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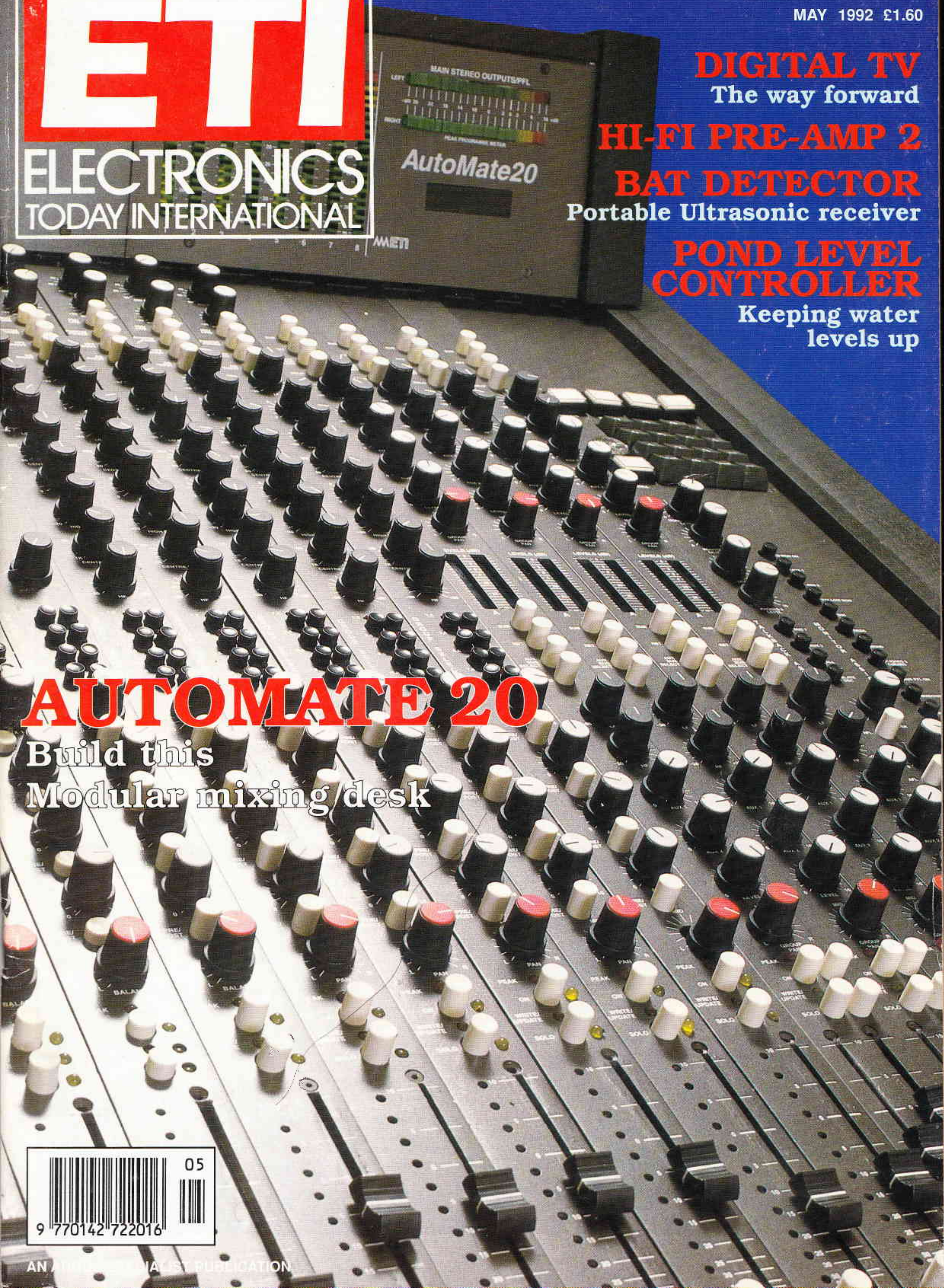

DIGITAL TV
The way forward

HI-FI PRE-AMP 2

BAT DETECTOR
Portable Ultrasonic receiver

POND LEVEL CONTROLLER
Keeping water levels up

AUTOMATE 20
Build this Modular mixing desk

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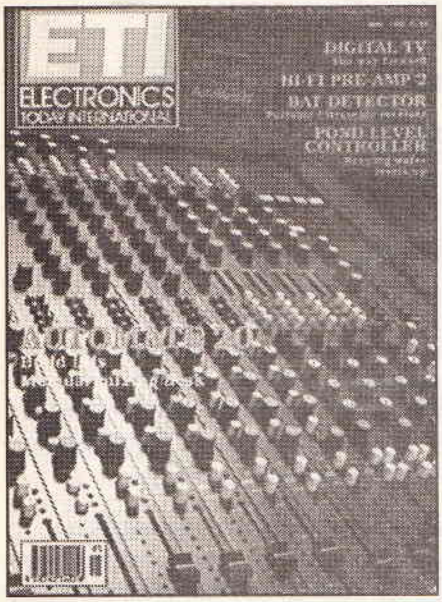

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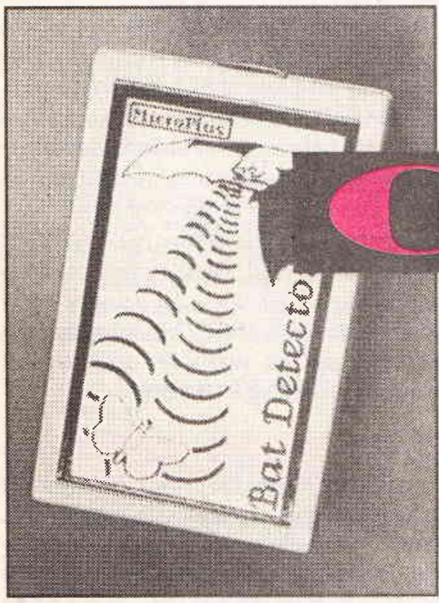
Features & Projects



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Editorial

By Paul Freeman

Welcome to our new look magazine. Looking through the contents you will see a Bat Detector project. This box will effectively extend our hearing into a section of the ultrasonic region.

Animals can hear in the ultrasonic region and even transmit frequencies above the audible spectrum.

Cats and bats have very similar shaped directional outer ears and respond to frequencies up to 40kHz. If the shape of the ear is an evolutionary optimum, one might question why it has developed into a pointed structure.

Evolution has appeared to provide a compromise between conflicting demands. A flexible structure is required to lower and flatten the ear when threatened from attack yet the surface should be hard and smooth to gain maximum directional reflectivity for the detection of the sound.

Physical laws of size says that smaller ear mechanisms such as in cats and bats will respond to higher vibrations. On this basis it could be argued that we humans in the stages of growth before birth are susceptible to ultrasonic frequencies. One wonders whether baby hears any of these frequencies from the ultra sound scanners which have become a standard part of the screening processes.

OPEN CHANNEL

Reports of the death of cable television are greatly exaggerated. I say this lightly, of course. Cable television operators — that is, the Government licenced franchise holders around the country, will go to great lengths to say cable television is far from dead. I suppose you could say, it's just hibernating — till the winter's over!

Cable operators have a basic problem, that in all but a couple of areas, systems can't start operating until cables have been laid. But the process of laying cables is both expensive and time- consuming. From starting to cable a franchised area to finishing it can take many years.

This gives franchise holders a high cash-flow hurdle. They need lots of capital to start the network and, possibly, it'll be years before they can generate sufficient revenue from customers to repay the capital.

A new system pioneered by Marconi Defence looks set to be able to help out here. It's called microwave video distribution system (MVDS). It uses small conical dishes mounted on rooftops, pointed at a central transmitter within the franchise area. The Marconi version looks set to work simply because it uses existing and cheap technology — running at 12GHz (the same frequency range current satellite receivers use) not at higher frequencies which had been promoted by some others.

The term pull-through is used to give an idea of how cable operators can use it. From very early on in the life of a franchised area, cable operators can sell the system to subscribers, on the basis that it gives 12 channels of television. It can be installed immediately — even if the cable network hasn't yet reached the subscriber's house. When, at a later date, the network has been laid far enough, the subscriber can take out the microwave dish and have the cable instead. So, MVDS metaphorically pulls the cable network through — hence the term.

For those cable operators legally able to use it (only some are licenced to use anything other than true cable!) it's a boon. Instant system, instant customers.

It Must Be A Good Idea, 'Cos Everyone Says It Is

I'm all in favour of research for research's sake, but a reported quote from the head of Taiwan's Industrial Technology Research Institute, 'takes the biscuit' as far as I'm concerned. He said 'We are not too sure whether there will ever be a market for high-definition television, but our ultimate aim is to develop it'.

Taiwan is spending $200 million over the next five years, simply to catch up with research already undertaken in Japan, Europe and the States. If they're not too sure whether it'll ever catch on why spend it? And if they are going to spend, why not spend an amount which will put them in the lead? To me, research is something you have to do to put you in front — not simply to copy others.

Meanwhile...

In Germany, the Deutsche Bundespost Telekom is proposing to spend some $500 million next year, purely on research into telecommunications systems. This is a considerable increase on amounts spent over previous years, and is a result of the Germans believing that telecommunications will account for about 7% of their gross national product by the end of the century.

Computers — Down In The Dumps?

Has the inevitable computer crusade come to its end? Do we all now have sufficient computers? Figures for computer sales in 1991 would appear to suggest so. For a start, worldwide sales of computers fell in 1991, for the first time in almost a decade. In fact, from the personal computer's entrance in the late 1970s to now computer sales have rarely been more lax.

This is demonstrated by trading figures for all (but one — see soon) computer manufacturers around the world. The Big Blue, for example, IBM recently had the big blues as it announced a loss of $2.8 billion (yes, billion, not million! for 1991. This compares with a profit of $6 billion for the year before. Other manufacturers are talking about losses too, phrases like the worst figures on record are being bandied about by many of them.

Overall computer sales worldwide fell by 8% last year, over the year before. And what's more, manufacturers alike are talking about this year being another tough one, even tougher than 1991. One manufacturer alone reported sales up last year over 1990: Apple reported an increase in sales, of over 10%.

Son of CT2

While telepoint has had a rough ride in the UK, it appears other countries may be about to make something of it. The old Zonephone telepoint network is being trialed in a number of countries worldwide, with the aim of installing complete systems. In Italy, there are 3000 handsets in 'use with a network comprising 400 base stations.

As you'll probably expect, these base stations and handsets are the very ones dismantled from the UK Zonephone service. Unlike our system, the trial stands every chance of working well because it overcomes the two main problems telepoint has in the UK.

First, there is only one system with one operator (not four, as we had here). Second, equipment has been modified to allow two-way calls (not the Government-enforced receive-only system we had).

Meanwhile Motorola is installing similar telepoint systems in the Netherlands, Singapore, Hong Kong, Thailand, Malaysia and China.

It's what I've always said — we invent the good ideas, the legislators cock'em up, and others take advantage.

Keith Brindley

ETI NEWS

FIRST LIVE HDTV SATELLITE BROADCAST IN NOMAC

It was in the early thirties that the Post Office and the BBC agreed the need for a Government committee to advise on the introduction of a high-definition television service and, interestingly, the term 'high definition' meant a standard of not less than 240 lines, a considerable advance on existing cathode ray tube (CRT) receivers based on a 30 line standard.

Following the publication of the Committee's report in January 1935, a trial BBC service was established in the London area from Alexandra Palace. Remarkably, the initial broadcasts switched between 405-line and 240-line transmissions on alternate weeks, and all receivers had to be convertable between the two standards.

Nearly sixty years on, Alexandra Palace witnessed yet another landmark in television history, as part of an international network showing the first ever large scale live satellite broadcast in 1250-line HD-MAC, the European standard for high definition TV. The event broadcast was the 1992 Winter Olympics in Albertville, France and, for the duration between 8th — 23rd Feb, Alexandra Palace was one of 50 European sites chosen to complete the satellite link. The Games appeared live in HD-MAC on widescreen TV.

Ferguson, selected Alexandra Palace as the ideal location for this demonstration of tomorrow's high definition technology at work today, because of the site's historic importance to the development of TV.

The event was shown on a Ferguson B86W 1250-line (ie HDTV compatible) wide-screen TV.

The technical feat involved in this, the world's first ever large scale live high definition broadcast was of mammoth proportions.

From a number of high definition studios and outside broadcast vans at Albertville, the signals were bounced off three satellites (Olympus, TVSat and TDF), and received at 50 international locations.

The signal received at Alexandra Palace was through a larger than usual TDF satellite dish, capable of handling the high definition information, and sent to the D2MAC tuner in one of the Ferguson B86Ws. From there, a baseband feed was taken to a separate HD-MAC decoder, with the resulting 1250-line signal fed out through a Golden Scart on RGB and separate horizontal (32kHz) and vertical (50Hz) sync. A relay system with repeater boxes enabled the RGB and mixed sync signal to be daisy chained to each of the B86W receivers being used in the demonstration.

The new 36" Ferguson B86W will spearhead a complete range of Ferguson wide-screen TVs with 16:9 aspect ratio screens.

BRIEFCASE OSCILLOSCOPES

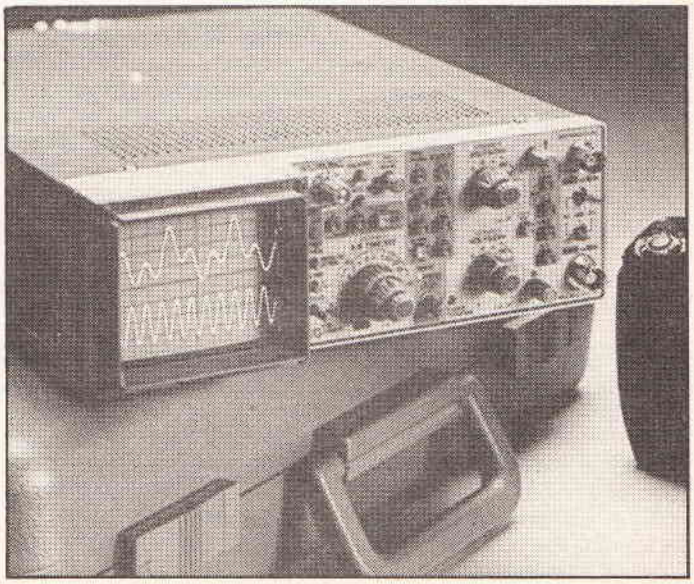
A range of highly portable oscilloscopes is now available from Thurlby-Thandar Ltd. Despite their compact size (230W X 75H x 290D mm) they provide a fully professional specification.

The 95mm rectangular CRT has 8 x 10 divisions (1 div =6.35mm) and either 2kV or 12kV acceleration potential dependent on model. Models with bandwidths of 60MHz (LBO-315/325) are available. All types feature TV-V and TV-H synchronisation for stable video waveform display enabling display of VITS signals for example. An ALT triggering function allows waveforms with no phase relationship to be displayed simultaneously. Complex video signals and digital word streams can be stabilised using the variable hold-off function.

The LC-2071 Ni-Cd battery pack is supplied as standard with the LBO-313 AND LBO-315. This is a 12V, 1.7Ah pack that can be charged during oscilloscope operation. The LBO-313/315 can be powered from the battery, by a DC voltage between 10 and 20V or by an AC voltage between 90 and 250V. No wiring change is needed for different AC voltages in this range.

Sensitivity may be varied between 5 mV and 5V/div over the full bandwidth. A X5 magnifier gives 1 mV/div sensitivity up to 5MHz.

A delayed time base is featured on the 60MHz models. Using the alternate sweep function the main time base (with intensified portion) may be displayed with the expanded B sweep. This allows a four trace display using both channels.



The LBO-315 (60MHz) costs £1595.00 plus VAT and the LBO-313 costs £1395.00 plus VAT.

INTEL AND SHARP FORM FLASH MEMORY PARTNERSHIP

Intel Corporation and Sharp Corporation has announced the formation of a long term partnership to jointly develop and manufacture future generations of flash memory products and technology. Intel, America's largest semiconductor company, supplies over 85% of the flash memory products sold in the world today, according to market research firm Dataquest. Sharp is one of Japan's leading manufacturers and suppliers of home and office information products, as well as a variety of audio-visual and communications systems.

The agreement calls for the two market leaders to combine their respective areas of technology, design and manufacturing expertise to foster greater flash memory market growth in both the portable computing and consumer marketplaces. The partnership will focus on joint design, manufacturing and process technology development of future high-density components based on submicron, eight-inch wafer processing.

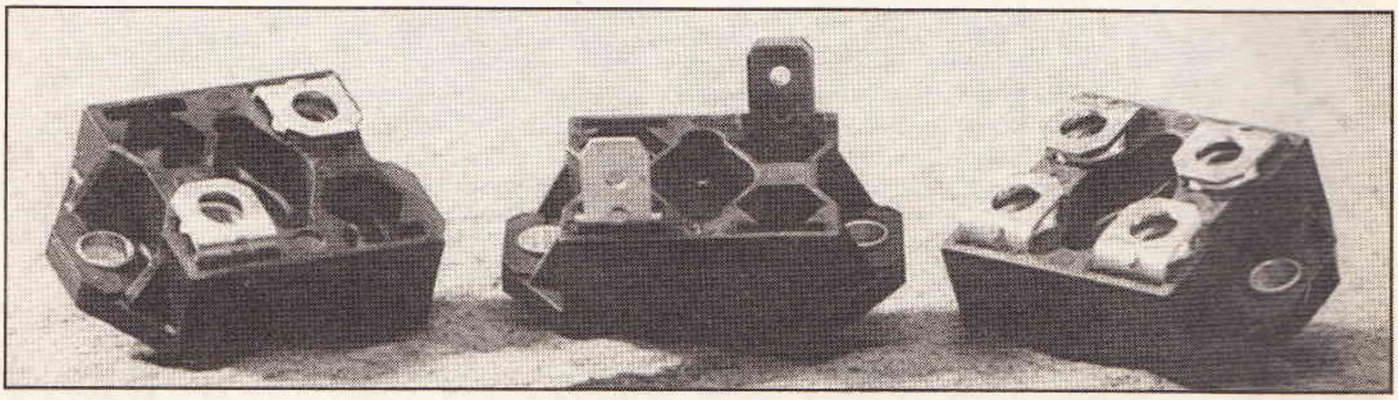
The partnership also allows Sharp to buy current flash memory products from Intel for use within its own products or for resale under Sharp's name. This arrangement allows Sharp to develop new applications for flash memory in its own consumer-oriented markets and to expand the base of products imported to Japan from the US. In turn, flash memories manufactured by Sharp will augment Intel's own flash volume production levels to meet the rapidly increasing demand of new and existing markets.

Flash memory is a high-density nonvolatile technology, meaning that it retains stored information even when the power is turned off. Further, flash can be rapidly erased and re-programmed electrically while in a system, hence the name 'Flash'. As a solid-state storage media alternative to disk drive, flash memory is well suited to an ever growing number of portable computing applications due to its cost effectiveness, reliability and performance. Sharp believes flash memory characteristics make it a vital capability for many future consumer oriented systems.

Dataquest projects the flash memory market to grow from approximately $130 million today to nearly $1.5 billion by 1995.

Intel is an international manufacturer of microcomputer components, modules and systems.

HIGH POWER RESISTORS



Affording excellent high heat dissipation, those lightweight heat-sink cooled resistors, use thick film technology bonded to a ceramic substrate.

The principle characteristics are:

Operating voltages	upto 1.5kV
Test voltage	2.5kV
Single shot	upto 4.0kV
Capacitance	36pF
Inductance	<50mH
Standard tolerance	10%

Produced in two versions (suffix F or V) denoting vertical or horizontal terminations, the Model 25 has a minimum/maximum resistance range from 0.33ohm to 1Mohm and a maximum power rating at 100°C of 50W. This is achieved in a size of 38 x 25 x 12mm.

The devices are suitable for semiconductor protection applications, including traction and HV switchgear.

Available from Cetronic Dynamics, the RCEC-ISO modules offer good volumetric ratio and tolerate close proximity coupling with semiconductor devices.

Effective cooling is maintained through either forced-air or re-circulated liquid cooling, determined by the thermal resistance of the heat sink.

For further information contact:

CETRONIC DYNAMICS LIMITED
Tel: 0920 871077

THE PC PRICE WAR

Competitive pressures and plunging margins will force more personal computing companies to develop innovative marketing strategies. Companies are already offering added-value products in the form of software/hardware 'bundles', extended guarantees, on-line help and staff training, according to a new report from Market Assessment on the Personal Computing sector.

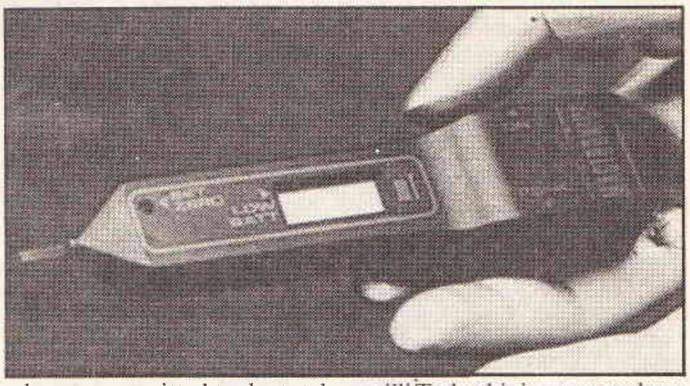
The market value for personal computers alone has nearly quadrupled since 1985. But a slowdown to growth of around ten per cent a year is forecast as the market matures and prices are cut. More powerful machines with higher specification (like extended memories and high-quality monitors) will be available at lower and lower prices.

And there's a similar picture in the £700m printers market, with manufacturers cutting up to one third off prices to maintain market share. However, market growth will keep well ahead of inflation because of the rising popularity of expensive laser, ink-jet, and twenty-four-pin dot matrix printers. In fact the volume share for laser printers shot up from just five per cent in 1985 to twenty-six per cent in 1990.

On the leisure side of the sector, there's been a boom in sales of home computers, video consoles and games. The 1990 and 1991 markets were undoubtedly boosted by new Nintendo and Sega consoles with very heavy promotional spends. Market Assessment predicts a buoyant future to the end of 1992 with no let-up in the Sega —Nintendo battle and an expected surge in PC games sales.

Overall, the future looks good for consumers, who'll find more powerful, sophisticated products are more affordable, with plenty of motivational extras.

MAGNETIC FIELD METER & POLARITY INDICATOR



Magtronics have introduced a new concept in the measurement of magnetic fields with their recently launched range of miniature field strength meters.

Applications for the new meters include monitoring the strength of permanent magnets, testing loudspeakers and DC Motors, checking computer disks for stray magnetic fields, or any material incorporating magnetically active components.

Three models cover the ranges 0-0.02 / 0-0.2 and 0-2 Tesla on a 3.1/2 LCD display. A peak hold facility is included for determining maximum field strengths. Made from impact resistant ABS, the battery powered instruments owe their small size to the use of surface mount technology.

They have been designed to safeguard the total quality requirements of technicians, production and Q.A. engineers and to meet a need for a low cost method of accurately doing so, with no sacrifice in performance.

The new field strength meters have been developed by Magtronics, the experts in the field, for magnetics specialists, in a wide range of industries, who are committed to the total quality concept.

Additionally, a polarity indicator is included in the range with a sensitivity of 9 — 5 milli Tesla: this is presented as a very inexpensive aid to the identification of polarity of permanent magnets, solenoids and relay cores.

THE DEMISE OF THE STEEL PYLON

It appears that nothing escapes the fashion catwalk of contemporary engineering design, for it was announced recently that the giant electricity pylons of old must go to be replaced by a more modern shapely equivalent. A product of electricity privatisation, the redesign prompts the demise of the original Meccano-type structures which bridge the gap from power station cross town and country to homes and business premises throughout the nation.

Since the formation of the national grid in 1935 the towers which serve to support the grids' high voltage lines have grown to keep pace with the power demands of consumers. Numerous advances have been made in structural design since the original pylon blueprint of the 1930s, a creation of the old Central Electricity Board.

A collection of several designs is to be assembled and placed before the National Grid Company, the newly formed establishment which inherited the majority of the national grid transmission system after privatisation. Current favourites include a rather elegant design; a folded plate column provides the foundation for three pairs of arms which support the six 400 000 Volt power cables — gone are the aged droopy arms, replaced now with upswept supports completing the neater pylon of the nineties.

Other contenders are variations on either the new design already mentioned or the seasoned steel structures of old. Whichever achieves the award of successor, it will be a long time before it becomes as familiar as its Meccano forefather, quashing fears of its effect on the nations countryside. Before replacement of existing pylons can begin, new stretches of the National Grid require attention — most notably the addition of the proposed 1800 MW power station at ICI's Wilton site in Teeside.

Steve Waddington

0898 TECHNICAL SUPPORT

Computer company Amstrad headed by Alan Sugar announced recently that they are to follow other companies by introducing premium rate telephone lines to provide technical support. Time was when only the perverted dialled 0898, however it soon became clear that people would pick up the telephone and pay 48p a minute to hear the latest cricket scores or daily horoscope. A portion of the call's cost on these lines goes to the information provider with British Telecom pocketing the rest.

Technical support lines have previously been available providing solutions for a relatively small cost to the user of a standard telephone call; costs to the company providing the information have proved highly expensive. Locoscript, another company having recently adopted premium charged technical lines were previously answering lengthy calls regarding their Wordprocessor package. Since the product retails at a cost of thirty pounds it was simply not financially viable to provide half an hour of technical support over the telephone.

Although customers are greeting the adoption of the new lines with reluctance, Amstrad are handling some twenty five percent more callers. The reason? Amstrad claims its because users are aware of the damage which their telephone bills would suffer if they talked too long. So increasingly people are tending to consult their manuals more carefully before reaching for the phone.

Reading the manuals before ringing is a good idea. However some of the manuals which currently accompany both hardware and software products are totally incomprehensible. In such cases it is surely unreasonable for a company to expect its customers to spend large amounts of money in order to receive solutions. Before calling BT engineers to switch over their lines perhaps companies should examine the manuals they provide; then there would be little need for such expensive after sales support.

Steve Waddington

JOINT 16Mb-DRAM MANUFACTURING

The agreement between Siemens and IBM for the manufacture of 16-Mbit DRAMs in France is proceeding according to schedule. According to a Siemens' spokesman, the production equipment has been set up and tested and manufacturing of the first eight-inch wafers began in December. First devices are scheduled for Spring 1992.

Data obtained from the first production run will be used to fine-align the production process and the 16-Mbit DRAM will be available in volume by the end of 1992.

The first product architecture will be 4M x 4 and will offer access times ranging from 50 to 70ns. It will be available in a 28/24-pin 400 ml SOJ plastic package and will consist of more than 35 million integrated components, with structure sizes as small as 0.5µm.

Further products will follow in 1993, including byte-wise organised memories (2Mx8, 1Mx16) and 16-Mb TSOPII housing.

Product enquiries to: Gordon Carmichael Tel. 0932 752630

NEW TRANSATLANTIC FIBRE OPTIC CABLE

BT has announced that a new transatlantic fibre optic cable, (TAT-9), is now in service. The cable, an undersea optical fibre network, links the United States, Canada, the United Kingdom, France and Spain.

The new 9,000 kilometre cable can carry the equivalent of 80,000 voice calls — twice that of TAT-8 — the first transatlantic fibre optic cable which was brought into service in 1988.

Mike Read, BT's Director of International Networks, said: "There has been massive growth in communications between Europe and North America in the past few years. TAT-9 is now essential to keep pace with the increasing flow of telephone calls, fax messages, plus video-conferencing and data communications.

The cable features 1.5 micron laser technology and strands of glass fibre which can provide 565 megabits of information over each of two working pairs of glass fibre. One additional pair is in reserve for restoration and maintenance purposes.

Landing points for the cable are in Goonhilly, Cornwall; Manahawkin, New Jersey; Pennant Point, Canada; St Hilaire, France; Conil, Spain.

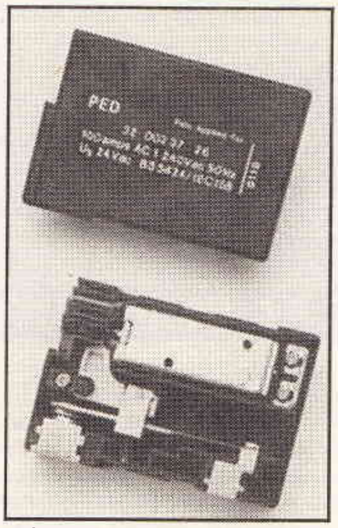
The cable is co-owned by 39 telecommunications operators. The major shareholders include BT, AT&T, Teleglobe and France Telecom.

POWER RELAYS

PED has announced the introduction of its Power Pulse Series 32, 100A power switching relay. The bi-stable design is compact and easily customised making it ideal for use in wideranging applications from energy management and domestic utility metering to process and industrial control.

The pulse operated compact design features single pole, single throw silver tinned contacts and is capable of switching 240V, 50Hz. Latching or monentary action designs are available.

Maximum switching voltage is 250V AC and maximum switching current is 100A AC or DC. Initial contact resistance is quoted at less than 0.5mΩ at 1A, 24V. Operating



voltages can be 6, 12, 24 or 48V as standard.

For further information contact PED, Tel: 0638 665161.

BR TELECOM PLACE OPTICAL FIBRE ORDER

BR Telecommunications Ltd (BRT) today announced it has placed an order for 200km of optical fibre cable from BICC Cables.

The cable will be used to extend BRT's existing optical fibre network, already in excess of 3,000 route km of optical fibre cable and representing over 28,000 km of cable.

The cable, consisting of 20 individual fibres, is scheduled for delivery over the next two months, for installation during 1992.

BRT has installed 650 km of optical fibre cable over the past 18 months. The cable is laid alongside the national rail network.

BRT's network is already the second largest fixed network in the country.

HITACHI FIRST WITH 1M EEPROM AT 3V

In another industry first, Hitachi has just introduced two new electrically erasable programmable read-only memory (EEPROM) products guaranteed for operation at a power supply voltage of 3.0V.

HN58V257 is a 256K bit device, and HN58V1001 has 1 Megabits of storage, and both are organised in the popular x8, byte wide, configuration.

Growing markets for hand-held computers and test equipment provide an increasing demand for devices operating from battery power. At the same time, the use of EEPROM as memory for retaining data and program information whilst the power is off is also increasing. Since EEPROM allows data to be erased electrically, devices need not be removed for this process and systems can also be accessed and reprogrammed remotely.

EEPROM offers the advantage over static RAM that it will retain data without the need for a battery back-up. Unlike FLASH EPROM, EEPROM does not require a separate higher (12V) programming voltage.

Manufactured in CMOS, the internal circuitry of the new devices has been optimised for 3V operation, enabling the operating power supply voltage to be qualified and guaranteed for the range 2.7 to 5.5 volts. Power consumption is low at 10mA (HN58V257) and 15mA (HN58V1001) — approximately 1/3 of the currents drawn by earlier 5V types. Access times are 250ns and 200ns respectively for the 256K and 1M devices.

New I/O circuits allow these devices directly to interface with CMOS logic ICs or ASICs, enabling further reduction in power consumption of surrounding circuits.

MANAGERS ARE SCARED OF COMPUTERS

Personal Computers (PC) are still regarded as glorified typewriters or calculators by the business community; over 50% of Britain's managers claim the most frequent use of a PC is for the production of documents. Although a central component to industry and commerce, 75% of managers say that they use computers directly in their work — of those only 8% are confident with the technology.

The joint Microsoft — British Institute of Management survey instigated earlier this year reveals a huge discrepancy between managers' perceptions of the benefits of Information Technology and the realities of its use. Three-quarters now rate IT as fundamental or important to their jobs. The advantages provided speed up basic tasks, enabling problems of hold to be attacked with ease. When questioned on whether they felt computers were becoming easier to use, surprisingly 90% said they were, citing user friendly software as the primary reason for this.

Yet the potential of IT is far from being realised; the capability provided by the current generation of computers is exploited only by a minority. Senior managers are petrified of computers, lack of training and the psychology fear of failing in front of staff and fellow colleagues leave the executive confined to a closed office complete with instruction manual through fear of humiliation.

Nor are managers using the PC to reduce their isolation. The free circulation of material is critical to business yet only 9% of managers use computers to share information with colleagues. Over a third use a stand alone PC solely for individual work.

A spokesperson for Business Industrial Management, a training consultancy which seeks to keep the business community in line with current computing trends, said "Many companies are losing out because of their reluctance to take advantage of IT. If money is to be committed to hardware and software then training must be considered too."

Steve Waddington

ETI NEWS stateside

Photoelectric joysticks

Photoelectric joysticks which use light to trigger electronic responses have replaced mechanical ones in applications that require high reliability because they do not have electrical contacts that can burn out. Most photoelectric joysticks, however, use return springs, ball joints, pivots, bearings, or other mechanical parts that both wear out and complicate manufacturing.

A recently patented photoelectric joystick, from Electronic Systems Design Inc., San Fernando, California, has a flexible shaft as its only moving part, so it is without the manufacturing problems of other joysticks,. The shaft is a heat-treated beryllium-copper alloy with a light-blocking commutator disc mounted to it. As the shaft is flexed, the disc interrupts light beams passing between LEDs and light-detecting phototransistors, triggering an electronic signal.

Since shaft movement is dictated by its length, diameter, and modulus of elasticity, it does not experience strain and thus always returns to the centre position without damage. Also, since shaft properties determine the force required to displace the joystick, by changing the material or diameter of the shaft, the force used to move the joystick can also be changed.

