course!

This meant that for the first time the average listener could now obtain better quality sound from his own digital Compact Disc equipment than could possibly come over the air from the broadcasters. Even though the broadcasters soon began to use CD players for their source equipment, and the links between the studios and transmitters have for years been carrying digital signals, there is no way of avoiding the fact that the quality of the transmitted signals must be degraded from that of the original CD because they must be transmitted over an FM analogue system that was designed and built a long time ago. Neither the signal to noise ratio nor the dynamic range of the broadcast analogue FM signals can compare with those of CD, and since there are already many millions of listeners equipped with standard FM receivers, it would not be sensibly practicable to change the transmission standard; various ideas for providing 'improved' FM signals have been put forward over the years, but in general they all suffered from the disadvantage that unmodified receivers would provide an output that was in some way distorted.

Television introduces digital sound

Television sound has always been of poorer quality than FM radio, but the last three years have seen the introduction of an extra digital sound carrier which is added to the existing TV vision and sound signals. This NICAM (Near Instantaneous Companded Audio Multiplex) system has brought high quality digital stereo audio to those who choose to buy new receivers, whilst still enabling existing receivers to receive the normal quality FM sound. The amount of digital data that is carried on the additional radio frequency carrier is 728Kbit/s, which is sufficient to provide two high quality audio channels, which can be used either for stereo or for two different languages to accompany the programmes.

Introducing digital sound radio

In an ideal world it might be thought possible to use a similar technique to add a digital sound signal on another carrier within the bandwidth of the FM radio signal, but in reality it turns out that there is insufficient bandwidth available. Figure 2 shows the baseband spectrum of a typical FM radio signal, and it can be seen that there is in fact an existing additional carrier at

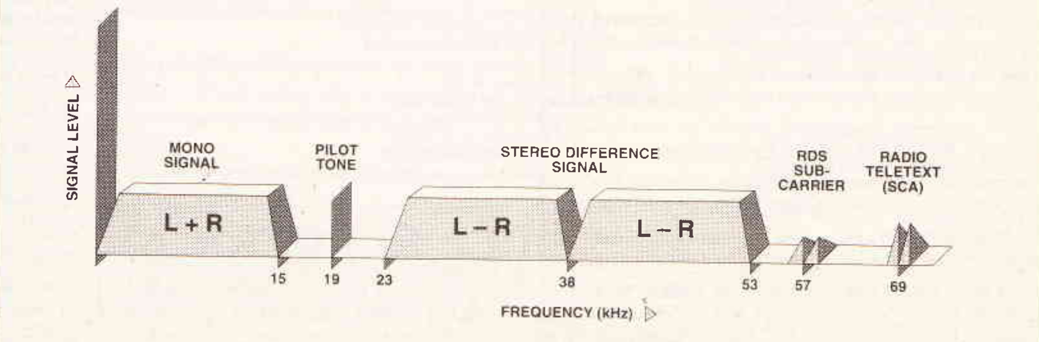


Fig.2 Baseband spectrum of an FM radio signal

57kHz, which is used for the Radio Data System transmissions which help listeners with special RDS receivers to make use of facilities such as automatic tuning and programme identification.

The amount of data that can be transmitted on the RDS carrier without causing interference to the main sound signal is limited to only about 1200 bits/sec, and even though it has also been found possible to carry some additional information for a Radio Teletext service on a third carrier at 69kHz, there is, unfortunately, nowhere near enough capacity for a high quality digital sound signal to be added as well. Since millions of listeners with existing FM receivers would be upset if they were told to replace these receivers with new ones, the only way that a digital sound radio service can sensibly be introduced is on a new frequency band, using newly designed equipment. This presents a wonderful opportunity for broadcasters to come up with completely new sound radio services of a quality better than anything heard before, and it is hoped that just as hi-fi addicts

dcasting

Fig.3 Flat-plate briefcase antenna

rushed out to buy CD players purely because of the improved quality which these gave, they will also be prepared to pay for new digital radio equipment. As with most new developments, different researchers and manufacturers have different ideas as to the best methods of providing a digital service, and there is still no agreement even on what might be thought of as the fairly fundamental point as to whether the services should be transmitted from satellites, and if so what kind of satellite, or from networks of terrestrial transmitters, or, as seems most likely, from both.

Radio from Satellites

All the high powered Direct Broadcast Satellites planned for European countries have the capability of carrying several digital radio services in addition to the normal MAC television pictures and sound, and the D-2 MAC system which France and Germany use for satellite broadcasting is capable of transmitting some 10.125 Million bits each second, in the absence of pictures, 9.576 Mbit/s of this being available for radio, which corresponds to about 13 stereo sound channels. The usual coding system for these FCDM (the Full Channel Digital Mode of the MAC family) transmissions uses 14/10 bit NICAM coding, similar to the NICAM sound system used for domestic TV in the UK, so it provides high-quality sound with a maximum bandwidth of around 15kHz, slightly less good than CD in theory, but in practice only the most 'golden eared' can hear any difference! The UK Marco Polo satellites, which are currently spinning around looking for a proper role in life after the ignominious failure of the UK DBS plans, use the higher capacity D-MAC transmission system which could provide twice as many digital radio programmes on each DBS channel, offering hi-fi buffs a real feast -maybe they should get together and make the ITC an offer it cannot refuse!

As an alternative way of providing even higher quality radio from DBS satellites, the Germans have developed a DSR (Digital Satellite Radio) system, which again can use some of the channels allocated for DBS TV, purely to carry large numbers of radio programmes. At the moment the fifth channel of their TV-SAT carries eight stereo programmes, but DSR can provide up to 16 separate stereo sound channels of CD quality, which are also extremely rugged and therefore well protected against transmission errors. This large number of channels could be sufficient to give European listeners in many countries a wide choice of listening.

Listeners currently wanting to make use of the DSR signals from the German Kopernikus satellite have to buy special receivers, which cost around £650, so it is not surprising that sales have been slow, although the German equivalent of BT, Deutsche Bundespost Telekom, feeds the digital radio signals into all the extensive cable networks so that any homes connected to cable systems can make use of these radio services. Twelve radio programme channels are currently available from Kopernikus, including three commercial channels, but there is much more capacity available if public demand should eventually make it commercially worthwhile to carry extra channels. A new lower cost DSR tuner has recently been brought out by a company called Technisat, and the company hopes that this will encourage new listeners to tune in, but even this costs around £300, so it is likely to appeal only to fairly well-off hi-fi fans.

The European Broadcasting Union recognises both the FCDM and the DSR standards, and suggests that DSR should be used when the predominant consideration is the transmission of a number of very high quality sound programmes over a wide coverage area, and that the FCDM mode of MAC should be used when broadcasters wish to transmit a flexible mixture of sound programmes and data broadcasts.

There are also several other different digital satellite radio systems in use around the world, including the MERIT EuroRadio system used for transmissions via Eutelsat Fixed Service Satellites (FSS), and Stanford Telecoms experimental 'CD-Radio', where every radio broadcast is 'frequency hopped' over a range of different frequencies at up to 2000 times per second, a system which is said to completely eliminate signal fading and to allow motorists to receive excellent sound signals in their cars.

Broadcasting satellites and FSS satellites do, however, suffer from one major disadvantage as far as sound radio is concerned; the fact that they operate on frequencies between 10.9 and 12.5 GHz in a geostationary orbit means that in general the signals will need to be received on a fixed dish of perhaps 30cm diameter. Whilst this is acceptable for television signals, which will generally be displayed on a large receiver and stays in one place, most radio listeners have become used to being able to listen to radio on the move, either from room to room in their houses, or when they are in the car, and the thought of lugging around and continuously repositioning a dish aerial is likely to deter all but the most fervent of hi-fi buffs!

Being close to the field of broadcasting research I thought that you might be interested in my newly-patented briefcase with inbuilt flat plate antenna, which might just make 12GHz satellite radio reception possible on the move!

