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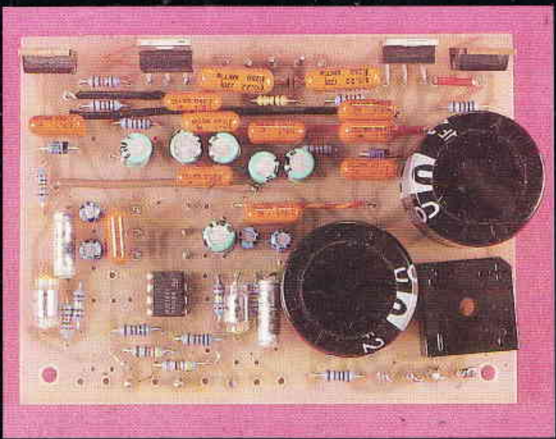

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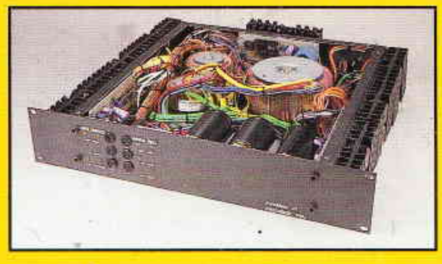

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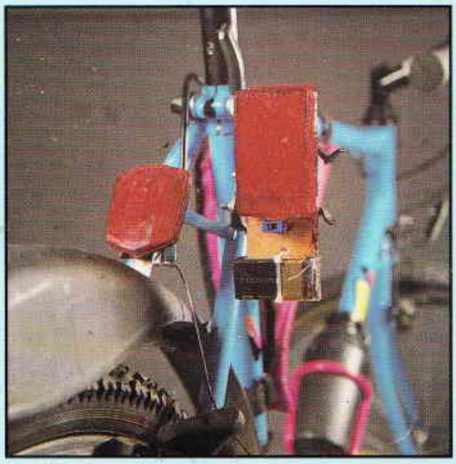

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AUDIO GENERATOR SCANNER

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Volume 21 No 6
June 1992

Features & Projects

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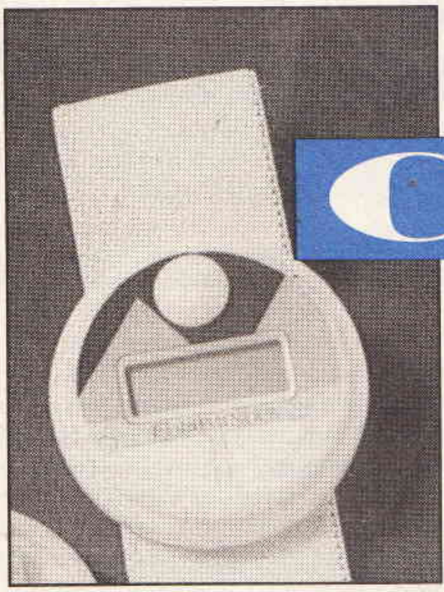

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Regulars

Editorial

By Paul Freeman

ETI now has more pages, more projects and more importantly, a complete PCB every month on our front cover to help you on your way with one of our projects. The launch PCB is for an IC stereo amplifier and could have a wide variety of applications for the beginner say in a school technology project. An established constructor might also use it for a bench monitor amp. Whichever way, it represents great value.

UV Detection

Increased Ultra-violet radiation arising from Ozone depletion over wide variations of the polar regions is continually in the news these days. It is also likely to remain so for many years to come.

Rising to the challenge, a small British company has invented a new UV detector (see page 14). They not only took the initiative in thinking up a revolutionary but simple inexpensive design but managed to get their sun monitors, one end product of their research, through development and ready for mass production. This apparent rarity in these inventive isles contrasts starkly with British lost achievements over the years. Those willing to invest risk capital in our ideas still remain very much overseas.

It is pleasing to know that in the case of this one small company, so much can be achieved by so few against the industrial might of Japan and the USA.

OPEN CHANNEL

The World Administrative Radio Conference (WARC) is the international procedural function organized by the International Telecommunications Union (ITU) to share out radio frequencies among its member countries and continents. It's convened every so often when it becomes apparent that new technological uses require frequency allocation, or that older uses simply require smaller or greater allocations. WARC 92 was held recently, and made an interesting decision to allow national licensees to create and operate mobile communications systems. Oh, what's new? I hear you ask. Well yes, I sympathize with your outburst. There does seem to be rather a lot of mobile communications systems around or planned for the near future. I can't disagree with you there. And whether they're all needed —or are going to be needed —is not a question which anyone seems to be asking yet. I guess each system has to be taken on its own merits, and if it can make a living then it's obviously needed.

However, technically at least, this new system is different to the others, in that it will use low earth orbiting satellites (LEOS) as the communications medium.

If you're aware, low earth orbiting satellites are used for some weather satellite systems as well as the so-called spy satellites. They orbit the earth at a much lower altitude than, say, television transmission satellites which are effectively geostationary —they appear in the same position all the time from a point on earth's surface. This is because a geostationary satellite makes an orbit round earth every 24 hours. So, it rotates at the same time as earth itself and is effectively stationary.

Low earth orbiting satellites, on the other hand, must orbit considerably faster than this to remain in orbit. The closer to the earth the faster this must be, simply in order to prevent themselves dropping down from the sky.

WARC agreed to make bands of 1.6-1.625GHz and 2.4-2.5GHz available for such systems. A number of manufacturers have already expressed interest in setting up satellite networks based on the decision.

Motorola, for example, has plans for a low earth orbiting satellite system based on the use of 77 such satellites. The network, nicknamed Iridium (the element iridium has an atomic number of 77) is apparently all ready to go.

00 Europe-Wide

By 1998, making an international telephone call from anywhere within the European Community will be possible with a single international code. In the UK currently, international telephone calls are always preceded by the code 010. This will change. The boys in Brussels have decided for us all, that international dialling in all member countries should be preceded by the code 00.

Currently there are seven different codes in use throughout Europe ranging from our 010, through Ireland's 16, Denmark's 009, Spain's 07, France's 19, Netherland's 09, and the rest of the mob's 00.

By 1998 we'll all have the opportunity to join the gang. Can I just ask, or is it heresy, does it honestly make any difference what international dialling code any particular country has?

Air Europe-Wide

While I can't see the international point in standardising dialling codes, I can see the point in standardising air traffic control systems. After all, 'phones can't kill if you dial a wrong number —'planes can kill if they're not properly supervised.

The same boys in Brussels (collectively, if not personally) who made the decision to standardise on an 00 international dial code have commissioned a study called Atlas, to consider ways in which a unified air traffic control system could be incorporated throughout Europe.

Have I got the whole thing wrong? As I see it, the European Commission is there to make international decisions which affect our lives as Europeans. In the Atlas study (and —in its own way —the international dial code I suppose) it is doing this. But isn't it all a bit mixed up when the international dial code will be incorporated long before a safe air traffic control system?

Down, Boy. Down!

Me? I love dogs. Smashing creatures. Bit noisy that's all. Somebody in Texas, though, has developed a special electronic collar which emits an ultrasonic tone whenever it detects its wearer barking. As you'll probably be aware, this is inaudible to humans but, as dogs' ears have a higher frequency response, it is most definitely annoying to the dog. After a while (noisy dogs aren't thick you know —just their owners, usually!) the dog will realize that to prevent the annoyment it simply has to keep its mouth shut. Pity they don't make such collars for a few people I know.

Before you get all hot under the collar (pun, what pun?) about cruelty to animals, and inhumane treatment of our best friend, bear in mind that vets have approved the system. They say it's more humane than shock collars, or vocal cord surgery. And I suppose it is. Thereagain there can't be much more inhumane than shock collars or vocal cord surgery, can there?

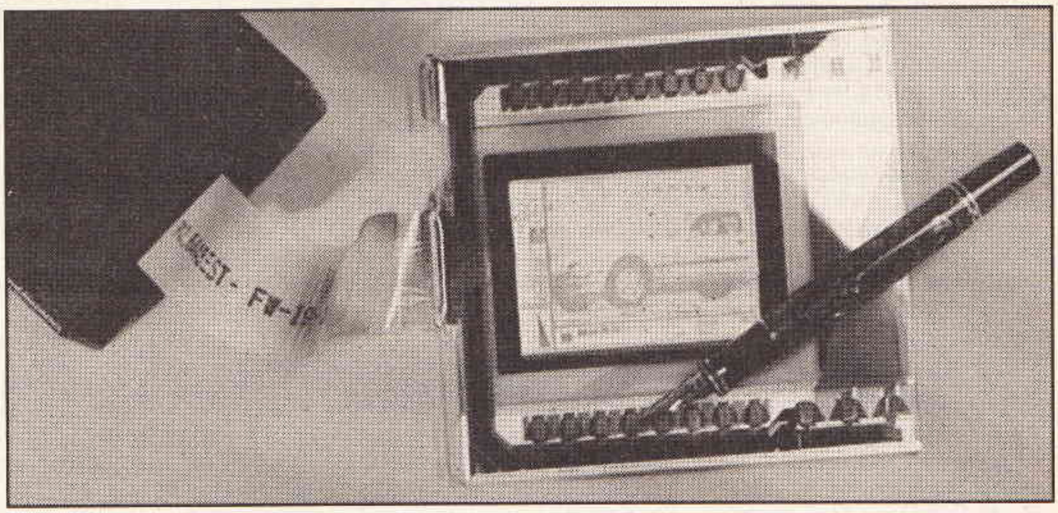
Now all they need to do (Canine Concepts, manufacturers of The Silencer, that is) is invent a device which gives the dog a kick up the jacksie whenever it does its business in the park, or on a footpath or, for that matter, anywhere except in its owner's own house. Better still, perhaps they could-invent a device which gives the owner a kick up the jackzie whenever the dog does its business.