Fastest laser

Scientists at Cornell University have created a laser that switches at 28GHz, thus eclipsing the record 24GHz that had been accomplished by researchers at GTE.

Whereas GTE's device is a conventional semi-conductor laser, Cornell's is a strained quantum-well laser.

The Cornell laser is made of gallium arsenide and contains three or four quantum wells, 40 microns thick, that are doped with larger indium atoms. The indium creates a strain in the crystal lattice of the GaAs, and the strain makes the quantum-well lasers switch faster.

The researchers are now working to create a 44GHz laser that could be used in communciations systems. The atmosphere is transparent to radiation in that range. According to the Cornell researchers, the theoretical limit for such a laser is 60GHz.

Preventing video wobble

Professional film makers use a camera balancer to combat camera wobble but the cost of it makes it well out of reach of the average home-movie producer. Recently, the inventor of the professional-size balancer has developed a similar one for lightweight camcorders, and it is priced at just over $500.

The Steadicam JR, from Cinema Products Corp., Los Angeles, has a gimbal in its handle that separates shaky hand movements from the camera. The balancer also has a 3.5″ monitor that displays what the camera is filming. This not only keeps a person's face from bumping the camera, but also allows more freedom of movement.

The balancer can be installed in about 15 min. This involves adjusting the front to back and side to side balance of the camera so its centre of gravity is directly over the gimbal. Because the balancer folds up under the camera when not in use, it can easily be left attached to the cameras.

The Steadicam JR can be used with 8mm, Hi-8, and VHS-C camcorders weighing 3.5lb or less. The balancer weighs 2lb, including batteries that power the monitor and camera light.

More technology for the foot soldier

Although the foot soldier of today uses relatively low-tech equipment when compared with that found in fighter aircraft and tanks, by 1995 they may carry a 1lb, high-speed portable computer with much of the communications and graphics capabilities of more sophisticated systems.

Called the Soldier's Computer, it is being developed by Texas Microsystems Inc., at Houston, under a contract from the US Army's Communications Electronics Command.

One possible version includes a pocket-size, battery-operated processing unit. This would initially use Intel's 80386 architecture coupled with several attachments: a radio capable of transmitting both voice and data, a heads-up display mounted to the helmet or worn like glasses to project virtual images, a global positioning system for pin-pointing location, and a microphone and hand-held joystick.

The system could be used to view a real-time map showing positions of troops or features of the terrain. It could also be used for field maintenance by transmitting instruction manuals stored on a remote computer to mechanics in the field. Likewise, a soldier could capture and transmit pictures to off-site experts.

Research with lithium

Lithium has become a standard electrolyte for batteries in many portable applications, but the metal can cause problems for VLSI researchers attempting to build lithium power sources into integrated circuits. Lithium microbatteries are built by layering a lithium-based electrolyte film between cathode and anode films. To charge and discharge such a system, Lithium ions must migrate between the centre electrolyte film and the cathode. Cathode materials become unstable during that process, shortening battery life.

Researchers at Bellcore of Red Bank, New Jersey, have discovered a new material that may solve that problem. Experiments with Lithium Manganese Oxide as the cathode film show promising stability with high Lithium-ion density. The oxide lattice allows the Lithium ions to migrate while retaining its structure intact. So far, the researchers have demonstrated working micro-batteries that sustain up to 70 charge/discharge cycles at 4.1V without any degradation in performance.

READ\WRITE

ETI LETTERS

Audio Design Power Amp Mod

I described some modifications to the stabilised power supply for my 'Audio Design' power amplifier in ETI, May 1989, in which, amongst some other small modifications, I replaced the 'Darlington' bipolar 'pass' transistors, Q17/Q18 with power MOSFETs, mainly in the interests of greater ruggedness.

This entailed adding a zener diode, for over-voltage protection, between the source and the gate of each the 'pass' transistors, Q17 and Q18, and increasing the value of the gate/source resistors. Unfortunately, it appears from experience that I have not allowed enough 'elbow room' in the drive voltage, so that, in practice, some of the MOSFETs —especially the 'P-channel' ones, (2SJ49/50) — can current-limit, through inadequate drive voltage, and this can both limit the available output power, and/or cause the power supply to 'trip' prematurely.

I would therefore recommend that the values of D32 and D33 be changed from 4V7 to 10V, and that R23 and R24 be increased to 10k. This will avoid this problem. (The component numbers are those shown in Figure. 5, ETI, May 1989, page 29.)

John Linsley-Hood, Taunton

The Acousdix Bridge Amplifier

W Harms in his comments on the Bridge Amplifer (February 1992) is correct in terms of the pre-amplifier frequency response and indeed the original design had two 2µ2 in parallel for C3. However, the final design was based on a series of listening tests, bearing in mind the existence of spurious low frequencies from some versions of turntable and/or the occasional warped or slightly off centre record. These low frequencies can drive the amplifier and loudspeaker into non-linearity and the clarity of the Bridge Amplifier is such that the effects become audible. Obviously, with a top range turntable and loudspeaker system all low frequency time constants could be increased but this amplifier is intended to be at the budget end of the market.

Regarding G Daniels and absence of loudness controls in the more 'serious' amplifier designs, if the volume control is considered as a distance control, then only a flat frequency response is valid. For example, as you walk away from the source of sound and the acoustic level goes down, so the response of the ear attenuates both low and high frequencies and any readjustment to the intensity of these frequencies is then not true to life. There may however, be deficiencies in either the input transducer or the loudspeaker and in these cases a different approach to the tone control is required unless such correction is part of the design.

J F Dix, Weymouth, Dorset

Bridge Amp Not Available

We regret that we are currently unable to supply kits of the Acousdix BC 40 Amplifier. Unfortunately the response to the published article was very disappointing and the minimum order quantity that was viable for manufacture of the specially designed items (notably the case and the PCBs) has not been reached.

As a result we have had to very reluctantly turn away the few orders that we did receive and thereby disappoint the people concerned who were hoping to build this fine amplifier.

The first version of this amplifier that was offered for publication, consisted of four PCBs, a hand wired power supply, and a mass of screened cable signal input wires in a very cheap, small case. Subsequent demonstrations of the superior sound of the amplifier prompted a strong desire to produce a much higher standard of build quality, combined with ease of assembly using specialised components.

We certainly hope that anyone who is interested may get an opportunity to build and listen to an exciting amplifier whose performance compares very favourably with units that can be purchased in retail outlets at much higher prices.

Martech Systems (Weymouth) Ltd.

To enable readers to build the amplifier with the freedom to choose switches, case and input connectors, we will print copies of simplified PCB foils for the pre-amplifier (1 channel) and amplifier (1 channel) on the PCB foils pages next month.

UV Detecting Agency

I read with much interest the UV article published in the March issue of ETI and I must say that we have not come across any journalist who seems to have as much knowledge as Mr. Clarkson. It was enlightening not to have to read an article that just concentrated on one aspect of UV but to read an article that encompassed the importance of UV and its relevance in every part of life.

N.R. Grunfeld, Uvisol Ltd, Bourton-on-the-water, Glos.

I have for some time, as a rather unknowledgeable electronics enthusiast, been wishing to build a small UV detector, but armed only with Maplin and RS catalogues have not been able to get any further than the glimmer of an idea. It was with both relief and disbelief that I saw your article in ETI this month!

Please would you be able to 'point' me to the sources of either the components e.g. the G3614, or the completed units — so I can save myself a lot of effort!

Many Thanks.

D A Ellis, Shipston-on-Stour, Warcs.

Douglas Clarkson replies:

Here are details of the source of Hamamatsu UV diodes.

Address: Hamamatsu Photonics UK Ltd., Lough Point, 2 Gladbeck way, Windmill Hill, Enfield, Middlesex, EN2 7JA. Tel: 081 367 3560. Fax: 081 367 6384.

Item:	*Price (ex VAT)*
G3614	*£7.44*
G3614-01	*37.21*
Post and packing:	*£2.50 (ex VAT)*

Delivery 6 - 8 weeks

It is important to indicate with order the nature of application of sensor — e.g. educational, medical etc. Cheque with order is appropriate for private individuals — no credit cards.

There is a minimum order charge of £25.00 (ex VAT).

NTSC Test-card Generator

A Canadian constructor has requested an NTSC version of my Test card generator — what an interesting thought!

I've taken a quick look at the circuit and data sheets, and it should be possible to convert the unit. I trust our Canadian reader is fairly experienced and understands NTSC.

The main change will be in the EPROM data since there is 100 less lines (525 as opposed to 625).

IC9 (TEA2000) will also handle NTSC, pin 14 will need to be connected to 0V to select NTSC, and XTAL2 needs to be changed to 8.867238MHz. The delay line and chrominance filter are no longer needed anyway (see Update). IC10 (SAA1043) also has an NTSC mode, pins 5 and 6 low and pin 7 high. XTAL1 should be 5.034964MHz. All this info is in the appropriate data sheets. Any other changes should be relatively minor, a different modulator will obviously be required which may require some value changes in the video amps.

If the constructor contacts me via ETI maybe we can discuss a modified project for the American and Canadian market.

Paul Stenning, Hereford.

Earth Charge Recorder

Since writing the article about the ECR I have discovered a snag with the probe (ref Fig.12 in the second part of the article). It seems that after a few months exposed to the weather the GUARD RING generates a negative offset to the input voltage. This is because I used an aluminium plate and the guard ring was copper. Because of the way the input is arranged this negative offset will cause the input amplifier to bottom, ie. go as far negative as it can, under damp weather conditions. The cure is quite simple, OMIT THE GUARD RING and do not connect the screen of the coax to anything at the probe end. Providing the body of the probe is made from plastic items as suggested the insulation resistance is sufficiently high.

K. Garwell, Technical Director, Newchapel Observatory & Natural Science Centre, Stoke-on-Trent

Weather Report

With refernce to your Earth Charge Recorder in the March issue, I would like to mention several points raised by your article.

I am interested in the electrostatic effects of thunderstorms and their effect on the atmospheric charge on the earth and found your article both intersting and informative. I intend to build the high resistance voltmeter for assessment, intending to replace my existing field strength equipment built around my ZX81!

The circuit will also presumably work with slow field strength changes associated with thunderstorm activity.

An article on bad weather activity was published some time around Sept 1969 in Practical Electronics. It was Entitled "Thunderstorms" by M A Michaels. Perhaps Mr Garwell would be interested about this.

Anyone else out there who is interested in this fascinating branch of electronics, please contact me!

Leslie Crossan, Tyne & Wear

Send any communication via the ETI offices

Energy the Radar Mile

My records suggest that the velocity of light is now agreed to be 299791.56 km/sec in clear air. Most current mathematical tables give the measurement of one International Nautical Mile as being 1.852 km or 6076.115 ft.

Since a radar wave is presumed to travel at the velocity of light and radar measurements are taken in nautical miles, assuming clear air, we get a velocity for a radar pulse of 161874.4924 nm/sec.

To travel from a radar station to an object at one nautical mile range will take 6.177625548 µseconds.

Your writer Mr A. P. Stephenson has fallen in a trap set many years ago. We have Statute Miles, American Miles, Data Miles, and of course the Kilometre to measure the longer distances. The economy of using naval charts to navigate meant aviators learned to use nautical miles. Those who fly want those on the ground who control them to use the same standards, hence the use in radar of the International Nautical Mile.

Since no one wants to use 12.355251 µseconds as a standard when talking or making a quick calculation most use 12.36 µs for a radar mile, 6.67 µs for a radar km and 2 nS for a foot!

T. Grant, Bletchley, Bucks

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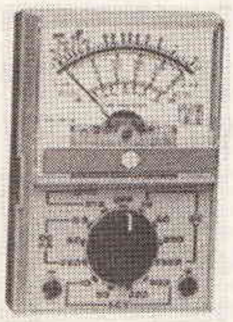
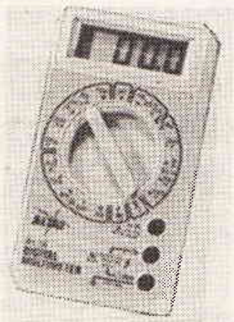
TEST AND MEASUREMENT





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2.2	—	—	£0.10	£0.10
4.7	—	£0.09	£0.10	£0.10
10	—	£0.12	£0.12	£0.12
22	—	£0.09	£0.13	£0.17
47	£0.10	£0.11	£0.16	£0.20
100	£0.10	£0.13	£0.21	—
220	£0.13	£0.18	£0.42	—
470	£0.21	£0.20	£0.69	—
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4030	£0.17	4515	£0.78
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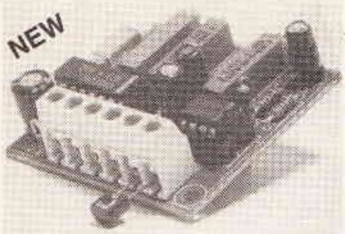

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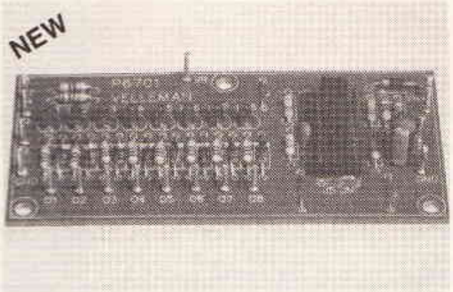
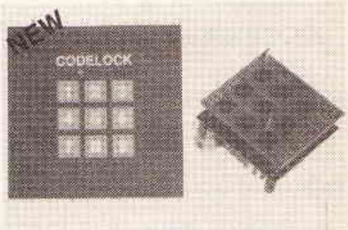
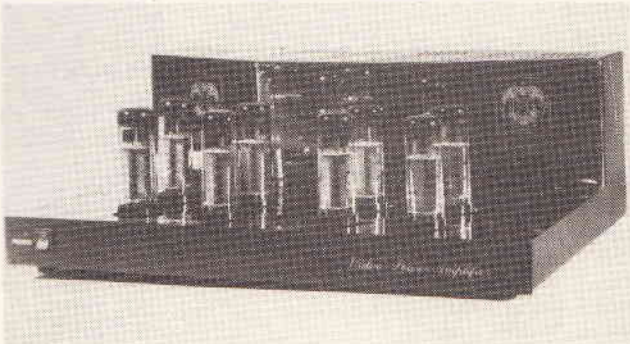


K6700: WIRE COMMUNICATION TRANSMITTER
K6701: WIRE COMMUNICATION RECEIVER

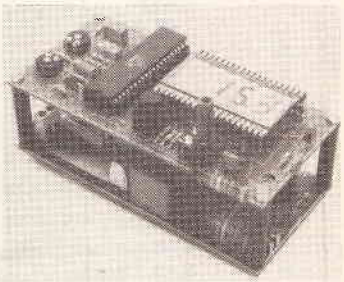


K6400 KEY CODE LOCK

K6002 uP TEMPERATURE CONTROLLER

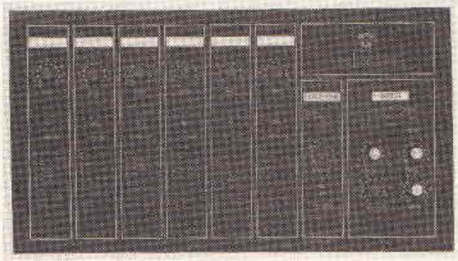


K4000 STEREO TUBE AMPLIFIER



K2649 THERMOSTAT

K2668 DUAL STEREO VU METER MODULE



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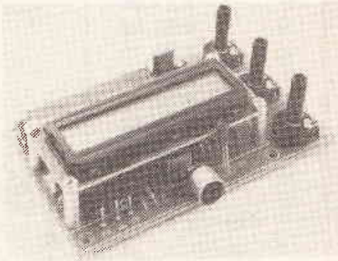
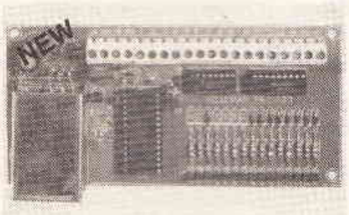


K2659 MORSE DECODER



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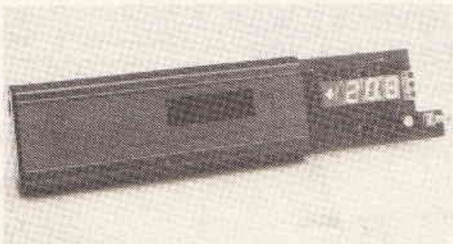

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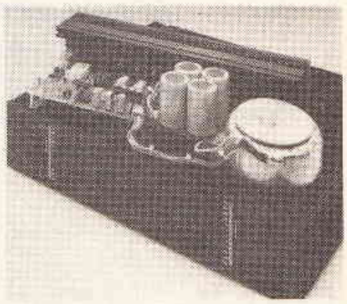

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E9201-5	Enlarger Timer Selector Board (double sided)	K
E9201-6	Enlarger Timer Switch PCB	E
E9202-1	Timer – Counter Driver (double sided)	F
E9202-2	Timer – Time Base (double sided)	F
E9202-3	Timer – Power Supply	C
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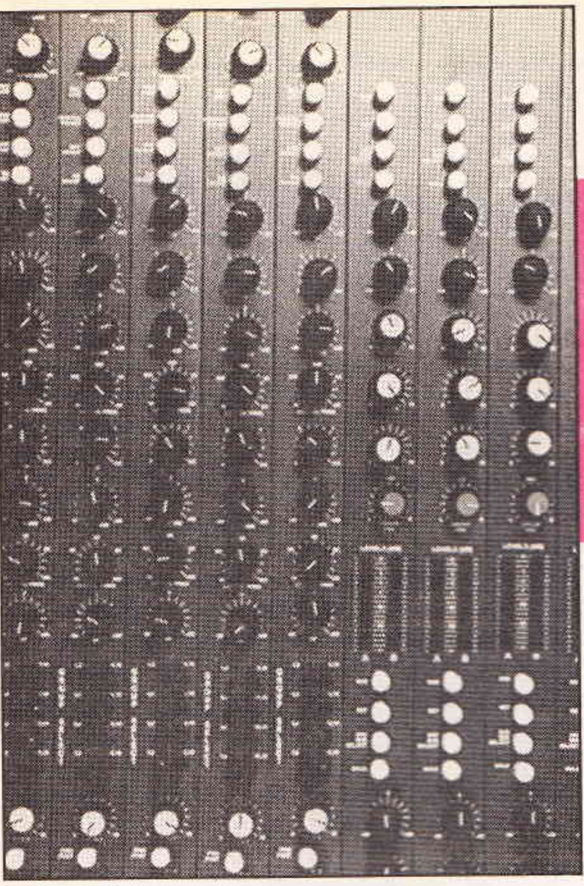


Anniversary Automate 20

2

Mike Meechan continues to explain the facilities available in this modular audio mixer.

Last month saw the introductory part of the magazine world's biggest ever mixer project, the Anniversary AutoMate 20. This is a mixing console of modular design philosophy allowing careful, cost-conscious tailoring to exact operational require-

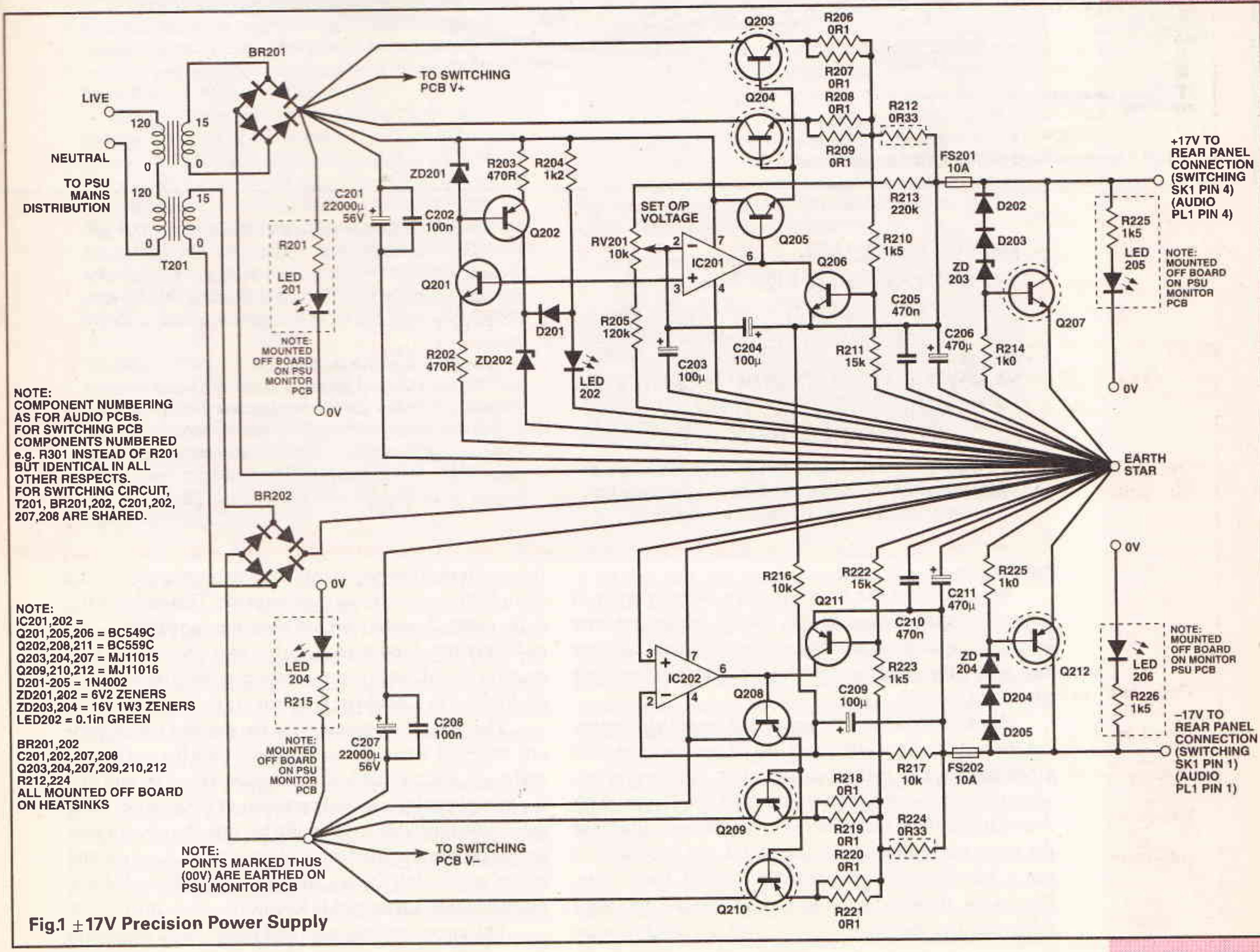


Fig.1 ±17V Precision Power Supply

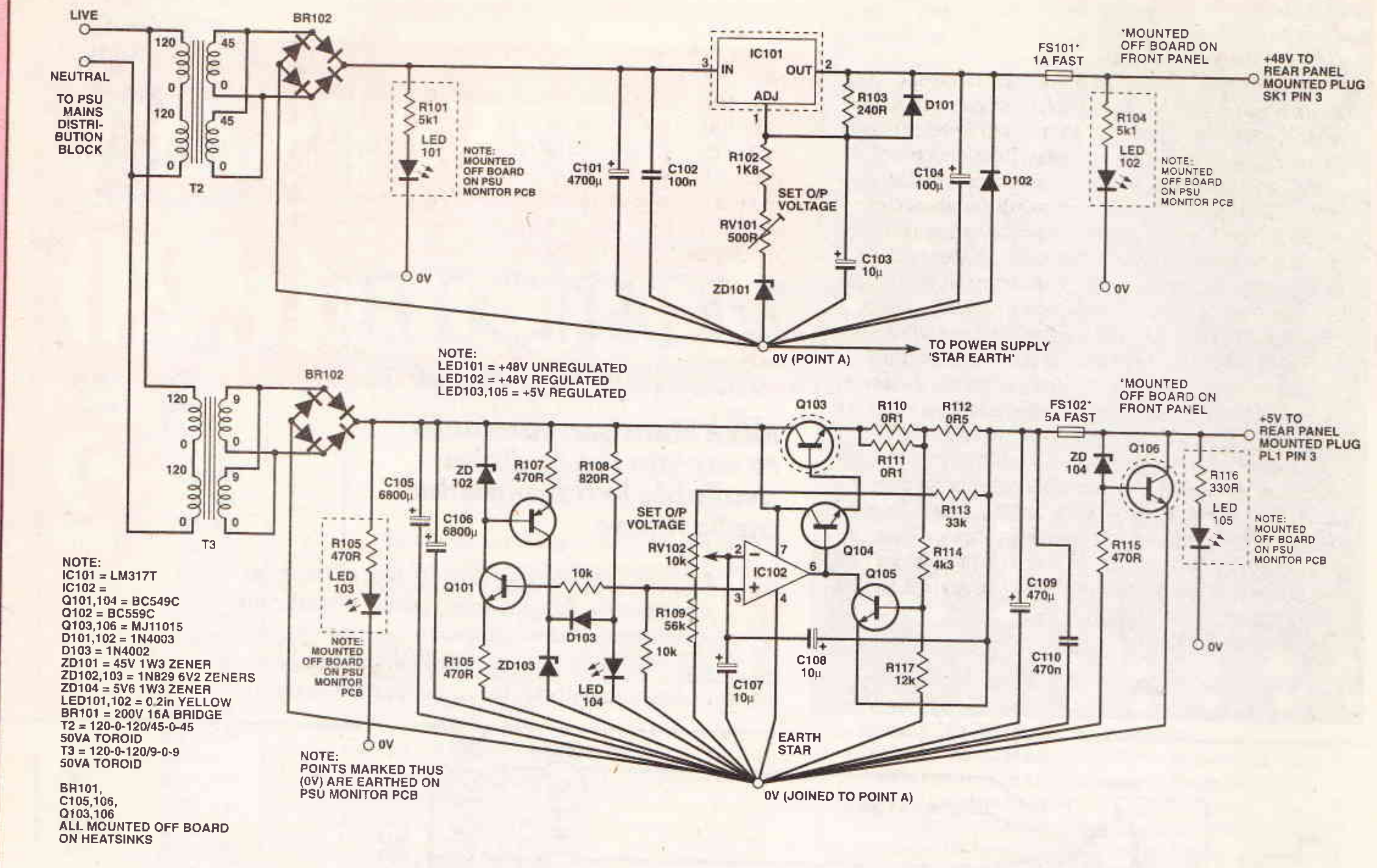


Fig.2 +48V Phantom Power Supply/5V Logic Supply

HOW IT WORKS POWER SUPPLY UNIT

Incoming 240V mains is transformed by T1, a dual primary, dual secondary 15-0-15-0 500VA toroidal. The use of a dual primary transformer allows easy conversion and connection to mains systems in countries abroad operating from 120VAC. It is rectified by BR1,2 and then smoothed by C1,2, two 22,000µ/56V audio grade electrolytics. Capacitors C3 and C4 placed across the bridge rectifiers provide a low impedance path at high audio frequencies.

A Williams 'ring of two' configuration is used to generate the accurate voltage reference required. This configuration uses two bipolar transistors, Q1,2 as constant current sources for the two zener diodes, ZD1,2.

These are 6.2V zeners chosen for the following reasons. The breakdown voltage of the majority of zener diodes varies with temperature and consequently, diodes designed for use below 5V depend for their operation on electron tunnelling and so exhibit a breakdown voltage which decreases with increasing temperature ie they are negative temperature coefficient devices.

Once above 6V, however, avalanche effect is dominant in the breakdown. This means that since breakdown voltage increases with increasing temperature, the devices now possess a positive temperature coefficient. Consider what happens in the region between the two limits specified, where breakdown is a combination of both tunnelling and avalanche mechanisms. Diodes with breakdown voltages around this region can be designed with very small temperature coefficients, so that very stable EMF

ments.

We explained the pros and cons of both types of microphone input stage design, namely the transformer balanced input stage and the electronic balanced stage and posed the question, which type of stage should we use in this mixer?

We revealed all in a metaphorical sense in the opening reels of the AutoMate saga. All of those who say the electronic stage go to the top of the class. For those of you who were wrong, the reasons are twofold. The primary drawback of the transformer is in its cost — to optimise the noise performance, we saw that it was necessary to use a transformer with a strictly defined turns ratio. Obviously, these aren't readily available off the shelf (although companies such as Jensen do stock a wide range of transformers) so the designer must specify to the manufacturer exactly his requirements. This adds greatly to the cost but can be justified when the consignment will be for two thousand or so of the beasties — for a small production run of twenty or thereabouts, the cost would be prohibitive to a hobbyist constructor such as you or I.

The other shortcoming is in the size and weight penalty incurred when our design brief calls for a compact and easily transportable unit although it must be said that the 20:8:2 model featured on the front cover is not quite easily transportable — it wouldn't fit into the boot or passenger compartment of my medium-sized saloon car and whilst not unduly heavy, its bulk and awkward shape make it somewhat unwieldy for one person to lift or carry.

The circuit offered uses one moderately expensive 's can then be produced from them.

In our circuit, the base of Q1 is held at 6.2V so that its emitter current adjusts to make V-emitter (6.2 — 0.6 = 5.6V). Q1 emitter current is consequently 5.6/1000 or approximately 5mA. The collector current of Q1 is also thus approximately equal to 5mA, and supplies ZD2, which in turn feeds the base of Q2, which conducts and passes a current also approximately equal to 5mA. ZD2 behaves as the reference and feeds Q1. The network comprising LED 2, R4 and D1 allows the circuit to be self starting since it draws current from the unregulated part of the circuit until such times as Q2 is conducting whereupon D1 is then reverse-biased and turns off. In this way, the reference voltage as seen by IC1 in operating conditions (as opposed to start-up conditions) is NOT degraded by ripple on the unregulated supply input which improves the line regulation by an order of magnitude.

This very temperature stable voltage reference feeds the non-inverting input of the error amplifier, IC1. This compares the reference voltage to a fraction of the output voltage applied to the inverting input via R8, PR1. The error amplifier output thus compensates for any fluctuations in the supply since the difference between these two voltages is the input to the amplifier, and as R5, R8 and PR1 form a negative feedback loop, the amplifier output voltage changes in such a way as to minimise this difference. The unregulated supply serves merely to provide power for the amplifier, since it is behaving as a high gain DC amplifier, and since Ao is very large, feedback theory suggests;

Out = V ref (Rx + Ry)/Ry

Variations in power supply, therefore, do not affect Vout since Ao is high and Vref is constant. The capacitors improve ripple rejection and reduce noise and the Darlington pairs reduce the output impedance whilst bringing current handling capability up to a value which is of use to us here, ie 7A. Q3 and Q6 provide the current limiting function.

At 17V output, the normal value, the circuit will start limiting at 7A since Q3's base is then at +17.6V while its emitter is at 17V. In a fault condition (shorted load) the short circuit current, however, is less, since Q3 now sources current from the error amplifier, thus holding the power dissipation of both pass transistors at a value much less than in a normal short circuit situation. To understand operation of the circuit, we must note that in a short circuit situation, the shorted Vout equals zero. Consequently, the voltage drop across resistor Rll is negligibly small. The voltage across R10 (at short circuit) is Isc x R10, and is designed to keep transistor Q6 just biased on. The equations governing the maximum output current, short circuit current and the ratio between the two are as follows;

General form

I max = 1/Rs[(1 + R2/R1) Vbe + R2/R1 Vreg]

Isc = 1/Rs(1 + R2/R1)Vbe

I max : Isc = 1 + (R2/(R2 + R1)]Vreg/Vbe

Component-specific form

Imax = 1/R13[(1 + Rl1/R12)Vbe + R11/R12 Vreg]

Isc = 1/R13 (1 + R11/R12)0.6

Imax Isc = 1 + (R11/(R12 + R11)]17/0.6

The small value resistor, R13, produces a voltage proportional to the load current drawn through it — regulation is unaffected since the resistor comes before the regulator. Q5 has its base connected directly across R13 such that when the voltage dropped across it approaches 0.6V, Q5 begins to conduct, its collector pulling the base of Q6 and hence the output Darlingtons towards ground potential. As the base voltages drop, so the output voltage drops, and if output current through R13 still continues to rise, Q5 eventually saturates, clamping all of the output transistor bases to earth and switching the supply output to 0V.

Each of the power transistors has its own low value emitter ballasting resistor of a value chosen such that around 0.2V is dropped across it at full loaded output. Were we to neglect these resistors, the spread in Vbe's of the transistors would mean that one transistor would 'hog' most of the current, with the distinct possibility of excessive conduction, dissipation of heat and subsequent destruction. The resistors provide a form of negative feedback, thus controlling the transistors and eliminating the chance of thermal runaway.

The dual tracking function is very easily implemented. The output from the positive regulator is simply used as the reference for the negative supply, the lower error amplifier controlling the negative output by comparing the average of the two output voltages with ground, thus giving equal positive and negative 17V requlated outputs. In this way, the origination of common mode signals in the power supply is eliminated.

Over-voltage protection is provided by ZD3, D1, 2, R14 and Q6 and its corresponding complements on the other supply rail. These components provide the popular 'crowbar' method of protection. If the output voltage exceeds the zener voltage (16V) plus the two diode drops of D1 and 2 plus one other diode volt drop (Vbe), the transistor is turned on at 17.8V and 'crowbars' the output to ground for as long as the over-voltage condition exists (or until the fuse blows). This method is preferable to using an SCR, which is prone to false triggering on spikes, and will remain turned on until reset — SCR's have memories like elephants in situations like these. With this circuit, the zener will stop drawing current the moment the over-voltage condition disappears, so the load is protected from damage from transient spikes and the PSU remains in operation except under dire fault conditions. The LED's on the unregulated DC rail serve to supply a bleed path to ground for the smoothing capacitors when the mains supply is removed.