In spite of this invention it has become apparent to most researchers that what is really needed is a frequency allocation for digital radio in a much lower frequency band. It might be ideal to use somewhere between 500MHz and 1000MHz, since good coverage with modest transmitter powers and small receiving aerials can be obtained — short stubby aerials rather like the ones used for cellular telephones would be quite acceptable. The problem is, that other services, including the aforementioned phones, all want a share of this useful band, and so broadcasters have reluctantly had to broaden their sights to look at the practicalities of using frequencies as high as 2500MHz or 3000MHz, and much hard negotiating is taking place with the European telecommunications regulators to try to find a suitable band. A World Administrative Radio Conference is due to take place in Geneva at the beginning of 1992, and the European Broadcasting Union, a professional association of broadcasters, has already started lobbying for a worldwide Digital Audio Broadcasting band to be allocated at around 1500MHz. It reckons that if a band at 2500MHz were allocated instead, then satellites would have to be four times the power and three times the cost of those for a 1500MHz service, and believes that this would put back the introduction of such services by ten to fifteen years.

A new approach for the 1990s — DAB — Digital Audio Broadcasting

Using some new techniques for digital radio transmission which have been developed over the last few years by a combination of European broadcasters and PTTs, a system with the name of Digital Audio Broadcasting, DAB, has recently been demonstrated, and this has the major advantage that it could be used equally well from satellites or from terrestrial transmitters.

As we have already mentioned, the nub of the problem with radio is that, unlike television, where the customer has been persuaded to accept that a fixed antenna is necessary, people want to listen to radio whilst they are on the move, either about their own homes, or whilst in their cars. Portable and car radios are therefore restricted to having antennas only three or four feet above the ground, which generally means that such aerials will pick up only a moderate amount of signal directly from the terrestrial transmitter and they will also be unable to avoid receiving signals which have been reflected from buildings and other large objects in the vicinity. These multi-path signals will have travelled to the receiving aerial over a longer path length than the direct signals, so that they will differ in phase, and the actual signal seen by the antenna will be the resultant of the algebraic addition of the various signals.

Normally this is a tremendous disadvantage, with the received signal going up and down in value as the mobile receiver travels over even a few feet, but using the DAB system, virtually perfect reception can be obtained under even the worst multipath reception conditions, and the reflected signals are actually made use of to improve the received signal. After the first tests using a mobile receiver were carried out by the French research organisation CCETT in Rennes in July 1988, initial demonstrations of the system were given to broadcasting engineers in Geneva in September 1988, using a UHF terrestrial transmitter. Further tests, by BBC Research Department from Crystal Palace at UHF, and later in Birmingham using Band III VHF, have confirmed that DAB can provide excellent reception at very low signal strengths, even in the presence of severe multipath interference.

DAB uses a combination of different techniques to provide its rugged signals, utilising the latest ideas in digital signal processing, bit rate reduction, and digital modulation.

Next month James Archer explains how DAB signals are put together, and shows that the latest in signal processing techniques can result in virtually perfect radio reception anywhere, whether at home, or on the move.

DAB (Digital Audio Broadcasting)

- A mix of new technologies
- Digital
- Bit rate reduction
- Data compression
- Audio masking

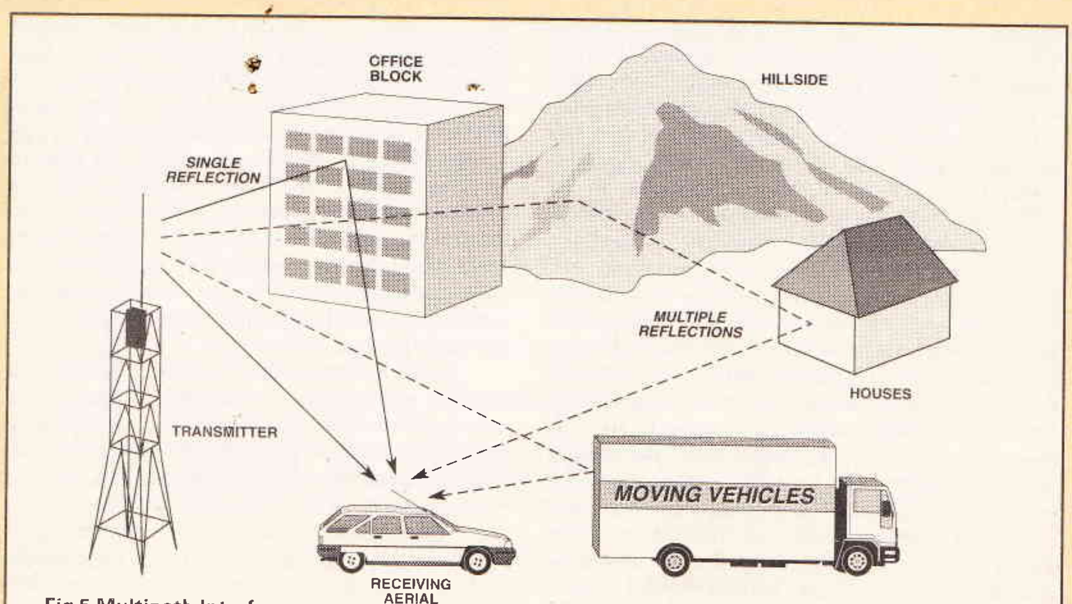
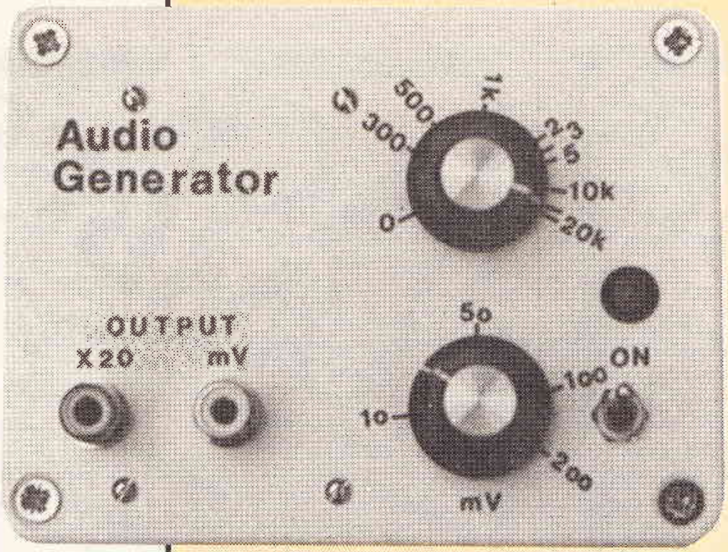


Fig.5 Multipath Interference

RADIO



Single Span Audio Sine Wave Generator

A miniature 20Hz to 20kHz voltage controlled signal generator using SMD construction by Bill Mooney.

A constant amplitude sine wave audio source was required which could be swept across the entire audio spectrum without switching and under voltage control. This was used to 'view' the response of audio filters on an oscilloscope by the addition of a suitable scanning voltage. The resulting circuit was very successful and the voltage controlled audio source is described here in the form of an excellent stand alone AF signal generator. It makes a very useful piece of test gear essential for anyone involved with the audio end of the spectrum. The quality of the sine wave is adequate for most purposes with a distortion level of around 1%. So how was this achieved?

As a radio amateur and short wave listener, I am used to tuning through the myriad of whistles on the short waves. These are caused by beating or mixing of RF signals with the receiver's BFO. It often occurred to me that this might be a good method of generating audio sine waves of reasonable quality. The RF source would of course be locally generated and not off-the-air. When the need for a scanning audio generator arose this was a method which had to be investigated and very successful it turned out to be.