Me? I love dogs.

Keith Brindley

ETI NEWS

SMALL IS BEAUTIFUL IN LCD PROJECTION TECHNOLOGY



Displays specialist Anders Electronics is introducing a 'super miniature' VGA-compatible LCD projection panel and PC-AT controller system.

Widespread applications include portable projection systems for PCs, low-cost low-power head-up displays, and miniature overhead projectors.

The LCD panel portion of the Anders projection system has an overall size of 128 x 120mm, giving an active viewing area of 72 x 55mm, compatible with most 'super miniature' projecting environments. To ensure maximum useability the LCD panel has been designed to operate in close proximity to a high intensity light source, such as those found in overhead projection systems and 35mm slide projectors.

Designed to work in tandem with the LCD panel is a custom controller system from Anders. The controller connects to the PC-AT bus, driving the LCD panel in 64 grey scales in VGA mode, with backwards compatibility for CGA, MGA, HGC, and EGA display modes. All the necessary power and connections rerquired to drive the LCD panel from the PC controller system are provided by a 16-bit half-length PC-AT expansion bus card.

For further information contact Lynn McGoohan, Anders Electronics Limited.

SIXTH FORMER TO ENGINEERING GRADUATE — A DIFFICULT TRANSITION?

The problem of 'Bridging the gap' between sixthform studies and the first year of an engineering degree course is the subject of a one day meeting to be held at the Institution of Electrical Engineers (IEE), London WC2 on Tuesday 26 May.

The academic divide between sixth form student and first year engineering undergraduate appears to be widening and is the cause of increasing concern. Many Universities and Polytechnics now offer pre-degree courses to bring prospective students up to their required first year entry standard — unheard of a few years ago!

What is going wrong and what can be done to bridge the gap? Does the fault lie with the new school curriculum and the Examining Boards? Should the Government do more to help schools or should Universities and Polytechnics expect less and bridge the gap from within?

These are just some of the issues to be debated at the IEE colloquium.

The meeting will open with a Keynote Address by Professor Sir Eric Ash CBE, Rector of Imperial College, London and Chairman of a Royal Society Study Group on Higher Education. Other speakers will represent the views of Industry, Schools, Examining Boards, Universities, Polytechnics and the Department of Education and Science, amongst others.

The meeting will include a general discussion and the issues raised will form the basis of a Report to be published by the IEE later this year.

Admission to the meeting is free although advance registration is necessary.

WORLD'S MOST ADVANCED DIGITAL NETWORK

Channel 4 has backed BT's commitment to broadcasting by signing a £50 million contract over ten years to take the world's most advanced digital TV network.

The new BT managed network is expected to lead to more flexible scheduling of Channel 4 commercials. They will have the ability to broadcast different advertisements simultaneously in six regional TV areas. The commercials will be transmitted direct from Channel 4 headquarters in London.

From January 1st, 1993, Channel 4 will sell and play out its own advertisements.

Digital technology gives the network greater flexibility and speed. Channel 4 can use the new technology and BT's management system to achieve cost-effective regional scheduling while improving its advertising on a local basis.

It will enable Channel 4 to compete more aggressively with ITV franchise holders for regional advertising revenue next year.

The digital network, operational from January 1993, is seen as fundamental to the success of the channel's regional network and gives Channel 4 a technological lead over other commercial broadcasters.

Chief engineer at Channel 4, Chris Daubney, said: "The digital network breaks new ground in broadcasting and confirms BT's leading role in developing complete solutions for their customers."

The new network will improve quality and consistency of pictures transmitted to all parts of the UK. The core network and programme contribution material carried on it will operate initially at 140 M/bits per second while sound, vision and associated signals carrying the output of the channel will be coded and delivered to transmitters at 34 M/bits per second.

BT's new digital technology is a response to the demand for even higher quality stereo sound and video transmission in today's 24 hour broadcast environment. BT has also built in new levels of network reliability and an upgrade path to wide screen TV.

GLOBAL PERSONAL COMMUNICATIONS SYSTEM

As a result of spectrum allocated during the World Administrative Radio Conference in Torremolinos, Spain, the Iridium project can now go ahead.

The Iridium system is a proposed global personal communications system which combines Motorola's space technology with its terrestrial radio communications expertise. Using low-earth orbit (LEO) satellites it will be designed to provide worldwide, portable and mobile telecommunications using hand-held phones. Current plans estimate the launching of the Iridium system's constellation of 77 satellites to begin in 1994.

The spectrum has been allocated in the 1610-1626.5MHz band by delegates attending the conference from countries around the world. It secures the future for Low Earth Orbit Satellites above 1GHz, the so-called big LEOs.

Jerrold Adams, President and Chief Operating Officer of Iridium Inc said "We believe investments will soon be made and licences applied for and granted in many countries".

Adams continued, saying "We are confident that the Iridium system will be able to provide truly personal, hand-held communications from anywhere to anywhere at anytime for the world traveller. This will also mean first time communication service for remote areas with no infrastructure at present, and immediate support to disaster relief situations".

HOME VIDEOPHONE AT IDEAL HOME EXHIBITION

BT has demonstrated a prototype videophone for use in the home at the Ideal Home Exhibition. The phone, which will cost less than £500 and is expected to be available later this year, allows customers to see as well as hear the person on the line.

The videophone will form part of a portfolio of videocommunications products from BT, which at present includes videoconferencing and will in future comprise desk-top videoconferencing, digital videophones, and personal computer-based multimedia equipment.

The new phone does not require a special line, it simply plugs into a standard telephone socket. To make a call a customer dials the telephone number in the normal way.

The videophone has a small camera and a three-inch colour screen, mounted on a flap that can be folded away. Privacy is assured by the press of a button or by lowering the flap.

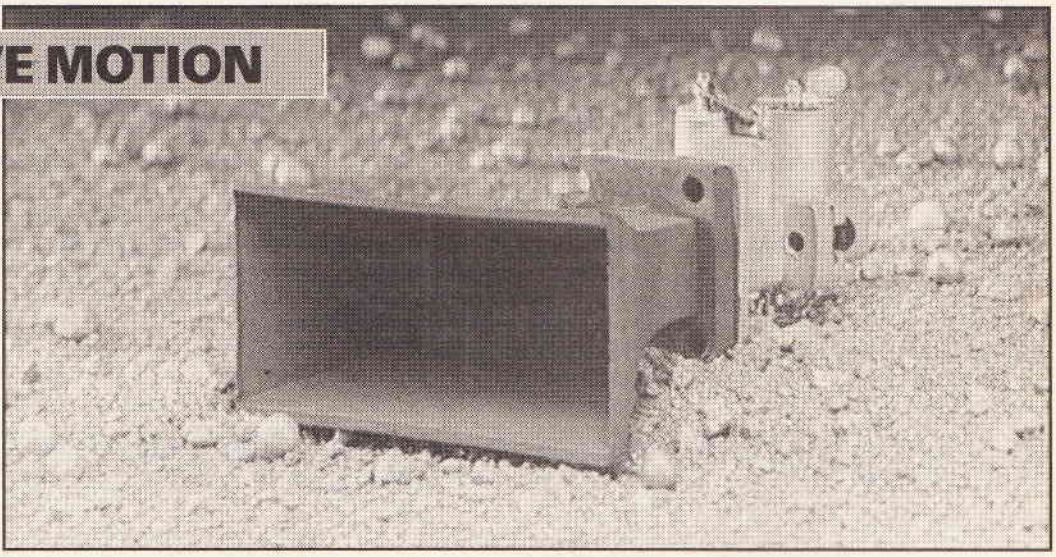
Calls on the videophone will cost the same as a normal telephone call.

Designed and manufactured by British company, GEC-Marconi, the telephone is currently undergoing extensive quality and reliability tests.

Andy Green, BT Director Public Communications Products, said: "BT has long recognised the benefits videotelephony can bring to customers and has made important inroads into the business market. However, the true worth of videocommunications will only be fully recognised when it becomes available to all our customers.

GEC-Marconi's video standard compresses both voice and a colour video picture into a 14.4 kilobit data stream which can then be sent over normal analogue telephone lines.

MICROWAVE MOTION



Cirkit are now stocking a new range of Alpha Industries microwave doppler modules. Using the radar principle of doppler frequency shift these modules are designed for all types of motion sensing applications, such as security alarms, auto door opening, traffic light control, speed measurement, industrial control and energy management.

Microwave sensors offer many advantages over alternative technologies, such as ultrasonic and PIR sensors, with a much greater range, smaller size and superior reliability; particularly important where false alarms must be eliminated.

Each of the modules use the same basic principle of operation detecting the difference between the transmitted and reflected return signal. This difference, or IF signal is typically 30Hz per mile hour of movement, which can be easily amplified and processed. The modules typically require only a +5V DC supply.