Keen-eyed readers and those who have been paying attention — questions will be asked at a later stage — will have noticed the one flaw in the dual-tracking/current-limiting interaction. Should the positive rail enter the current-limiting region, the negative rail will follow suit since its reference is derived from Q5 emitter. However, if a current-limiting situation exists on the negative rail, its positve counterpart will remain in full operation. I have to admit that I could see no easy way around this but it has to be said that some form of protection, although inadequate in some situations, is better than none at all (as parents everywhere will bear testimony to!)

The 17V switching supply is identical in all respects to that just mentioned, save for the fact that it derives its unregulated supply from BR1,2 and C1,2 of the audio power supply.

device, the Precision Monolithics' SSM2015 IC, a one-chip ultra-low noise microphone preamplifier in the input stage. These cost about £4.00 each but offer superlative noise and distortion performances and since the constructor will already be making substantial savings when the overall cost is compared to that of ready-built mixing consoles, the author thinks that their inclusion on the channel is fully justified.

The SSM2015 is one of a number of specialist audio IC's manufactured by PHI (Precision Monolithics Incorporated) and is itself specially suited to microphone or other low level pre-amplification. I had fully commited myself to using two of the LM394 devices when I discovered the 2015 and was convinced when I realised that utilising it within my design would incur no cost penalty at all over the 394's and in fact saved something in the order of £8.00 per module.

The 2015 has true differential inputs and provides both excellent common mode rejection with an ease of interfacing to floatation transducers such as balanced microphone outputs whilst providing facility for connection to single ended devices.

The very low voltage noise performance (1.3nV/√Hz) is enhanced by a programmable input stage which allows overall noise to be optimised for source impedances up to 4k.

However, for those of a canny disposition and thrifty Scots origin (and I say that with my tongue firmly in my cheek as I'm of decidedly Celtic extraction myself!), operating on a tight budget, and able to accept a slightly

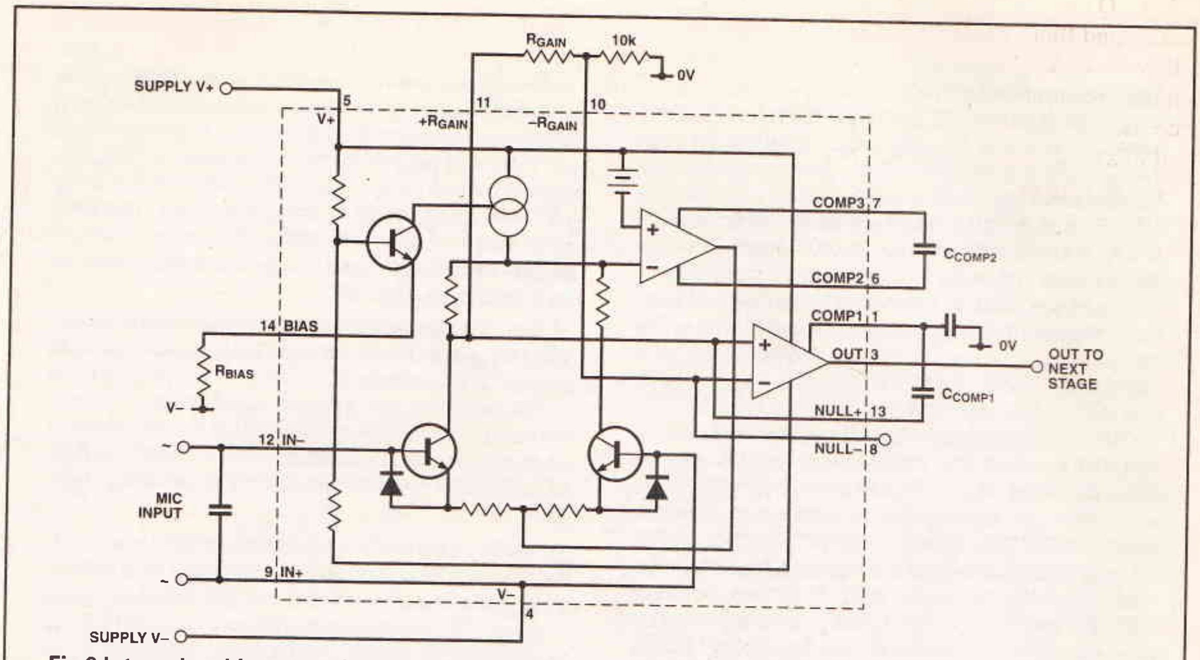


Fig.3 Integral architecture of Precision Monolithics SSM2015 Low-Noise Microphone Pre-Amplifier IC

less stringent noise specification (E_{IN} of a mere 760nV over the full audio bandwidth, and a distortion figure of less than 0.01% at full gain), I have included a circuit which may be used.

Current Concerns In The Designs Of PSU's

We'll leave the input stage circuitry for the moment and move onto the Power Supply Unit which should really have been first on the list since its construction then allows testing of any subsequently fabricated modules before the whole kitten caboodle is bolted together to create a working mixing console —I deviated from this more logical ordering in order to whet your appetites.

The foundation of any good audio design should begin with the power supply. Many otherwise good designs of signal processing circuitry have excellent performances needlessly impaired because they use poorly designed or quite simply, use power supply units which are woefully inadequate. A good PSU, for use in critical situations such as this one, namely ultra low noise audio, should have the intrinsic qualities of very low drift, excellent ripple rejection and very low noise. The circuit described here fulfils all of these needs.

The design is somewhat more sophisticated than that found in some audio projects, the author having forsaken the use of the ubiquitous 3-pin monolithic SC regulators sometimes found in mixer power supplies and created one from discrete components.

The supply rails for all of the audio circuitry were kept entirely separate from all others so that any glitches or noise introduced by the switching processes employed in the mixer didn't degrade the noise performance of it. Separate earth busses were also provided for the same reason.

For this project, the power supply unit had to provide the following;

Very stiff (well regulated) plus and minus 17V supplies for all of the op-amp and audio circuitry. This bipolar supply would have to possess good current-handling capability and excellent ripple rejection.

Separate bipolar supply for all of the switching circuitry. 48V supply for phantom powering of microphones. 5V supply for any logic circuitry.

I've always been a firm believer in the 'big is beautiful' philosophy in the design of both power supply units and related equipment such as amplifiers, and I prefer to put my faith in the performance of a 4U, 50kg 1000W hernia-inducing power amplifier than in one of the new-fangled 1U plastic-encapsulated 1kW class D (pulse width modulated) type which is light enough to be lifted with two fingers and whose performance might be summed up with a similar gesture! For me, and in this respect anyway, might is right!

This design philosophy prevails throughout the mixer, but in no other area is it so in evidence than in the power supply unit which to some of you may seem excessively over-large and over-rated.

Any hi-fi preamplifier with pretentions towards greatness is always endowed with a power supply capable of sustaining ANY current demands which the audio circuitry puts upon it. No-compromise commercial preamps may use 200 or 300VA power supplies although the current consumption of the unit may only be in the order of milliamps or perhaps tens of milliamps when the circuitry is stressed under transient, high signal level conditions. In this way, headroom is increased and overload margins improved.

In any case, the ripple current rating of smoothing capacitors is directly proportional to their physical size, so it follows that capacitors of similar capacitance rating but smaller physical size just CANNOT perform equally well in terms of transient current delivery and it is this which enables faithful response in the high level, lower register area of the sound spectrum.

It should also be remembered that the unit must be capable of powering, without modification, the largest, automated consol configuration possible with the increased current consuption which this will bring (an automated fader, 8-group input module features some

25 LED's alone). If we consider a typical driving current of around 10mA per LED, each module would require at least 250mA. At this rate, it is very easy to suddenly accumulate many amps of current sinking circuitry. This is, of course, a slight over-simplification — isn't it always. Not all LED's are likely to be on at any one time, and in any case, all of the LED's are programmed for much smaller currents. This example does serve to illustrate why we need such a beefy power supply (apologies to vegetarians everywhere!)

The unit itself is housed in a separate 19" rack-mounting case, thus minimising any opportunity for the mixer circuitry to pick up mains hum. It is very conservatively rated and will run reasonably cool even under arduous operating conditions, such as may be encountered on a fully-endowed, 48 input, 16 output automated desk.

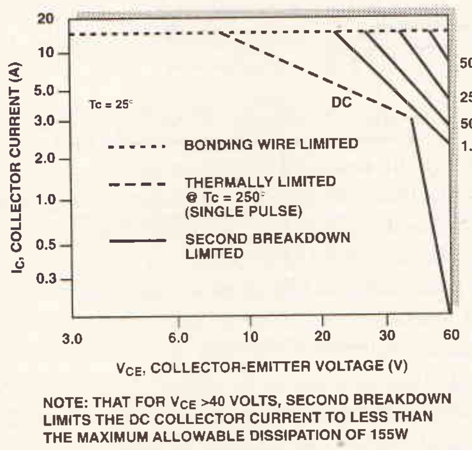


Fig.4 Graph of safe operating area (SOA) of popular regulator pass transistor — Motorola 2N3055

As mentioned earlier, the normal 3 pin regulators were not considered for use in this application because of the serious shortcomings of these devices at high frequencies. I think that the decision to design one from scratch first entered my head when I had cause to measure the noise coming from a selection of what are termed 'laboratory standard' power supply units — and some very expensive ones at that — of the type normally encountered in test-room/workshop environments and was, quite frankly, appalled at the high level of hum and noise, especially hum, which emanated from the output terminals! In the interests of maintaining a quiet(!), trouble-free existence and a desire to avoid the libel courts, the manufacturer shall remain anonymous.

The design offered here is unlikely to bring gasps of surprise from the audience as it features no specially innovative circuit topology, but it performs rather well, having a quite exemplary noise performance — less than -73dBu unweighted noise and below a measurable level when measured using a filter as recommended in the CCIR/468-2 weighted noise measurement specification — and as I said before, is very conservatively rated. Although this figure may seem to be rather mediocre, the noise level of the lab PSU which I measured was –48dBu. I think that it would be fair to say that if fitted with higher voltage transformers, and with a few changes of component value in and around the error amplifier and current-limiting section, the power supply would do justice to the finest Class-A power amplifier! Now there's an idea for a follow-up project to the mixer — a 100W per channel class A studio monitor amplifier, monoblock in design and with a completely regulated power supply!

Careful thought was given to the layout of the PCB trackwork. Students of audio engineering design will doubtless be familiar with the creation of a central earth point — 'star earth' — so that fluctuations in the current of one load will not affect the voltage seen by other loads and create the opportunity for hum loops to form. What is less commonly known is the merit of adopting this 'star' philosophy in the layout of the supply rail wiring, thus eradicating or at least drastically minimising the opportunity for heavy, possibly dirty, currents (which will probably have noise and voltage spikes superimposed on them) to influence and degrade the noise performance of sensitive, lighter load circuitry. Crosstalk performance can be dramatically improved if separate supplies are used for left and right channel circuitry — consider the exemplary performance in this respect of the true 'monoblock' power amplifier which uses isolated and separate power supply units for each of the two stereo channels. This eliminates crosstalk between the stereo outputs because the separate power supplies mean that the impedance of a common power supply interacting between channels can no longer occur. There has been much argument and debate about the way that power supply regulation and distortion are inter-related. Whilst not wishing to enter the argument, in my humble opinion, and without digressing even further than I have done so

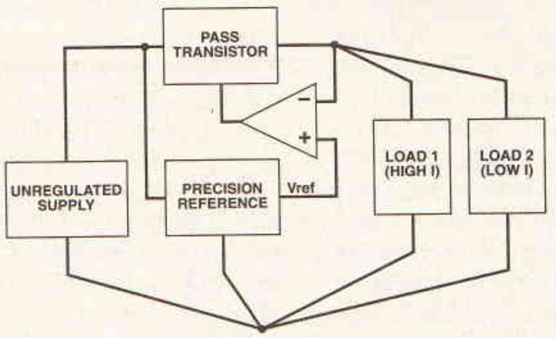


Fig.5 Power supply 'star earth'. Mecca — and corresponding power distribution star

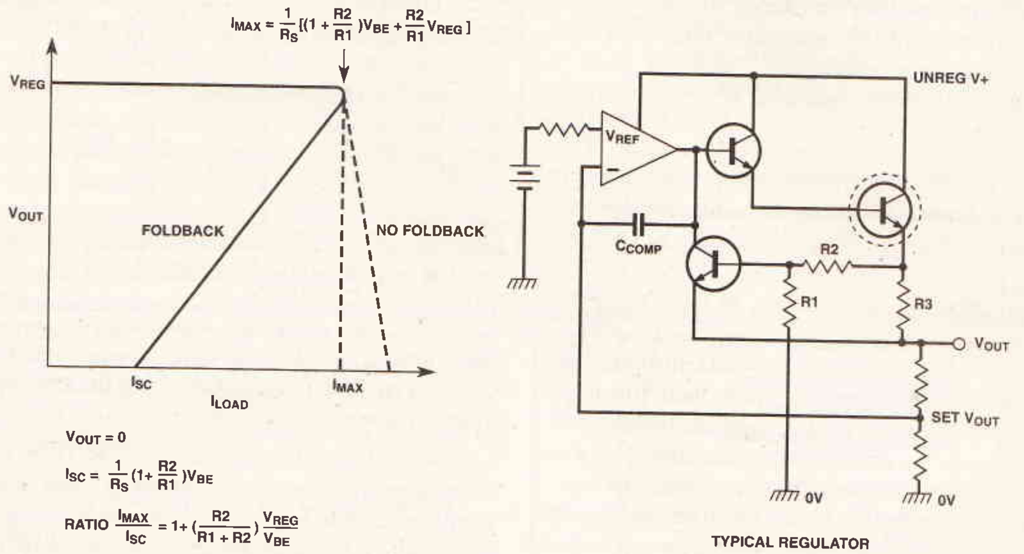
already, the application of good engineering design principles in the power supply cannot but fail to improve overall performance of the active circuitry connected to it. The main elements are as follows;

Transformers
Rectifiers
Smoothing Capacitors
Voltage Reference Circuits
Error amplifiers
Re-entrant current-limiting circuitry
Power Output Stages

I used a hefty 500VA toroidal transformer for the main plus and minus rails, this type being preferable to C or I laminated types for a number of reasons, not least of which is the smaller physical size for a given Volt-Ampere rating. The toroidal also produces less magnetic interference (hum fields), lower noise, better regulation and ease of mounting than its C/I core counterpart. The example used within this design was kindly supplied by Newmarket Transformers who have, over the years, supplied many prestigious clients within the pro-audio amplification field with similar transformers. This toroidal is specially designed for audio in that it has 20% more copper within the windings which reduces accoustic hum (as opposed to electrical hum). Acoustic hum is that hum or buzz which is audible from most types of transformer when in use and varies greatly from type to type and manufacturer to manufacturer. It is a great nuisance when the unit has to be sited and used within an otherwise low ambient noise situation (such as might be encountered in a typical presentation studio) and because it intrinsically is of a mechanical nature, there is very little we as electrical engineers can do about it. It is obviously of less importance when the desk is used as a front of the house monitor mixer at an ear-splitting 130dB SPL rock concert! Ordinary types are available if this is envisaged to be a frequent or exclusive scenario. The toroidals also feature electrostatic screens which reduce the chance of pick-up of electrically-induced hum in the surrounding circuitry.

The Bridge Rectifiers are 25A/400V PIV rated encapsulated types which use 0.25″ spade connectors and bolt to the chassis as an aid to heat dissipation when the bridge is passing large currents. I specified the highest quality smoothing electrolytics which I could find available in the commercial marketplace. These are similar in many respects to the massive 'computer-grade' electrolytics to be found in the PSU's of digital equipment, differing only in the fact that these capacitors have been designed and manufactured specifically for use in high-quality audio applications. The excellent response at frequencies within the audio bandwidth is achieved by lowering the equivalent series resistance to a value which is around 50% lower than other capacitors of similar size and type. The high grade materials employed also give superior ageing qualities and tonal stability over the whole audio range whilst reducing the level of high frequency harmonic distortion which certain capacitors are prone to inducing into any audio which passes through them. They are manufactured by Elna under the trade name of 'Cerafine' and are without doubt the best electrolytics for use with audio.

It has to be said that because of the amount of 'hardware' involved in the construction of the power supply unit (heatsinks, case, large transformer, expensive capacitors etc), it is not the most inexpensive mixer supply. However, it is still small in relation to the the overall cost of the project and in any case, a quick scan through the PSU section of any of the component distributors' catalogues would reveal that the cost of similar precision high current power sources is greater by an order of magnitude.



$$I_{MAX} = \frac{1}{R_S}\left[\left(1 + \frac{R2}{R1}\right)V_{BE} + \frac{R2}{R1}V_{REG}\right]$$

$$V_{OUT} = 0$$

$$I_{SC} = \frac{1}{R_S}\left(1 + \frac{R2}{R1}\right)V_{BE}$$

$$\text{RATIO } \frac{I_{MAX}}{I_{SC}} = 1 + \left(\frac{R2}{R1 + R2}\right)\frac{V_{REG}}{V_{BE}}$$

Fig.6 Graph of output voltage Vs Load Current for PSU fitted with re-entrant-foldback current limiting

Getting A Good Reference For Your CV (Controlled Voltage)

A zener diode/resistor combination provides a very stable reference voltage for the error amplifier, and the paralleled output transistors (each with its own ballasting emitter resistor to provide negative feedback and so a measure of temperature stability) boost the power handling capability of the stage to somewhere in the region of 7A.

Protection Is A Racket

Both current limiting and over-voltage protection were thought to be mandatory requirements for each of the different power supplies. In the first instance, a power supply of this size can supply an whole lot of amps in a short circuit situation, this obviously being somewhat destuctive to both load and PSU.

One way around this is to completely over-engineer the series pass transistor section, using both heftily-rated transistors and heatsinks around three times the normal size. In this way, power can safely be dissipated under worst case conditions ie short-circuit load. Only then will the pass transistor survive more than momentary shorted outputs. This design approach has its merits but huge heatsinks and over-rated components can sometimes be inconvenient and in any case, will add considerably to the cost. It is also unwise to allow heavy currents to flow into the powered circuit under fault conditions.

A much more elegant and favoured method is to use some form of current limiting, if for no other, reason than that the prevailing reason for pass transistor failure is over-dissipation caused, of course, by excessive current flow or inadequate heatsinking.

Re-entrant or foldback limiting is the more preferable of the two types available since simple corrent limiting will still allow the PSU maximum current to flow in a fault situation, causing the pass transistor power dissipation to rise dramatically and perhaps terminally as the voltage dropped across each rises to the full unregulated input voltage. Maximum voltage AND maximum current simultaneously is a very bad state of affairs in any type of semiconductor control circuit and is to be avoided at all costs if the longevity of the power components is to be maximised — I avoided using the word 'guaranteed' because the life of any electronic component can only be estimated.

Foldback limiting, on the other hand, reduces the output current (and voltage) under short circuit or overload conditions, both protecting the load and forcing the transistors to maintain operation within their 50A (safe operating area). Referring to the Graph of a typical limiting characteristic, we can see that the regulated output voltage remains constant until Imax is approached Then the current begins reducing (or folding back) to a lower short circuit level Isc to produce a lower power dissipation in the pass transistor.

Table 1 —SPECIFICATIONS OF PRECISION MONOLITHICS' INCORPORATED SSM 2015 MICROPHONE PREAMPLIFIER

PARAMETER	MINIMUM	TYPICAL	MAXIMUM	UNITS	CONDITIONS
Total Homonic Distortion (THD)					
Gain = 60dB					
f = 1KHz		0.007	0.01	%	V_{out} = 7V rms
f = 10KH		0.015	0.02	%	V_{out} = 7V rms
Gain = 40dB					
f = 1KHz		0.007	0.01	%	V_{out} = 7V rms
f = 10KHz					
Gain = 20dB					
f = 1KHz		0.01	0.015	%	V_{out} = 7V rms
f = 10KHz		0.01	0.015	%	V_{out} = 7V rms
Input Referred Voltage Noise (EIN)					
Rbias = 33KΩ					Input Shorted to Ground
Gain = 60dB		0.2	0.3	µVrms	20KHz Bandwidth
Gain = 40dB		0.31	0.5	µVrms	20KHz Bandwidth
Gain = 20dB		1.1	1.7	µVrms	20KHz Bandwidth
Rbias = 150KΩ					Input Shorted to Ground
Gain = 60dB		0.28	0.45	µVrms	20KHz Bandwidth
Gain = 40dB		0.41	0.65	µVrms	20KHz Bandwidth
Gain = 20dB		1.1	1.7	µVrms	20KHz Bandwidth
Input Current Noise (In)					
Rbias = 33KΩ		250	380	pA rms	20KHz Bandwidth
Rbias = 68KΩ		200	300	pA rms	20KHz Bandwidth
Rbias = 150KΩ		130	200	pA rms	20KHz Bandwidth
Gain Equation			Gain=(20kn/Rg)+3.9		
Error from Gain Equation (ΔGain)					
Gain = 60dB		0.1	0.3	dB	R_1=R_2=10KΩ
Gain = 40dB		0.1	0.3	dB	R_1=R_2=10KΩ
Gain = 20dB		0.2	0.3	dB	R_1=R_2=10KΩ
Common Mode Rejection Ratio (CMRR)					
Gain = 60dB	90	100		dB	R_1=R_2=10KΩ
Gain = 40dB	70	95		dB	R_1=R_2=10KΩ
Gain = 20dB	60	75		dB	R_1=R_2=10KΩ
−3dB Bandwidth (Gain Bandwidth Product)					
Gain = 60dB		150		KHz	
Gain = 40dB		700		KHz	
Gain = 20dB	1000		KHz		
Slew Rate		6		V/µs	

Table 1 Specifications of Precision Monolithic's Inc SSM 2015 Microphone Pre-amplifier

Over-voltage protection is provided for both analogue bipolar and logic supply rails. Since there is much TTL circuitry in evidence throughout the console, the reason for the inclusion of over-voltage protection on the 5V rail should be obvious. A similar reason exists for it being included on the plus and minus 17V supply, namely, that all of the analogue IC's are operating within a few volts of their specified maximum supply voltages, so it makes sense to protect perhaps three or four hundred

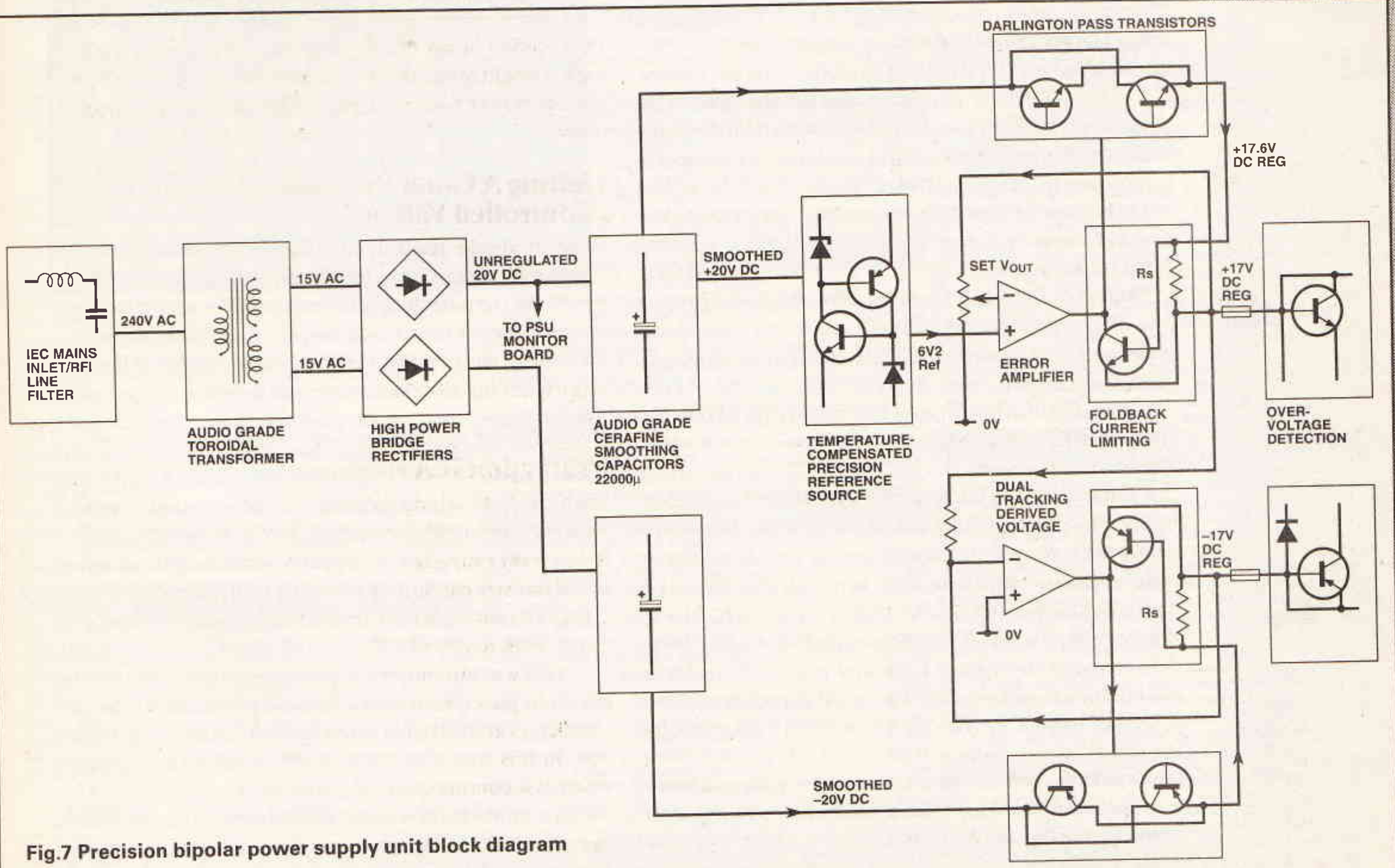


Fig.7 Precision bipolar power supply unit block diagram

IC's from death by misadventure at high voltages, as can happen if the pass transistor fails in its favoured mode (short circuit) causing the full, unregulated input voltage to be applied to the load.

Staying On The Right Tracks

The regulators are also of the dual-tracking type, thus minimising any common-mode errors in the circuitry, and forcing shutdown of a neighbouring rail if a fault exists on one (op-amps make the most terrible noise when powered by one rail but biased for two!).

It can be seen from the circuit diagram that as mentioned previously, I have adopted very careful grounding layouts so that the voltage is sensed at the correct point and so that hum and instability are avoided. The ideal would have been to include remote voltage-sensing of the load, but this is impractical in this application and so I put my faith in connectors of adequate current rating and cable of the correct cross-sectional area so that volt drops in the interface between source and load were minimised.

A Phantom Supply

48V Power Supply

This supply DOES use the monolithic 3 pin regulator IC's referred to in such derogatory terms in the general text. The quality of this rail is not quite so important, being used only to provide a polarising voltage for capacitor mics. It uses the industry standard 317 series of variable voltage regulators with the ADJUST pin held some voltage from ground potential via the zener diode, ZD101 and some jiggery-pokery with judiciously-placed capacitors improves regulation to 80dB. The output voltage can therefore be calculated as follows;

$V_{out} = V_z + 1.25(1 + R102/R103)$

Preset PR101 allows precise setting of the output voltage. The bypass capacitor, C103, on the ADJ pin of the regulator is the conjuring trick just mentioned and improves the ripple and spike rejection of the IC by about 15dB, and the diode, D101 provides a safety discharge path for this capacitor.

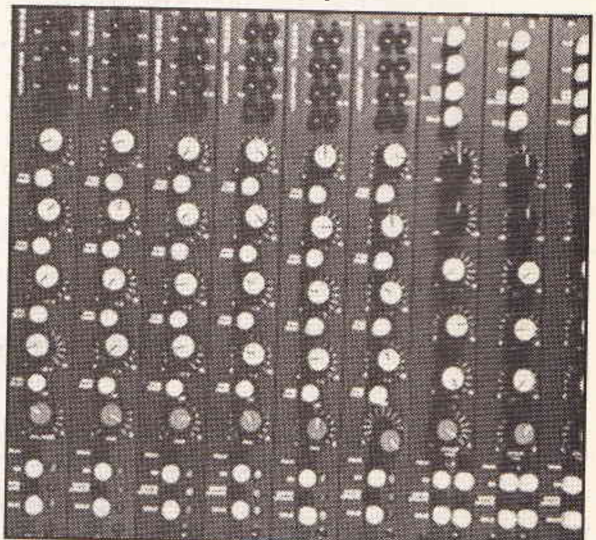
5V Logic Supply

This is identical in all aspects to the high power biploar supplies, the only difference being in the magnitude of the output voltage. As the explanation of the workings of all of the important modules of this supply have already been covered in the Bipolar 17V section, no further text is deemed to be necessary.

Power Supply Construction

The power supply unit is housed in a separate 19", 2U rack-mounting unit which means, as we said earlier, that any circuitry with 50Hz AC is kept well away from sensitive audio circuitry. It also makes for a much safer unit since mains voltages are all contained in one sturdy and secure unit, well away from any low level signals and operational surfaces and the possibility of fatal electric shocks caused by dire fault conditions are thus eliminated.

Whilst on this rather serious note, it should be mentioned that new Health and Safety (Electricity) legislation make the individual much more culpable in matters such as these. To comply with the recent recommendations for any unit requiring mains power, all of my guidelines with respect to shrouding of connectors, specification of wiring and terminal blocks etc should be strictly adhered to. If I sound like a harbinger of doom at this point, it is merely because the nature of this particular project means that it is quite possible that the unit will be used by or in conjunction with other people, or even the general public. Consequently, you as the constructor could well be found to be liable for any mishaps which occur during its use (or mis-use as the case may be) and I as designer could become an accessory after the fact! As my specification calls for good, approved materials and safe constructional work practises, my obligation is fulfilled and the ultimate safety of the unit will be dictated by the way in which you, the reader, builds the unit. This is all somewhat theoretical since I have yet to hear of any test cases being brought forward. In any case — no pun intended — the interior of some items of consumer electronic equipment of a more Oriental than Occidental origin, shall we say, bear testimony to some very dangerous wiring practices, with inadequate shrouding of mains terminals in the cases of equipment deemed to be 'double-insulated' and inadequate earthing arrangements in Class 1 types of equipment.



As the mechanical construction is rather awkward and definitely not to be attempted on a Friday night after downing one or two pints of your favourite ale at the pub, the PCB foil layouts, component overlays and full constructional details for the power supply unit will be published in next months Part Three, thus affording all interested parties — and those shunning earlier "don't build yet" advice — the opportunity to scan the parts list and order the special parts from the companies specified.

This seems like an opportune moment to mention that many of the specialist components used in the mixer are available only from dedicated pro-audio sources (via mail order). Although this might seem a mite awkward, all of the companies mentioned are readily able to deal with large quantity orders. I found it immensely dis-satisfying and frustrating when developing the Nightfighter to have to make three or four trips to the local high street outlet before my quota of components was fulfilled. This new method completely eradicates these frustrations, as well as offering bulk savings which more than compensate for packaging and carriage costs.

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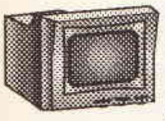

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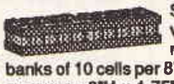

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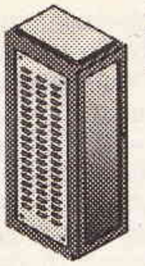

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2 Attenuator Circuits

By Ray Marston

The March edition of this mini-series dealt with the design of 'L'-type attenuator networks. This month's article continues the theme by showing how to design 'matched-resistance' attenuators.

A serious weakness of the 'L'-type attenuator is its output impedance varies with the attenuator setting and its input impedance varies in a similar way if the output is externally loaded. The significance of this latter effect is illustrated in Figure 1, where the attenuator is represented by the load on the output of the waveform generator, which has an output impedance of 100R. If the generator is set to give 1 volt output into a 1k0 load, the output varies between 1·048 volts and 0·917 volts if the load is then varied between 2k0 and 500R, thus invalidating the attenuator's calibration.

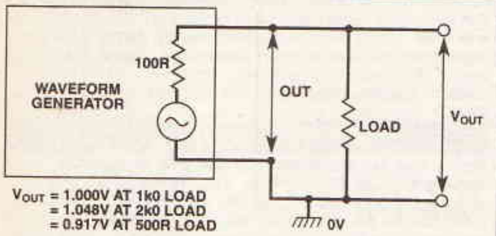


Fig.1 The output voltage of a generator varies with changes in its load impedance.

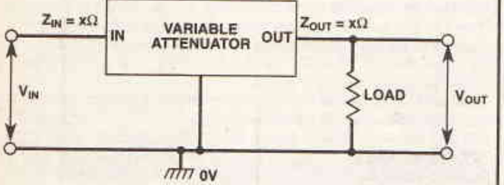


Fig.2 The 'ideal' variable attenuator presents constant input and output impedances.