Practical Circuit Design

The detailed schematic of the signal generator is shown in Figure 2. As can be seen the component count is quite low considering the complexity of the process outlined in the block diagram. The fixed reference oscillator is a standard colpitts circuit using a high gain FET, Q1. This is set to 1MHz and a 10p capacitor injects sufficient signal into the NE602 mixer IC1. The active device for the variable oscillator is contained within IC1 along with an internal buffer amplifier. Pin 6 and Pin 7 of this IC are connected to an external colpitts pair of capacitors C13 and C14 and form part of the tuned circuit around L2. The varicap diode D1 is a high value type and if the on board regulator is used as a source of tuning voltage for RV1. Its minimum capacity will be about 50p at 5V. Acceptable linearity was achieved down to about 1V when the capacity, on paper, is about 100p. With the component values shown a frequency change of 1MHz to 1.027MHz was achieved, producing audio from zero frequency to 27kHz. With a log law potentiometer for VR1 the scale is highly cramped at the 20kHz end but nicely spread out around 1kHz where most of the action is. The mixer is a balanced type and this results in very little RF signal at the output. Nevertheless an RC filter is necessary. This is effectively a 2 pole filter if the internal resistance of the mixer coupled with C11 and R3 and C17 are considered. An external potentiometer with a log characteristic serves as an output attenuator (RV2) covering over 40dB. The maximum level of audio is determined by the level of the reference oscillator signal reaching the mixer via the 10p capacitor C4, with values shown the maximum output was 300mV and it was possible to set the output pot to any value down to about 1mV. For accurate work a step attenuator could be substituted. For testing loudspeakers and systems which require a higher input than 300mV an audio power amplifier will prove invaluable. An LM386, IC2 serves to produce x20 amplification of the low level signal to a power suitable for driving an 8R loudspeaker. This amplifier is supplied directly from the battery supply and the level at which clipping occurs will depend on the state of the battery. IC3 is a low drop out, low current regulator producing 5V for the oscillators and the mixer. This will ensure stable performance right down to the last dregs of battery life. A NiCad or an alkaline PP3 size battery is ideal. The frequency response achieved is shown in Figure 3. The slight drop off at the high end is due to the closeness of the turning point of the output filter to 20kHz. The turning point of this filter could be increased and this device has the potential to produce supersonic signals if required.

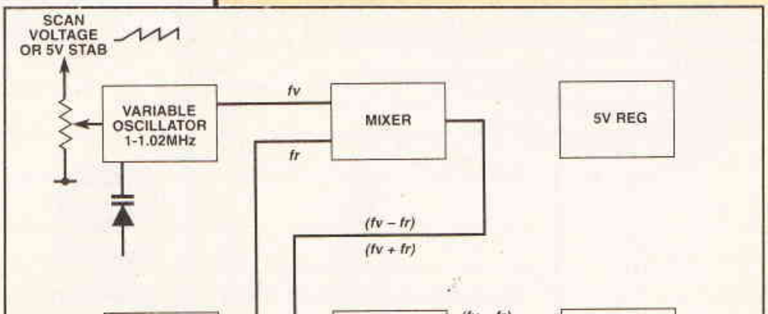


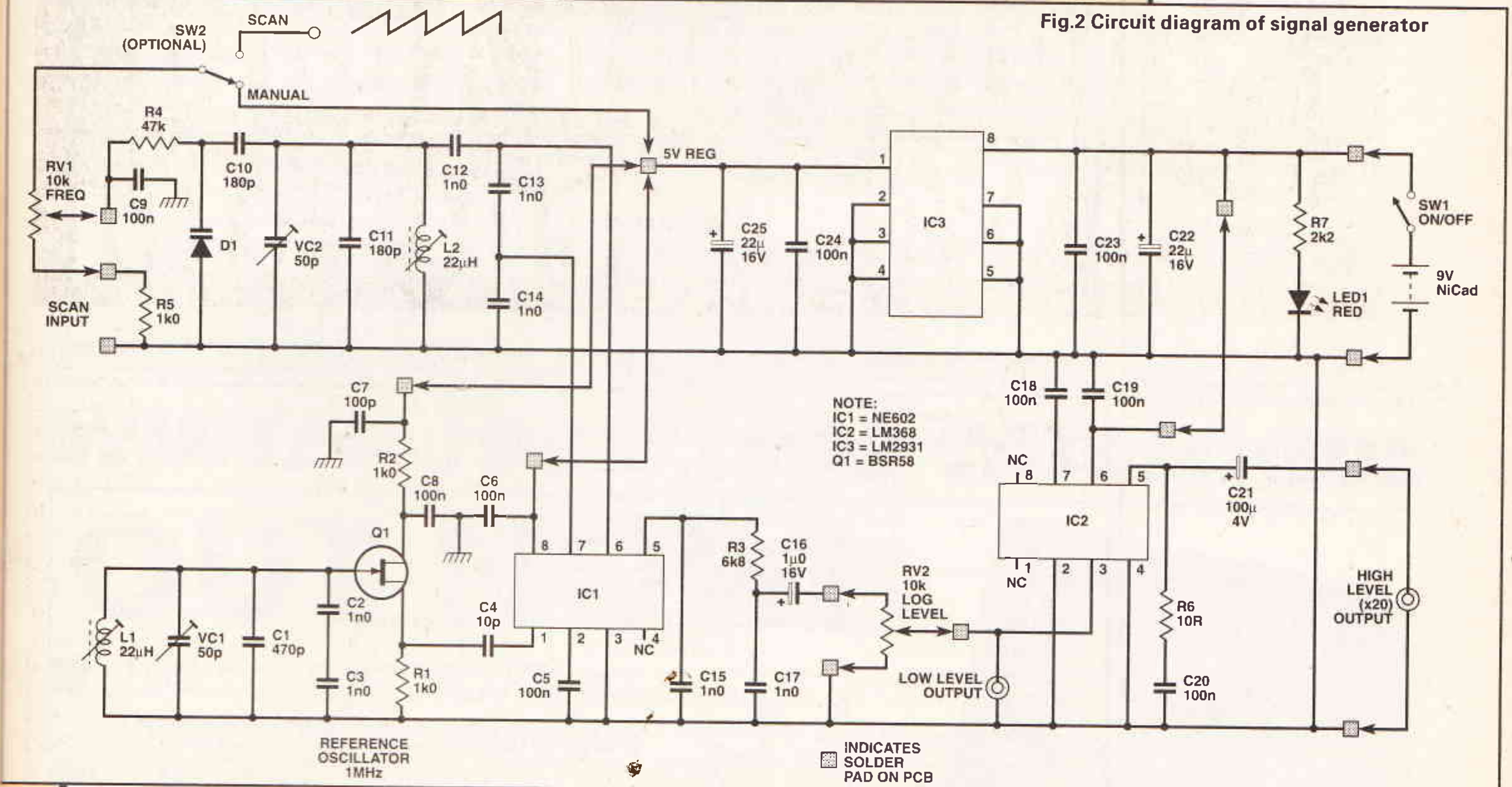
Fig.1 Block diagram of signal generator

Construction

The layout of any RF circuit should be considered carefully. With this circuit there is one area where great care is needed. It is imperative that there is no coupling between the RF oscillators. The Surface Mount layout shown in Figure 4 works fine but if you intend to design your own circuit L1 and L2 must be kept far apart. The effect of coupling is to cause severe distortion in the wave form below 1kHz and for the audio output to drop to zero below about 300Hz. The PCB foil pattern and component positions are shown in Figure 4. No attempt was made to miniaturise the circuit. Standard "1206" size SMD chips are used throughout and the layout is generous for ease of servicing and modifications. Double sided PCB is highly advised for SMD circuits as this ensures maximum stability. Single sided PCB tends to warp and puts strain on the chips. Double sided board also provides a ground plane/screen and this should be connected to the action-side ground tracks in one or two places, using Vero pins or wrap round wire links.