The DRO2980 is especially suitable for shorter range applications, 3-5m, with microstrip patch antenna for transmission and reception. This unit has DTI approval and is ideal for intrusion alarms and presence sensing applications.

Other types have tuned cavities with Gunn oscillator diodes for X band, 10GHz and K band, 24GHz operation. A horn antenna may be fitted to extend the range. These are suitable for more demanding applications such as speed measurement, direction sensing and low power communication links.

NEW S-VHS-C NV-S7 FROM PANASONIC

As palmcorders are becoming more popular due to their portability and easy operation, so higher quality and performance, especially picture and sound, are being demanded. The new S-VHS-C NV-S7 from Panasonic responds to these demands, offering users impressive videos through enhanced digital technology. The new S-VHS-C model boasts Hi-Fi stereo sound, is VITC compatible and has a host of digital functions that have been enhanced from the previous S-Series, for example, 16X Digital Zoom, Digital Wipe, Digital Mix and Digital Gain-up.

The NV-S7 has a 16X digital zoom, as compared with 12X on the NV-S5. At the push of a button the camera shifts smoothly to digital zooming up to 16 times. The digital technology enables 16X zooming equivalent to a 690mm telephoto lens with a compact lightweight lens section.

As with its predecessor, the NV-S7 is equipped with the Digital Image Stabiliser —now even more necessary to achieve a steady picture on a palmcorder with 16X zoom. To determine the best cut-out area to yield a stable picture on screen, the NV-S7's Digital Image Stabiliser has 5 detection areas (compared with 4 previously) on the CCD each containing 30 detection points. Picture movement is thus detected more accurately.

The NV-S7 offers excellent picture quality with Super-VHS. Incorporating a 1/3inch CCD with 420,000 pixels, a world first, the NV-S7 delivers a horizontal resolution of more than 400 lines.

To complement the picture quality the NV-S7 offers dynamic Hi-Fi stereo recording with a new triple capsule 2-way stereo microphone. Combining three omnidirectional ECM's, even sound from the front is recorded in stereo and this new system effectively cancels wind, vibration and acoustic noise.

In addition to the Digital features on the NV-S5, the NV-S7 is equipped with some new digital functions for fun and creative shooting, they are:-

Digital Wipe

This replaces a memorised still picture with the scene being shot, or vice versa. The new scene is wiped smoothly across the screen, from right to left, thus replacing the memorised picture.

Digital Mix

This function can be used in a variety of ways. A memorised still picture can overlap an existing scene and gradually replace it. Alternatively, when the 'start' button is pushed for a few seconds, both the memorised and still picture and the new picture remain mixed.

Both functions can also be used as a digital titler. Users can save any written text and placed in shots as a full colour titler.

Digital Gain-up

This feature permits clear shooting in the dark. Digital Gain-up boosts the camera's sensitivity in two steps —either four or eight times normal sensitivity. The camera is able to shoot in light as low as 1 lux. This function is also used for a slow shutter effect of 12.5 and 6.25 a second.

The NV-S7 will be available from authorised Panasonic dealers nationwide from April and will sell for an average selling price of £999.95.

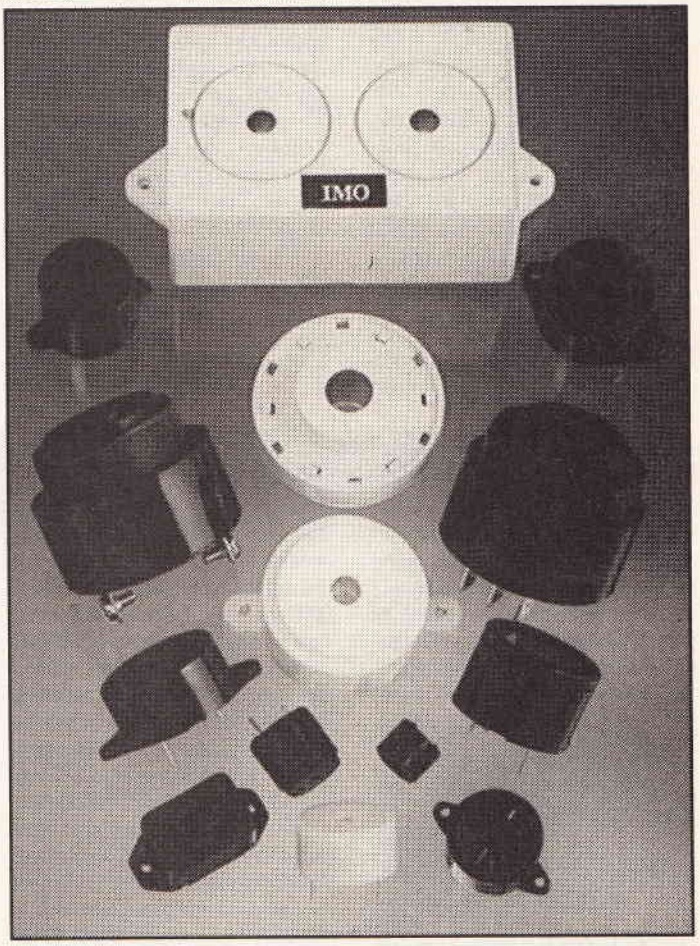
NEW RANGE OF AUDIBLE DEVICES

An entirely new range of IMO Buzzers, Piezos, and Transducers has been launched by the Electronic Components Division of IMO Precision Controls. The new range has not previously been available in Britain and includes many devices with specifications not offered on the UK market until now.

Among the DC-powered mechanical buzzers in the IMO range are devices designed for voltages from 3V to 24V DC, either PCB or panel mounted. Sound outputs are in the range 75 —80dB at 30cm. Extremely compact, the IMO buzzers are all in impact-resistant black ABS enclosures.

The new range of IMO piezo devices is similarly available for either PCB or panel mounting and is available with built-in oscillators for DC drive voltages from 3 to 28V DC.

The third major group in the new range is a substantial range of coil/diaphragm sounders and transducers which provide a much wider frequency response than piezo-based devices so are suitable for multitone applications. The tone produced by the coil and diaphragm sounders is richer and lower-pitched than that from a piezo device and is more pleasant for the user in situations where the device sounds frequently. An extensive range of operating voltages can be catered for by the new range.



UNITED NATIONS ENVIRONMENTAL AWARD

The United Nations Environment Programme (UNEP) has presented Northern Telecom with the 1992 North American Environmental Leadership Award for outstanding environmental achievement.

Dr Noel Brown, North American Director for UNEP, thanked Northern Telecom for "pioneering solutions to address the problem of ozone depletion". Dr Margaret G. Kerr, Northern Telecom's vice-president for environment, health and safety, accepted the award at the Globe '92 environmental conference held last week in Vancouver.

In 1991, Northern Telecom became the world's first large electronics company to fulfil its commitment to eliminate ozone depleting CFC-113 solvents from its manufacturing and research operations. The company developed a 'no-clean' technology that eliminates the need to remove flux residue from printed circuit boards, thereby eliminating the need for CFC-113 solvents. The new process is used in the company's manufacturing plants worldwide.

Northern Telecom is sharing its environmental technologies and processes with governments and corporations around the world. The company is currently working with the U.S. Environmental Protection Agency and the government of Mexico to eliminate ozone-depleting solvents from Mexican industry.

NEW AID TO TRACK CRIMINALS AND JOYRIDERS

The West Yorkshire Police Constabulary has purchased a THORN EMI Electronics indirect view thermal imager to provide 24 hour aerial surveillance. The imager is installed in a Flying Pictures stabilised Europod mounted on the force's MBB BO 105 helicopter and will be used for surveillance in darkness, poor visibility or where the area under surveillance is obscured.

This is the second constabulary to purchase a THORN EMI Electronics' thermal imager following its successful introduction to the Devon and Cornwall Constabulary who have used the dual sensor (thermal imaging and television) system since September 1990. Other police forces are also interested in the system.

The size and weight of such systems are important factors for smaller helicopters and fixed wing aircraft, and considerable attention has been given to these factors. The imager weighs less than 6kg, including the engine used for detector cooling; the overall weight of the Europod, which also contains a colour TV camera, is around 20kg.

The dual field of view (8° — 20°) makes the system suitable for surveillance activities as well as search operations where a wider area needs to be covered. The police can use the thermal imaging system to search at night or in poor weather conditions for people lost in desolate areas or to track criminals and joyriders.

The thermal image is displayed on a TV monitor within the helicopter's cockpit. This can show thermal images and TV pictures either separately or together on a split screen. Operator controls are kept to a minimum — a joystick to control the pod's movement, with keys to control fields of view and the displayed image. Alternatively, the image can be linked by radio to a police operations centre on the ground for coordination purposes.