So in Figure 2, the 'ideal' variable attenuator should have input and output impedances that remain constant irrespective of the attenuation setting. Such attenuators do exist, and are usually based on a number of switch-selected fixed-value attenuator pads. These pads come in a variety of types, and the five most popular of these are shown in Figures 3 and 4, together with their design formulae. These attenuators are perfectly symmetrical, enabling their input and output terminals to be transposed, and that they are each designed to feed into a fixed load impedance, Z, which actually becomes part of the attenuator network. Note that the pad's input and output impedances are designed to equal that of the designated load, thus enabling impedance-matched pads of any desired attenuation values to be cascaded in any desired combination, as shown in Figure 5.

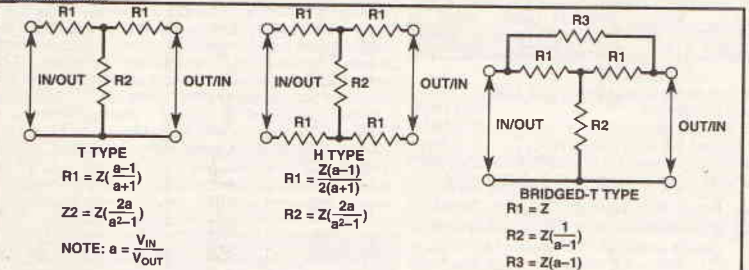


Fig.3 Circuits and design formulae of the basic 'T' type attenuator and its 'H' and 'Bridged-T' derivatives.

The two most popular types of pad attenuator are the 'T' and π types; the 'H' and 'O' types are simply 'balanced input' versions of these, and the 'bridged-T' type is a derivative of the basic 'T' type.

Figure 6 shows a practical version of a π-type attenuator, designed to give a matched impedance of 1k0 and to give 20 dB of attenuation. Working through the design of this example from the back, note that the 1k0 load shunts R2 and brings its effective impedance down to 550 ohms, which then acts with R1 as an 'L'-type attenuator that give the 20dB of attenuation and has an input impedance (into R1) of 5·501 ohms, which is shunted by R3 to give an actual input impedance of 1000R. Note that the output load forms a vital part of the attenuator, and that if it is removed the pad's attenuation falls to only 5·052, or –14·07dB.

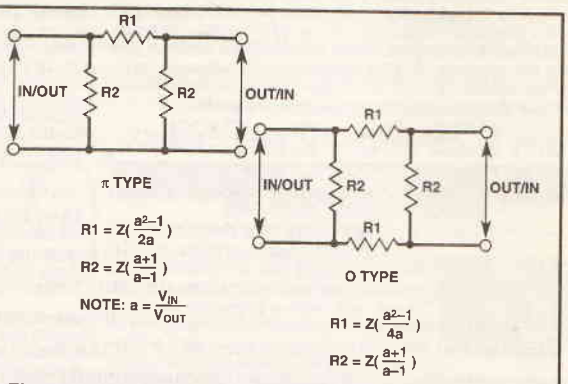


Fig.4 Circuits and design formulae for the basic π type attenuator and its '0' type derivative.

Figure 7 shows a practical version of a T-type attenuator, designed to give a matched impedance of 1k0 and 20dB of attenuation. R3 and the 1k0 load form an 'L'-type '÷1·8182' attenuator that has an input impedance (into R3) of 1,818·2 ohms. R1 and R2 also form an 'L'-type attenuator, but in this case R2 is shunted by the above 1,818·2 ohm impedance and has its effective value reduced to 181·8 ohms, so this stage gives an attenuation of ÷5·5 and has an input impedance of 1000R. Thus, the T-type attenuator actually consists of a pair of cascaded L-types, which in this example give individual attenuation ratios of 1·8182 and 5·5, or ÷10·00 overall. Note that if the output load is removed from this attenuator its attenuation falls to only ÷5·50, or –14·81dB.

Figure 8 shows a chart that makes the design of 'T' and π attenuators very easy. To find the correct values of R1 and R2, simply read off the chart's r1 and r2 values indicated at the desired attenuation level and multiply these by the desired attenuator impedance, in ohms. Thus, to make a 100R, –20 dB pad, R1 and R2 need values of 818R and 202R respectively. Note that this chart can also be used to design 'H' and 'O' attenuators by simply halving the derived R1 value.

Switched Attenuators

Matched-impedance attenuator pads can be cascaded in any desired sequence of values and types, and this fact makes it easy to design switched-value attenuator networks and 'boxes', as shown in Figures 9 and 10. Figure 9

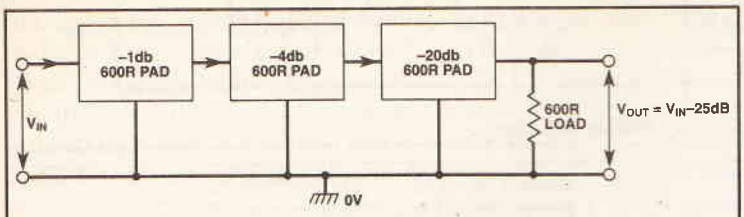


Fig.5 Matched attenuator pads can be cascaded in any combination.

shows how four binary-sequenced '1-2-4-8' attenuator pads can be cascaded, using 2-pole 2-way selector switches, to make an attenuator that can be varied from 0dB to –15dB in 1dB steps, and Figure 10 shows an alternative arrangement that enables attenuation to be varied from 0dB to –70dB in 10dB steps. These two circuits can be cascaded, if desired, to make an attenuator that is variable from 0dB to –85dB in 1dB steps.

The three most widely used values of 'matching' impedance are 50R and 75R for 'wireless' work and 600R for 'audio' work, and Figures 11 and 2 show the appropriate R1 and R2 values needed to make 'T' and π pads of these impedances and with attenuation values of 1,2,4,8,10,16,20, or 32dB. Note when designing attenuator pads that the R1 or R2 values may be adversely affected by stray capacitance if the values are excessively large, or by the resistances of switch contacts and wiring if excessively small. Thus, it can be seen from Figures 11 and 12 that a –1dB pad would best be made from a π section if designed for 50R matching, but from a 'T' section if intended for 600R matching.

Design

If large (greater than –32dB) values of pad attenuation are needed, it is best to make the pad from two or more cascaded attenuator networks. If the multi-stage pad is to be made from *identical* π-type stages, as shown in Figure 13a, an economy can be made by replacing adjoining pairs of R2 resistors with a single resistor with a value of R2/2, as shown in Figures 13b. A similar technique can be used if the cascaded sections do *not* have identical attenuation values, but in this case the single replacement resistor needs a value equal to the parallel value of the adjoining pair of resistors that it is replacing.

Although the Figure 13b ladder attenuator is described as a π-type design, it can be described as a set of cascaded 'L'-type attenuators with a shunt across its main input terminals. With this description in mind, a most ingenious development of the circuit is the switched ladder attenuator, a 5-step version of which is shown in Figure 14, together with its design formulae and with worked values for giving ÷10 (=–20dB) steps and a 1k0 matching impedance. The input signal's effective source impedance forms a vital part of this attenuator network, and needs a value of 2Z.

To understand the operation of the attenuator shown in Figure 14 it is best to first imagine it without the external load connected, and to work through the design from right to left. The 5th (output) section (R2-R4) acts as a ÷10 'L' attenuator with an 11k input impedance. This impedance shunts R3 of the preceding section and reduces its effective value to 1100R, so that section (the 4th) also gives ÷10 attenuation and an 11k input impedance. Similarly, sections 2 and 3 act in precisely the same way. The '1' input 'L'-type section consists of the generator's source impedance (2k0) and R1, which

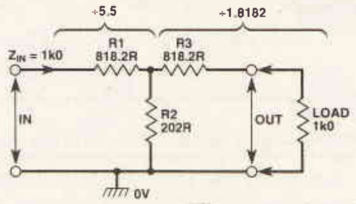


Fig.7 Worked example of a 1k0, –20db 'T'-type attenuator; its unloaded attenuation is ÷5·50, = –14·81 dB.

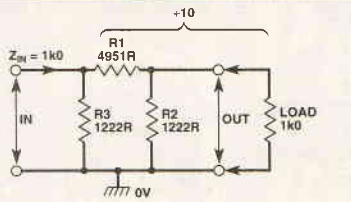


Fig.6 Worked example of a 1k0, –20dB π-type attenuator; its unloaded attenuation is ÷5·052, = –14·07 dB.

dB LOSS	a (V_{in}/V_{out})	'T'-TYPE r1	'T'-TYPE r2	'π'-TYPE r1	'π'-TYPE r2
0	1.000	0	∞	0	∞
0.1	1.012	0.00576	86.9	0.0115	174
0.2	1.023	0.0115	43.4	0.0230	86.9
0.3	1.035	0.0173	28.9	0.0345	57.9
0.4	1.047	0.0230	21.7	0.0461	43.4
0.5	1.059	0.0288	17.4	0.0576	34.8
0.6	1.072	0.0345	14.5	0.0691	29.0
0.8	1.096	0.0460	10.8	0.0922	21.7
1.0	1.122	0.0575	8.67	0.115	17.4
1.5	1.188	0.0861	5.76	0.174	11.6
2	1.259	0.115	4.30	0.232	8.72
3	1.413	0.171	2.84	0.352	5.85
4	1.585	0.226	2.10	0.477	4.42
5	1.778	0.280	1.64	0.608	3.57
6	1.995	0.332	1.34	0.747	3.01
7	2.239	0.382	1.12	0.896	2.61
8	2.512	0.431	0.946	1.057	2.32
9	2.818	0.476	0.812	1.23	2.10
10	3.162	0.520	0.703	1.43	1.92
12	3.981	0.598	0.536	1.86	1.67
14	5.01	0.667	0.416	2.41	1.50
15	5.62	0.698	0.367	2.72	1.43
16	6.31	0.726	0.325	3.08	1.38
18	7.94	0.776	0.256	3.91	1.29
20	10.00	0.818	0.202	4.95	1.22
25	17.78	0.894	0.113	8.86	1.12
30	31.62	0.939	0.0633	15.8	1.07
32	39.81	0.951	0.0503	19.89	1.052
35	56.23	0.965	0.0356	28.1	1.04
40	100.0	0.980	0.0200	50.1	1.02
45	177.8	0.989	0.0112	88.9	1.011
50	316.2	0.994	0.00632	158	1.006
55	562.3	0.996	0.00356	281	1.0036
60	1000	0.998	0.00200	500	1.0020
64	1585	0.9987	0.001262	800	1.00126

Fig.8 'T' and π attenuator design chart. To find the correct R1-R2 values, read the r1 and r2 values indicated at the desired attenuation value and multiply by the desired attenuator impedance.

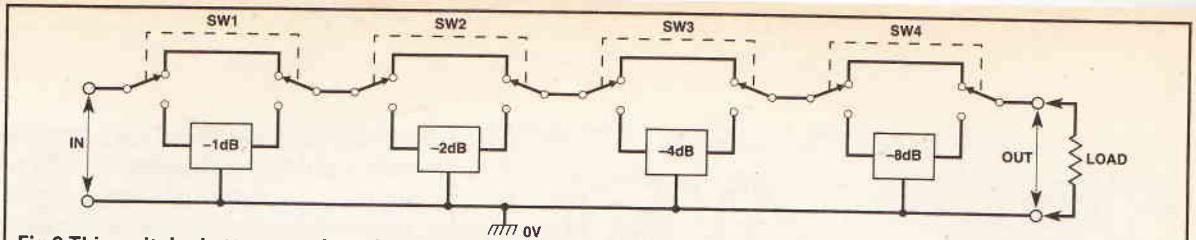


Fig.9 This switched attenuator is variable from 0 to −15dB in 1dB steps.

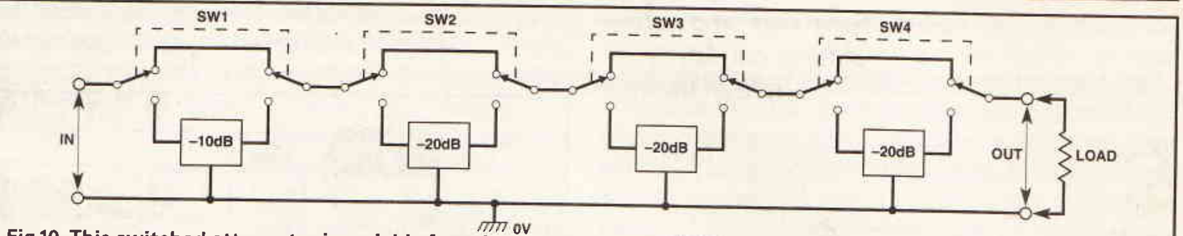


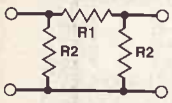
Fig.10 This switched attenuator is variable from 0 to −70dB in 10dB steps.

(since it is shunted by the 11k input impedance of the '2' section) has an effective impedance of 2k0; this section thus has an *effective* attenuation of ÷2.

Now imagine the effect of connecting the external 1k0 load to any one of the attenuator's output terminals. If it is connected to the output of the 5th section it shunts R4 and increases that section's attenuation to ÷19·9 and reduces its input impedance to 10,424R, thereby also increasing the attenuation of the preceding section by 0·5%. The net result is that the attenuation at the output terminal increases by a factor of 1·995, or precisely 6dB. Similarly, if the load is connected to the output of any of the '2' to '4' sections, increases by precisely 6dB. Finally, if the load is connected to the output of section '1', that section's attenuation increases by a factor of 2·000 (to ÷4), or precisely 6·021dB.

Since the load is connected to SOME part of the circuit, it does not affect the *step* attenuation of the network. If the load is shifted a 20dB step down the line, from the output of section '2' to that of section '3', the output of section '2' (and the input of section '3') rises by 6dB but the attenuation of section '3' increases by 6dB to −26dB, to give an overall step change of precisely −20dB. This accuracy is maintained with great precision on all except the 1st step position, where a trivial error of +0·25%, or 0·021dB, occurs. It is widely used in the output of audio and RF generators.

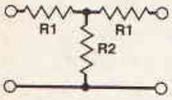
Figure 15 shows a 4-step 600R ladder attenuator suitable for audio generators. It is meant to be driven from a low-impedance source; with a 4V RMS input, it gives outputs of 1V, 100mV, 10mV, and 1mV. Switch SW2 enables the output to be loaded with an internal 600R resistor when driving high-impedance external loads.



'π'-TYPE ATTENUATOR PADS

dB LOSS	50Ω IMPEDANCE		75Ω IMPEDANCE		600Ω IMPEDANCE	
	R1(Ω)	R2(Ω)	R1(Ω)	R2(Ω)	R1(Ω)	R1(Ω)
1	5.750	870.0	8.625	1305	69.00	10,440
2	11.60	436.0	17.40	654.0	139.2	5232
4	23.85	221.0	35.78	331.5	286.2	2,652
8	52.85	116.0	79.27	174.0	634.2	1,392
10	71.50	96.0	107.2	144.0	858.0	1,152
16	154.0	69.0	231.0	103.5	1848	828
20	247.5	61.0	371.2	91.5	2970	732
32	994.5	52.6	1492	78.9	11,934	631.2

Fig.11 Design chart for 50R, 75R, and 600R 'T'-type attenuator pads.



'T'-TYPE ATTENUATOR PADS

dB LOSS	50Ω IMPEDANCE		75Ω IMPEDANCE		600Ω IMPEDANCE	
	R1(Ω)	R2(Ω)	R1(Ω)	R2(Ω)	R1(Ω)	R1(Ω)
1	2.875	433.5	4.312	650.2	34.50	5202
2	5.750	215.0	8.625	322.5	69.00	2580
4	11.30	105.0	16.95	150.0	135.6	1260
8	21.55	47.30	32.33	70.95	258.6	567.6
10	26.00	35.15	39.00	52.73	312.0	421.8
16	36.30	16.25	54.45	24.37	435.6	195.0
20	40.90	10.10	61.35	15.15	490.8	121.2
32	47.55	2.515	71.32	3.772	570.6	30.18

Fig.12 Design chart for 50R, 75R, and 600R 'π'-type attenuator pads.

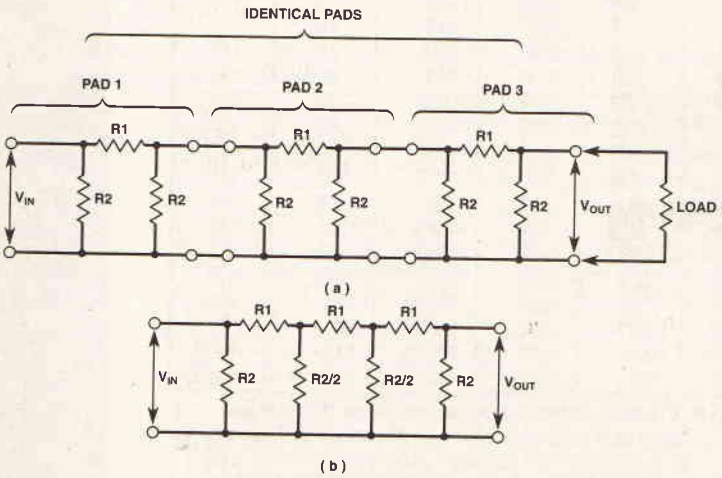


Fig.13 The 3-stage 'π'-type ladder attenuator of (b) is a simple development of the 3-pad circuit shown in (a).

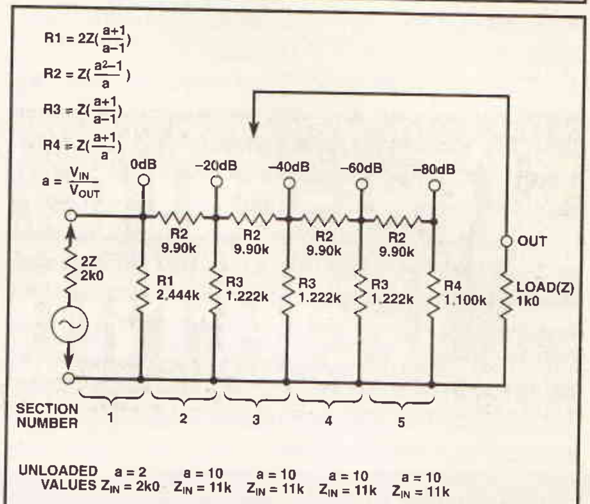


Fig.14 A worked example of a 5-step switched ladder attenuator, giving −20dB steps into 1k0, with design formulae.

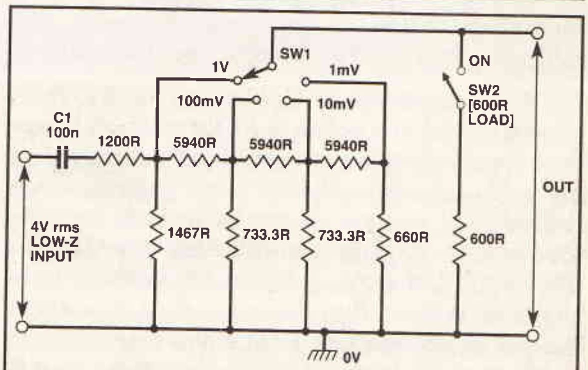
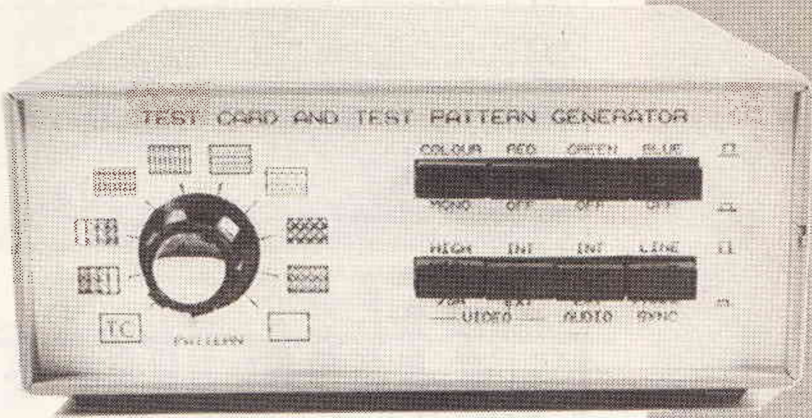


Fig.15 Practical 600R 4-step switched ladder attenuator for use in an audio generator.



Paul Stenning provides some additional information

Since this project was published in the December 1991 and January 1992 issues of ETI, several errors have come to light (most were the fault of the author, not ETI), and a few small modifications have been carried out. Also a few of the components have proved difficult to obtain, so suppliers or alternatives have been found.

Test-card And Test Pattern Generator – An Update

Errors

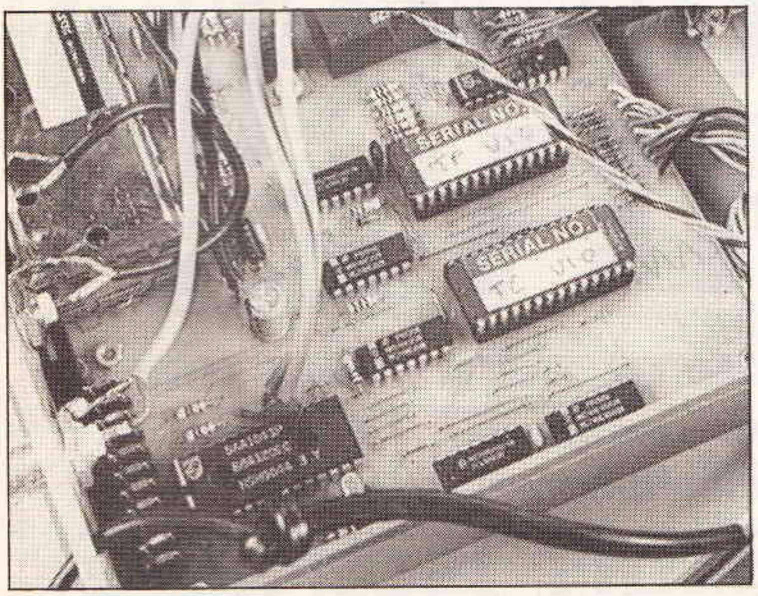
Part 1 (December 1991)

In Figure 1, the Int-Video-Out signal should go to SK6 pin 19, not pin 9 as shown.

Other errors in Part 1 are noted in Part 2.

Part 2 (January 1992)

In Figure 3, the Front Panel Design, two of the patterns around the Pattern Switch (SW2) are incorrect. The position shown as a coarse checkerboard pattern should be a fine checkerboard pattern, and the fine checkerboard pattern should be solid black. See the list in the diagram, in Part 1 corrections, on the same page.



In the Parts List, C21 & C28 should be 220p, and C26 should be 220n. The circuit diagram is correct.

In the PCB Component Overlay, Figure 2, the R43 between R37 and R32 should be R34.

Also in Figure 2, D13 and D14 are shown the wrong way round (ouch!). They should be mounted with the bar upwards (towards MOD1).

In Figure 1, the Interwiring Diagram, the bottom screened cable from SW8 to the PCB (near CV1), has the connections shown reversed at the PCB end.

Also in Figure 1, the Colour/Mono switch should be labeled SW6.

The author and ETI would like to apologise for these errors, particularly to anybody who has spent hours struggling with a non-working unit because of them.

Modifications

The wire from colour switch (SW6) to the PCB should be co-ax to prevent stray pickup affecting chrominance level, a hole is available on the PCB for the screen. The 0v link between SW6 and SW3 should be removed and the switch mounting brackets connected to 0v at SW5.

There was a slight, but significant problem of ringing on the video signal, particularly visible in the cross-hatch sections of the test-card pattern. This was caused by the luminance delay line, and after much experiment it was found that the only way to get rid of the problem was to remove the delay line completely, and replace it with it's equivalent resistance. The purpose of the delay line was to compensate for the delay caused to the chrominance signal by the chrominance filter circuit, so the chrominance filter had to go too. When the resulting video signal was examined on an oscilloscope the ringing was gone completely, the edges of the luminance signal were much sharper and the chrominance timing was spot on. The picture, when viewed on a high quality monitor via the scart socket, is much improved and the lack of a chrominance filter appears to have no adverse effects at all. To carry out this modification, remove L1 (delay line), L2 (15μH) and C10 (82p, next to L2). Fit a 910R resistor between the lower two holes of L1 (delay line) position. Yes — I know it's a waste of two pounds worth of bits — I'm sorry!

The video signal to MOD1 is slightly too high, to correct this, reduce R39 from 390R to 360R (4k7 in parallel with the 390R has the same effect).

Acknowledgements

The author would like to thank all those constructors who wrote to him with details of errors and problems. In particular he would like to thank Mr C. Oliver from Cheshire who provided the modifications and made several helpful comments. The Author would also like to hear from other constructors with their comments and suggestions, please write to the address given in Buylines in Part 2 of the project.

BUYLINES

It has come to the author's attention that 150ns 27C128 EPROM's are not too easy to come by. The prototype has since been tested with 250ns EPROM's which work fine. It should be noted that the EPROM's must be the CMOS 27C128 types, as normal 27128 devices consume far too much power and will overload IC13 (the 78L05 regulator) causing it to current limit.

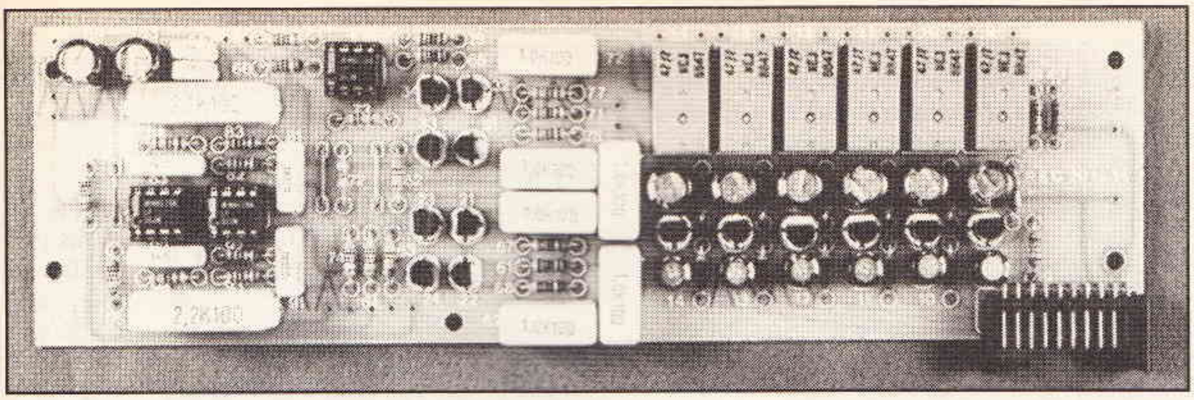
A few constructors have reported problems obtaining the 74HC574 IC, it is available from RS/Electromail and Cricklewood Electronics. Anyone who is repairing televisions and video recorders should definitely obtain a copy of the Cricklewood Electronics catalogue, since they stock almost every obscure IC and transistor you are likely to come across, as well as video heads, belts etc. Write to Cricklewood Electronics Ltd, 40 Cricklewood Broadway, London, NW2 3ET or 'phone 081 452 0161 (The author has no connection with this company, other than as a satisfied customer).

Maplin have recently changed their range of 0.1" pitch ceramic plate capacitors to ceramic disks with a 0.2" pitch, without changing the order codes! These will fit the PCB if the leads are bent, or the correct type can be obtained from RS/Electromail. Most other suppliers seem to omit the lead pitch of capacitors in their catalogues.

The Maplin order codes for the more critical or obscure parts are listed below:

CV1	22pF	TrimmerWL70M
IC9	TEA2000	UH66W
IC10	SAA1043	UK85G
MOD1	UM1286	BK66W
SK6	R/A	ScartFV89W
SW1,3-9	DPDT	LatchFH76X
XTAL1	5.000000	MHzUL51F
XTAL2	8.867238	MHzUH85G

Regrettably the author can no longer offer a printed HEX listing of the EPROM data, since it runs to 64 pages of A4, which is expensive to photocopy and post, and the 32K of data would be almost impossible for anyone to type in without error! The EPROM programming and HEX dump to disk services are still available and will continue to be indefinitely. Please ensure that any disk you send to the author is formatted (several haven't been), and if writing from outside the UK please enclose 2 International Reply Coupons for return postage.



Input buffer stage options and relay driver board

A high quality modular preamplifier

2

by John Linsley-Hood

In the first part of this article, I showed the general layout of the preamp., and explained my choice of a moderately elaborate gramophone input (RIAA) equalising circuit.

For the rest of the unit, I am, by inclination, a 'minimalist'—by which I mean that I prefer to have the smallest possible number of signal handling circuit blocks between the signal inputs and the power amplifier. This is partly because what one doesn't include doesn't cost money, and won't go wrong, but mainly because I feel that however pure one's circuitry may be, it can never be any better in its quality than a direct wire connection.

By and large, most contemporary sources of programme material are sufficiently good in quality that they don't require much modification, but there are still, occasionally, instances where the source material is a bit 'woofly' in its sound, or perhaps a bit 'over bright' in tone. There are also some instances where there is a persistent LF 'rumble' accompanying the signal, usually due to poor turntable bearings on recording or replay, or studio background noise, and even occurring, I regret to say, in some FM broadcasts originating from the BBC.

So, my preference, as a practical compromise, is to provide both a 'rumble' filter, and some form of 'tone control', within the system. If one allows for these to be switched out of circuit, or bypassed, when not required, this should avoid any possible signal degradation, on the majority of occasions when the programme material is good enough not to need any tailoring.

Both of these modules can be omitted entirely from the preamplifier layout if wished.

The other modules are two unity-gain buffer stages, and a high quality symmetrical class-A headphone amplifier, which can also serve as an output line driver for use with power amplifiers of lower sensitivity, or without gain and channel balance facilities on their inputs.

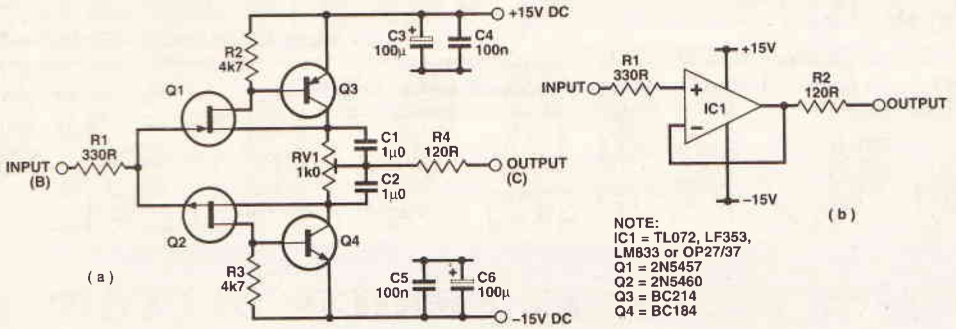
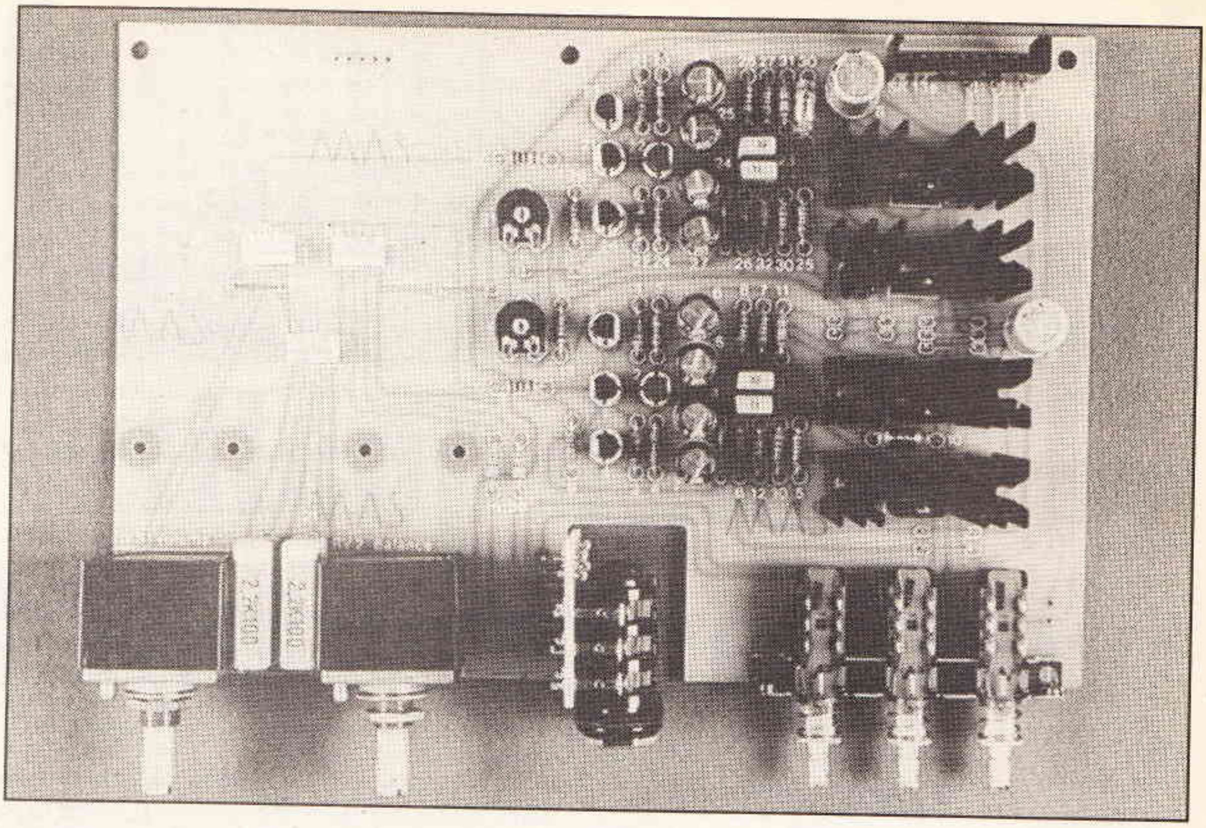


Fig.1 Input buffer stage options a) Discrete component b) Ic op-amp

Buffer Stages

It saves a lot of possible operational problems, such as 'cross-talk' or unwanted 'hum' and noise pick up, if all the signal routing within the preamplifier is handled at a low impedance. All of the incoming signals from the input selector switching are therefore taken to one or other of the impedance converting unity-gain buffer stages.