If you have not used SMD's before don't be afraid of them, they are very robust. The 1206 size resistors and capacitors are quite easy to manipulate and are therefore ideal for hand working. Many constructors find chip components more convenient to work with than leaded types since they are soldered directly onto the PCB. There is no need to turn the board over to solder them in or remove them. To solder a chip in place hold it down with a toothpick or use an Assembly Jig. Solder one end first so as to anchor it. The second end can then be soldered without holding the chip down. Use low melting point (LMP) silver loaded solder and use the minimum quantity to hold the chip in place. Look closely at the solder contacts at each end of the chip and make certain that they are properly wet by the solder. The IC's are similarly quite simple to solder in place. First anchor them by soldering any two diagonally opposing pins. Needless to say a fine tipped iron is needed but it should not be under powered. A rating of 12Watts is adequate.

Fig.2 Circuit diagram of signal generator



HOW IT WORKS

The block diagram of the resulting generator is shown in Figure 1. Two RF oscillators will be noted, a reference oscillator producing a signal Fr and a variable oscillator producing a signal of frequency Fv. When Fr and Fv combine in the mixer, sum (Fr+Fv) and difference (Fr-Fv) signals appear at the mixer output. Here we are interested only in the difference frequency. If 1MHz is selected for Fr and Fv is tuneable from 1MHz to 1.02MHz the difference output will be an audio signal in the range 0-20kHz. An increase in the frequency of the variable oscillator of 20kHz from 1MHz to 1.02MHz is a relatively small change and can easily be achieved by using a variable capacitance diode. Further the amplitude of the oscillator signal remains constant over such a small change and therefore the resulting audio signal will have constant amplitude.(Figure.3.) This small change in frequency is also linear with applied tuning voltage. The mixer output will contain a residual level of RF at the frequency of the two oscillators as well as mixer products. In this design therefore a simple low pass RC filter is included with a cut off frequency of 23kHz. At this stage we have some 300mV RMS of audio but in some applications a higher level is required so a x20 audio power amplifier is included which will deliver 0.5Watt in to 8R if needed.

PCB's for SM constructors are produced in the normal manner using photoresist and etchant. After etching, washing and drying the board it is a good idea to spray it with a light coating of solder-through lac-

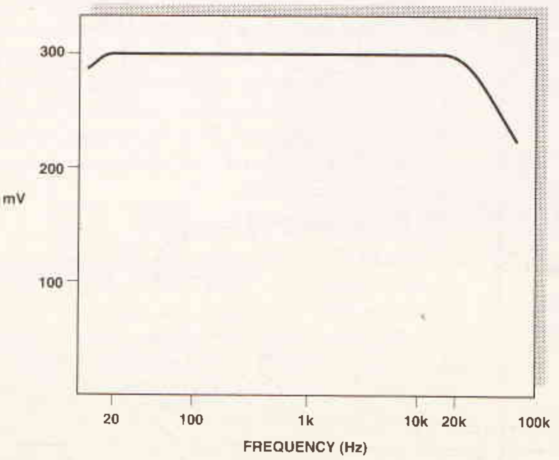


Fig.3 Low level output showing constant amplitude

quer and allow it to dry completely before population. This keeps the copper from tarnishing due to finger prints and atmospheric attack but more important it makes chip components easier to hold down since they don't slip as much as on bare copper.

There is no preferred order of placement of the SMD's in this project as there are no tight spots. But when placing a chip always make sure there is room for its neighbours. Tantalum capacitors have their positive end marked with a line, reversal will destroy them. Pin 1 on the IC is indicated by a chamfered edge. The pointed end of the type CTZ trimmer capacitors is the 'live' electrode. Connect this to the active part of the circuit to reduce hand capacity effects when setting up. Resistors are marked with a 3 digit code but capacitors are unmarked so must be kept in their marked packets until required as they all look alike and if you mix them up you will need a capacitance meter. The TOKO 5CD coils have three pins on the coil side and two NC anchorage pins on the other. It is important to solder the screening cans to ground. Finally, the circuit may be sprayed with a conformal or other coating to protect it once it is up and running. The resistor feeding the LED is made from a 1206 chip resistor with two short lengths of kynar connecting wire soldered to the ends, it is thus self supporting and soldered into the circuit as a normal leaded component might be.

frequency counter. Now get it on frequency using the coil L1 and the trim cap TC1. Connect the stabilised supply link to the mixer/variable oscillator, consisting of IC1. Check that the varicap diode, D1 is receiving a variable voltage of about 1V to 5V as the 'frequency potentiometer' is rotated. Again the frequency of this oscillator should be adjusted to 1MHz with the tuning pot turned almost fully anti-clockwise. Now check that the power amp, consisting of IC2, is taking about 3mA quiescent current when connected to the unstabilised supply. If this is the case, wire in the appropriate link. Connect an 8R loudspeaker to the output with the level control, RV2, turned down. The frequency of the variable oscillator should be adjusted for 'zero beat' using L2, TC2 at any time for scale calibration. At this stage the frequency range should be checked by turning the frequency controlled potentiometer towards the fully clockwise position. A good quality sine wave should be heard ranging from a few cycles to super sonic, setting the frequency control potentiometer to say about 1kHz and increasing the level control it should be possible to drive the power amp into clipping indicated by a harshness of tone, at about 100mV or around the 180° position. Obviously the clipping position will depend on the battery voltage and the device will normally be operated below the clipping level.

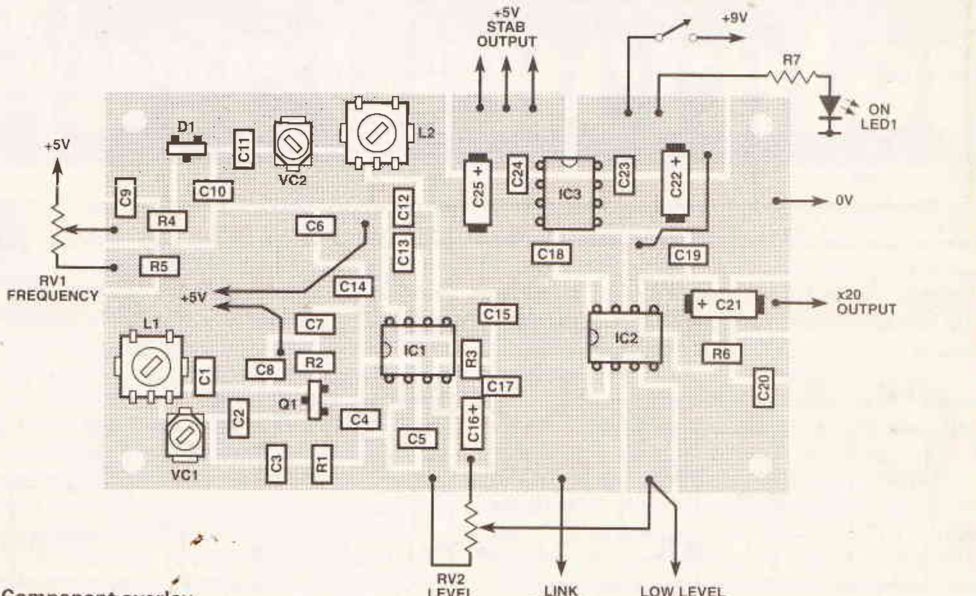


Fig.4 Component overlay

The signal generator is boxed up in a type B3B project box. The machine screws holding the lid on this box have brass inserts which won't wear out. This is important because the internal battery will need to be changed many times in the life of this instrument, and self tapping screws tend to wear out rapidly. At 12mA quiescent current an internal NiCad PP3 lasts some 10 hours at low volume which is very adequate for test gear, where use is more often intermittent. All working parts of this circuit are bolted to the lid of the project box, as shown in Figure 5. This means that there are no wires to bend and break off during setting up and adjustment or servicing.