MOST COST-EFFECTIVE FIBRE-TO-LASER DIODE

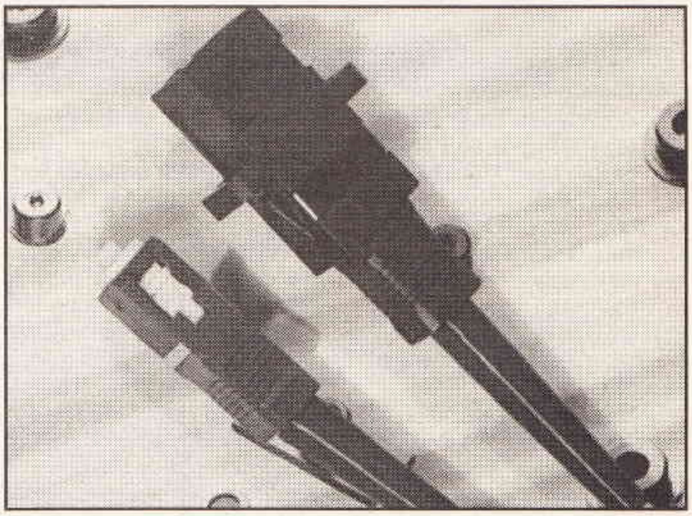
Mitsubishi is announcing the launch of the FU116SLD-1 and FU116SLD-3, a pair of SC connector laser diode modules that have been developed for coupling single-mode optical fibre with a 1.3μm wavelength InGaAsP laser diode.

Initially the laser diode modules are housed in diecast SC connectors with a view to moving to plastic in the near future. The SC connector based design for the laser diode is said to provide the most cost effective solution for fibre to the home and other high speed applications, with connector costs between 30 and 50% cheaper than FC/PC arrangements.

Both devices incorporate a photodiode for optical output monitoring and feature a low threshold current of 9mA plus wide operating case temperature ranges.

The FU116SLD-1 and -3 provide continuous wave, typical optical power outputs from the fibre end of 1.5 and 0.2mW, respectively.

Additional specifications for both devices include laser diode reverse voltage of 2V and photodiode reverse voltage and current of 15V and 2mA.



NEW DISK DRIVES AND OPTICAL DRIVES FROM IBM

IBM today announced nine new storage products for sale to manufacturers of different kinds of compuqters and storage subsystems. The new products significantly expand IBM's offerings to the marketplace.

Among the products are two new 2.5-inch disk drives, rewritable optical disk drives, tape drives and a 1.2-gigabyte (GB) 3.5-inch disk drive that uses a unique disk head technology.

Manufacturers of personal computers (PCs), laptops, notebooks, minicomputers and workstations, as well as makers of a wide variety of storage subsystems, such as optical libraries, are some of the firms that can use IBM storage devices in their own products.

New 2.5-inch disk drives — 60-megabyte (MB) and 120-MB models - have already been introduced, expanding IBM's family of smaller drives. Ideal for small PCs, laptops, notebooks and other products where physical space is at a premium, these drives are 12.7 and 17 millimetres high, respectively, and are among the most reliable, high-capacity 2.5-inch drives in the industry.

IBM also announced a higher capacity version of its acclaimed magnetoresistive (MR) head 3.5-inch disk drive that can store up to 1.2 billion bytes of information, or more than 550,000 double-spaced typewritten pages of text.

Available during the second quarter of 1992, it will be among the first 1.2-GB 3.5-inch disk drives in full production.

These drives can achieve higher capacities to a large extent because of their use of magnetoresistive head technology, developed by IBM engineers in Rochester, Minnesota and introduced by IBM last year. This technology allows a disk drive's read/write head to fly extremely close to the disk surface. As a result, the head can read data more accurately and quickly than traditional heads, allowing information to be packed more densely on to the drive surface.

This highly reliable drive — mean time between failures is over 500,000 hours, can be used in minicomputers, workstations and disk arrays. In addition, IBM will sell a separate storage unit which contains two 1.2-GB drives and can be used in other subsystems, such as external drives for workstations.

Also introduced are new models of IBM's optical disk drive products. The 127-MB 3.5-inch rewritable optical drive now offers a data seek time of 40 milliseconds, compared with 60 milliseconds in the model originally announced last spring. It can be used in personal computers and optical libraries for multimedia applications.

A rewritable model of IBM's 5.25-inch optical disk drive is now offered to OEM customers. This product offers 650-MB of removable storage making it an excellent product for larger archival and optical library applications.

ETI NEWS stateside

Autosophy

A new computational storage technique that could have dramatic consequences for both data storage and communications, called autosophy, is a patented machine-learning mechanism that assembles information representations in such a way as to minimize the amount of redundant items stored.

Klaus Holtz, president and founder of Omni Dimensional Networks of San Francisco, invented autosophy. He coined the term from the Greek words autos (self) and sophia (knowledge).

Content addressable memories are employed as supercomputer caches, among other uses. They are usually boards full of standard ICs, but several singlechip CAMs are available; one is the 99C10 from Advanced Micro Devices Inc. In CAMs, information is retrieved by content, rather than by specific location, or address.

With a conventional computer memory, a specific address would be required to access the information at that address. Since exact addresses are often unknown, a time-consuming search mechanism is usually invoked. In a CAM, however, if a person's name were entered the associated information would also be displayed.

In an autosopher, the basic unit of storage, called an 'engram,' can include any number of information items, or elements, and each element contains the address of the previous element in the engram.

Without using this engram model, so many CAMs would be necessary for information-processing applications that it would be prohibitively expensive to accomplish.

When a new piece of information —unrelated to anything else —is entered into an autosopher, a new engram is originated. That starting point is called a 'seed.' For each subsequent item, previous seeds and other elements that have already been learned are used, so that only those elements that are uniquely different require new memory locations.

Beginning elements are always shared, but the last element of an engram is always unique.

In an autosopher-based HDTV system, engrams would be constructed of blocks of pixels of various sizes. Two or more autosophers can be taught the same groups of engrams. If an autosopher were to communicate with a matching one, the first could, by transmitting a few simple addresses, instruct the second autosopher to retrieve any engram(s) they share in common.

Shorter method of making PTFE PC boards

A process that reduces from eight to three the number of steps required to deposit copper circuits on polytetrafluoroethylene substrates has been developed at Sandia National Laboratory and the University of New Mexico.

PTFE is a good insulator with a low dielectric constant, but its non-stick property makes it difficult to bond copper to the material. Manufacturers now use mechanical rolling to bond a thick copper film to the PTFE, followed by a series of photoresist steps to create the copper circuits.

In Sandia's technique, the surface where no copper is desired is irradiated by X-rays for electrons. The substrate is next chemically etched, but the irradiated area is not affected, perhaps because the irradiation cross-links the surface molecules.

Chemical vapour deposition then deposits copper on the etched pattern. The process can make thinner circuit lines and make them closer together.

Researchers at Sandia have also developed an improved method of etching silicon to create miniature sensors and other devices. Sculpting of these three-dimensional structures is difficult to control precisely with conventional photolithography and chemical etching, and results in a matt, rather than a mirror, finish.

The new method starts with electrolysis in hydrofluoric acid to form a very thick porous layer on top of a silicon wafer. The layer's depth can be precisely controlled by regulating the charge in the electrochemical cell. The porous silicon is then etched by immersing the wafer in a hydroxide solution at room temperature. It is possible to duplicate the process repeatedly, with no more than a 0.3% variance in results. A patent has been filed for a humidity sensor made by the process.

Programmable I/O chip

I/O-intensive systems, such as data concentrators, data-acquisition boxes and the like, can be a serious problem for micro-processors. An interupt-driven I/O scheme theoretically frees the CPU to process data while the I/O devices run, but the CPU often falters in a mass of context switches.

Signetics Co., a subsidiary of North American Philips, has announced a possible solution. Their answer is a programmable I/O processor — a dedicated chip that goes between the I/O devices and the system bus.

The IOP autonomously does all the things that would cost the CPU most dearly. It responds to device interrupts, checks status, moves data between main memory buffers and the devices, and has limited ability to preprocess the data in passing. The IOP can even be induced to chain buffers, in cases where a transfer moves a great deal of data, and to bring in the CPU when something goes wrong on a device and more extensive intervention is necessary.

This sort of job has often been done in the past with dedicated single-ship microcontrolers. But the distinctly unusual architecture of the IOP gives it significant advantages over an MCU, according to design engineer Robert Bradfield II. "As the number of I/O channels goes up, it's pretty hard for a microcontroller to keep up. Most MCUs require several clock cycles to execute any instruction, and they tend to have very long context-switch times. In comparison, the IOP does most instructions in two cycles at 16MHz, and has essentially a one-cycle context switch."

The IOP is based on a 15 instruction state machine instead of on a conventional general-purpose ALU. State-machine instructions move data, read device status, interrupt the host CPU, or alter programme flow. Computation and decision-making are done not in logic, but through an elaborate structure of decision tables. Indirect branches through the tables permit the chip to respond to any foreseen device status or data.

The IOP communicates through its own external bus, using 23 address bits and 16 data bits. Through the bus, the chip fetches its instructions accesses decision tables and manages I/O buffers, all of which are in external memory. The bus is also the link to I/O devices. A handshaking scheme permits the chip to take the host CPU bus for moving data into main memory.

More Stateside Next Month

READ\WRITE

ETI LETTERS

Programmed EPROM Service

In answer to your request for someone to programme EPROMs, I am willing to take on the task. I can program 2716 / 2632 / 2654 / 26127 /26512 and low power devices. The price will be about £5 each plus the cost of the device and postage.

J Lister, G1YNG 40, Rossall Grange Lane, Fleetwood, Lancs FY7 8AD

In response to the Read/Write column, EPROM Service required. First of all Mr C Graham refers to a hex dump, as though it were related to a project previously published; is this so?