My preferred circuit for this position is the balanced FET/bipolar unity gain block shown in Figure 1a. I cannot hear any difference between this, or a good quality 'op-amp' (such as an LF351/353), used as a non-invert-



Headphone Amplifier Board (Stereo)

ing, unity gain module, or a direct wire connection, when I have done switch-over comparisons, on quite a wide range of material —though I have often found noticeable differences in sound quality between other bits of circuitry which I have tested in audio applications.

However, I feel that, other things being equal, the FET/bipolar circuit ought to be better, because it is simpler, and has better HF phase linearity. I therefore recommend this for the main input buffer position, though the module shown in Figure 1b. can be used without any concern on the grounds of quality, and I suggest the op-amp. unit as the output buffer to 'Tape No. 2' output, since it is extremely probable that any commercial tape recorder unit will be based on op-amps anyway.

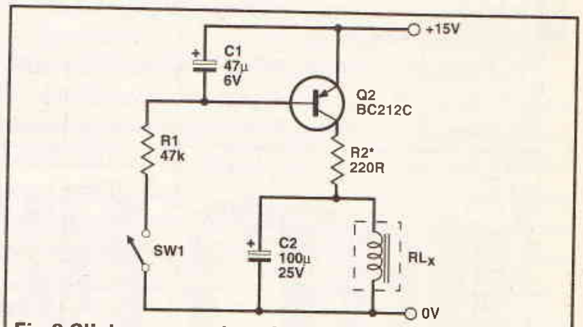


Fig.2 Click suppression circuit for relay switching

Signal switching

The power amplifier is sufficiently versatile, on its own, for it to be worth while to ensure that the preamplifier has some unique additional facilities to justify the trouble of building it. These lie mainly in the input switching and signal selection facilities offered, which not only permit the direct recording from one tape recorder (No.1) to another, (No.2), but also allow one programme to be taped while listening to another, or even to monitor one programme on headphones while another is being routed to the power amplifier.

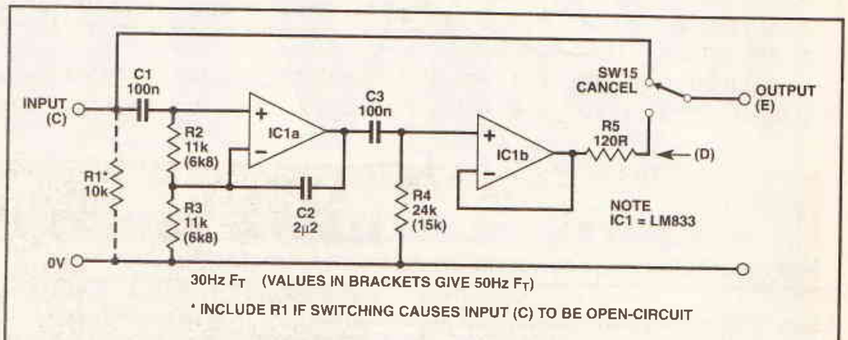


Fig.3 Rumble filter for 'ETI 80 watt' pre-amp

Hart have proposed, and included in their kit, another option which I had overlooked, and that is to make available to the constructor the choice, by way of an optional PCB link, of taking the output 'low-level' drive from either the input to, or the output from, the headphone 'balance' and 'gain' controls.

Ideally, all small signal switching should be by way of nonsliding, gold-plated contacts, operated in the absence of air. 'Reed' relays, or other inert-gas filled, or vacuum relays are among the best choices for this, if the cost can be supported, particularly since it would save the need for signal wiring to be brought to the front panel of the unit. (The use of relay switching is the option-which has been adopted by Hart Electronic Kits, in their kit of parts for this design). Care needs to be taken though, with relays, to avoid switching 'clicks' as the coil is energised or de-energised. A suggested relay switching layout is shown in Figure 2.

Rumble Filter

This is shown in Figure 3, and is a third-order 'bootstrap' filter with a substantially flat response, (within ±1dB), down to its cut-off frequency, and a -22dB/octave attenuation slope below this point. I have amended its cut-off frequency to 30Hz, from the 50Hz value which I suggested in June 1980, but it is otherwise largely unchanged. This choice of cut-off frequency is, however, at the discretion of the user, depending on the values chosen for R2, R3 and R4. The 11k bootstrap resistors are within the 1% preferred value' series, but, if hard to find, can be made from a pair of 22k resistors in parallel.

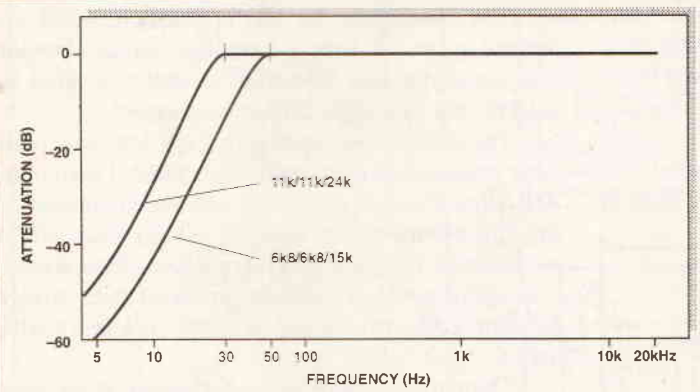


Fig.4 Attenuation characteristics of 'rumble' filter

The op-amps used can be of any type the user prefers, but I would suggest either LF353s or, at a somewhat greater cost, the technically superior TL052s, which are a pin for pin replacement. Since IC4 is used at unity gain, and so is IC3, over the bulk of the audio spectrum, I wouldn't expect that there would be any audible difference between these options.

I have shown the frequency response of the rumble filter in Figure 4.

The Tone Control Circuit

As I mentioned in the first part of this article, I have done a lot of heart searching over the design to offer for this purpose. Most programme material is good, and LS units are also getting better, so much of the one-time justification for providing some means for tinkering with the system frequency response has disappeared.

Nevertheless, there are still records which can be a little shrill, or lacking in bass, and broadcasts or tape sources which may sometimes be a bit dull or lacking in treble. My earlier suggestion for a push-button selected choice of ±3dB steps, at four regions of the audio band, has coped with most of my needs in practice, but there have been times when I would have liked rather greater

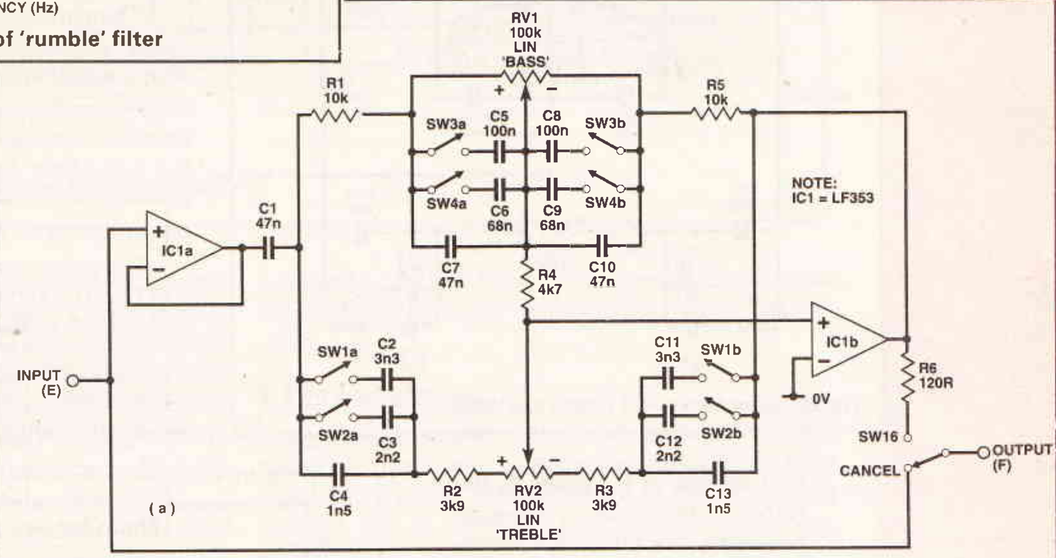
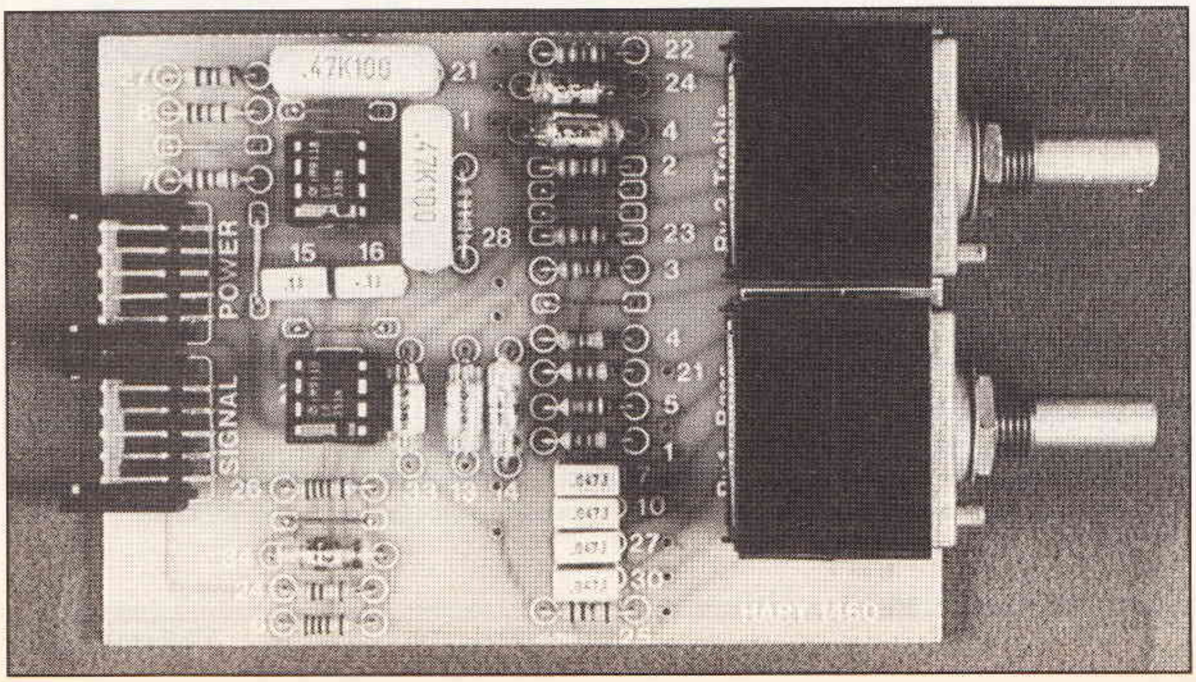


Fig.5 Modified 'Baxandall' type tone control a) Using single switches



'Baxandall' type tone control board

delicacy in the choices offered.

I had played for a while with a simplified 'graphic equaliser' type of layout, which divided the spectrum into three chunks, (bass, mid, and treble) and allowed each of these —basically flat —portions to be lifted or lowered in relation to the others, but this did not allow the possibility of a dB or two lift or cut at the extremes of the audio band.

I have therefore reverted to the layout which I thought I had liked best overall, the switched operating frequency modification of Peter Baxandall's celebrated circuit, which I had used in my 1972 'Hi-Fi News' 75 watt amplifier design. With modern, 'third generation' op. amps., such as the LF351/3 devices, or the even better TL051/2 units, a very low distortion and low noise performance can be guaranteed.

By switching the values of the capacitors in the treble and bass control circuitry, one can have either three or

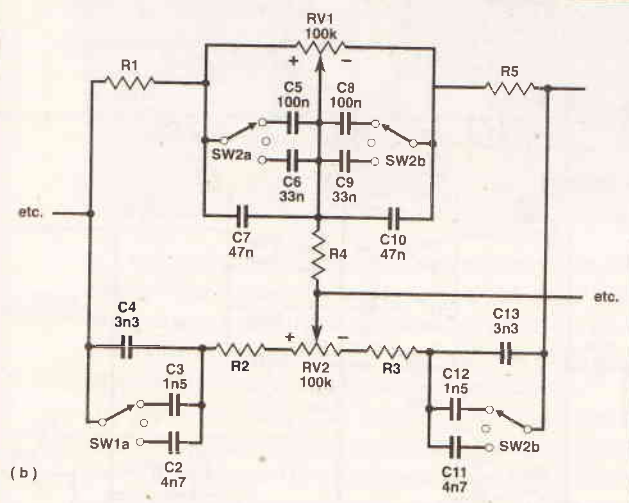


Fig.5b Using centre-off toggle switches

four choices of the shape of the lift/cut frequency response, coupled with a smoothly variable range of control, from zero up to some 15-20dB. In addition, by lifting or cutting both treble and bass simultaneously, one can also, relatively, lift or lower the midband for a form of 'presence' control.

In the circuit shown in Figure 5, IC1 is used as a unity gain buffer, and could also be of any type one wishes, but a FET-input op-amp. is by far the best choice for IC2. There will be a small advantage in maintaining high channel separation, if one is using dual ICs, in making IC1 and IC2 the two halves of the dual amp.

I have shown the possible response curves given by this circuit in Figure 6.

The Headphone Amp

Part of the design intention of this preamp. was to provide a self contained unit, with very high quality headphone listening facilities for those whose domestic circumstances or preferences led to the use of headphones rather than loudspeakers. One observes with regret that a growing number of commercial power amplifiers do not offer headphone outputs, or, if they do, they merely offer a parallel connection to the standard LS output sockets, with perhaps a resistor attenuator included for signal level matching.

This, I feel, does not allow one to take full advantage of the high impedance, low power demand of most headphone units, which will permit the use of circuitry designed specifically for this application, which can operate in class-A, with its complete intrinsic freedom from crossover type distortion products, without the need for any 'quiescent current' adjustment.

The circuit shown, in Figure 7, is a derivative of the same symmetrical push-pull design which I used in the RIAA input buffer stage; though with the small signal and small power transistors reversed in their roles; and its performance is equally good in respect of distortion and transient response. It also has an excellent ability to drive awkward loads, which could be useful if it is used as a line driver.

The current drawn by each channel of the headphone amplifier, (controlled by R11/R12), is about 80mA, which will lead to a heat dissipation in each of the output transistors of about 1.2 watts, so a small heatsink for each output device is needed. The headphone amplifier is fed from a separate ±15V DC output from the power supply, to avoid the possibility of any unwanted supply line signal feedback to the earlier stages.

The potentiometers RV2 and RV102 are used to set the DC offset at the output to the headphones to within about 50mV of the zero level.

I have also included a changeover switch, (SW18), on the input to this amplifier to allow it to be used to monitor the output to Tape No. 2, where the main amplifier is being used on the other input selector channel.

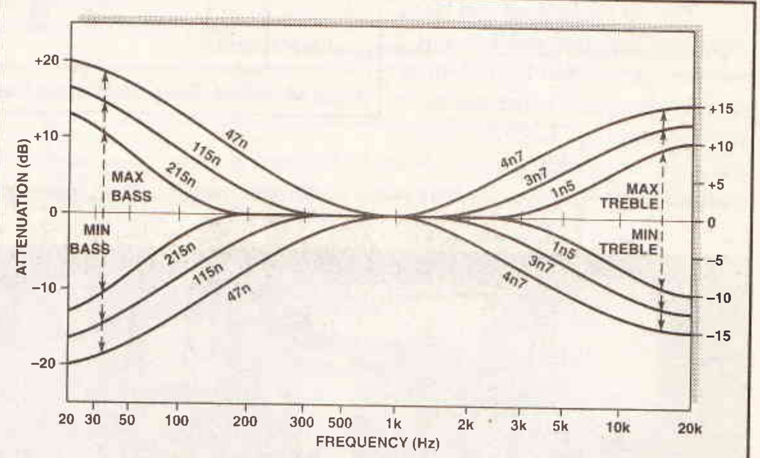


Fig.6 Tone control circuit — possible frequency response

The Power Supply

The layout of this is shown in Figure 8, and is an entirely conventional circuit, with a bridge rectifier and four (or five) (78../79.. type) IC voltage stabilisers. Each of these should be fitted with a small heatsink, to allow for worst case dissipation figures of about 1.5 watts.

PROJECT

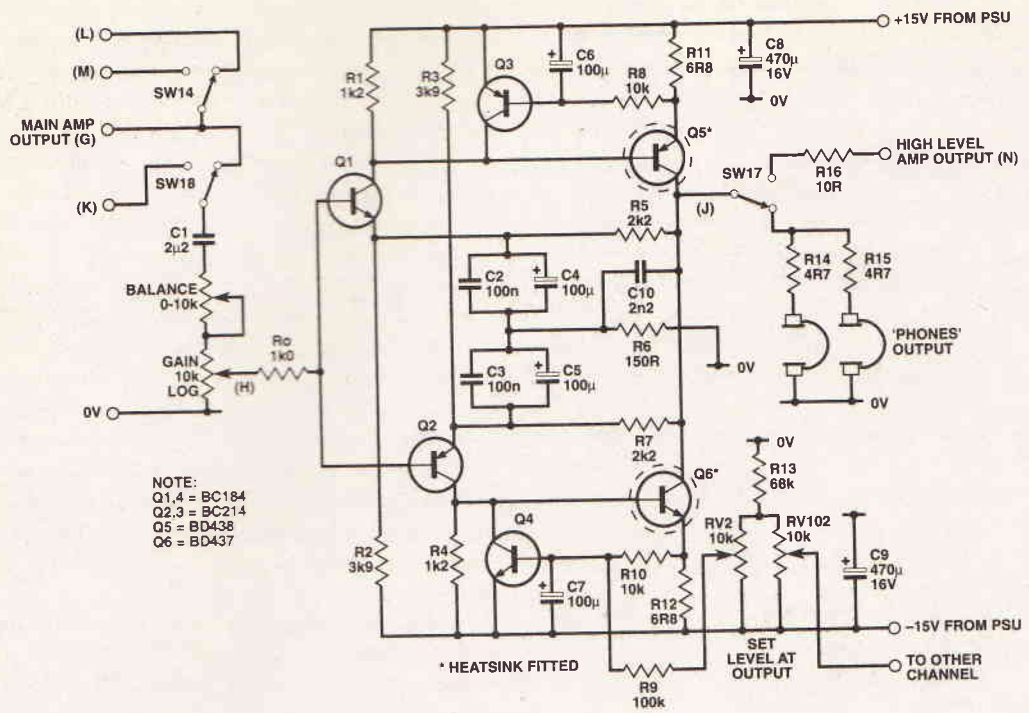


Fig.7 Class 'A' symmetrically driven headphone amplifier

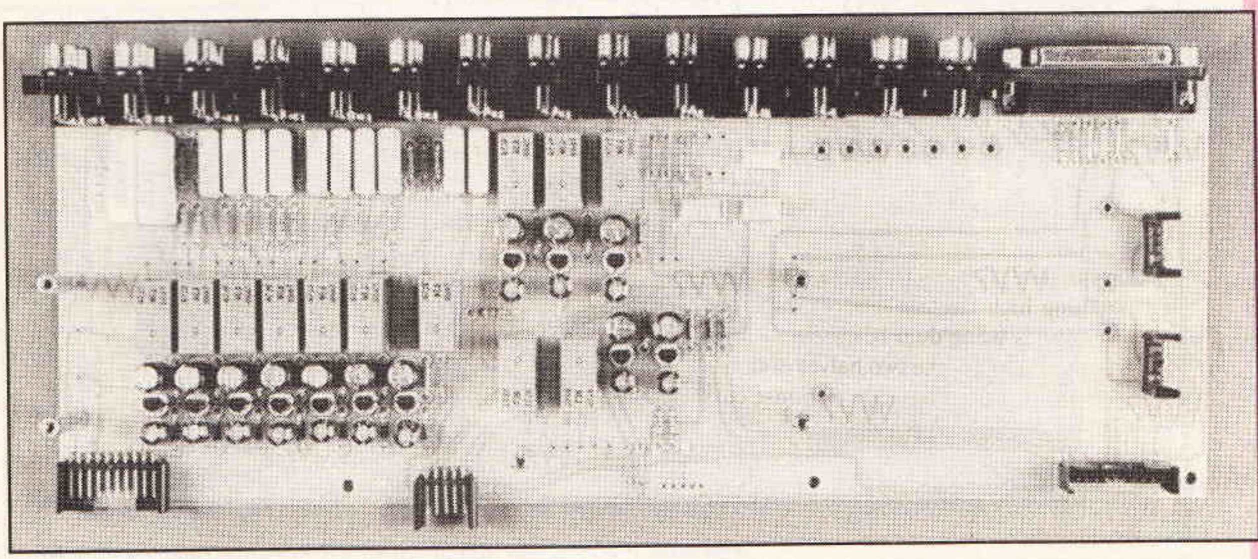
It is recommended that a screened toroidal transformer is used, with a rating of at least 21 watts if relay switching is to be used. If conventional mechanical switching is to be employed, a 15 watt rating will be adequate. I would also suggest that the transformer is located as far away from the MC input (RIAA) stage as is practicable. None of the other modules should be particularly susceptible to hum pick-up from its magnetic field.

On the power supply lines to the buffer, rumble filter, and tone control stages, where not shown, the supply lines should be decoupled to the local, on-board, '0V' line by a pair of 100µ, 15V DC working electrolytics, bypassed in turn by 0,1 non-polar capacitors, to avoid the occurrence of HF or AF loops along the supply line network.

LED Indicators

In my 1980 preamplifier circuit, which had, admittedly, rather fewer switching options, I arranged that a front panel LED would indicate which of the inputs was selected, and if either the filter or the tone control module was in circuit.

I think that this is quite a useful idea, and worth retaining. If relay switching is used, the LED can be con-



Input switching circuitry

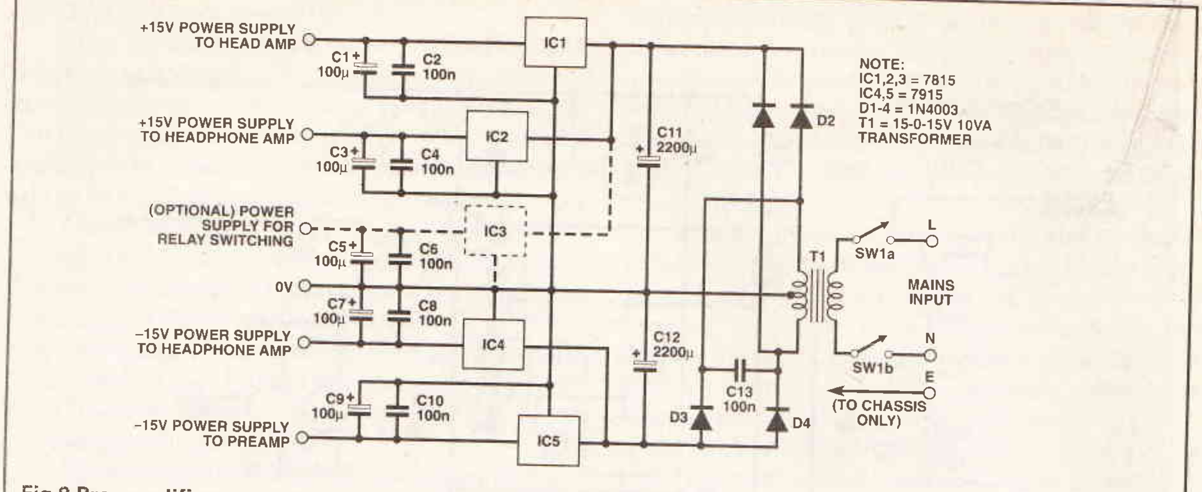


Fig.8 Pre-amplifier power supplies ±15V (also +12V if relay switching is used)

nected in series with the live side of the relay operating coil, but, in this case, allow an extra 3V on the relay supply. If simple push-switches are employed, a spare contact on the switch can be used to route 5mA DC from, say, one of the +15V DC supply lines, through a 2k7 resistor to the LED.

PCB Layouts

Suitable PCB layouts for the input buffers, the rumble filter, the tone controls, the headphone amplifier and the power supply unit, are shown in Figures 9 – 13.

Overall performance

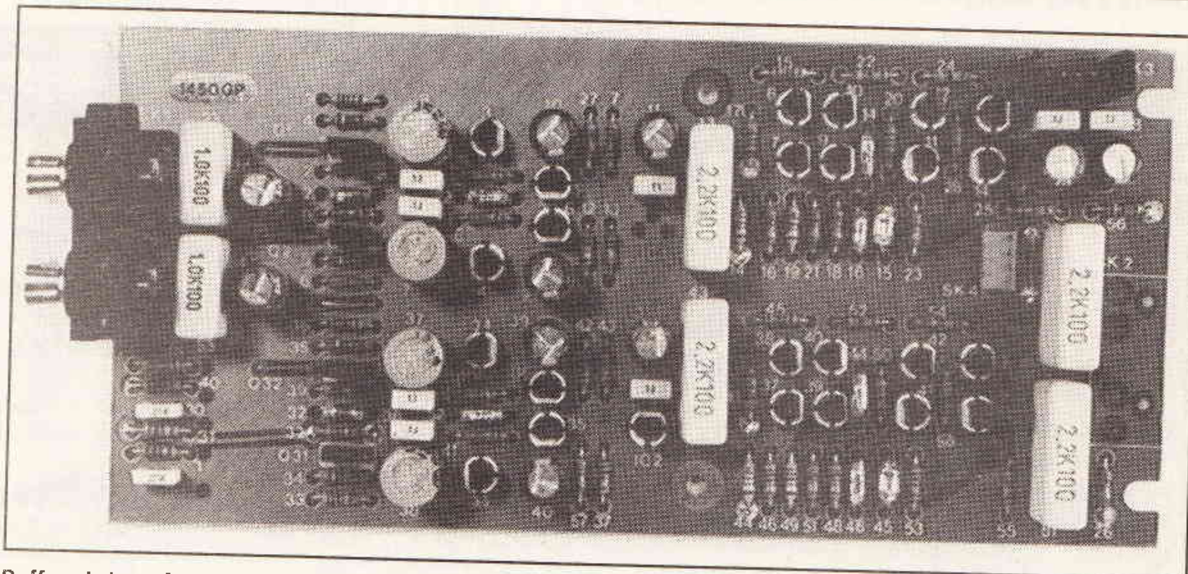
The thing any potential constructor always wants to know about any project is 'How good will it be when I've finished it'. Since DIY audio designs are very seldom reviewed by the 'Hi-Fi' press; who mainly cater for the buyers of commercially available 'black-boxes'; and the designer himself is likely to be prejudiced in favour of his own brainchild, this is a difficult question to answer.

There have been some very kind comments about the performance of the '80 Watt' 'Audio Design' power amplifier, which have appeared in one or two magazine correspondence columns, and I have, myself, met a few people who have built this amplifier, and are delighted with its sound quality. With regard to this preamplifier, I am very pleased with both the new RIAA stage, and the headphone amplifier, both of which do, I think, offer a better performance than any other comparable circuitry which I know.

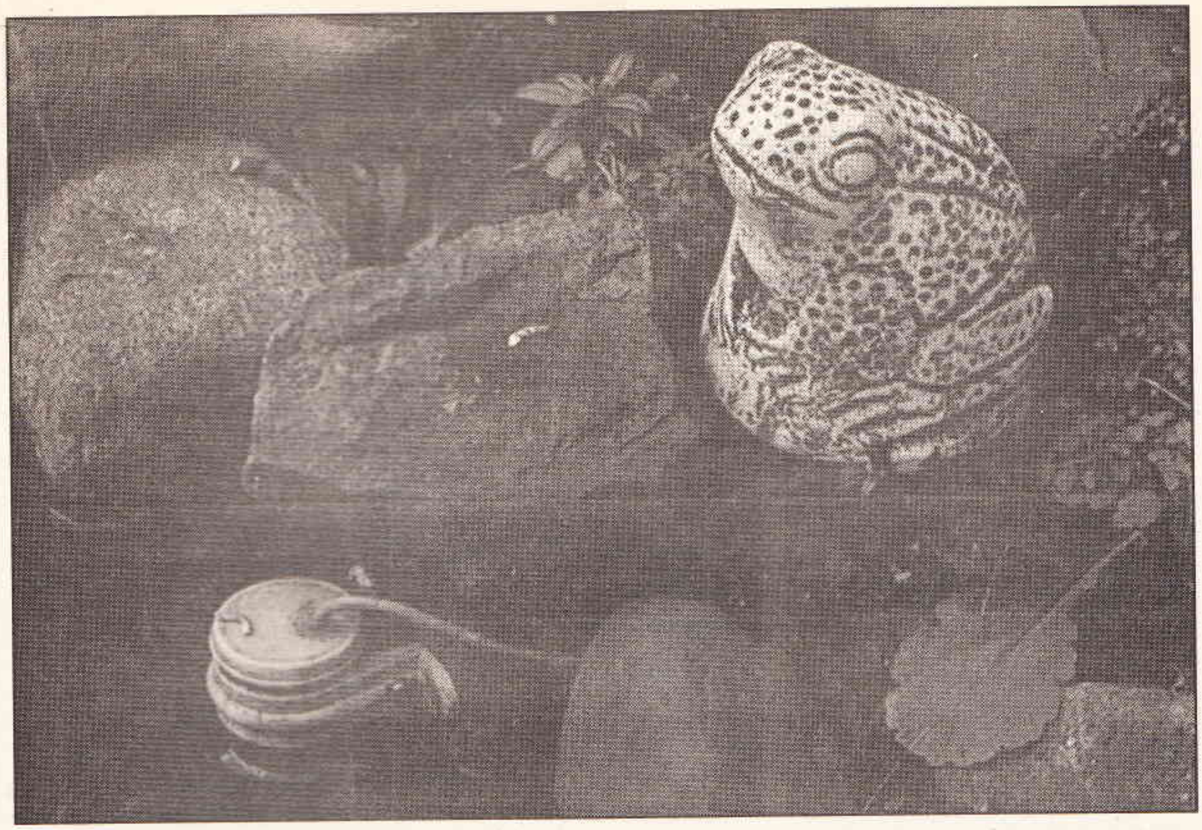
A very 'up-market' gramophone record headphone monitor unit could be built by just hooking these two units together, with a suitable twin output ±15V DC power supply.

BUYLINES

The bulk of the components I have used should be readily available from electronic component suppliers. However, I am advised that Hart Electronic Kits, of Penylan Mill, Oswestry, Shropshire, have assembled a complete kit of parts, complete with metalwork, to match the very nice looking kit which they have built for my power amplifier., and this should greatly assist the would-be constructor. They are also often helpful in tracking down and supplying other, sometimes unusual, components.



Buffered shunt feedback RIAA equalisation stage



Pond Level Controller

***Andrew Chadwick* provides a solution to an evaporating water problem.**

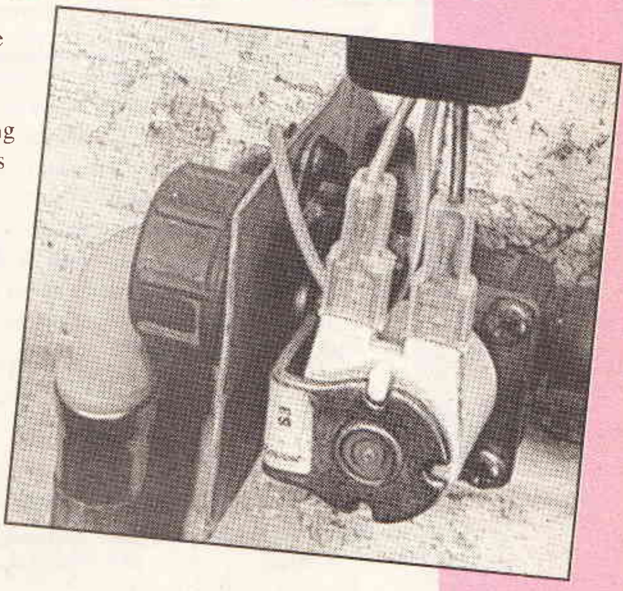
Having spent a back-breaking weekend installing a garden pond I consoled myself with the thought of sunny afternoons lazing in a deck-chair, watching the ripples play amongst the reeds. It wasn't long before I was disillusioned.

Although sunshine is a fairly rare phenomenon during the British summer, when it does occur its surprising how quickly water evaporates from a pond. A few days of good weather leaves the edges of the liner glaringly exposed and carefully designed shallows looking like Blackpool beach at low tide.

The answer is of course to top up the pond regularly which I'm sure keen gardeners would simply add to their list of seasonal chores. However as I had intended spending my leisure relaxing by the pond, not carrying buckets of water to and from it, I considered whether there might be an electronic solution.