Up And Running

With the PCB layout shown, wire links are used to supply stabilised voltage to the main functional sections, which can thus be isolated for setting up purposes. First of all check that the stabiliser is giving 5V. Next wire in the supply to the reference oscillator with a thin kynar wire link. Check that it is working by listening for the 1MHz signal on a medium wave receiver or using a

Calibration

For accurate work the device would normally be used in conjunction with a frequency counter and millivoltmeter. Also there will be considerable spread in the characteristics of varicap diodes and the frequency control potentiometers. For this reason a detailed calibration scale is not given and is probably not required. The prototype frequency scale was calibrated at 100Hz, 1kHz, 10kHz and a few interesting frequencies in between. If a log potentiometer is used for VR1 the interesting range around 1kHz will be well spread out and the 15kHz to 20kHz end will be cramped. The frequency change is linear with applied tuning voltage. A constructor may therefore choose a linear law potentiometer and get a linear frequency scale. Since the x20 power output clipping levels depending on the state of the battery it is more useful to calibrate the level potentiometer VR2 in terms of the low level output. The prototype instrument was marked at 10mV, 50mV, 100mV and 200mV. These are RMS voltages so don't forget the power amp must cope with the peak to peak value which is much higher for example 100mV RMS input will result in 5.6V PP which does not leave much headroom when the battery dropps to 7V.

An audio generator like this one will find many uses in any electronics workshop. This particular device is very versatile and the potential for automatic scanning is a real advantage. I used it with a linear ramp generator based on a 555 timer to plot the frequency response of a band pass audio filter. My scanner allowed the audio spectrum to be swept in a fraction of a second or over a period of 10 seconds. In any case it is great fun producing your own police siren effects and surprising just how piercing a ½ Watt of audio sine wave can be.

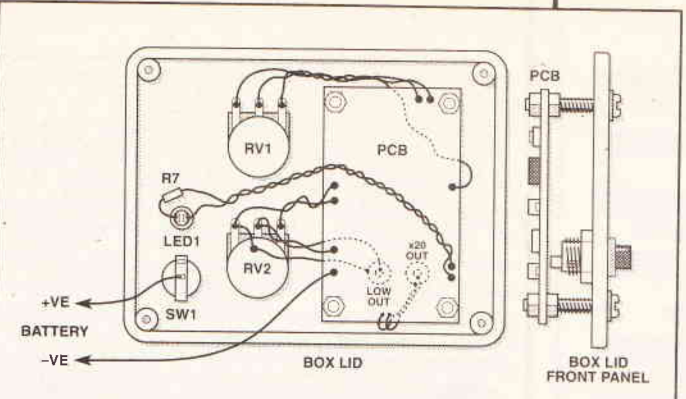


Fig.5 Placement of off-board components

PARTS LIST

RESISTORS

R1,2,5	1k0 1206 2% chip resistor
R3	6k8 1206 2% chip resistor
R4	47k0 1206 2% chip resistor
R6	10R 1206 2% chip resistor
R7	2k2 1206 2% chip resistor

CAPACITORS

C1	470p COG 1206 ceramic chip capacitor
C2,3	1n COG 1206 ceramic chip capacitor
C4	10p COG 1206 ceramic chip capacitor
C5-9	100n X7R 1206 ceramic chip capacitor
C10,11	180p COG 1206 ceramic chip capacitor
C12-15,17	1n COG 1206 ceramic chip capacitor
C16	1u 16V tantalum capacitor
C18-20	100n X7R 1206 ceramic chip capacitor
C21	100u 4V tantalum capacitor
C22,25	22u 16V tantalum capacitor
C23	100n X7R 1206 ceramic chip capacitor
C24	100n X7R 1206 ceramic chip capacitor

TRIMMER CAPACITORS

TC1	10-50p CTZ type
TC2	10-50p CTZ type

SEMICONDUCTORS

D1	varicap diode type ZC836A SOT23 package
D2	standard red LED in holder (non SM)
Q1	BSR58 FET SOT23 package
IC1	NE602 SO8 package
IC2	LM386 SO8 package
IC3	LM2931 SO8 package

MISCELLANEOUS

L1,2	22µH type TOKO 5CD variable
SW1	miniature on/off switch
Box	plastic box type B3B (100×76×41mm)
Phono plug	2 × metal case

Intuitive Electronics

Mike Barwise encounters the problems of electrical resistance.

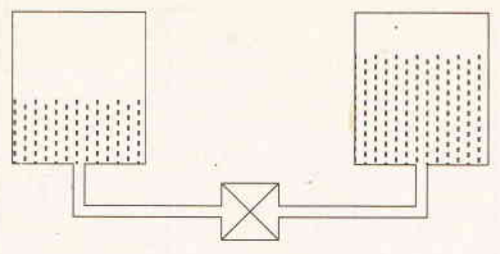


Fig.1 Equalizing tanks of water

Last month, we defined some terms of reference common to both plumbers and electricians. These were, Potential Difference or differential pressure, Charge or volume (quantity) and Current or flow rate.

While these definitions are quite crude, and could be faulted if we were inclined to be pedantic, they will serve for the most basic analysis of electronic systems. However, before we can go much further in our discussion of principles, we must develop a couple of additional basic definitions, LOSSES and RESISTANCE, which are in fact quite closely tied together.

At its most vernacular level, resistance implies that more than the expected effort is needed to accomplish something. For example, if your boss is resistant to the idea of your pay rise, you will have to argue a lot more before you get it: some of your effort is wasted or lost.

Superficial though this example is, it encapsulates the concept we are looking for; that of losses in a system.

Perpetual Motion

At least as long ago as Leonardo da Vinci, and sporadically since, people have tried to design perpetual motion machines: contrivances which operate for ever with no energy input after the first starting impetus has been supplied. Until the advent of the superconductor (more later), this was never achieved, and it is a moot point whether even the superconductor fulfils the brief. For now, let us consider the energy flow implications of the generalised perpetual motion machine. The first point to ponder is: can such a machine perform any useful work?

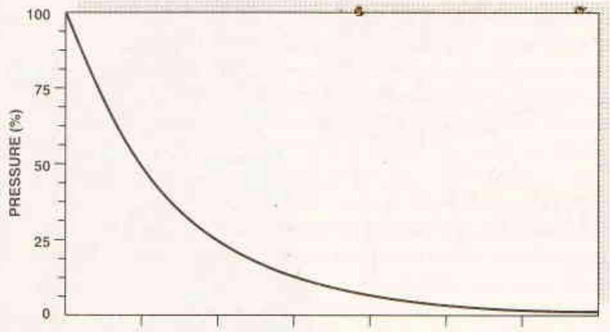


Fig.2 Pressure of water against time graph

Familiar machines range from coffee grinders and motor cars to washing machines and chainsaws, all of which have a fundamental property in common. They all act on the environment to modify it in some way. Whether coffee beans get mashed or your groceries get carried home, there must be a transfer of energy to the beans or groceries for the result to be achieved. This means a net loss of energy from the acting machine. A perpetual motion machine implicitly has no source of spare energy, so the perpetual chainsaw could not operate. However, there is a machine which is not required to perform any work in this manner: the clock.

If any of us can remember the old-fashioned clock with hands (!), we will also remember that it does no actual work (it does not act on the environment as does the grinder or the car). O.K., so it does have to find the energy to lift its hands against the force of gravity when they are in the left-hand half of the dial between 6 and 12, but when the hands are in the right half of the dial, they are falling and should recover this energy into the system. This means that the average energy lost is zero.

So, why do you have to wind the clock up? In principle, it should not need it, and it might not if the mechanism were perfect. Viewed under considerable magnification, every moving part of the real clock is imperfect. Each bearing surface drags a little, because it is rough. On an even smaller scale, the molecules at the surfaces of mating parts attract each other with forces which must be overcome by extra effort. The system has losses, and the excess effort is converted to heat. You may not believe it in the case of the clock, but we actually harness the concept of losses in an equally familiar system: the brakes on your car. The function of the brakes is to extract energy from the car, converting forward motion into something else. You've guessed it: heat. I don't think anyone would dispute that brakes can get hot, but it is a little known fact that the loadings on the bearings of a wristwatch are of the same order as those on the bearings of a bicycle! The absolute forces are much smaller, but so are the areas they act on.