Secondly if he has a disc file of a code he wishes to program the EPROM with, then I have this facility. Furthermore I am in a position to assemble neumonic 6502/Z80 instructions into appropriate machine code. This may similarly sent to EPROMs.

The following shows a list of charges to program EPROMs with standard binary files:

2716 £7 +Current EPROM charge +VAT

2732 £7 +Current EPROM charge +VAT

2764 £9 +Current EPROM charge +VAT

27128 £12+Current EPROM charge +VAT

Please ring 0243 830564 for other types. Further requiremnets are negotiable.

JJ Hackett, 2 Christopher Ct, Brooks Lane West, Bognor Regis, West Sussex PO22 8AJ.

Where have you been for the last few years Mr Hackett? ETI has published several projects that include EPROMs but thank you for offering your services - Ed.

The Alpha Plan

I hope you can help me with a bit of information about a 1987 edition of ETI. It is this The authors, Paul Chappel and Nick Hacking, of 'The ETI EEG Monitor' (September and October 1987) mention a book called 'The Alpha Plan' by David Lewis, published by Methuen. Now, the book is out of print, and I need to know where to find a copy. Can anybody help?

Any ideas? I'd be grateful for your comments.

Gary Bates, 24 Landseer Road, Leicester LE2 3EE

Hazardous Waste Problem

I work repairing VHF equipment, most of which have output transistors, which are labelled to the effect. 'Contains Beryllium Oxide, Hazardous, Dispose of carefully'.

The repair and service manuals usually give the same advice, but no real details of what safe disposal is. I have a fair collection of these devices which I have refrained from binning.

Is there anyone who knows of a safe disposal service or better still recycling of this waste?

A Ward, Londonderry, Northern Ireland

Wrong Place For The Sunshine

In our Solar Powered Tech Tips article in the April edition of ETI we gave the wrong address for Chartland Electronics at the end for the supply of solar cells. The correct address is: Chartland Electronics, Charland House, Old Station Approach, Randalls Rd, Letherhead, Surrey KT22 7TE.

Channels Crossed

I just have to write to take Keith Brindley to task for his Open Channel in April about the alleged unfairness of ETSI trying to standardise on 80cm satellite dishes. This offends my sense of fair play. Back in the bad old days of the mid-eighties the idea of satellite was mooted. Frequencies had been allocated at WARC in 1977 for direct broadcast by satellite, together with orbital slots, to give each country a reasonable share of channels without mutual interference. The UK channels were allocated by the government to a company called BSB (not BSkyB!), remember them?

A lot happened between 1977 and the mid-eighties, and in particular the noise figure of satellite LNB's dropped. SES-Astra came along and thought "Let's be terribly smart here. If we put up a satellite in the frequency band allocated to telecommunications traffic, we do not have to get permission from national governments. Now we can get by at the allocated telecomms power and 60cm dishes." So they were awfully clever, choosing a quick solution of transmitting PAL at not-quite-DBS powers which has now condemned us to towns disfigured by the sprouting of 60cm dishes all over the place. The technique worked — Sky transmitting on Astra totally scuppered the competition who were working within the planned system. and finally absorbed them into what is now BSkyB. It cannot be said that the original BSB did not make mistakes and the government could perhaps have helped just a little bit, but essentially we have a classic example of what happens when a free-market solution is taken in a field (radio planning) which unfortunately does need to be centrally planned. We get a low-quality, premature short-term solution.

So here we have Keith's diatribe in support of what is basically, 'a cuckoo in the nest' as far as the telecommunications band is concerned. The frequencies Astra is using were allocated by international agreement to telecommunications use. Astra have therefore no right to complain when legitimate users of the band who do want to use it for telecommunications use set rules that do not suit DBS needs. It is quite acceptable to require an 80cm dish for a telecomms satellite, as telecomms earth stations come as a few large installations. where the difference between an 80cm and a 60 cm dish is not terribly relevant. If Astra wants to live in the telecommunications band rather than the DBS band, they've got to play by the rules of the telecomms guys and that means the rules set by ETSI. This is why there is no representation of and consumer electronics users in ETSI; they should not be there in the first place!

I'm sorry Keith. but you are backing the wrong side here. Astra deserve no sympathy -they took a chance with their money and that of their four million viewers when they started transmitting in the telecom band. Although I have an Astra dish. I won't be that sorry to see SES get their comeuppance — sooner or later the mess of European satellite TV will have to be sorted out, and it would be nice to see it in the band allocated to DBS TV, with higher powers so our cities are not disfigured by ugly metalwork. Take a look down the next street of terraced houses you see, Keith. and imagine a 60cm dish on every one with a UHF TV aerial. Is that really the vision of the future you want to see?

Richard Mudhar, Ipswich, Suffolk.

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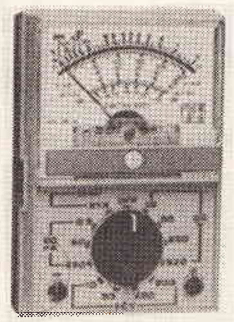

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10	—	£0.12	£0.12	£0.12
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47	£0.10	£0.11	£0.16	£0.20
100	£0.10	£0.13	£0.21	—
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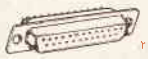

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4024	£0.21
4025	£0.15
4026	£0.40
4027	£0.18
4029	£0.27
4030	£0.17
4033	£0.56
4035	£0.31
4040	£0.29
4042	£0.22
4043	£0.28
4046	£0.31
4047	£0.25
4049	£0.20
4051	£0.25
4052	£0.25
4053	£0.24
4055	£0.30
4060	£0.31
4063	£0.29
4066	£0.18
4069	£0.20
4070	£0.17
4071	£0.21
4072	£0.17
4075	£0.17
4076	£0.30
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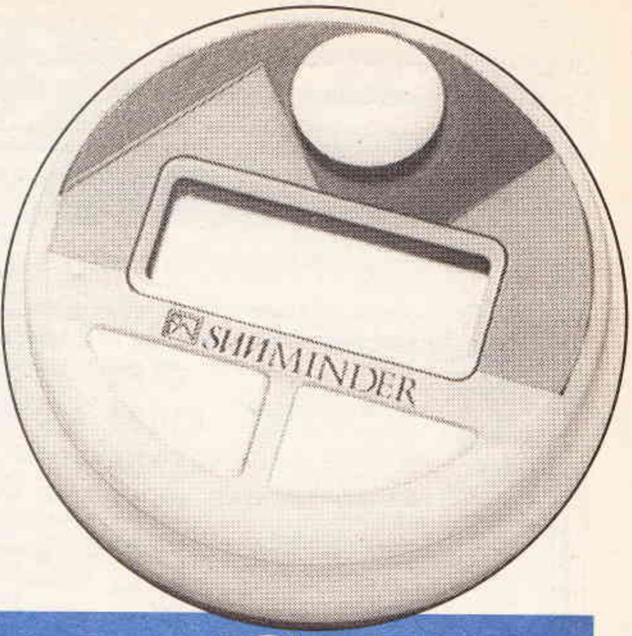
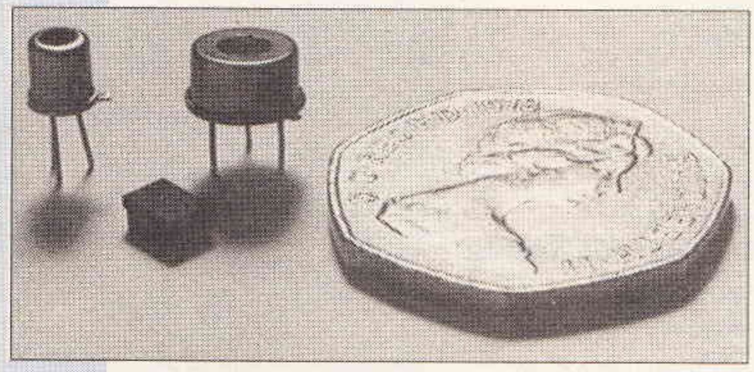


An innovative British company Uvisol Ltd has announced exclusively to ETI Electronics its revolutionary low cost detector design for monitoring harmful solar ultra violet radiation. By making a detector with a wavelength response tailored to the skin's erythemal response which peaks at about 300nm and falls rapidly with increasing wavelength, the sensor can directly detect the level of effective skin exposure without complex additional circuitry. This achievement is all the more remarkable considering the race has been won in the face of fierce competition from large Japansese and American Corporations with all their vast R&D facilities. The example of Uvisol in scoring a global 'first' is another splendid demonstration of the unique British gift of invention.



Leading photo Uvisol's sunminder ▲Above — Differential sensor elements, including a surface mount device.

There is, nevertheless, great significance in the fundamental technology used to develop the solar UV detector. The fabrication method can readily be used to produce other low cost, wavelength specific detectors in the UV, visible and infra red spectrum.

Prior to the successful development of the Uvisol sensor, only systems costing tens or even hundreds of pounds which employed specialist detectors were available to monitor dose levels of ultra violet B (UVB) radiation. Using innovative semiconductor technology, however, a superb level of sensing performance has been achieved at a price appropriate even for the consumer market place. The way in which the various problems of detector design were eventually solved appears simple in retrospect. The road to discovery however was paved with the sheer determination to succeed.