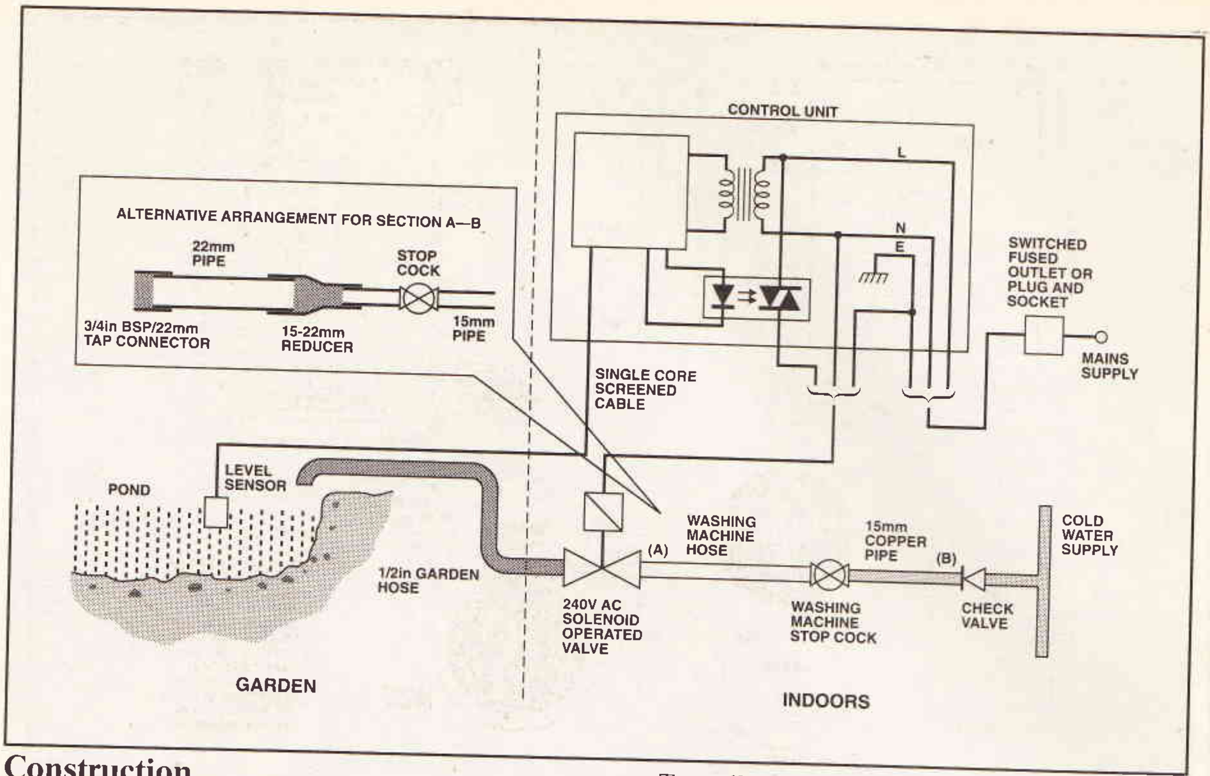
A low level alarm would be easy enough to devise but would only tell me what I could already see. What was needed was a level control system which automatically topped up the pond.

The system I designed does just that and is shown in the block diagram Figure 1. It can be conveniently divided into three sections; the control circuit, the level sensor itself and the plumbing.



The control circuit and plumbing are situated indoors so that there is no need for weather-proofing of the control unit and no hazard from mains cables outdoors. The level sensor and associated circuit operates at low voltage and is isolated from the mains so that screened audio cable can be used for the connection to the level sensor.

The level control circuit is based on the LM1830 level control integrated circuit which monitors the resistance between two probes in the sensor immersed in the pond. When the level falls below the tip of one of the probes, the increase in resistance is detected and the output of the integrated circuit energises a solenoid operated valve via an opto-coupled triac. The valve opens, allowing water from the cold water supply into the pond until the level rises sufficiently to contact the level sensor probe again.



Construction

I have described the plumbing first as this is an area that readers may be unfamiliar with. If you don't feel happy about tackling this part of the project then ask a keen DIY friend or even a plumber to do the job for you. You won't be thanked for creating another pond indoors.

Decide on the location of the control unit and solenoid valve. Ideally the position should be indoors close to a cold water supply and a mains electricity supply and not too far away from the pond.

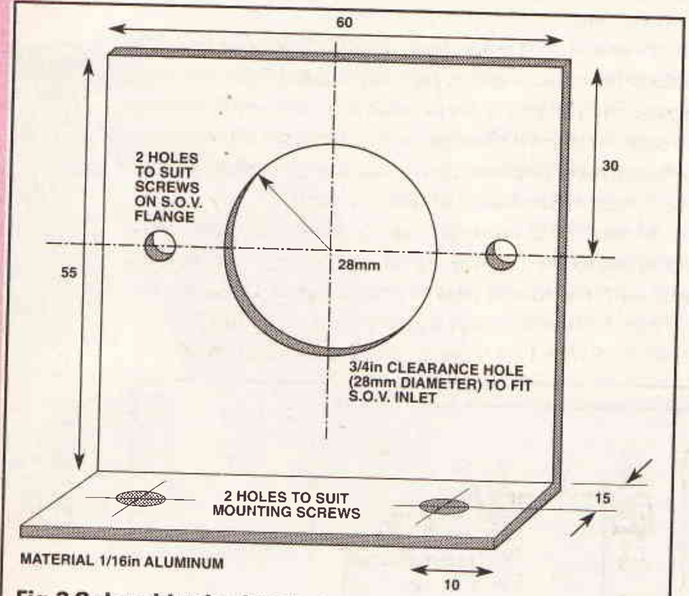


Fig.2 Solenoid valve bracket

There should be an easy route for the hose from the solenoid valve to pass through the wall of the house for example via air bricks or adjacent to existing waste pipes. The length of hose running indoors should be as short as possible. All plumbing should be below the control unit and wiring so that any leaking water will not drip onto electrical equipment.

Turn off the cold water supply and install a tee in the pipe. Run 15mm pipe to the intended location of the control unit. Fit a check valve then a stop cock. The solenoid valve I used was obtained from an old automatic washing machine and has a 3/4" BSP thread on the inlet side. I installed a washing machine stop cock which also has 3/4" BSP thread on the outlet and connected this to the solenoid valve with a flexible washing machine hose. However I could just as easily have used a normal stop cock with a short length of rigid pipe and a 3/4" tap connector on the outlet.

If a flexible washing machine hose is used, the solenoid valve will have to be mounted on a suitable bracket such as the one shown in Figure 2. From the outlet of the solenoid valve run 1/2" garden hose to the pond. Choose a route that will minimise the chance of the pipe being damaged by garden hazards such as spades, lawn mowers and children. The cable to the sensor should be run along the same route and tywrapped to the pipe so that it is protected to some extent. The end of the pipe should be *above* water level. This precaution together with the check valve in the supply pipe is to prevent pond water being drawn back and contaminating the mains water supply. Secure the hose to the solenoid valve with a jubilee clip or similar.

Details of the sensor are shown in Figure 3. A plastic 35 mm film container is used to house the two probes. The central probe is made of 3/16" brass rod (obtainable from model shops) and it is the position of the tip of this probe that determines the water level in the pond. The outer probe is made of 22swg tinned copper wire and is normally submerged. The two probes are supported on a piece of thin polythene cut from the lid of a plastic container. The external dimensions of this support may have to be adjusted to suit the particular film container used. Single core screened cable is soldered to the two probes and leaves by a tight fitting hole in the lid. A 1/8" vent hole is drilled in the side of the container. The 3/32" hole in the

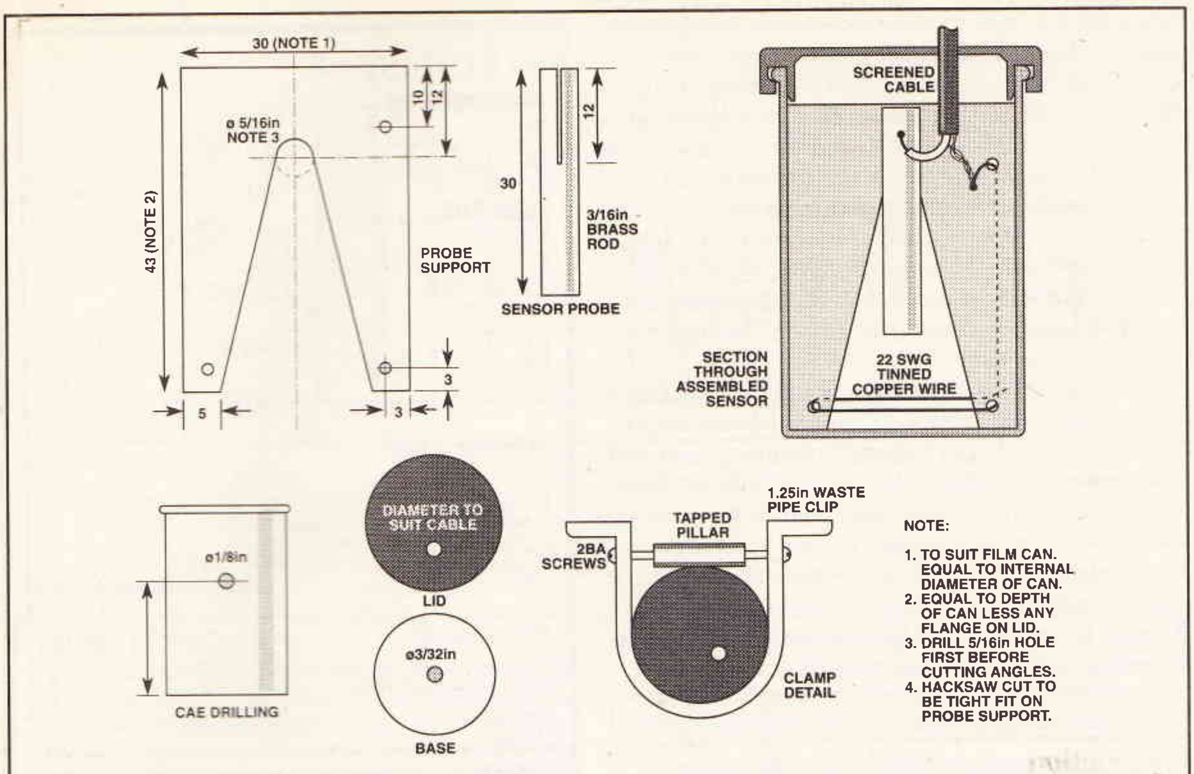


Fig.3 Sensor construction details

base of the container allows water to enter but is sufficiently small to act as a restrictor and with the capacity of the container produces a sort of RC filter which damps out any oscillations in water level caused by wind, fountains etc.

The sensor is supported by a 1¼″ waste pipe bracket (plumbing again!) which can be clamped by two 4BA brass screws joined by a brass tapped pillar. The bracket was attached to the vertical face of a brick using brass screws and plastic plugs. The brick was concealed at the edge of the pond overhanging the water. When fixing the sensor in position remember that the water level will be controlled at the height of the tip of the central probe which is at approximately 15 mm from the base of the film container. Fine adjustments to the level can be made by slackening the clamping screws and sliding the sensor up or down in the bracket. Position the sensor so that the air vent hole is at the back and so not obstructed by the bracket.

Finally to the electronics. The control unit is built on a single printed circuit board and housed in a suitable enclosure. A cheap folded aluminium type was used in the prototype.

To ensure safe operation, the PCB has been laid out so that the mains voltages are segregated from the low voltage circuits and it is essential that this separation is maintained during construction. The earth terminal on the board must be connected to the mains earth and if the case is metal this should also be earthed.

Mount the components on the printed circuit board according to the overlay shown in Figure 4 starting as usual with the lowest profile components. Connect the LED to the board using two short lengths of flex. Sleeve the joints to the LED legs to avoid short circuits. Refer-

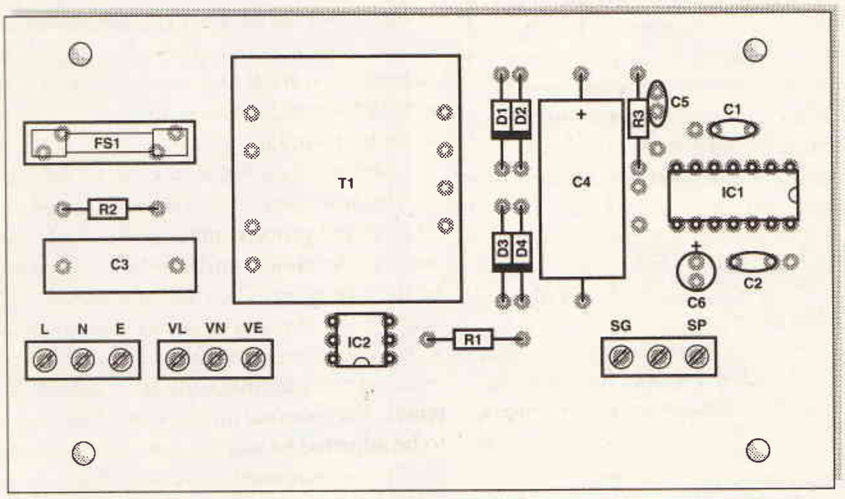


Fig.4 Component Overlay

ring to Figure 5 place the circuit board in the enclosure and mark through the mounting pillar holes. Drill holes in the case for the mounting pillars, and temporarily fit the board in the case. Mark the position of the three cable entries opposite the terminals and drill suitably sized holes, allowing for grommets if a metal case is used. Drill holes through the base for screws to attach the control unit to the wall or other suitable surface and drill a hole in the side for the LED.

Mount the enclosure on the wall, fit the board to the mounting pillars and locate the LED in the hole in the side of the enclosure.

Wire up the enclosure as shown in Figure 5. Run a three core flexible cable from the mains terminals to a suitably fused plug and socket or a dedicated switched fused outlet. The cable to the solenoid valve will probably require push on connectors to suit the terminals on the solenoid. Use the insulated type and for extra protection thread a cable gland shroud (obtainable from electrical wholesalers) over the solenoid terminals as shown in Figure 5 If a metal bracket has been made up to support the solenoid valve connect the earth wire to it.

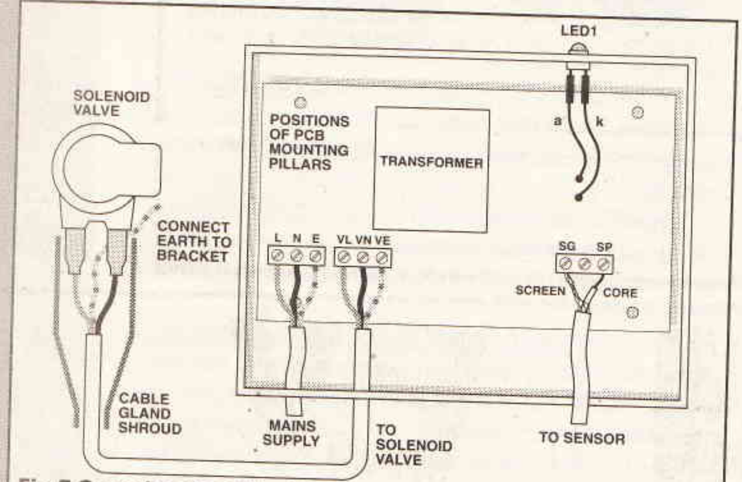


Fig.5 Case details and wiring

Testing

Check that the mains circuitry is well separated from the low voltage circuits. Disconnect the mains cable at the socket or outlet and check that there is continuity between the earth conductor and the screen of the level sensor cable. Then use a megger or failing that a multimeter set to the high resistance range to measure the resistance between the live and earth and neutral and earth conductors. Both tests should give an infinite reading.

Reconnect the mains and switch on. Ask an assistant to raise and lower the level sensor and listen for the solenoid valve operating or monitor the voltage across the terminals. Don't forget that there will be a delay due to the restriction in the base of the level sensor. If the system seems to be operating satisfactorily, position the level sensor in roughly the desired position and open the stop cock. The pond should fill to the correct level when the solenoid valve should close. If the pond is already full, remove a few buckets of water in order to lower the level and activate the solenoid valve.

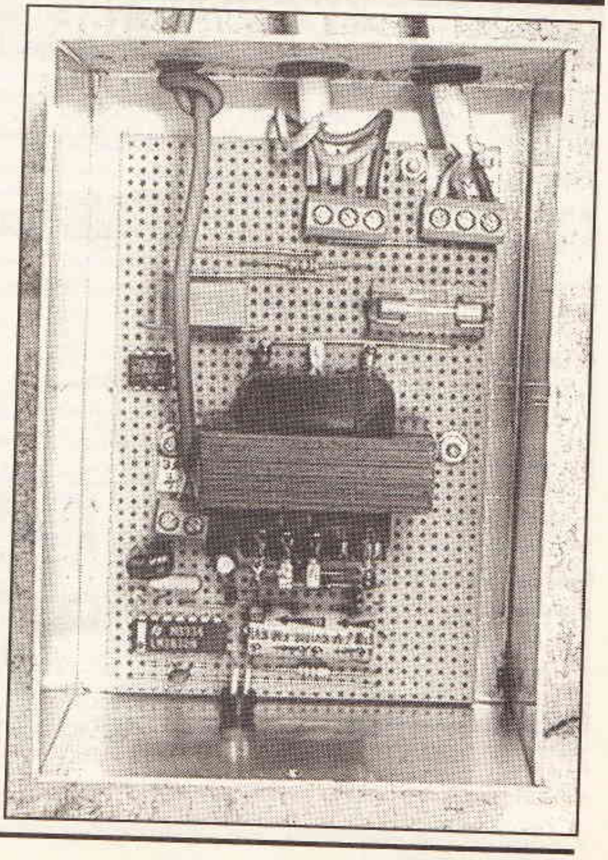
All that remains is to get the deckchair out and wait for some sunshine!

PARTS LIST

RESISTORS (All ¼W)	
R1,3	680R
R2	1k
CAPACITORS	
C1	1n
C2	47n
C3	100n 400V
C4	1000µ 16V
C5	100n
C6	22µ 16V
SEMICONDUCTORS	
D1-4	1N4001
D5	Red LED
IC1	LM1830
IC2	TIL3022
MISCELLANEOUS	
FS1	20mm T100mA
TI	9V 3VA PCB mounting
Terminals	3 3-way PCB type
LED clip	
Fuse clips	
Case	MB3 or similar
	Solenoid valve
	Screened cable

BUYLINES

Most parts are available from the usual suppliers. IC2 can be any opto-coupled triac rated at 100mA RMS with a trigger current of no more than 15mA. T1 can be obtained from Farnell. Check the layout of the PCB pins if any other type is used. The solenoid valve in the prototype was obtained from a scrap washing machine. Try your local washer spares shop!



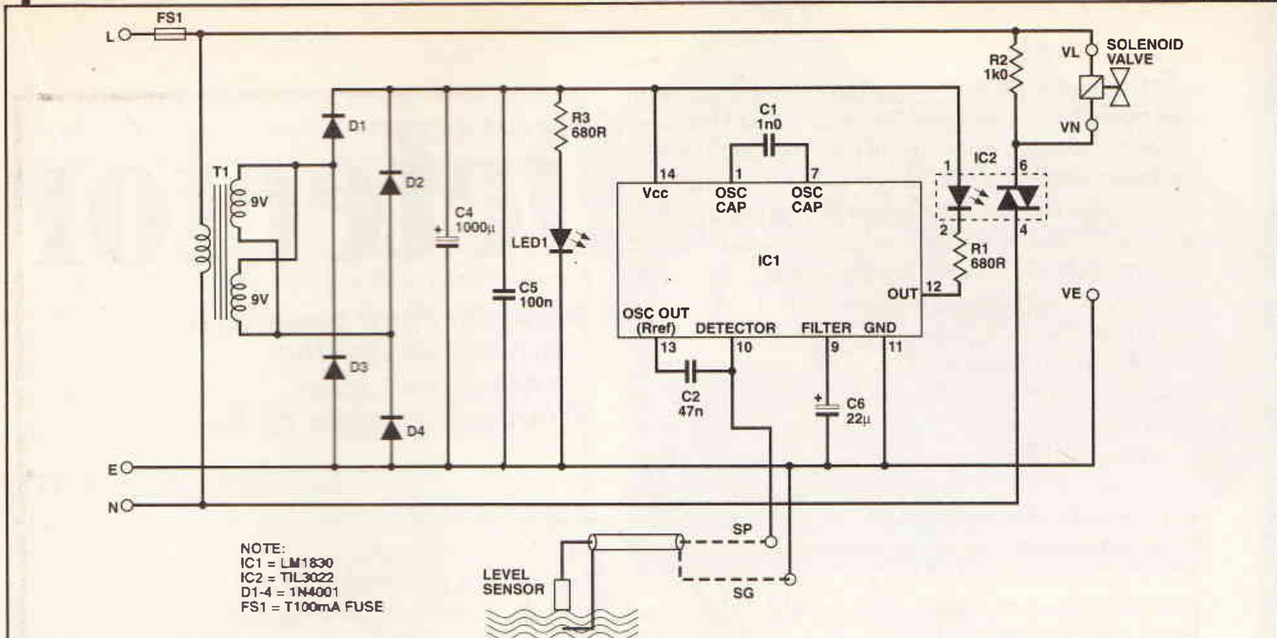


Fig.6 Circuit diagram

HOW IT WORKS

Figure 6 is the circuit diagram of the level controller which is based around the LM1830 level control integrated circuit, IC1. The LM1830 monitors the resistance between two probes by passing an AC current between them. When the probes are immersed in a reasonably conductive liquid (such as pondwater) the resistance between them is low and the output transistor is off. If the level falls so that the probes no longer make contact with the liquid, the resistance between them increases and the output transistor turns on.

C1 sets the frequency of an internal oscillater to roughly 1kHz. The output of this oscillator is a square wave of amplitude 4Vbe which is fed via an internal reference resistor to pin 13. C2 couples the AC signal to the level sensor whilst blocking any DC component present which could cause electrolysis and corrosion of the probes. The AC signal across the level sensor is monitored by the detector input, pin 10, and if it exceeds 2Vbe, the open collector output, pin 12, will be turned on. This will occur when the resistance between the probes exceeds the internal reference resistor which is set at about 13 k.

C6 smooths the output of the detector and provides some protection against noise picked up on the sensor cable.

The output of IC1 turns on the opto-coupled triac, IC2 which energises the solenoid valve.

R2 and C3 damp any transients when the highly inductive solenoid is turned off.

T1, D1-D4, C4 and C5 provide the low voltage supply for IC1

Bat Detector

Malcolm Plant presents a portable sensor for hearing ultra sonic frequencies made by bats.

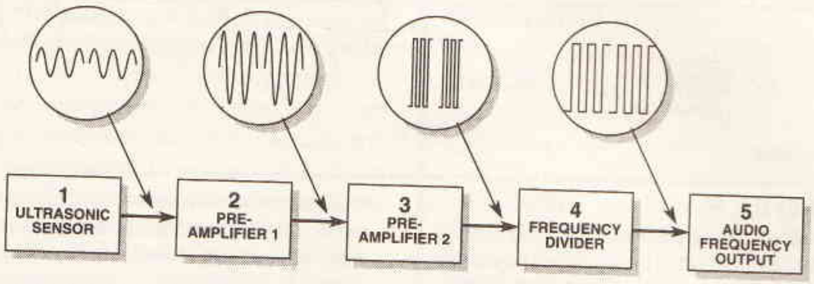


Fig.2 Building blocks of the bat detector

About Bats

Everybody is fascinated by bats. They are animals that fly like birds yet have fur not feathers, rest and sleep upside down and, magically, they feed and find their way about in complete darkness. They are very clean and groom frequently, and the British variety eats only insects and gives birth to live young as do rabbits, foxes and seals. Yet many people, their imaginations fired by the myths that surround bats even today, actually seem to be afraid of these harmless and fascinating creatures.

Surprisingly, bats make up a third of the species of mammals in Britain but, like so much of our wildlife, the numbers of bats have declined seriously in the last few decades. Their need for plenty of insect food and different options for roosting make them vulnerable to the way we have changed the natural environment: trees and hedges lost to agriculture and building developments, the reduction of insects through modern farming methods; the use of pesticides to control wood beetle in roof spaces; and the blocking up of their resting quarters in caves and tunnels which are often used as waste dumps or stores, have all affected them directly or indirectly and reduced their range, habitat and numbers.

In addition to the fact that bats are interesting to watch and understand, they also have an essential part to play in maintaining biological diversity in the Earth's ecosystem. For example, their importance as pollinators of plants all over the world is only just begining to be realized.

Indeed, so many species of bats have been destroyed worldwide that June 21 to 27 in 1990 was designated National Bat Week in Britain in order to bring to the public's attention the plight of bats.

Bat Sonar

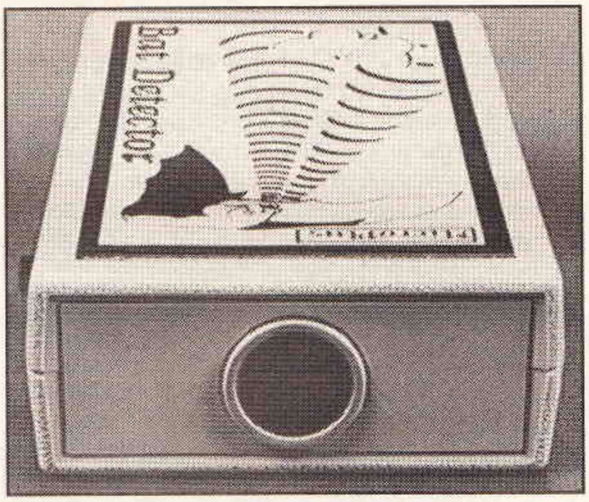
When you see bats flying over your gardens and along hedgerows and woodland edges at dusk and after dark, you must have wondered how they are able to avoid bumping into things let alone be able to catch night flying moths and other insects for food. Their secret, which is also shared with dolphins is that over the last 50 million years bats have evolved a superbly sensitive sonar system which is exquisitely adapted for navigation and finding

Fig.1 The general appearance of the Bat detector

PROJECT

food while flying about. Their built-in sonar produces bursts of ultrasonic waves which bounce back from objects, including insects, to give bats a 'sound picture' of their surroundings in probably as much detail as our sight gives us.

Until about 1940, nobody knew that bats used echo location. But when the word got about, some scientists couldn't believe their ears. The idea that bats could do anything even remotely like the latest triumphs of electronic engineering, namely sonar and radar which in 1940 were still military secrets, struck them as being very improbable. So much for open-minded science!



Using the Bat Detector

The Bat Detector is powered by a PP3-type battery housed in an integral battery compartment, and you listen to the sounds bats make through a pair of stereo headphones plugged into the headphone socket. You can test that the Bat Detector works as follows: press the 'on' switch and rub your thumb and fingers together near the ultrasonic sensor at the front of the unit. A scraping sound should be heard since the rubbing of the fingers produces ultrasonic sounds. The splash of running water from a tap, the rustle of paper and friction between many types of surface also produce ultrasonic sounds which can be heard with the Bat Detector.

The Bat Detector is used rather like a torch. You scan the sky with it but it receives signals rather than sending them out. Remember that the bat you hear could be flying behind you. You should avoid rubbing your fingers over the Bat Detector when you are using it as this will cause interference that masks the sounds you are hoping to hear from the bats.

The bursts of ultrasonic sounds that bats make will be heard as a "chick, chick . . . chick . . ." sound, repeated at a rate of between about 10 and 100 per second depending on what the bat is doing. For example, when a Little Brown Bat is cruising about, the rate is about 10 per second, rising to about 200 which sounds like a "buzz" or a "burp" when it moves in on an interception course with an insect.

Design Decisions

The ultrasonic sound made by bats has a wide frequency spectrum most of which is well above human hearing in the range 20kHz to 200kHz. In order for us to hear these sounds they must be reduced to audible frequencies that are below about 16kHz —at least for the average human ear. Wideband ultrasonic sensors are available but they are expensive so it was decided to try and sense the ultrasonic sounds using a standard low-cost ultrasonic sensor which, typically has a narrow bandwidth centred on 40kHz (+1kHz). They are usually sold as matched pairs which means that the receiver sensor has its maximum sensitivity tuned to that of the transmitter sensor. They are in fact transducers, since their function is determined by piezoelectric (usually ceramic) material which provides small amplitude voltage variations on receiving 40kHz sound waves (in the case of the receiver transducer), and the transmitter produces 40kHz sound waves when fed with pulses at this frequency.

The narrow bandwidth of the receiver transducer is a limitation since the Bat Detector only samples a small portion of the range of ultrasonic pulses the bat emits. However, the unit is sensitive and responds well to the calls of bats commonly found in our countryside.

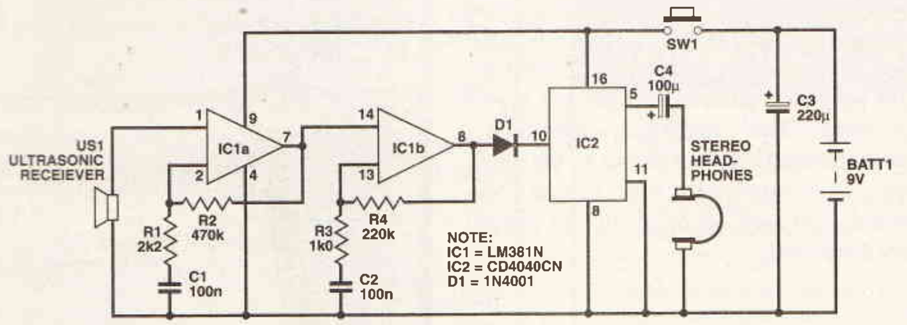


Fig.3 Circuit diagram of the bat detector

The output from the receiver transducer is analogue but it was decided not to faithfully amplify this signal throughout the circuit design as this would complicate the design and make it more difficult to lower the frequency so that it could be heard. In any case, the small bandwidth of the transducer did not merit such a design. Instead, as shown in Figure 2, the signals from the transducer are amplified by two low power audio preamplifiers in a single IC package, the LM381 device. The two amplifiers each have a 75kHz bandwidth so are ideally suited for amplifynig 40kHz signals from the receiver transducer.

The final part of the circuit design is a frequency divider which is based on a CMOS 4040 frequency divider, one output (pin 5) of which is chosen to give a frequency division of 2^5, ie 32. Thus an audio frequency version of the original ultrasonic pulses is heard in headphones at around 1.2kHz. It was decided not to use a Schmitt Trigger to condition the waveforms from the amplifier as tests showed that the signals from the second amplifier had an acceptable shape to 'clock' the divider. The voltage step introduced by the silicon diode IC attentuates noise in this high gain preamplifier.

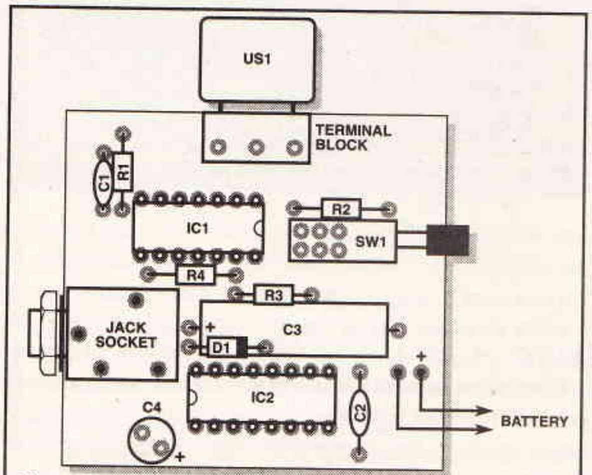
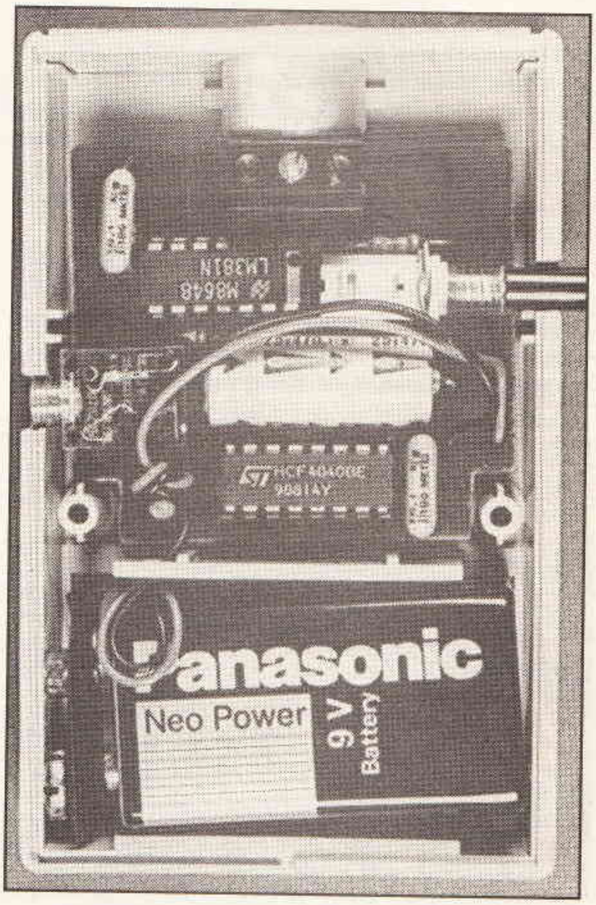


Fig.4 Component Overlay

The above design considerations have been incorporated in the circuit diagram shown in Figure 3. A push-to-make release-to-break switch, SW1 is used to power up the circuit as the Bat 'Detector is always hand-held. A 9V PP3 battery provides the circuit power and was chosen to fit inside a ready-made box —see below. Stereo headphones are used to listen to the bat calls —not that the reception is in stereo! But stereo headphones are readily available with other audio equipment such as personal cassette players. The CMOS frequency divider chips vary in their ability to deliver power to the headphones and the one recommended from Farnell Electronic components was more effective in this respect than others that were tried.