While we are talking about heat, I will take the risk of being shot down in flames, and make a broad generalisation:

No energy conversion is 100% efficient, and a by-product of every energy conversion is heat. This means that a little bit more energy goes into every operating system than comes out as useful work, and the mechanism gets a little hot. This is really why perpetual motion cannot be attained. A continual top-up is required to counteract losses.

Funnily enough, were it not for the losses, many electronic systems would be impossible. However, some clever people have been working for the last 80 years or so on superconductors. These are special electrical conductors which exhibit no losses under suitable conditions. They have been proven to work: rings made of superconducting material have been transported long distances with electric currents circulating inside, and only when the current is measured is the energy of the system extracted. But... as usual there is a catch. Most superconductors must be kept at a ridiculously low temperature (in the region of absolute zero, the lowest temperature theoretically possible) to operate at all. In a way, this is cheating, as a very large energy input is required to the overall system which maintains these conditions. Such superconductors cannot, therefore, be considered as valid perpetual motion machines.

Resistance And Flow For Plumbers And Engineers

We discussed last month the general implications of the size of the pipe joining our two tanks of water. The larger the pipe, the quicker the two levels equalise. It follows that, for the same differential pressure, more water flows per second in the larger pipe: the larger pipe has less resistance to the flow of water. If we simply invert this argument, we see that, if the flow rate is maintained constant, a larger pressure differential appears across the smaller pipe. Whether the pressure differential, the flow rate or the pipe size is taken as the point of reference, the other two parameters remain in this relation to it. In principle, there is a simple proportionality between the three, so that pressure differential equals the product of flow rate and pipe size (area). In the case of real fluids, there are several complicating issues which change this a bit, but it's a good enough approximation for our argument. If you put your thumb across the end of your garden hose (an old gardeners trick), making the outlet smaller, the pressure in the hose rises, and you can generate a spray jet for watering the vegetables, but a smaller volume of water will pass through the hose.

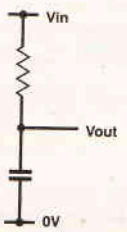


Fig.3 RC Network

From this analogy, we can go directly to the concept of the resistor in electronics. This is a device which limits current proportionally to the potential difference across it. The relationship between resistance, current and potential difference (frequently called voltage drop in this context) is just the same as for the water system: Potential Difference (Volts) = Current (Amps) x Resistance (Ohms). This relationship, which is fundamental to all of electronics, is described by Ohms Law, named after its discoverer, who also gave his name to the unit of resistance as a result. The current limiting effect is produced by the conversion of some of the input energy into heat (just like the car's brakes). The actual temperature rise will depend on the ratio of the rate of heating to the rate of cooling by radiation, convection and conduction. This is again no different from the water scenario. Water happens to be a very good dissipator of heat, and the order of pressures and flows you can control with your thumb is small, so the heating effect is not noticeable, but it's there all the same. In the case of the electronic resistor, there is frequently no doubt at all about the heating effect. The ordinary bathroom wall heater is in fact a resistor, specifically designed to get really hot.

Back To The Future

Returning to our two tanks (Figure 1), is there any way to predict how long it will take for a given level difference between them to equalise? Remembering that water is incompressible, we might think that a simple calculation based on volumes might work. It goes something like this: Let's suppose there is one gallon more water in one tank than in the other. The gallon has to flow through the pipe, which allows a flow rate of... Oh bother: that depends on pressure, doesn't it?

Let's start again. We begin from the assumption that the tanks are identical, and have parallel sides (they are cylindrical or cuboid). This means that the pressure difference between them is directly proportional to the difference in their water content.

At the moment the tap is opened (time T_0), there is a given pressure difference (dP_1) between the two tanks, and therefore across the connecting pipe. The resistance of the pipe is R. The instantaneous flow rate is therefore dP_1/R. However, a moment later, the pressure difference across the pipe will be less than dP_1 (as some water has flowed, so the levels are no longer what they were), so the flow rate will already be a bit less than dP_1/R. At some time after water started flowing (time T_1), the pressure difference across the pipe will be $1/2dP_1$, as half of the water will have flowed from one tank to the other. This will result in half the original flow rate. Later still (time T_2), the pressure difference will have halved again, so the flow rate will be a quarter of what it was, and so on. If we look at these time intervals, we find that the interval $T_{0\text{-}1}$ is equal to the interval $T_{1\text{-}2}$. If we were to note the time whenever the difference in level halved, we would see that all the time intervals were equal, and that the flow rate was constantly reducing. This leads us to the interesting conclusion that *the levels will never equalise.* How odd! In fact, the amount of water which has flowed between the two tanks after n intervals is the sum of the infinite series $1/2 + 1/4 + 1/8 \ldots + 1/(2^n)$, which never quite adds up to 1.

Variation of the differential level in the tanks (voltage), the differential volume (charge) or the pipe size (resistance) will affect the absolute duration of the time interval to achieve $1/2dP_1$ and subsequent equivalent changes (50% of previous pressure), but the nature of the characteristic (Figure 2) is inherent in the pressure/flow/pipesize (Volts/Amps/Ohms) relationship.

In practical terms, we can get near enough to full equalisation for the error not to matter. Supposing we need to be accurate to 1%, it will take seven intervals (whatever their absolute duration) for the levels in the tanks (the potential difference) to settle to this limit. To settle to 0.1% (1 part in 1000), it will take 10 intervals, to 0.01% (100ppm) will take 14 intervals, and so on. The extra time to gain each next decade order of accuracy gets longer and longer.

It is worth checking back to our analysis of the 'infinitely large pipes' which result in constant sea level (see part 1). The instantaneous equalisation of level in that argument would seem to contradict our results above, but it doesn't in fact. Given the Ohms Law relationship, the time interval for a pressure change of 50% is entirely dependent on resistance if all other factors are equal. An infinitely large pipe has zero resistance, so the time interval is zero. Multiply this by anything you like, and you still get zero. At the other end of the scale, the closed valve has infinite resistance, making the time interval infinite in duration, so the water levels stay put.

Radio Active

We have jumped about a bit between the wet and the shocking in this short tour of flow rates and resistance, but I hope the similarities are reasonably clear. In fact, we have done much more than immediately apparent: we have described the charging characteristics of a series resistor-capacitor circuit (Figure 3). Next month we will look at the capacitor in more detail. In the meantime, I would like to leave you with another, curiously similar, idea from an apparently unrelated field. The decay of radioactive materials (Radium, Uranium and so on) is measured in half lives: the time intervals required for half the mass of the material to break down. This seems from observation to be a valid measure, regardless of the starting mass of material.

ETI
ELECTRONICS
TODAY INTERNATIONAL

PCB SERVICE March

E9203-1 MIDI Switcher — Main Board L
E9203-2 MIDI Switcher — Power Supply .... E
E9203-3 Sine Wave Generator (surface mount) .... F