The History

The origins of the Uvisol sensor can be traced back to Cowes Week in 1989 when a founder member of the company and various colleagues got badly sunburnt. Having extensive experience of similar sensing technology, primarily in infra red applications, it was apparent that it should be possible to design and build a device to alert sunbathers of their 'safe' limit of solar exposure. An extensive search through electronic component catalogues, revealed that no suitable sensor was available. The project to develop the 'missing link' sensor began soon after when the significance of a successful outcome became apparent. Project motivation stemmed from the desire to develop sensors that would help reduce the rapidly mounting toll of skin cancers related to chronic UVB exposure.

Design Considerations

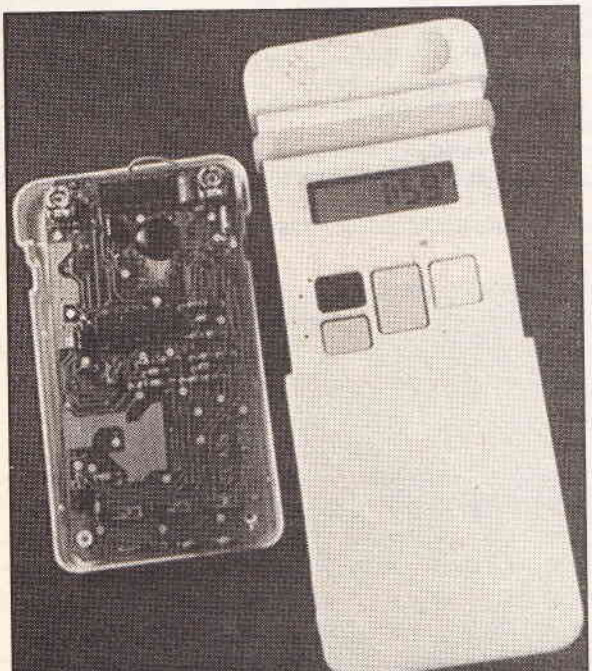
The two problems overcome by the revolutionary design of the Uvisol detector are the highly specific wavelength response and invariance of response with angle of incidence of the UV radiation. Both of these are essential for accurate UV dose measurement.

The revolutionary sensing principle used is one of 'differential sensing'. It makes use of simple principles of photo detectors and optical filter materials. While this principle will create the desired wavelength response for 'chunky' sensing elements, there remains a problem of incident geometry of UV radiation.

Adopting a 'differential' process with existing discrete photodiodes (Silicon or Ga-As), would produce a considerable problem of response with angle of incidence. To the team, it was important that a contribution of UV from a specific direction is sensed with a high degree of angular invariance. It is easy to see that even the differential sensing method will prove inaccurate if this is not the case.

The revolutionary design of the Uvisol sensor gets round this problem by fabricating elements of semiconductor adjacent to each other. The sensors are mounted in three legged cans and also a surface mount (SMD) version. The active element of this new generation of photodiodes is therefore no bigger than two grains of sugar.

Considerable problems had to be overcome in optimising the optical properties of component materials. One of these difficulties was the tendency of elements to fluoresce and so adversely alter the wavelength response of the differential device. Fundamental investigation of



◄Uvisol's UVISCAN product for monitoring of solar UVB skin dose.

optical components often showed that even the manufacturers were not aware of the adverse fluorescent properties of their devices.

The saga of development within the project highlights the value of establishing and maintaining fundamental technological skills related to materials science. Without an adequate core of such technica information, development processes are invariably slower and hence more expensive.

Diverse Applications

This patented development held by Uvisol Ltd and which is exclusively licensed to Sensatech Industries Ltd, represents a fundamental breakthrough in sensor design technology and is certain to have major implications for the design of future generations of photodiode detectors. It also indicates an area which is likely to see very significant developments in terms of manufacturing technol ogy and the range of detectors that could be developed in the future. Could this, for example, be a way of fabricating a low cost spectrum analyser? Rather than break light down into its spectral components using a diffraction grating, it would be possible to customise an array of detector elements, each with a specific wavelength response. A basic array employing this technology would be adequate for a broad range of requirements.

The Uvisol UVB detector is seen as an initial 'ideal' application where there is a large demand for such low cost/high performance devices and an excellent 'shop window' for the application of the new differential sensor technology. It is likely that significant new product areas will be created by the availability of such technology where the key factor is the low cost and highly specific wavelength response of the particular sensing elements.

Environmental and Scientific Applications

Solar UV radiation reacts in a specific but highly wavelength dependent way with a broad range of ecological systems, and so complicates monitoring. The specific wavelength response of the human skin to solar UV radiation is important for us in a direct sense. Almost all life forms in the biosphere —ranging from the teeming plankton in the seas around Antarctica to individual ears of wheat in the bread basket of North America have their own individual 'action spectrum' to solar UV radiation. Rather than determine whether skin turns red and blisters, these responses determine crop yields and even the survival of entire species in food chains.

The developers at Uvisol indicate that by altering the optical characteristics of sensor components, wavelength responses appropriate for other UV interaction mechanisms can be produced using the same low cost manufacturing methods. This opens the way, therefore, for arrays of multi parameter UV environmental monitoring elements to be developed. In future, for example, the crop in a vineyard may be harvested based on information related to how much UV radiation the grapes have been exposed to, thus preventing costly errors in inappropriate time of harvesting.

There are already schemes being planned to monitor global UV levels in order to assess health and environmental impact. The unique Uvisol sensor technology allows such schemes to be rapidly implemented at dramatically reduced cost compared with sensor conventional technology.

As environmental agencies are aware, it is important to measure environmental 'impact' of changing levels of solar UV radiation in order to apply the necessary pressure on governments world wide to secure the necessary environmental controls on ozone depletion chemicals being released into the atmosphere. The sooner the full impact of ozone depletion is realised the sooner the necessary controls are likely to be adopted.

The breakthrough of the Uvisol sensor will initially provide a major breakthrough for personal solar UVB monitoring. This comes at a time of increasing anxiety from Health Organisations about the dramatic rise in incidence of skin cancer as a result of changing social and leisure trends. The depletion of the ozone layer and the resulting increase in UVB levels heightens such concern.

Uvisol Consumer Products

In addition to licensing the technology to a broad range of market applications, Uvisol are launching three separate consumer products which use their unique sensor technology. Their initial wish is to make available sensibly priced consumer products which provide a high level of quality in their monitoring function. Initially Uvisol is targetting the Australasian and Pacific Rim markets where awareness of the dangers of solar UV radiation is particularly acute. The products will be launched into the Australian market in September 1992, the beginning of their summer season and UK High Street shops in the spring of 1993.

The SUNMINDER is basically a clip on badge which when activated counts up the dose detected. The unit is primarily intended to be used with children with an assumed skin type 1. The unit 'counts up in terms of numbers of suns indicated on its liquid crystal display. When tens suns are counted, corresponding to a maximum dose, an audible alarm is sounded —indicating that the allowed exposure has been received. It is at this stage that the wearer should go indoors.

The UVISCAN is a more numerate device into which details of skin type and sun protection factor being applied can be entered. When primed, the unit indicates at 30 second intervals the calculated 'safe' time remaining for solar UVB exposure. An alarm is sounded when this degree of exposure is exceeded.

The UVISPORT combines the functions of a digital watch with those of the UVISCAN, providing compact functionality in a stylish package. The UVISPORT is appropriate for a broad range of outdoor sports activities and in addition is also highly appropriate for large numbers of individuals with a high occupational exposure to solar UV radiation such as road workers, traffic wardens, telecom and electricity line repair workers, construction and agricultural workers. The SUNMINDER and the UVISCAN can be seen on the previous pages.

There is increasing awareness of the liability of employers to monitor the working conditions of employees. In occupations where there is the likelihood of exposure of high levels of solar UV radiation, Uvisol's products provide a practical means of limiting exposure.

A prime difficulty with public awareness schemes of the dangers of over exposure to UVB radiation has been the lack of affordable instruments to indicate exposure levels. With the availability of these Uvisol products, this difficulty should be overcome. This will help with education in relation to the risks of 'sun and sand' holidays and also problems of higher general solar UV levels arising from ozone depletion.

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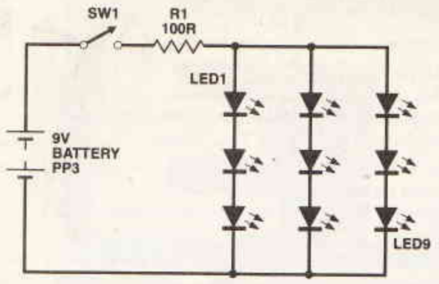

Fig.1 Circuit for LED rear lamp

An economical and portable rear light by Andrew Armstrong

LED bicycle Rear Lamp

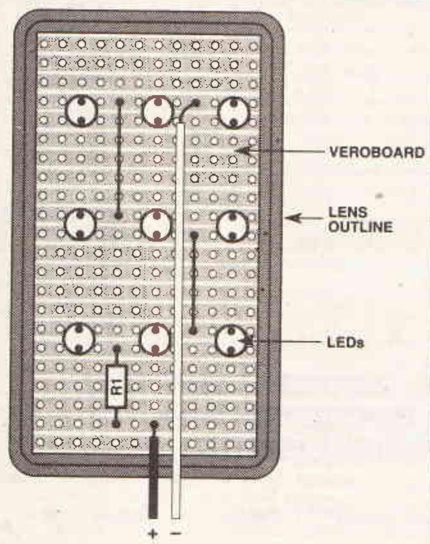

Fig.2 Arrangement of LEDs

If a conventional rear lamp was left attached to our bicycle, while it was in the cycle shed at the station, then every now and again it would be found damaged or missing. The obvious answer was to remove it and carry it around all day. Unfortunately, the size and shape of the lamp made carrying it around a real nuisance. It was pretty well unavoidable that a lamp employing two D cells would be too big for easy carrying.