Assembly

The size of the printed circuit board for the Bat Detector is shown in the component overlay in Figure 4. The switch, jack socket and terminal block are mounted on the PCB. Note that all holes for component leads should be 1mm diameter except those for the jack socket which should be 2mm. diameter. The battery leads go to the PP3 battery in the integral battery compartment via whole drilled in the dividing panel. The battery should be padded with a small piece of foam to prevent it moving about for this generates ultrasonic interference. Use sockets for the ICs and only insert these once the sockets have been soldered in place. The terminal block needs raising 1mm off the surface of the PCB to ensure that the transducer is dead centre in the end plate. (Use a small piece of stripboard as a spacer). Carefully measure the diameter of the transducer before making a neat hole in the end plate for a push-fit so that the transducer projects about 1mm through the plate. Cut the two corner pieces off the board and, if necessary, slice off one of the pillar ribs on each side of the box. Position the PCB in the base of the box. Carefully mark the positions of the jack socket and push switch. Remove the PCB and screw the two halves of the box together before drilling two holes neatly and carefully through the sides of the box — the holes cut into both halves. The holes should be a tight fit for the jack socket but allow some freedom for the black cap of the push switch to move in and out of its hole. There should be no need for PCB fixing screws as the PCB will be held firmly in place via the jack socket and ultrasonic transducer. The layout of the main components in the box is shown in Figure 5. Remember to cut a small piece of polystyrene foam to fit inside the battery compartment to prevent movement of the battery. It is important that there is no movement of the circuit board or other components inside the box as this will cause ultrasonic noise and mask what you want to hear. Finally copy and cut a label to stick in the panel of the box.



Testing And Use

Plug in a pair of stereo headphones press the push switch and rub the fingers together in front of the transducer. A scraping sound indicates that the unit works. At night or at dusk when looking for bats, make sure that you do not rub your fingers over the surface of the box as this will mask the 'chick, chick, chick . . .' audio frequency version of the ultrasonic pulses made by bats. Note the increase in frequency of 'chick' sounds when bats dive or swerve to capture an insect. If you buy a dual headphone adaptor, two people can enjoy the music! The circuit draws a few milliamps so that a new or fully charged PP3 battery will last you for many balmy Spring and Summer evenings listening to the calls of bats.

Further Information

There are many books to help you understand bats better and how to identify them. Bats are having a tough time and need your care so join a local bat protection society! And the following books contain information about identifying and caring for bats:

Amazing Bats, Greenaway F. Dorling Kindersley (1991)

Bats, Richardson,P, London Whittet Books (1985)

The Likes of Bats, Schober W. London Croom Helm (1984)

Which Bat Is It'? Stebbings R E, The Mammal Society (1986)

The Blind Watchnaker. Dawkins R, Penguin Books (1986)

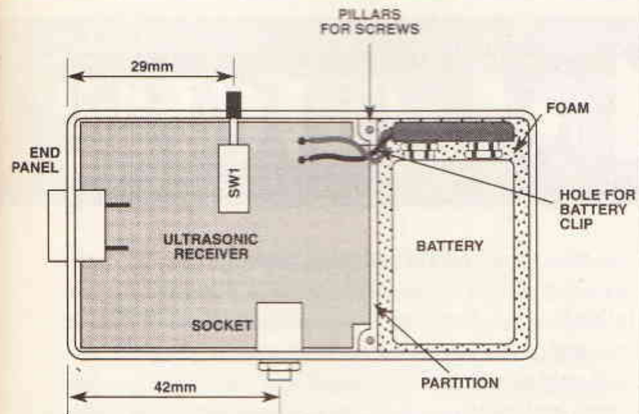


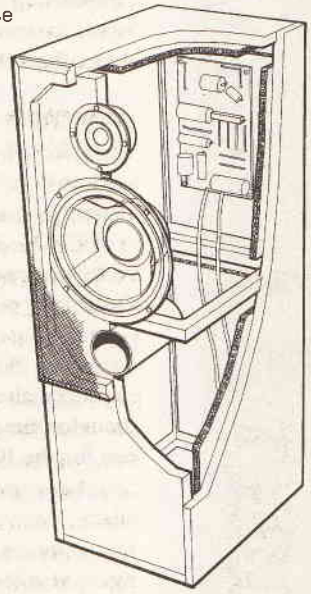
Fig.5 Component arrangment in box

PARTS LIST

RESISTORS (1/4watt metal film)
R1 2k2
R2 470k
R3 1k
R4 220k
CAPACITORS
C1,2 100n poly
C3,220µ/10V
C4 100µ/50V
SEMICONDUCTORS
IC1 LM381
IC2 CD4040CN
D1 1N4001
MISCELLANEOUS
US1 Ultrasonic transducer type R40-16 sold as a pair
SW1 Sub-min DPDT momentary action
SK1 3.5mm PCB stereo jack
IC socket 14 pin and 18 pin
Terminal block 3-way standard 300 series
BATT 1 9V PP3 and battery clip
Box Pocket type with integral battery compartment
Label
Copy the label shown in this article, or make your own, and stick it in the panel oil the top of the box

BUYLINES

All components from Maplin Electronic Supplies Ltd unless otherwise stated.



Introduction to Genetic A

by Douglas Clarkson

Perhaps the best secrets of Nature are in fact the simplest. The field of Genetic Algorithms (GAs) is attracting increasing interest from a range of different application areas. While this mathematical tool may appear to be driven by a high level of mathematics, this is in fact not so. Many of the operations are in fact very simple binary bit manipulations of binary data, so at any level of activity, the computer is actually doing very simple work.

While computers are an essential part of implementing GAs, the programming is not over complex, so anyone who is reasonably competent in say BASIC, can implement a demonstration programme. Where GAs are used for serious work, powerful machines running optimised software packages are required. In summary, GAs are simple and can be readily understood.

Problem Solving

In solving problems the term 'problem space' is often used. This as it were is the range over which possible solution can be found. Where there is an optimised solution, this could be for example 1 out of 100 options, 1 out of 10,000 options or 1 out of a very large number. Different problems have different problem spaces. GAs are used to speed up the process of finding an optimised solution for a problem area where it is not practical to check each solution individually. GAs as it were sniff out the components which lead towards success. An essential part of implementing GAs is the use of a so called 'fitness function'.

Consider the equation :

$$Y = -X^2 + 256X \qquad (1)$$

Figure 1 shows how the function behaves between 0 and 256. The value of Y can be described as the fitness function of X. In this example we do not need GAs to show that a maximum value of Y is obtained for a value of X of 128. This example of a fitness function, however, shows how a problem space of values of X between 0 and 256. There are numerous problems, however, where problem spaces are vast—values of 10 raised to power 10 or 10,000 million are typical of large spaces. It is not practical to go and evaluate a function for each one. This is the area where GAs can play a part in finding a solution.

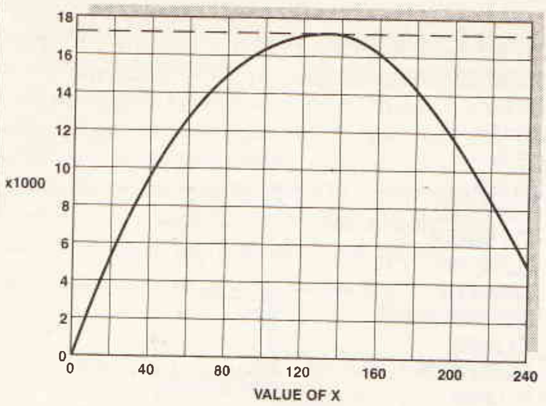


Fig.1 A standard fitness function

Consider Figure 2 which shows a 8×8 grid in which 4 objects are placed at random. The solution is required which will lead to a minimum of 'energy' of the system where the energy of a given object with respect to another object is inversely proportional to the square of their separation. That is all the objects want to be as far from each other as possible.

If the first object is placed in any one of 64 squares, then the next one is placed in any one of the remaining 63 and so on until all are placed in separate squares, there are 64 ×63 ×62 ×61 =15,249,024 placement possibilities. So this is a non trivial problem space. Where all the objects influence each other equally, then there is probably many duplicate solutions. This indicates that some problems can have a great number of possible states and that there is a requirement to develop tools to arrive at the optimum solution in as short a time as possible. This problem can be also simulated in a test program.

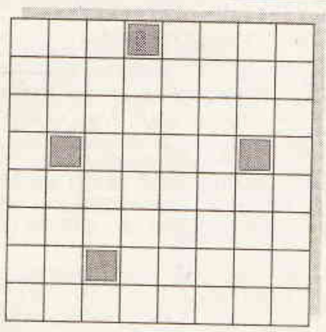


Fig.2 Showing the four objects in an 8×8 grid

Implementing GAs

Binary arithmetic is a natural tool for implementing GAs. It is first necessary, however, to decide on the extent of information required to be represented a specific 'solution' to the problem. In the case of equation 1, the range of X is between 0 and 255, so 8 bits are required. Thus binary numbers such as 01011000,11010011 and 01010001 would be values of X in the problem space.

In the example of Figure 2, each co-ordinate varies between 0 and 7, so 3 bits are required for each X value and 3 bits for each Y value making a total of 6 bits. Thus to code 4 points 24 bits will be required. Thus sequences of binary data such as:

ALGORITHMS

01010101010101010101010101
00101010101010101010101011
01010101010101001010110101

will define the co-ordinates in the problem space.

The demonstration program can generate and manipulate values between 4 and 24 bits.

In terms of parallelism with genetics, the string of binary bits corresponds to a chromosome and a gene to a value of a location on such a binary string.

Defining the Population

Once the extent of the 'genetic' information has been defined for each 'solution' —it is necessary to define the size of the population. It is difficult to define hard and fast rules about what constitutes a 'correct' population size. Where the problem space is say 1000 entries, a population of 20 might be appropriate. Where the problem space is 1,000,000, a higher value would be indicated. GAs will typically tend to have high values of problem space, otherwise simple numeric calculation would yield a faster way to optimising the solution. It can be imagined that where a very large problem space is defined, a small initial population may not contain sufficiently 'rich' material to allow useful optimising of the problem.

lgorithms

Generating the Initial Population

Initially elements of the population space are generated by a random number generation as outlined in Table 1. The standard fitness option is selected.

Element	Value	Binary	Fitness	Norm.	Replification
1	23	00010111	5359.0	0.051	0.51
2	56	00111000	11200.0	0.106	1.06
3	251	11111011	1255.0	0.012	0.12
4	172	10101100	14448.0	0.137	1.37
5	94	01011110	15228.0	0.145	1.45
6	233	11101001	5359.0	0.051	0.51
7	144	10010000	16128.0	0.153	1.53
8	51	00110011	10455.0	0.099	0.99
9	54	00110110	10908.0	0.104	1.04
10	90	01011010	14940.0	0.142	1.42

Table 1: Initial population of 10 from a problem space of 256 states.

The following headings are explained.
The sequence number 1 to 10 of the population.
Value: The value of the element.
Binary: Binary representation of the element. Most significant bit on left.
Fitness: This is the value derived from the fitness equation derived in equation 1 or appropriate fitness function.
Norm: Value of the fitness divided by the total of all the fitness values.
Replication: This is the value of 'Norm' divided by the average chance of a member of the population to survive. For a population of 10, each has a 0.1 average chance of surviving.

Even from this initial random spread of elements, there is a significant spread in the replication factor. This factor can be identified with the likelihood that the element will carry forward to the next generation. The value 23 is much less likely to survive than element 144. The next phase in the survival process is to replicate the more successful and remove the less successful. Table 2 shows the typical set of limits used to drive this process of replication.

Replification value	Action
<0.5	Remove
>= 0.5 to 1.25	Replicate ×1
>= 1.25	Replicate ×2

Table 2: Limits used for replicating population elements.

After the first replication pass, the elements with the 10 highest fitness values are retained in the population. The entries retained are shown in Table 3. As the process of optimising proceeds, the 'Replification' values approach unity, so replication becomes less important in the functioning of the GA.

list of maximum entries for maximum fitness		
seq.	entry	fitness
1	144	16128
2	144	16128
3	94	15228
4	94	15228
5	90	14940
6	90	14940
7	172	14448
8	172	14448
9	56	11200
10	54	10908

Table 3: List of elements carried forward after first 'replication'.

Typically for a populationq of 10 elements, this will expand to about 12 or 13 with replication and the most fit 10 elements are retained for the next 'mating'.

Mating Elements

This is the process in which information is swapped between two elements as shown below where in the example of an 8 bit element, mating takes place at the 5th bit position.

Bit Position	1	2	3	4	:	5	6	7	8
Initial A	0	1	0	1	:	0	1	1	0
Initial B	1	1	1	0	:	0	0	0	1
Final A	0	1	0	1	:	0	0	0	1
Final B	1	1	1	0	:	0	1	1	0

Thus bit positions 1, 2, 3 and 4 of A and B remain while each swaps bit positions 5, 6, 7 and 8. This 'mating' process is a way of moving round patterns of data between the elements of the population. The character shows where the break occurs.

Mating takes place in pairs and a number of 'mating' processes can be undertaken on a given population. The fitness of a 'mated' element is checked. If it does not provide a better fit the altered element is not put back into the population. In the demonstration program there is allowance for up to 50% mating cycles of a given population.

Mutation

The other main process in which optimising of bit patterns can be achieved is mutation. The mechanism of 'mating', however, can be of greater importance. In the demonstration program, mutation can take place within a given cycle such as the 5th, 10th, 15th etc depending on the frequency initially specified. When mutation takes place a specific element is selected and a specific bit position altered. No check is made if the mutation event leads to an improved progeny.

Figure 3 shows the essential function of the GA.

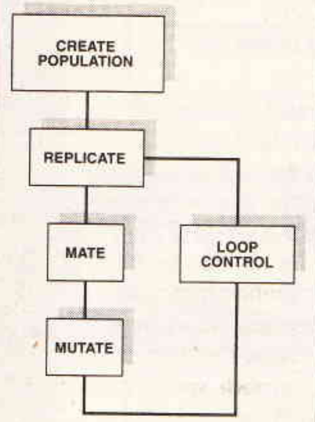


Fig.3 Flow diagram

Using The Program

The demonstration program can implement the fitness function of (1) for up to 24 bit arithmetic where:

$$Y = -X^2 + X2^n$$

where $n=4 \ldots 24$ .... (2)

Equation 1 is therefore an example of (2) where $n=8$.

Table 4 below illustrates the size of the problem space for various values of n.

Value of n	Problem space
8	256
10	1024
12	4096
14	16384
16	65536
18	262,144
20	1,048,576
22	4,194,304
24	16,777,216

Table 4: Diversity of problem states as a function of n.

Thus as n increases, the problem space increases sharply.

Driving the program

Initially the program prompts:

Input the number of items in the population (max 100)

For small problem spaces (less than 1000), a value of 10 is probably adequate. The maximum value available is 100.

The program will prompt:

select fitness function 1 standard 2 8×8 array

Where the standard option is selected the program will prompt:

input number of bits in string (max 24-min 4)

This is the term which indicates the diversity of problem states as indicated in Table 4.

The program will then prompt:

input number of breeding cycles

A breeding cycle is a complete process of replication, mating and mutation. Problems may require only a few such cycles or thousands. There is no limit set on the value. At the end of a breeding sequence, the program will prompt:

run complete: press C to continue or any other for new run Type therefore C to continue with the problem.

The program will then prompt:

input the number of mating cycles

This is the number of pairs of elements mated within a given population. Up to 50% of a population can be mated if required. Values will be around 25%.

The program will then prompt:

specify no. of breeding cycles before a mutation eg. value of 3 will mutate an element every 3 main cycles.

Thus a value of 10 will result in a mutation in a single element of a population every 10th breeding cycle.

The program will then prompt:

specify display details 1 minimum 2 additional

When 1 is input, a single line summary is provided. When 2 is selected, additional entries are displayed and it will be required to press a key when prompted in order to step through the program. When option 1 (minimum) has been selected key 2 should be pressed to toggle to the option 2 (additional) screen display mode. This can be useful if it is required to see what is taking place internally as a specific population is being developed.

When the program is run, the process of initial population creation, replication, mating and mutation then will be undertaken for the specific number of breeding generations.

The next section deals with a basic outline of how performance of the GA behaves as various factors such as population size, problem space, number of mating cycles and mutation frequency. The program in the (minimum) configuration usefully indicates the elapsed time into a simulation.

Population Size

The initial population of elements is the genetic richness with which the problem starts out. For a very large problem space, a limited population will restrict the growth towards an optimised solution. The examples outlined relate to the standard fitness function of format of Equation 1. Table 5 shows the time taken to solve for a 10 bit wide problem with 30% mating cycles within each population and with no mutations.

There is considerable variability in time to solution between different equally sized populations though the trend is to reduce the time with increasing population.

Population Size	Time to Solve (mins)
20	1.8
30	1.4
40	1.1
50	0.9
60	1.7
70	0.1

Table 5: Effect of population size on time to solve for 30% mating cycles and no mutation of data.

Problem Space

For a given initial population, the time to solution increases as the problem space increases. Table 6 shows an initial population of 20 with 6 mating cycles.

No. of bits	Problem space	Time to solution
8	256	0.3
9	512	0.2
10	1024	1.8
11	2048	1.1
12	4096	0.7
13	8192	3.8
14	16384	8.8

Table 6: Time to solution as a function of problem space for a population of 20 elements with 6 mating cycles (no mutations)

Mating Cycles

Table 7 shows a given configuration of a 10 bit problem with an initial population of 20 entries the time to solution varies with the number of mating cycles.

No. Mating Cycles	Time to Solution (mins)
1	4.4
2	2.4
3	3.8
4	0.6
5	0.2
6	0.3

Table 7: Variation of time to solution as function of the number of mating cycles for an initial population of 20 for a 10 bit wide problem space.

In general terms, the more mating within a generation then times to solution are reduced.

Level of Mutation

Table 8 shows the results on time to maximise based on an initial population of 40 with a 12 bit wide problem space and 8 mating cycles per generation.

While the introduction of mutation cycles reduces the time to solution, it is more difficult to determine an 'ideal' level of mutation. For the specific problem depicted, a level of one cycle in five could be appropriate.

Optimising the Array Problem

The problem space of the 8×8 array is very large and the demonstration program is hard pressed to find a solution quickly. The typical screen will display for an intermediate state:

```
00000000        10000400
00300000        00000000
00000000        00000000
00000000        02000000
```

generation 1, fitness 23.80, time 0.15

The array of 8×8 points indicates the locations of the 4 objects within the array. With increasing 'fitness' the objects should move further apart. The calculation of the fitness function is the main computing component of the program.

Conclusion:

The field of Genetic Algorithms offers a new approach for optimising problems in a range of different environments. The basic mechanism of GAs is simple and programs are not over long or complex. It is important, however, to have a good 'fitness' function in order to optimise the 'fitness' of individual entries. Once the main features of a GA program have been structured, it can be readily converted to new problems by configuring the fitness function appropriately. The demonstration program indicates how this is done in practice. The demonstration program has not been designed with 'speed' in mind. Rather it is intended to indicate in general terms how GA programs can be designed.

A photocopy of the program is available by sending an SAE to ETI editorial.

Mutation Cycles	Time to solve (mins)
None	>5
1 in 10	1.2
1 in 5	0.9
1 in 4	1.5
1 in 3	2.0
1 in 2	2.0
1 in 1	0.6

Table 8: Time to solution as function of the level of mutation for 12 bit problem space, 40 wide population and 8 mating cycles.

Further Reading

Genetic algorithms in search, optimisation and machine learning. David E. Goldberg, Addison-Wesley.

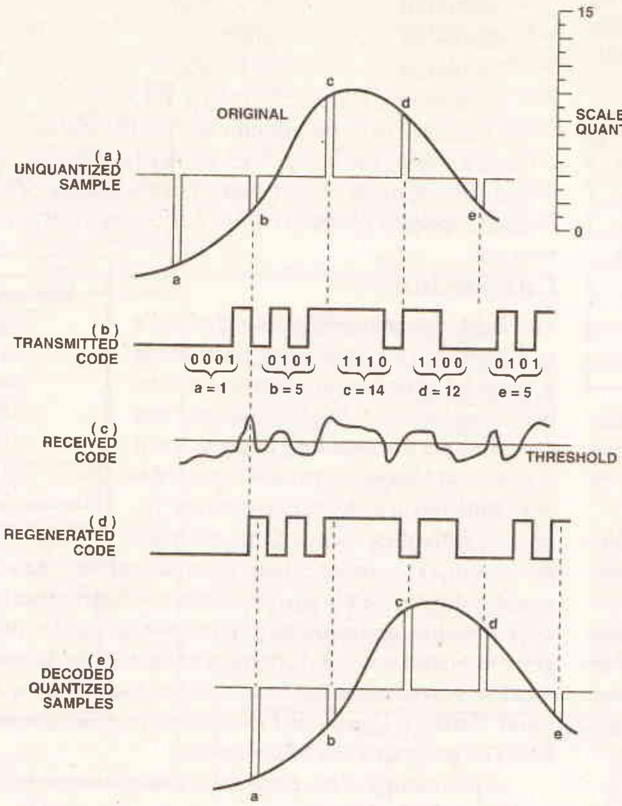


Fig.1 The various stages in digitising an analogue television picture and then returning it to its analogue state. Note that a four-bit, sixteen level code is used for simplicity, whereas in a real system eight bits, 256 levels are used. (a) shows the original waveform and the samples which are taken and then converted to the nearest whole number, a process known as quantisation. (b) shows the quantised numbers converted into a four bit binary number code, the digital system proper. (c) shows the signal as it might be received after it has been transmitted over a typical path, and it can be seen that the original signal has been subjected to much distortion (d) shows the regenerated code after the incoming signal has passed through a threshold detector and appropnate new pulses have been generated. (e) shows how the decoded samples may be reconstructed to form a representation of the original analogue system. Notice that the regenerated signal has been delayed by the period of one digital word, since decoding cannot begin until all the digits have been received.
Diagram Courtesy IBA.

Digital Television

1

TV

A View of the Future by James Archer

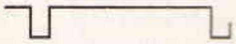
There is absolutely no doubt that the future lies with Digital Television, but it is also true that the future could well be a long time coming! In recent months stories from across the Atlantic and from nearer home in Europe have given the impression that digital television transmission is just around the corner; the truth is likely to be rather more prosaic, in that there is still a lot of work needs to be done in the research laboratories of the world before we find digital television signals coming down our aerial leads. In this series we shall take a look at the basics of digital television, and will then move on to consider the applications of digital television in studios, in receivers, and in transmission. The latest developments in the American proposals to adopt a digital approach as the answer to the problems they have found in their quest for an Advanced Television system will be explained, as will the completely different ideas from the European company Philips, in which they propose to use digits to provide a 'plug-free' digital TV service which will be so rugged that a portable receiver could be used to provide excellent quality pictures virtually anywhere, without being connected to an external aerial. As is often the case in research, it is not always those developments that are given the highest publicity profile that turn out to be the most significant in the long run, and the series will be examining research work going in the laboratories of UK broadcasters, work which could lead the way to digital transmissions being broadcast over the existing networks, offering viewers higher quality and more choice of programmes without destroying the existing networks. Video recording too can benefit enormously from the use of digital techniques, and although it is only the studios that have so far benefitted from digital video recorders, there are already in the manufacturers' back rooms prototype domestic versions, machines which could allow us to make recordings of a quality previously undreamed of. All these developments rely on the exciting new techniques of bit rate reduction and data compression that are currently being revealed in research laboratories all over the world. Such techniques could lead to a complete revolution in the way we communicate, making it possible to record superb digital pictures in the home, to send these along the public telephone service to our friends and relations, who could display them on the large flat screens that we have been promised for so long.

Digital Television — The Beginings

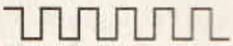
Digital television began, not in studios, but with the networks carrying television signals between studio centres and transmitters. Although analogue television systems have served us well, and will continue to do so for the foreseeable future, they only give excellent *pictures provided that all the equipment in the broadcasting chain is kept in first class condition*, something that requires eternal vigilance, much measuring, and a good deal of maintenance. This is the major reason why broadcast engineers originally became interested in digital techniques, and why they became keen to adopt a system that offers a way of providing more rugged and reliable signals. The analogue television system works only if each piece of equipment is precisely lined up to work within very narrow tolerance limits. Just consider the number of amplification and equalisation stages that a television signal originated in London must go through before it arrives on the screen of a viewer in the Outer Hebrides. Unless every care is taken at each stage of that signal's journey to ensure that the amplitude and frequency response of the signal remain constant, there is very little chance that the shade of grey that appears on the viewer's screen in Scotland will be the shade that was generated in London, and it is something of a tribute to the engineers of British Telecom, the company in the UK responsible for carrying the TV signals from the studios to the transmitters, that the received analogue pictures are usually excellent.

INFORMATION BOX

Analogue TV - varying voltage levels represent different levels of brightness & colour in the picture.



Digital TV - a stream of data pulses indicates the brightness & colour of each sample of the picture.



We will begin our look at digital television by reminding ourselves of the basic techniques of pulse code modulation which are used when converting an analogue picture signal, perhaps from a television camera, to its digital equivalent.

In an analogue to digital conversion system like that in Figure 1 there are two main factors of importance:

(i) The number of bits which we use to describe each sample, or in other words, the number of levels of brightness which we need to provide.

(ii) The rate at which we take samples of the analogue waveform.

The number of sampling levels required was decided upon after much careful examination of digital pictures made with different numbers of bits per sample, and it was found that eight bits per sample, giving 2^8 i.e. 256 levels, gave excellent results, although we shall see later in this article that the wisdom of this decision has since been questioned.

Sampling Frequency

It can be seen from Figure 1 that the more samples taken in a given time, the more bits of information will be available to rebuild the analogue signal at the end of the coding and decoding process. We therefore need as high a sampling frequency as practicable, but have to remember that the higher the sampling frequency the greater the amount of memory required to store each picture, and since semiconductor memory costs money, this has economic implications. Sampling rates are discussed in more detail later, but a fundamental limitation which gives the minimum possible sampling rate for any signal was laid down by the Swedish mathematician Nyquist. His work showed that in order to sample an analogue signal so that it can be reconstructed from the derived samples without distortion, the samples must be taken at a rate greater than twice the highest frequency contained in the signal. For a typical modern television system, like the one used in the UK, CCIR system I, the frequency band used by the video components stretches up to 5.5MHz, and this therefore implies that we need to use a minimum Nyquist sampling frequency of

$$2 \times 5.5 = 11\text{MHz}$$

Since, as we shall see later, it is often convenient to use a sampling frequency which is a multiple of the subcarrier frequency, the first multiple of the CCIR System I PAL subcarrier frequency (4.43MHz, approx.) which exceeds the 11MHz Nyquist limit is three, which is why three times the subcarrier frequency (13.3MHz, approx.) was much used in the early days of digital television.

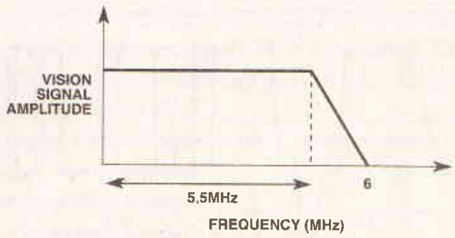


Fig.2 The baseband frequency spectrum used by the UK PAL TV System I

Sub-Nyquist sampling

Whilst we are discussing sampling frequencies it is worth noting that in 1975 BBC Research Department published a paper which showed that, because of the repetitive nature of the television video signal, under certain specified conditions it is actually possible to sample the PAL signal at a frequency below that stipulated by Nyquist, with very little loss of quality. Although this at first sight seems paradoxical, it is not in fact an example of Nyquist's rule being defied. What happens is that the television signal is sampled below the Nyquist rate (usually at twice the frequency of the subcarrier), and as the theory would predict, various distortions do arise. It is possible to calculate in advance what these distortion products are likely to be as the video waveform is very repetitive. It is therefore possible to design filter circuits which remove the distortion. We are then left with the original signal undistorted, but considerably reduced in amplitude.

The Advantages Of Digital Television

Television pictures can be considered as being constructed from many individual picture elements, just as newspaper photographs are built up from hundreds of thousands of tiny dots. Digital techniques allow a television picture to be broken into these picture elements, pixels, and instead of transmitting an analogue signal, a varying voltage waveform, which directly represents the brightness and colour of a television picture, what is sent along the microwave links or cables to the transmitters is a coded message which effectively says 'picture element number x has brightness level y and colour z'. At the far end of the link the message can be decoded, and a completely new picture can be reconstructed, a pixel at a time, according to the brightness and colour levels specified in the coded message. The received picture should therefore be a perfect recreation of the original. In the case of the analogue signals, any variation of the voltage level between the transmitting end and the receiving end of the link would result in an alteration of the grey level of the picture, i.e. distortion. In the digital case, the actual level of the digital signal should make no difference to the quality of the received picture; provided that there is sufficient signal to allow the decoder to distinguish between the coding pulses, the picture can be rebuilt into a clone of the original. As a further advantage, whereas a small amount of drift in an analogue circuit, perhaps due to temperature changes, would cause noticeable distortion, the same amount of drift would be most unlikely to disturb a digital circuit to the extent that the pulses cannot be decoded.

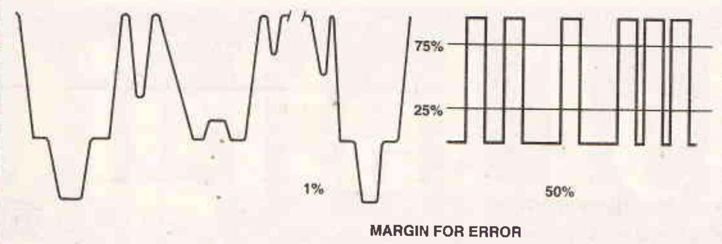


Fig.3 A comparison between the accurary needed to decode analogue signals and digital signals

It was soon realised that similar advantages could be obtained if digital video recorders could be made. When a composite analogue televison signal, i.e. a signal such as PAL which consists of a multiplex of colour information, monochrome information, and the synchronisation signals, is recorded on tape, it is subject to noise and distortion. This increases significantly with each generation of recording, and results in noisy pictures with moiré patterning occurring in the highly-saturated coloured parts of the picture.

In a digital recorder, on the other, hand, just the coded pulses representing the brightness and colour of each picture element are laid down on tape. When the tape is played back there will inevitably be noise produced from the record/playback process. Provided the level of this noise is insufficient to mask the signal levels representing the coded pulses, the picture can once again be re-built as new. It is rather like listening to a very weak Morse-code message from a distant part of the world. The code might contain a great deal of background hiss on the received radio signals, but provided that your ear can make out the individual dots and dashes from amongst the noise, the original message can be written down without distortion or errors. Digital video recording was first shown to be practicable by engineers of the UK IBA in 1979, and there are now three recognised digital VTR formats on the market. Two of these, known as D1 and D2, use 19mm wide tape, whilst a third, called DX or D3, uses half-inch tape in VHS-type cassettes. Other digital formats are also currently being displayed at exhibitions of broadcasting equipment, and the Ampex company, which was once the major name in professional video recording, is claiming to have designed and built a new digital recorder which can pack more data into a given area of tape than any other format.

The Need For A Digital Standard

During the late 1970s and the 1980s studios started to make use of many individual pieces of equipment, notably time-base correctors, special effects units, and noise reducers, which made use of digital techniques as an indispensable part of their internal operation. Unfortunately, there was virtually no cooperation between different manufacturers as to the digital coding techniques used, each wishing to keep its commercial secrets from its competitors. This meant that in a PAL studio, for example, each item of digital equipment had to have a PAL-to-digital coder at its input, and a digital-to-PAL coder at its output, in order that these units could be connected as part of the normal chain of PAL equipment in the studio. In a studio using time-base correctors and digital special effects units it was not uncommon for the signal to be converted from analogue PAL to digital form and then back again to analogue PAL several times during the course of its journey through the studio equipment, and each time a television signal passes through the coding-decoding process it is unavoidably degraded to some extent. Several passes through the inevitable 'codecs' (coder-decoders) caused noticeable picture impairments, basically caused because studios were using what came to be known, in unusually poetic language for engineers, as 'digital islands' in an 'analogue sea'. What was needed was to be able to connect all digital processing units together directly, without going through the analogue-digital conversion process every time, and it was this realisation that led the world's broadcasters to get together to try to agree on a standard for digital equipment in studios.

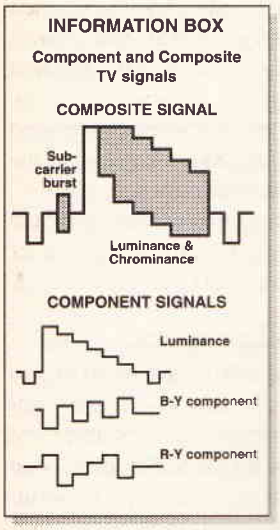
Composite Digital Video

All the early research work on digital television was done on composite signals such as NTSC and PAL, because these were the signals in day to day use in the studios. Composite television signals are those in which the luminance (brightness) and chrominance (colour) signals are combined together to form the complete video signal, the colour signals being carried on colour subcarriers.