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

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

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

E8802-1	Electric Fencer	E
E8802-2	Telephone Intercom	L
E8802-3	Transistor Tester (2 bds)	L
E8802-4	Spectrum Co-processor CPU	N
E8803-1	Co-processor RAM board	N
E8803-2	Beeb-Scope (3 bds)	O
E8804-1	Spectrum Co-processor Interface Board	N
E8804-2	Combo-Lock	E
E8804-3	Kitchen Timer	E
E8805-1	Virtuoso 2U PSU	M
E8805-2	Virtuoso 3U PSU	N
E8805-3	Bicycle Speedometer	F
E8805-4	Dynamic Noise Reduction	E
E8806-1	Universal Digital Panel Meter	L
E8806-2	Universal Bar Graph Panel Meter	K
E8806-3	Virtuoso Power Amp Board	N
E8806-4	Virtuoso AOT Board	G
E8806-5	Metal Detector	E
E8806-6	Bicycle Dynamo Backup	D
E8807-1	Bar Code Lock (2 bds)	N
E8807-2	Analogue Computer Power Board	L
E8807-3	Bell Boy	F
E8807-4	Logic Probe	C
E8807-5	Updated FM Stereo Decoder	J
E8807-6	Breath Rate Display Board	F
E8808-1	Breath Rate Main Board	H
E8808-2	Breath Rate Switch Board	C
E8808-3	Telephone Recorder	D
E8808-4	Analogue Computer Main Board (2 bds)	M
E8809-1	Spectrum EPROM Emulator	M
E8809-2	Frequency Meter (2 bds)	P
E8809-3	Travellers" Aerial Amp	E
E8810-1	Gerrada Marweh Bikebell	E
E8810-2	Peak Programme Meter (2bds)	N
E8810-4	TV-to-RGB Converter	E
E8810-5	Electron RGB Buffer	C
E8811-1	NiCd Charger	E
E8811-2	Chronoscope (3 bds)	P
E8811-3	Digital Transistor Tester	G
E8812-1	Doppler Speed Gun (2 bds)	K
E8812-2	Small Fry Mini Amp	D
E8812-3	Thermostat	E
E8812-4	Burglar Buster Free PCB	D
E8812-5	Burglar Buster Power/relay Board	E
E8812-6	Burglar Buster Alarm Board	C
E8812-7	Burglar Buster Bleeper Board	C
E8901-1	EPROM Programmer mother board	M
E8901-2	Variat-Ion updated Main Board	H
E8901-3	Variat-Ion Emitter Board	E
E8901-4	In-car Power Supply	C
E8901-5	Granny"s Hearing Booster	E
E8902-1	Compressor/Limiter/Gate	L
E8902-2	Ultrasonic Horn	D
E8902-3	Stepper Motor Driver Board	L
E8902-4	Quest-Ion (2bds)	K
E8903-1	Intelligent Plotter Solenoid Board	H
E8903-2	MIDI Programmer	L
E8903-3	Balanced Disc Input Stage	F
E8903-4	Digitally Tuned Radio	G
E8904-1	Camera Trigger	E
E8904-3	Intelligent Plotter Main Board	O
E8904-4	Kinetotie Tie Board	N
E8904-5	Kinetotie Control Board	E
E8905-1	Guitar Tuner	H
E8905-2	Camera Trigger Ultrasonics (2 boards)	F
E8905-3	Bench Power Supply (2 boards)	H
E8906-1	PC edge connector	F
E8906-2	MIDI converter CPU	N
E8906-3	MIDI converter keyboard	N
E8906-4	MIDI converter control	M
E8906-5	AF signal generator	G
E8906-6	Mini bleeper	C
E8906-7	Caravan heater controller	G
E8907-1	MIDI Patch Bay	G
E8907-2	Priority Quiz Switch	E
E8907-3	Camera Trigger Infra-reds (2 boards)	G
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E8907-5	Aerial Amplifier power supply	E
E8908-1	Intercom master station	L
E8908-2	Intercom slave station	F
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E8910-2	MIDI Mapper	M
E8911-1	Smoke Alarm main board	F
E8911-2	Smoke Alarm power supply	F
E8911-3	Frequency Meter (3 boards)	O
E8911-4	Serial Logic Scope	L
E8912-1	Mains Failure Alarm	D
E8912-2	Surveilance PCB	D
E8912-3	Slide/Tape Synch	E
E8912-4	Pedal Power	L
E8912-5	Digital Noise Generator	K

E9001-1	20 metre Receiver	J
E9001-2	Wavemaker FG	L
E9001-3	Motorcycle Intercom	F
E9001-4	Low Voltage Alarm	C
E9002-1	EPROM Emulator	N
E9002-2	Superscope Mother Board	M
E9002-3	Superscope CRT Driver Board	K
E9002-4	Superscope Timebase Board	K
E9003-1	Superscope Y1 input board	J
E9003-2	Superscope Y2 input board	J
E9003-3	Superscope switch generator	E
E9003-4	Business power amp board	L
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E9003-6	Business pre-amplifier board	L
E9003-7	Water hole	G
E9003-8	Super Siren	D
E9003-9	Val's badge	F
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E9011-3	Infra-lock receiver	H
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E9112-3	Nightfighter Sensor Switch Sound Trigger	H
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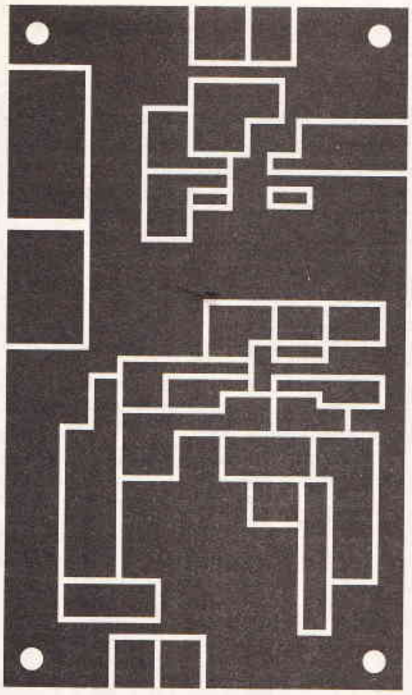


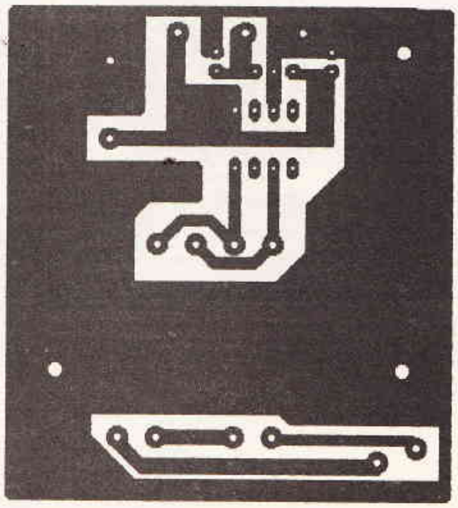
Single Span Audio sine wave generator (copper uppermost)

Freeze Arlarm Oct 91
In Parts List R2 should read 12k and R3 is a 2% resistor. R4 should be 6k8.

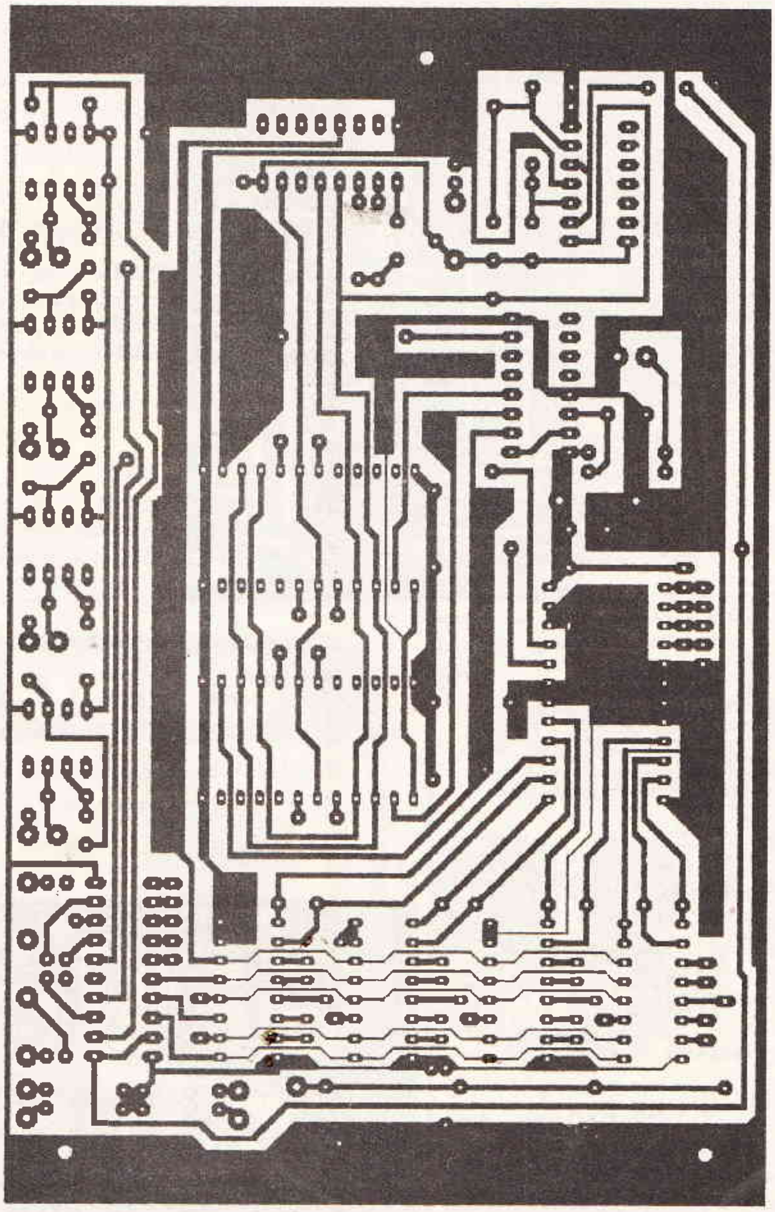
Op-amp Display Chart Dec 91
Column D should read 'Real OA'. In 6B the arrow for I_B current should be reversed. In 18D, fc_e should read fc.