The answer to this was to adapt the lamp to use a smaller battery, and a differ[illegible] batteries were to be used, a more efficient type of light was needed, so LEDs were chosen for this purpose. Not all LEDs are created equal; some of them are much more efficient than others. Clearly, the choice of LED was crucial in order to maximise battery life while still providing enough light output.

LED specifications must be read with care in order to discover what types are suitable. It is no good choosing an LED specified at several candelas output, but with a very narrow viewing angle. By the time the light has been diffused to give a suitable viewing angle for a rear lamp, such an LED may not turn out to be very bright. The criterion for choice was that the LED should have the maximum light output over an adequate viewing angle (say 90°). The prototype lamp used LEDs purchased from Farnell, but the Maplin catalogue contains at least one suitable type.

Experiments show that nine LEDs laid out in a square grid provided sufficient light output when each LED was supplied with twenty milliamps. Experiment also showed that, if all the LEDs were of the same type, they could be connected as three parallel chains, and each chain would draw the same current. In order to provide a fairly constant current, the battery voltage had to be significantly above the LED voltage, so that a small reduction in battery voltage would not noticeably affect the light output. The voltage drop across the LED chains is approximately six volts, so a 9V battery type PP3 was chosen, as shown in the circuit, Figure 1.

The current-limiting resistor is chosen to feed 60mA into the circuit, which splits into 20mA down each chain. Using alkaline manganese batteries, the lamp lasts for a total of about five to seven hours between battery changes. This equates to almost 50p an hour, which would not be practical if a lot of cycling after dark was anticipated. However, for commuting to and from the station the convenience is well worth the cost, and the battery lasts from between one and two months of normal use.

Physical Construction

To make the lamp, the red plastic lens from a defunct lamp was salvaged, and a piece of Veroboard was cut to fit just inside the red cowling. The LEDs were laid out on the Vero board in an even grid with wire links and a current-limiting resistor as shown in Figure 2. A piece of Paxolin (any thin insulating material will do) was cut to a size big enough for the reflector and a PP3 battery to be fitted to it, with enough space between the two to fit in a sub-miniature switch glued to the bottom of the lens.

The Vero board was fixed to the Paxolin with double-sided adhesive pads, the reflector (with a small cutout for the wires) was fixed over the top of it using silicone rubber sealant, and the battery was held in place with a cable tie, as shown in Figure 3. The lamp was held on the luggage carrier, when in use, by a couple of stout rubber bands.

The lamp has given good service for two years, and should continue to do so for many more.

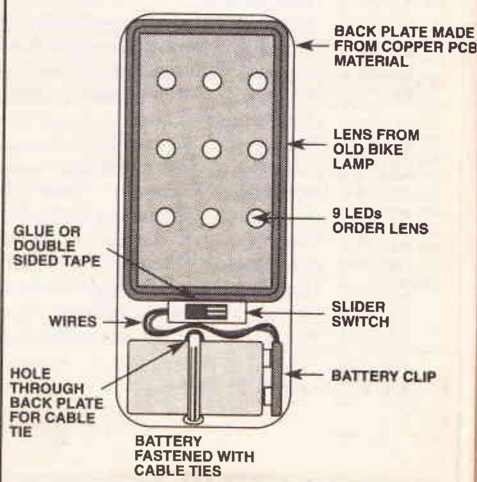

Fig.3 Complete structure of bike light

PROJECT

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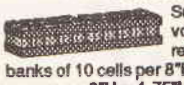

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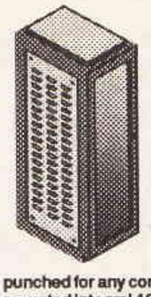

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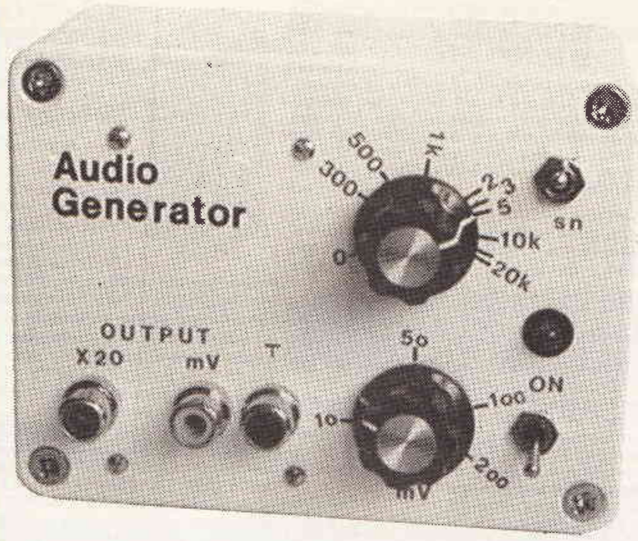

Another surface-mount project to accompany the sine wave generator given in March by Bill Mooney.

Scanner for the Audio O

The varicap tuned audio oscillator described is a very useful instrument in its basic manually tuned form. But manual tuning does not make full use of its voltage control capabilities.

The most obvious modification is to remove the stabilised DC supply to the manual control and replace it with a sawtooth voltage source. This will cause the oscillator to scan all or some selected part of the audio spectrum repeatedly. Add an oscilloscope to this and you have the facility to automatically map out the frequency response of an audio filter, amplifier etc. Of course the tuning voltage may be derived from many sources to give some weird modulation effects.

For a meaningful response plot of a filter system we need the setup shown in Figure 1 The CRO time base will be in sync with the scanner and the position along the x-axis will represent the frequency. Since there is no detector in the system the plot will be in the form of an envelope as shown. It would be simple to add a detector to produce a classic line graph. Whilst we might be happy with a non linear plot of frequency along the x-axis, it does make calibration a little more difficult. The design requirements for the add-on scanner are therefore as follows:

Linear voltage / time sawtooth output waveform.
Variable scan rate, slow (5 sec) to fast (1/100 sec)
Sufficient output to cover full tuning range (0-5V)
Low current consumption for battery operation.
A sync output for an oscilloscope

Construction

As with the oscillator, the scanner is constructed using SMD's and it fits on a small PCB measuring 30mm by 34mm. The layout, Figure 3, is again generous and should present no population problems. The PCB can be produced in the usual manner but without the hassle of drilling holes. Use double sided PCB for Surface Mount projects to reduce strain on the chips. It has less tendency to warp and provides useful screening. It would be useful to consult the construction notes from the previous article at this stage. There is no preferred order of component placement except that the CA3140 op amp is a little static sensitive and should be soldered in last of all. The unit is sufficiently small to fit inside the oscillator project box with the addition of suitable plugs and switches. The PCB can be conveniently glued to the back of the frequency control pot. The small current requirement can easily be provided by the same battery.

The scan rate preset, RV1, could be replaced by a panel mounted control if preferred.

Operation

The scanner will draw some 7mA at 9V and this should be checked when power is first applied. Note that three links are needed from V+ to the two IC's and RV1. Make these with thin (30swg) solid core Kynar wire. It is important that the supply voltage should not drop below 7V otherwise the op-amp IC2 will not have sufficient headroom to produce the required 5V swing. To get it going, disconnect the 5V stabilised supply from the oscillator frequency control pot. Connect the scanner output to this pot. Connect the oscillator power output (X20) to a loudspeaker. You should now be able to adjust the scanning rate with RV1 on the scanner PCB. A little complication will be noted here in that in order to get the fre-