The earliest tests on digital composite signals suggested that it would be advantageous for the sampling frequency to bear a simple relationship to the horizontal line frequency. When this is the case the individual samples will automatically be arranged in equally spaced vertical rows, i.e., the sampling pattern will be orthogonal and spatially static, as shown in Figure 4.

Research engineers soon found there were big advantages if the horizontal sampling frequency bore a simple relationship to the colour-subcarrier frequency of the system. It minimised impairments resulting from sampling and quantisation errors, and also made life easier in the design of colour coders and decoders, reducing patterning between the subcarrier and harmonics of the digital clock. In the American NTSC system both requirements could easily be satisfied, since the colour subcarrier frequency is 455/2 times the line frequency. The PAL system, used in most of Europe except France, lacks this simple relationship between line frequency and colour subcarrier, because the designers deliberately offset the frequency of the subcarrier to reduce patterning problems on black and white receivers, and the simplest relationship we can obtain is:

f_{sc} =(1135/4 +1/625) times line frequency.



For the French SECAM system, there is no direct relationship at all between line frequency and subcarrier frequency, because the frequency modulated subcarrier is continuously varying with the modulation.

In most of the early research work frequencies such as $2f_{sc}$, $3f_{sc}$ and $4f_{sc}$ were used for different purposes, and many digital timebase correctors and field-store synchronisers using $3f_{sc}$ were built and sold. In America broadcasters developed a specification for the interconnection of digital equipment in studios using 4 times the NTSC subcarrier frequency and eight bits per sample. The search for a common standard was headed by engineers of the American SMPTE and of the European Broadcasting Union (EBU). Much of the initial work towards digital standardisation was concerned with trying to find ways of coping with the three very different colour subcarrier frequencies used in NTSC, SECAM, and PAL systems, and a lot of time and effort was spent on this, before the researchers set off on a completely different track.

Digital special effects units came into being as engineers realised that a digitised television picture need no longer be thought of as a complete image, but that each picture element was effectively represented by a group of numbers (address, brightness, colour), and that these numbers could be and were being stored inside what were effectively just large computer memories. Once you have numbers inside a computer store you can then treat those numbers like any other numbers, reading them in and out at different rates, carrying out mathematical operations upon them, or selecting just some of the numbers to create your final display with the desired effects. The manufacturers of these digital effects units found that it was very difficult and restrictive to try to obtain many of the effects which they were seeking if they used composite signals, and so inside the digital special effects units that were being manufactured, virtually all the processing was done on signals that had been decoded from composite to component form. The realisation that this was happening inside digital special effects units led to a rethink among those engineers who were seeking a common standard.

Component Digital Video

Component based television systems, like the MAC Multiplexed Analogrne Component system, for example, are those in which the luminance and chrominance signals are kept separate throughout the studio and transmission chain; this can lead to higher quality pictures, since the receiver is not presented with the problem of having to separate out the colour information from the black and white, as it must with a composite signals like PAL.

Those working in the field of digital television realised that all existing television systems began with the component signals Red, Green, and Blue (R,G,B) in common. Some work was done on digitising these RGB signals, and excellent pictures resulted, but the problem with this method is that each of the R,G, and B signals require the full video bandwidth. The result is we effectively end up storing and processing three separate television signals, an expensive and wasteful operation. It is possible to use a different set of components, for example Y, a full bandwidth luminance signal, and the two narrowband colour-difference signals (B-Y) and (R-Y). The first step along the road to standardisation was therefore for engineers to agree that the sought-for digital television standard should be based on digitising the three component signals, Y, B-Y, and R-Y. 8 bits per sample would provide an adequate number of video levels. Tests were carried out at different numbers of bits per sample, and it was generally agreed that eight bits, offering 256 (i.e. 2^8) quantizing levels, or about 220 useable grey levels, provided excellent pictures under the standard conditions for critical viewing laid down in CCIR Recommendation 500. The agreed aim of those trying to decide on the parameters of a digital standard was that the resulting pictures should be of a quality to match the original R,G,B source pictures. This would be a considerable improvement on the picture quality provided by the current NTSC, SECAM,or PAL systems.

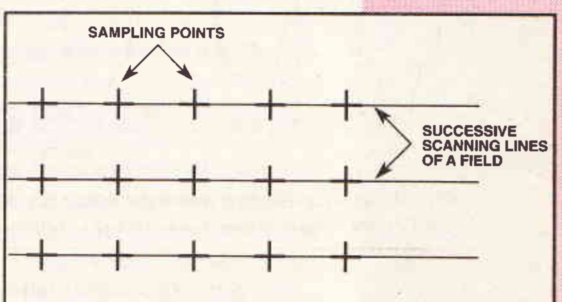


Fig.4 Showing how when the sampling rate is an integral multiple of line frequency the sampling pattern is static and orthogonal.

Although a significant step, it still left major items such as sampling frequency and component signal bandwidth unresolved. Much experiment and debate was to take place before the final agreement was reached. The higher the sampling frequency, the greater the overall bit rate would be required, and consequently the greater the storage area. So choice of sampling frequency has significant financial consequences.

Although we have so far just spoken of sampling fre-

	525-line, 60 field / sec systems	625-line, 50 field / sec systems
Coded signals: Y, C_R, C_B		
Number of samples per total line: —luminance signal (Y) —each colour-difference signal (C_R, C_B)	858 429	864 432
Sampling structure	Orthgonal, line, field and frame repetitive. C_R and C_B samples co-sited with odd (1st, 3rd, 5th, etc.) Y samples in each line	
Sampling frequency: —luminance signal —each colour-difference signal	13.5 MHz 6.75 MHz The tolerance for the sampling frequencies should coincide with the tolerance for the line frequency of the relevant colour television standard	
Form of coding	Uniformly quantized PCM, 8 bits per sample, for the luminance signal and each colour-difference signal	
Number of samples per digital active line: —luminance signal —each colour-difference signal	720 360	
Correspondence between video signal levels and quantization levels: —scale —luminance signal —each colour-difference signal	0 to 255 220 quantization levels with the black level corresponding to level 16 and the peak white level corresponding to level 235. The signal may occasionally excurse beyond level 235 225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128.	

Fig.5 Basic details of CCIR Recommendation 601

quency, i.e. the frequency with which we take samples along a television picture line, it is important to notice that another way of looking at the same thing is to consider the number of samples along each line of a television picture from the sampling process. Both ideas will be used as we discuss the choice of a sampling frequency.

From the EBU proposed that the luminance (Y) signals should be sampled at 12MHz, and that each of the two colour difference signals should be sampled at 4MHz. This type of system became known as 12:4:4 in the engineers' shorthand, and an American proposal to use 14MHz for luminance sampling and 7MHz for colour difference signals was similarly known as 14:7:7.

Sampling a 64µsecond televison line at 12MHz gives:

$$12 \times 10^6 \times 64 \times 10^{-6} = 768 \text{ samples per line}$$

The Americans carried out a series of tests which showed that picture quality improved as the sampling frequency was raised from 12MHz to 14.35 MHz, and so they were not prepared to adopt the EBU idea of 12MHz. Experiments and demonstrations were carried out by EBU and SMPTE groups, and after much work and a good deal of horsetrading, and not without some misgivings on the part of some of the Americans who felt that 14.3MHz, a multiple of the NTSC subcarrier, would be better, the two groups agreed to recommend a luminance sampling frequency of 13.5 MHz, and colour difference sampling frequencies of 6.75MHz. After discussions and demonstrations, The Japanese, the Russians, and various other broadcasting organisations supported the proposals, and the various parameters were adopted as a world standard, Recommendation 601 of the CCIR, in 1982.

The choice of 13.5MHz as the luminance sampling frequency was an interesting one, since as well as being a compromise between the initial 12MHz EBU proposal and the 14.3MHz that some SMPTE members wanted, it gave rise to some very useful figures when compatibility between the 525-line and 625-line systems was considered, and was one of the very few figures that could have permitted the same sampling frequency to be used for both systems.

Interestingly 13.5MHz was the only frequency which gave rise to an integer or whole number of samples per line for both 525 and 625-line systems.

The 625-line system has a total line time of 64µseconds.

At 13.5MHz this gives 13.5 x 64 = 864 samples

The 525-line system has a total line time of 63.56µseconds.

At 13.5MHz this gives 13.5 x 63.56 = 858 samples

In the 625-line system the line blanking period is 12µseconds, so that the active line time, the part of the TV line that can actually be used to carry picture information, is 52µseconds, i.e. (64-12).

In the 525-line system the line blanking takes 11.56µseconds, giving an active line time of 52µseconds, so that we have the same nominal active line time for both systems.

In terms of samples per active line, we have, for both 525 and 625-line systems:

52µ seconds x 13.5MHz = 702 samples per active line

Thus the choice of 13.5MHz for a common sampling frequency gave the advantage of an identical number of samples per active picture line, and allowed the current line blanking periods to remain the same for each system.

It was these features that finally led to the adoption of this 'magic number' of 13.5MHz for the luminance sampling frequency.

Tests showed that a rate of half this, i.e. 6.75MHz, was sufficient for sampling the colour-difference signals so as to provide excellent pictures.

Although the length of a complete television line in each system must be kept the same as in the existing standards, corresponding to 864 bits for a 625-line system and 858 bits for 525-line systems at 13.5MHz sampling rate, so long as the length of the active line sampling is kept the same, there is no real reason for it to remain at 702 bits long (52µseconds active line). Instead, the researchers working to develop the standard felt that it would be a good idea to have an active line slightly longer than the 52µseconds, with the line beginning slightly earlier and ending slightly later than a standard 52µsecond line. The reason for this was to allow for a short period of a reference black level at each end, and to reduce the rate of change of transients when a picture line starts or finishes at peak white. For all these reasons, it was decided to use a larger number than 702, and 720 was chosen because it had a large number of factors, in fact a number that would be suitable for conversion if other higher or lower order members of the Rec.601 family were used.

The colour difference signals each have 360 samples per active picture line, for both 525 and 625-line systems. These sampling arrangements give rise to an orthogonal line and field sampling structure, and the colour-difference samples are arranged so that they are effectively co-sited with alternate, odd-numbered luminance samples.

The basic features of the world standard for digital television studios, CCIR Recommendation 601, are shown in Figure 5, and in order to allow equipment using signals of this type to be connected together, an 8-bit parallel digital interface has also been specified in a separate CCIR Recommendation, number 656. Interconnections take place via 25-pin subminiature D-connectors, carrying eight separate pairs of conductors, each carrying a time-multiplexed stream of bits of the three component signals, in the order C_B, Y, C_R, Y, where C_B and C_R are the two colour difference signals. Ancillary data is also carried on these pairs, and a ninth pair carry a 27MHz synchronous clock signal.

Quantisation Levels

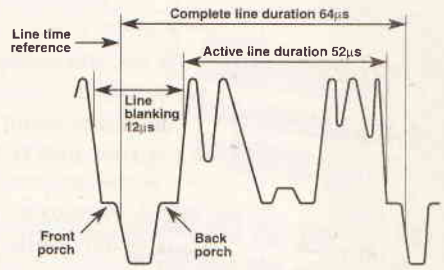
As mentioned earlier, the system utilises 8 bits per sample, which, in a binary coded system, would permit a maximum of 28, which is 256 Quantising levels. Rather than use all these levels for the grey scale, black level is chosen to correspond with level sixteen, and a further 220 quantising levels above this are given to the grey scale, peak white normally being at level 235. Levels above 235 allow for occasional white overshoots.

The colour difference signals use 225 of the 256 possible quantising levels.

At the time that the standard was being developed, prior to 1982, most of the test sources used were cameras, telecines, and test generators where the signal to noise ratios were poor enough (although the equipment was then state of the art) to mask some of the effects of low-level quantising errors arising in the eight-bit analogue to digital convertors that were used. Quantising errors arise when the number of steps available to describe the brightness of the picture is insufficient. For example, if the sample of the analogue brightness signal actually gave a value of 201.5 on the scale of 256 which is available on an eight-bit system, then it is just not possible to describe 201.5, and we have to approximate to either 201 or 202, and it is this type of approximation which gives rise to quantising errors, which generally show up as noise on the picture. Some digital processing effects were tested at this time, but the main emphasis was on chromakey, and the sophisticated digital processors that we have today were no more than a twinkle in the designer's eye.

INFORMATION BOX

One TV line, showing the complete line duration of 64µs, and the active line i.e. that part of the line which can carry picture information, duration 52µs.



Since the introduction of the CCIR Recommendation 601, it has become the norm to use electronically generated graphics and characters as part of the normal studio output, and many special effects generators are also now used routinely as day to day equipment, rather than purely being utilised for exceptional special effects as they were in earlier years. Such electronically generated signals can be virtually noise-free, so that there is not enough noise to mask any quantisation errors, and when multiple generations of these very clean signals are utilised, it has been found that undesirable effects can occur. One of these effects is known as contouring, because what are effectively contour lines are seen between adjacent areas of brightness or colour, which seem to indicate that the number of brightness levels, that is the number of bits per sample, is inadequate under certain circumstances.

Rounding Errors

The problem is that mathematical rounding errors occur as the digital signals are passed from one piece of digital equipment to another, or through the same analogue to digital conversion equipment several times. To illustrate the effect of rounding errors in a field other than television, try the effect of using a basic electronic calculator to work out the simple expression:

(10/3)x3

Although the correct answer should obviously be 10, many calculators give the answer 9.9999999 due to the microchip being unable to cope with enough digits to give the correct answer. A more sophisticated calculator or a computer will often be able to utilise more bits for its calculations, and so will give the correct answer.

During multi-stage digital processing the numbers representing the brightness and colour of individual picture elements can be subject to these rounding errors. When an eight bit digital word is multiplied by another eight bit word, 16 bits will be required to store the answer, and this is readily achievable within any individual digital device. Unfortunately, when CCIR Rec.601 digital signals are passed from one piece of equipment to another they must be passed via the 8-bit digital interface detailed in CCIR Recommendation 656, and so the internal signals must be truncated or rounded so that only an eight bit signal is presented at the interface.

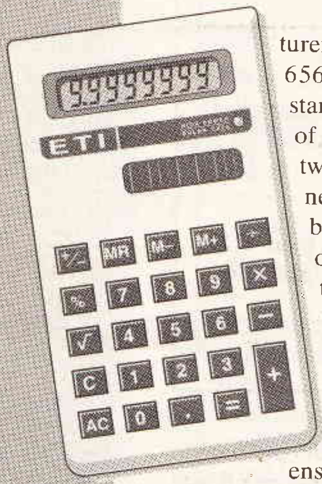


Fig.6 Simple calculator showing result of entering (10/3)×3

These problems have led some manufacturers to say that Recommendations 601 and 656 are inadequate for present day circumstances, and they have increased the number of bits which they use to ten, and have used two spare connections on the 25-pin D-connector specified in Rec.656 to carry the extra bit streams. Unfortunately this solution can only work if pieces of equipment made by the same manufacturers are used, and whilst it is undoubtedly true that ten bits give better results than eight in some circumstances, many people are unhappy with this idea, since even ten bits may not necessarily be sufficient to ensure perfection under all conditions, and since it goes completely against the idea of the hard-won world standard laid down in Rec.601.

One of the largest manufacturers of complex digital picture processing equipment, Quantel, has demonstrated a technique called Dynamic Rounding, which removes the unwanted contouring effects of multiple processing without resorting to changes in the specification of the digital standard, and many broadcasters have been convinced by demonstrations that this technique will prove adequate for some time to come. A somewhat different technique discovered by the Research Department of the BBC, known as Error Feedback Rounding, has been shown to achieve similar improvements with the standard eight-bit digital signals.

In the longer term, however, it now seems likely that more bits will eventually be required, as more and more processing of the digital signals takes place, and the reduction in cost of semiconductor memory makes it practicable to accommodate sufficient storage at a realistic cost. CCIR Recommendation 601 actually makes provision for future higher-level systems, as explained below, and it seems likely that there will eventually be a supplementary standard for a digital system using at least 16 bits per sample, with a corresponding parallel digital interface.

The 4:2:2 Shorthand

We have seen already the use of a shorthand notation such as 12:4:4 or 14:7:7 to describe digital component systems. In those systems that used sampling frequencies tied to the subcarrier frequency it was common to refer to them as 4:2:2, meaning that the luminance was sampled at $4f_{sc}$ and the colour-difference signals were sampled at $2f_{sc}$. As the work on digital standardisation progressed a different notation came into use, and the Recommendation 601 system is not known as 13.5 : 6.75 : 6.75, but as 4:2:2. The '4' in this coding scheme is used to mean the universal luminance sampling frequency of 13.5MHz, and any other numbers, such as '2' refer to appropriate proportions or fractions of that frequency, so that '2', which is half of '4', indicates a sampling frequency of 6.75MHz.

An advantage of this notation is that it can be used to describe other members of a digital hierarchy of systems, based upon 4:2:2, but including higher quality and lower quality systems as well, for specialised purposes. Recommendation 601 does in fact provide for an extensible family of compatible digital coding standards, any of which may be simply interfaced with any other.

An example of a lower level system would be 2:1:1, a narrower bandwidth 6.75 3.375 : 3.375MHz system which might be suitable for newsgathering purposes, where the highest quality pictures are not essential. A future higher quality digital system might be described as 4:4:4, having equal sampling frequencies for luminance and chrominance signals, and CCIR Recommendation 601 actually provides a tentative specification for a digital system of this type, as shown in Figure 7.

To add to the possible confusion over this shorthand notation, it should be noted that in some research papers occasional use is made of a fourth component in the ratio, e.g. 4:4:4:4. The extra number denotes a special key signal channel that may be used to provide the very highest quality special effects, where one television signal is to be keyed into another.

Recommendations 601 and 656 have certainly provided the breakthrough needed to persuade manufacturers to undertake the costly business of making many different items of digital studio equipment, and it is now possible to build virtually all-digital studios, although the economics of changing from existing standards make it likely that it will still be some years before such studios are the norm.

Composite Digital Reappears

We saw earlier that the initial work on digital television was carried out on composite signals such as NTSC and PAL but that this work was discontinued when it was agreed that to carry out digital processing on the individual component signals was likely to give better results, as well as to make it easier to reach an international standard. The first major triumph of the component digital system described in CCIR REC.601 was probably the component digital videotape recorder, using what became known as the D-1 format. These machines can cope with 525-line 60Hz and 625-line 50Hz signals without modification The efforts taken to achieve standardisation can produce virtually transparent copies over as many as fifty generations and has revolutionised

	525-line, 60 field / sec systems	625-line, 50 field / sec systems
Coded signals: Y, C_R, C_B or R, G, B	These signals are obtained from gamma pre-corrected signals, namely: E'_Y, $E'_R - E'_Y$ $E'_B - E_Y$ or E'_R, E'_G, E'_B	
Number of samples per total line for each signal:	858	864
Sampling structure	Orthgonal, line, field and frame repetitive. The three sampling structures to be coincident and coincident also with the luminance sampling structure of the 4 : 2 : 2 member	
Sampling frequency for each signal	13.5MHz	
Form of coding	Uniformly quantized PCM, 8 bits per sample	
Duration of the digital active line expressed in number of samples	At least 720	
Correspondence between video signal levels and the most significant bits (MSB) of the quantization level for each sample: —scale —R, G, B, luminance signal —each colour-difference signal	 0 to 255 220 quantization levels with the black level corresponding to level 16 and the peak white level corresponding to level 235. The signal may occasionally excurse beyond level 235 225 quantization levels in the centre part of the quantization scale with zero signal corresponding to level 128.	

Fig.7 Tentative Specification for a 4:4:4 member of the REC 601 family

studio post-production. Unfortunately they are very complex, difficult to manufacture, and therefore very expensive, perhaps two or three times the cost of the 1″ C-Format recorders that have been the standard studio machines of the nineteen eighties. They also suffer from the disadvantage that being component machines, requiring luminance and colour-difference signals at input and output, they are difficult to install in a standard studio which has been built to deal with composite PAL signals. Indeed, to make full use of the D1 format the whole studio distribution system must be replaced, at considerable expense.

Realising this, the Ampex Corporation, whilst carrying out its research and development on the component digital D-1 machines, also carried out parallel work on a composite digital video recorder, which records composite NTSC (or PAL) signals directly, using the sampling frequency of 4fsc that we discussed earlier. This type of machine, using what has now become known as the D2 Format, is cheaper to manufacture than the D1 machines, and also has the immense advantage that since it uses composite signals, which are carried along one wire, the machine can be used as a direct plug-in replacement for a C-Format NTSC machine, without making any modifications to the studio wiring.

Another important plus factor is that the predicted price will eventually be about the same as C-Format machines. Since the machine is a digital recorder it gives excellent multi-generation performance, perhaps up to the twenty generations claimed by the manufacturer, and is probably the major requirement in many production centres. Since the D2 machine is recording composite signals it suffers from some of the disadvantages of composite signals, such as cross-colour effects. The use of 4fsc sampling does help to minimise some of theses effects. Sony also make and sell these composite digital D2 machines, which many people are predicting will become the standard workhorses of television studios for the next decade, although I would guess that some new digital mini-format from the far East is likely to take over long before then.

Although it is virtually the only major standard affecting television which has been agreed by broadcasters and administrations throughout the world, Rec 601, officially titled 'Encoding Parameters of Digital Television for Studios' suffers, as its title might suggest, from the restriction that it currently applies only to studios, and programme production equipment. Although we shall see later that digital signals can be transmitted using special coding techniques, at the present time the high bit rates that would be required for the transmission of digital television signals render digital transmission impractical, but the significant advantages that digital processing can bring to television have made a knowledge of Rec. 601 essential for anyone who wants to understand digital television.

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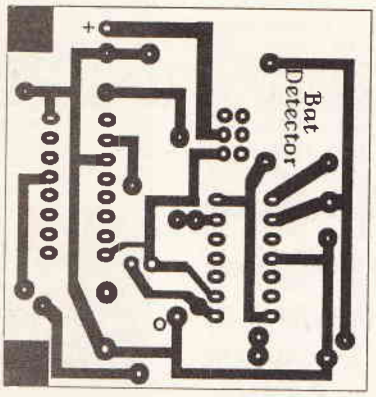

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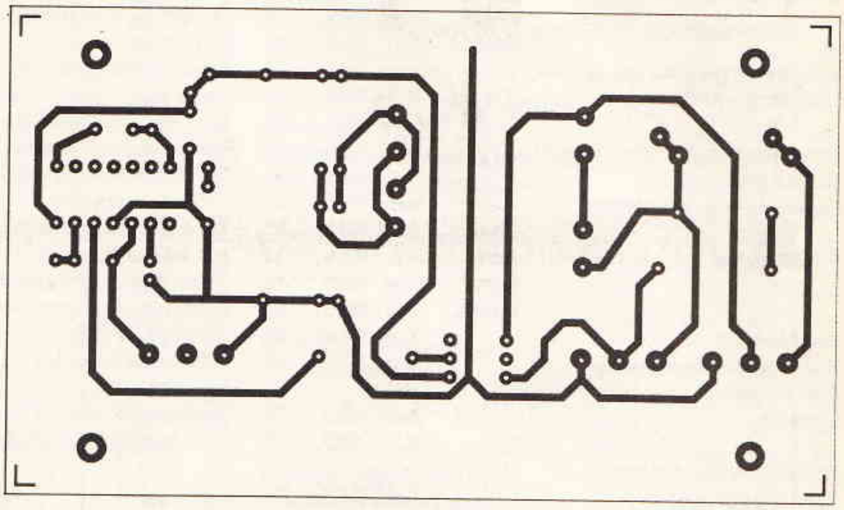

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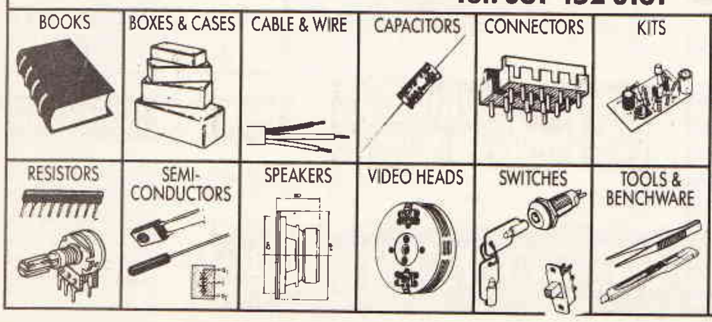

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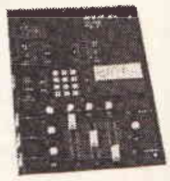

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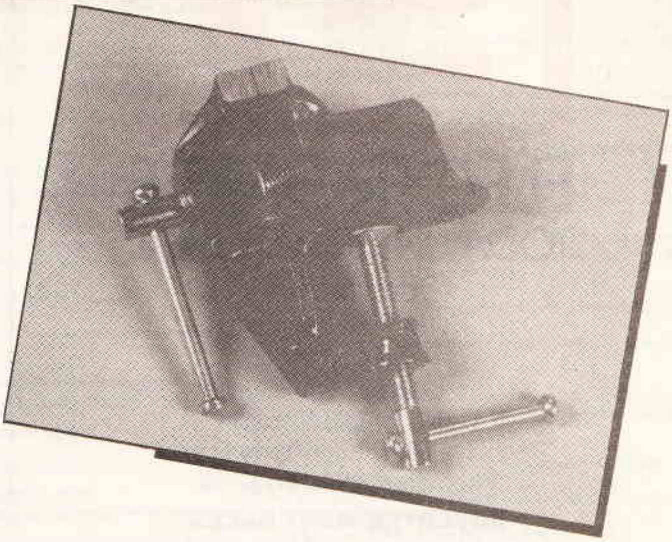

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UNIVERSAL BATTERY CHARGER. Takes AA's, C's, D's and PP3 nicads. Holds up to 5 batteries at once. New and cased, mains operated. £6.00 ref 6P36R

IN CAR POWER SUPPLY. Plugs into cigar socket and gives 3,4,5,6,7.5,9, and 12v outputs at 800mA. Complete with universal spider plug. £5.00 ref 5P167R

RESISTOR PACK. 10 x 50 values (500 resistors) all 1/4 watt 2% metal film. £5.00 ref 5P170R

MIRACOM WS4000 MODEMS
V21/23
AT COMAND SET
AUTODIAL/AUTOANSWER
FULL SOFTWARE CONTROL
TONE AND PULSE DIALLING
£29

IBM PRINTER LEAD. (D25 to centronics plug) 2 metre parallel. £5.00 ref 5P186R

COPPER CLAD STRIP BOARD 17" x 4" of .1" pitch "vero" board. £4.00 a sheet ref 4P62R or 2 sheets for £7.00 ref 7P22R

STRIP BOARD CUTTING TOOL. £2.00 ref 2P352R

50 METRES OF MAINS CABLE £3.00 2 core black precut in convenient 2 m lengths. Ideal for repairs and projects. ref 3P91R

4 CORE SCREENED AUDIO CABLE 24 METRES £2.00 Precut into convenient 1.2 m lengths. Ref 2P365R

TWEETERS 2 1/4" DIA 8 ohm mounted on a smart metal plate for easy fixing £2.00 ref 2P366R

COMPUTER MICE Originally made for Future PC's but can be adapted for other machines. Swiss made £8.00 ref 8P57R. Atari ST conversion kit £2.00 ref 2P362R

6 1/2" 20 WATT SPEAKER Built in tweeter 4 ohm £5.00 ref 5P205R

WINDUP SOLAR POWERED RADIO! FM/AM radio takes rechargeable batteries complete with hand charger and solar panel 14P200R

PC STYLE POWER SUPPLY Made by AZTEC. 110v or 240v input. +5 @ 15A,+12 @ 5A,-12 @ .5A,-5 @ .3A. Fully cased with fan, on/off switch, IEC inlet and standard PC flyleads. £15.00 ref F15P4

ALARM PIR SENSORS Standard 12v alarm type sensor will interface to most alarm panels. £16.00 ref 16P200

ALARM PANELS 2 zone cased keypad entry, entry exit time delay etc. £18.00 ref 18P200

MODEMS FOR THREE POUNDS!! Fully cased UK modems designed for dial up system (PSTN) no data or info but only £3.00 ref 3P145R

TELEPHONE HANDSETS Bargain pack of 10 brand new handsets with mic and speaker only £3.00 ref 3P146R

BARGAIN STRIPPERS Computer keyboards. Loads of switches and components excellent value at £1.00 ref CD40R

DATA RECORDERS Customer returned mains battery units built in mic ideal for Computer or general purpose audio use. Price is £4.00 ref 4P100R

SPECTRUM JOYSTICK INTERFACE Plugs into 48K Spectrum to provide a standard Atari type joystick port. Our price £4.00 ref 4P101R

ATARI JOYSTICKS Ok for use with the above interface, our price £4.00 ref 4P102R

BENCH POWER SUPPLIES Superbly made fully cased (metal) giving 12v at 2A plus a 6V supply. Fused and short circuit protected. For sale at less than the cost of the case! Our price is £4.00 ref 4P103R

SPEAKER WIRE Brown twin core insulated cable 100 feet for £2.00 REF 2P79R

MAINS FANS Brand new 5" x 3" complete with mounting plate quite powerfull and quite. Our price £1.00 ref CD41R

DISC DRIVES Customer returned units mixed capacities (up to 1.44M) We have not sorted these so you just get the next one on the shelf. Price is only £7.00 ref 7P1R (worth it even as a stripper)

HEX KEYBOARDS Brand new units approx 5" x 3" only £1.00 each ref CD42R

PROJECT BOX 51/2" x 31/2" x 1" black ABS with screw on lid. £1.00 ref CD43R

SCART TO SCART LEADS Bargain price leads at 2 for £3.00 ref 3P147R

SCART TO D TYPE LEADS Standard Scart on one end, Hi density D type on the other. Pack of ten leads only £7.00 ref 7P2R

OZONE FRIENDLY LATEX 250ml bottle of liquid rubber sets in 2 hours. Ideal for mounting PCB's fixing wires etc. £2.00 each ref 2P379R

QUICK SHOTS Standard Atari compatible hand controller (same as joysticks) our price is 2 for £2.00 ref 2P380R

VIEWDATA SYSTEMS Brand new units made by TANDATA complete with 1200/75 built in modem infra red remote controlled qwerty keyboard BT approved Prestel compatible, Centronics printer port RGB colour and composite output (works with ordinary television) complete with power supply and fully cased. Our price is only £20.00 ref 20P1R

AC STEPDOWN CONVERTOR Cased units that convert 240v to 110v 3" x 2" with mains input lead and 2 pin American output socket (suitable for resistive loads only) our price £2.00 ref 2P381R

SPECTRUM +2 LIGHT GUN PACK complete with software and instructions £8.00 ref 8P58R/2

CURLY CABLE Extends from 8" to 6 feet! D connector on one end, spade connectors on the other ideal for joysticks etc (6 core) £1.00 each ref CD44R

COMPUTER JOYSTICK BARGAIN Pack of 2 joysticks only £2.00 ref 2P382R

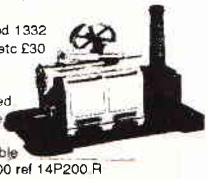
BUGGING TAPE RECORDER Small hand held cassette recorders that only operate when there is sound then turn off 6 seconds after so you could leave it in a room all day and just record any thing that was said. Price is £20.00 ref 20P3R

IEC MAINS LEADS Complete with 13A plug our price is only £3.00 for TWO! ref 3P148R

NEW SOLAR ENERGY KIT Contains 8 solar cells, motor, tools, fan etc plus educational booklet. Ideal for the budding enthusiast! Price is £12.00 ref 12P2R

286 AT PC
286 MOTHER BOARD WITH 640K RAM FULL SIZE METAL CASE, TECHNICAL MANUAL, KEYBOARD AND POWER SUPPLY £139 REF 139P1 (no i/o cards or drives included) **Some metal work req'd phone for details.**

35MM CAMERAS Customer returned units with built in flash and 28mm lens **2 for £8.00** ref 8P200



STEAM ENGINE Standard Mamod 1332 engine complete with boiler piston etc £30 ref 30P200

TALKING CLOCK LCD display, alarm, battery operated. Clock will announce the time at the push of a button and when the alarm is due. The alarm is switchable from voice to a cock crowing! £14.00 ref 14P200 R

HANDHELD TONE DIALLERS Small units that are designed to hold over the mouth piece of a telephone to send MF dialling tones. Ideal for the remote control of answer machines. £5.00 ref 5P209R

COMMODORE 64 MICRODRIVE SYSTEM Complete cased brand new drives with cartridge and software 10 times faster than tape machines works with any Commodore 64 setup. The orginal price for these was £49.00 but we can offer them to you at only £25.00! Ref 25P1R

ATARI 2600 GAMES COMPUTER Brand new with joystick and 32 game cartridge (plugs into TV) £29.00 ref F29P1 also some with 1 game at £19.00 ref F19P2

BEER PUMPS Mains operated with fluid detector and electronic timer standard connections. Ex equipment. £18.00 ref F18P1

90 WATT MAINS MOTORS Ex equipment but ok (as fitted to above pump) Good general pupose unit £9.00 ref F9P1

HI FI SPEAKER BARGAIN Originally made for TV sets they consist of a 4" 10 watt 4R speaker and a 2" 140R tweeter. If you want two of each plus 2 of our crossovers you can have the lot for £5.00 ref F5P2

VIDEO TAPES E180 FIFTY TAPES FOR £70.00 REF F70P1

360K 5 1/4" Brand new drives white front. £20.00 Ref F20P1

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