Test card and Test pattern generator Part 1 Dec 91
In Figure 1, the Int Video Out signal should go to SK6 pin 19, not pin 9 as shown.

Part 2 Jan 92
In Figure 3, the Front Panel Design , two of the patterns around the Pattern Switch (SW2) are incorrect. The position shown as coarse checkerboard pattern should be a fine checkerboard pattern, and the fine checkerboard pattern should be solid black.
In the Parts List, C21 and C28 should be 220pF not 220uF, and C26 should be 220nF not 220uF.
150ns 27C128 EPROMs are not too easy to come by. Texas TMS27C128-25JL 250ns EPROMs work fine.
The Texas TM27C128-15JL as used in the prototype are available from STC Electronic Services, Harlow, Essex, Tel: 0279 626777, their Stock No is 044704H, price £3.61 each plus £1.90 p&p plus VAT. STC accept credit card orders (Access, Visa, Diners and Am-Ex) over the phone.



MIDI Switch — Power Supply



MIDI Switch —Main Board

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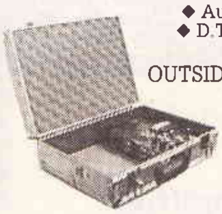

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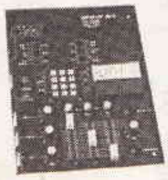

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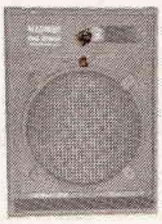

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ISSN 0142-7229

ABC Member of the Audit Bureau of Circulation

● Subscription rates — UK: £19.20. Europe: £24.90. Middle East: £26.80. Far East: £26.80. US$49.00. Cheques payable to A.S.P.

Published by Argus Specialist Publications, Argus House, Boundary Way, Hemel Hempstead HP2 7ST. Tel: (0442) 66551. UK newstrade distribution by SM Distribution Ltd., 6 Leigham Court Road, London SW16 2PG. Tel: 081-677 8111. Overseas and non-newstrade sales by Magazine Sales Department, Argus House, Boundary Way, Hemel Hempstead, HP2 7ST. Tel: (0442) 66551. Subscriptions by Argus Subscription Services, ETI, Queensway House, 2 Queensway, Redhill, Surrey RH1 1QS. US subscriptions by Wise Owl Worldwide Publications, 4314 West 238th Street, Torrance, CA90505 USA. Tel: (213) 3756258. Typesetting and origination by Ashford Scanning, Whitstable. Printed by Wiltshire Ltd, Bristol.

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NEXT MONTH

Next month we celebrate twenty years of existence. Our project line up lies within the audio scene. We bring you the much awaited John Linsley Hood Audio Pre-amp. This is designed to go with his updated 80 watt MOSFET power amp we published in May 1989.

Also we start work on our Audio mixing desk, a project that has to be the most complex and comprehensive mixer ever produced. A modular desk with programmable facilities the design will attempt to bring the most up-to-date in analogue circuitry.

A handy accesory for the car is the provision of automatic car lights, we have a circuit for that and a whole range of Solar powered circuits under our Tech Tips column.

Our features include an article on the alternative keyboard to replace the existing qwerty version and we continue our in-depth look at digital audio broadcasting.

For those wondering what sort of projects have appeared in ETI over the last 20 years, we are publishing a complete project index for you to select and buy any article you may have missed using our photocopy service.

The celebration issue of ETI appears in your shops on Friday 6th March.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

The February issue contained articles on:

- 20W Integrated stereo amplifier
- Mains switched timer
- Bootstrapping
- Introduction to Audio Mixers 2
- Comets
- Star-delta transforms

A supply of back issues are available from: Argus Subscription Services, ETI, Queensway House 2 Queensway, Redhill, Surrey RH1 1QS. Tel: 0737 768611.

ADVERTISERS' INDEX

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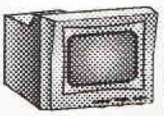

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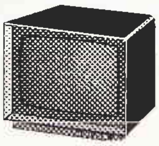

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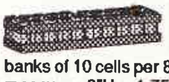

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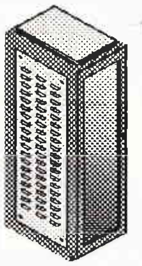

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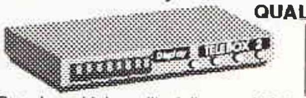

TV SOUND & VIDEO TUNER!

Brand new high quality, fully cased, 7 channel UHF PAL TV tuner system. Unit simply connects to your TV aerial socket and colour video monitor turning same into a fabulous colour TV. Dont worry if your monitor does'nt have sound, the TELEBOX even has an integral audio amp for driving a speaker plus an auxillary output for Headphones or Hi Fi system etc. Many other features: LED Status indicator, Smart moulded case, Mains powered, Built to BS safety specs. Many other uses for TV sound or video etc. Supplied BRAND NEW with full 1 year guarantee.

Telebox ST for composite video input monitors.........**£32.95**(B)

Telebox STL as ST but with integral speaker............**£36.50**(B)

Telebox RGB for analogue RGB monitors..................**£68.95**(B)

RGB Telebox also suitable for IBM multisync monitors with RGB analog and composite sync. Overseas versions VHF & UHF call. SECAM / NTSC not available.

BRAND NEW PRINTERS

TEC Starwriter Model FP1500-25 daisywheel printer renowned for its reliability. Diablo type print mechanism gives superb registration and quality. On board microprocessor gives full Diablo/Qume command capability. Serial RS-232C with full handshake. Bidirectional 25 cps, switchable 10 or 12 pitch, 136 cpl in Pica, 163 in Elite. Friction or tractor feed. Full ASCII including £ sign. Font and ribbon Diablo compatible........**£199**(E)

DED DPG21 miniature ball point pen printer plotter mechanism with full 40 characters per line. Complete with data sheet which includes circuit diagrams for simple driver electronics......**£49**(B)

Centronics 150 series. Always known for their reliability in continuous use - real workhorses in any environment. Fast 150 cps with 4 fonts and choice of interfaces at a fantastic price!

159-4 Serial up to 9.5" paper, fan fold tractor...............**£ 99.00**(E)

150-4 Serial up to 9.5" paper, tractor, roll or s/sheet.....**£129.00**(E)

152-2 parallel up to 14.5" paper, tractor or s/sheet.....**£149.00**(E)

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