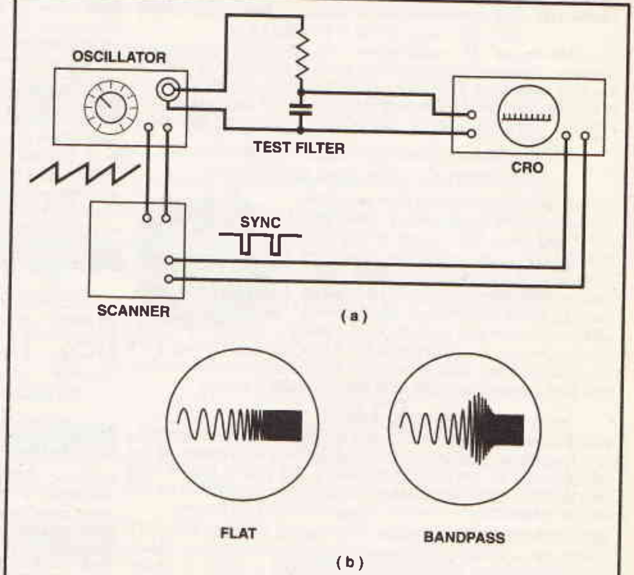

Fig.1 Scanner used with oscillator and oscilloscope

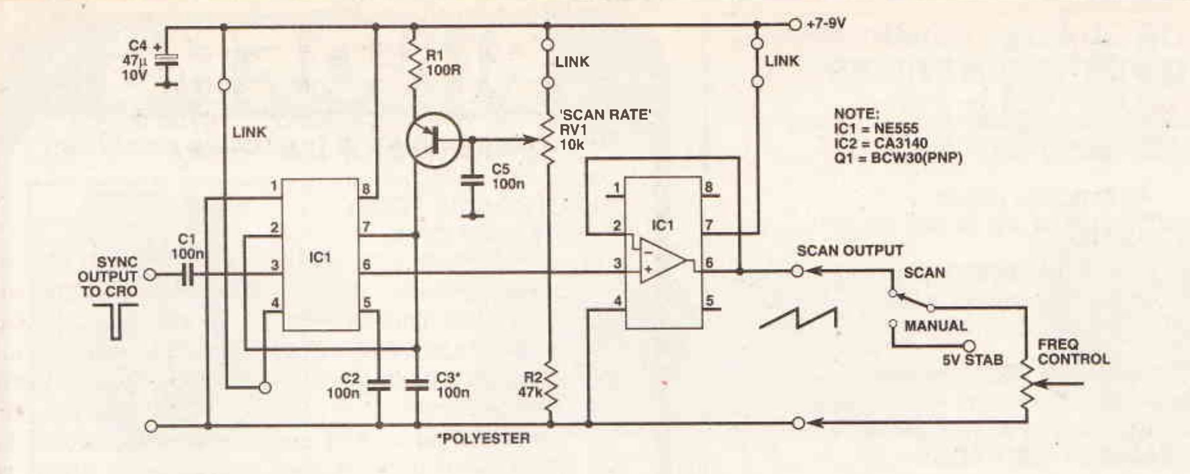

Fig.2 Circuit diagram of scanner

quency scan to start at zero frequency and increase it will be necessary to set the oscillator pot to about the 5kHz position and the scan will stop at about 15kHz. The reason for this is the presence of R5 at the lower end of the frequency control pot giving a minimum of 0.5V when manually tuned. When the scanner is connected the tuning voltage can drop to zero and thus the controlled oscillator frequency would need to be adjusted to zero beat

Generator

with zero input voltage. It is easy to do this if you really want the full scan range. However this is the time to impress your friends and you will soon find out just how annoying a room full of wobbulating audio can be to unappreciative non technical members of the family.

The serious matter of plotting the response of an audio network is now up to the constructor. You may or may not require accurate frequency calibration, you may want to give the amplitude a Log response (dBs), or you may want to use a non linear frequency plot to expand the lower frequency end. All these mods can be easily engineered. The simplest way to calibrate the CRO frequency axis would be to note the audio frequency at say 5 different DC levels from 5V down to say 0.5V. Then with the scanner running from 0V to 5V linearly, 5 equal divisions along the x-axis from the left side of the CRO screen will correspond to these five frequencies. Don't forget the oscillators are running at 1mHz and may therefore drift from time to time. Reset the calibration by setting the pointer to your previously marked 1kHz position and adjust the appropriate trimmer (TC2) until the counter reads this frequency.

HOW IT WORKS

The schematic diagram of the scanner is shown in Figure 2. The 555 timer IC is wired to run in the astable mode with C3 as the timing capacitor for this function. When the voltage on C3 reaches 2/3 of the supply voltage the condition is detected by an internal comparitor through pin 6. C3 is then immediately discharged through pin 7. This is accompanied by a short negative pulse from pin 3 which serves as our sync pulse. C3 then starts to recharge and the process is repeated. The required scanning voltage therefore appears across C3. In order to get a linear voltage build up on C3 it must be fed from a constant current source in the form of Q1. RV1 injects current into the base and hence the charging current is issued from the collector. RV1 is therefore used to adjust the scanning rate. The timing capacitor C3 is central to the operation and we take no chances with it. A polyester low leakage device is recommended. These are available in leadless SM versions although they are a little large. Now we cannot take our scanning voltage straight from C3 as any loading would upset the linearity and range. A high input impedance buffer amplifier IC2 gives the required isolation. This is a FET input op-amp and it operates in unity gain giving excellent isolation. The circuit needs at least 7V to operate so a Ni-Cd PP3 is fine as a power source.

PARTS LIST

RESISTORS
R1 100R 2% size 1206
R2 47k 2% size 1206
Rx zero ohm jumper size 1206
RV1 10k min preset type 3315.

CAPACITORS
C1 100n ceramic chip size 1206
C2 100n ceramic chip size 1206
C3 100n polyester surface mount type
C4 47µ/10V Surface mount tantalum
C5 100n 1206 ceramic chip

SEMICONDUCTORS
Q1 BCW30 PNP SOT23 package
IC1 NE555 single timer in SO8 package
IC2 CA3140 FET input OP amp

MISCELLANEOUS
Phono sockets for outputs, 2 off.
Miniature on/off switch.

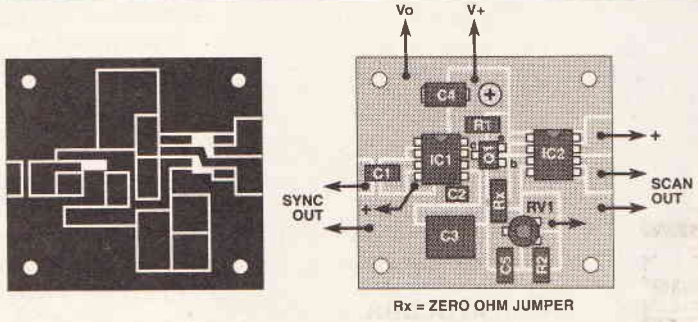

Fig.3 Component Overlay

BUYLINES

The surface mount components required for this project can be acquired from several sources such as Blue Rose Electronics, Electrovalue, Farnell, Verospeed. More and more commercial PCB's are now appearing on the surplus market with useful SMD's on board. Thin Kynar wire is obtainable from BRE.

HIGH-Q

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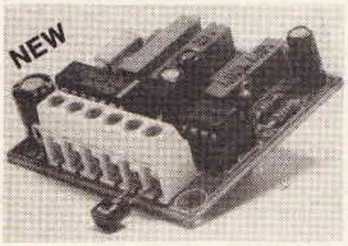
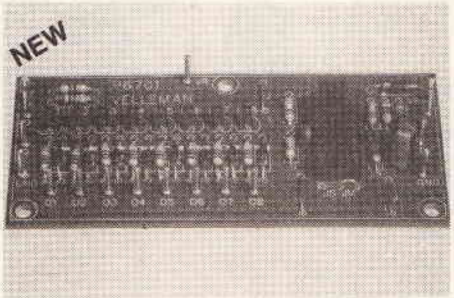
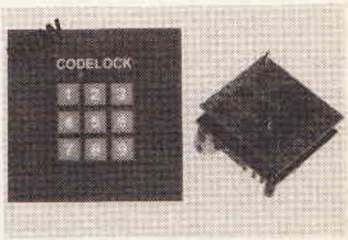


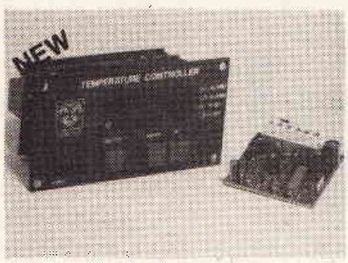
K6001 TEMPERATURE SENSOR



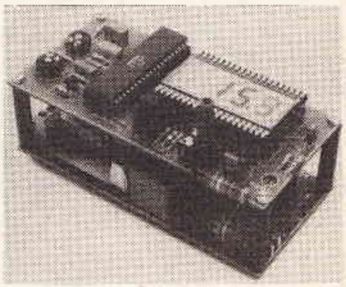
K6700: WIRE COMMUNICATION TRANSMITTER
K6701: WIRE COMMUNICATION RECEIVER



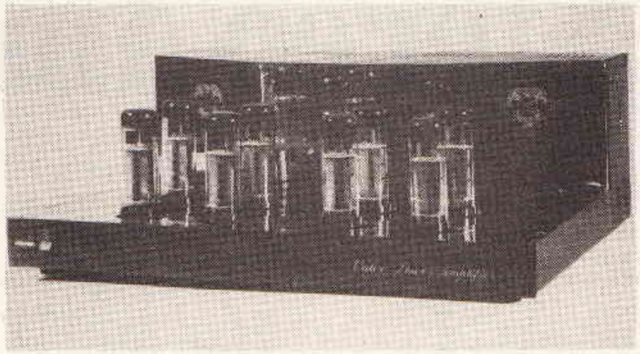
K6400 KEY CODE LOCK



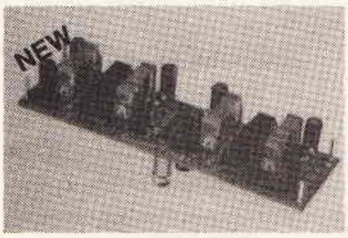
K6002 uP TEMPERATURE CONTROLLER



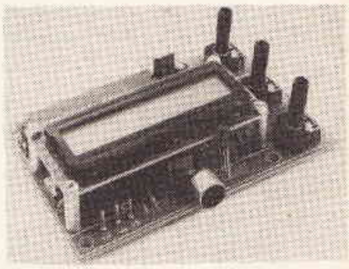
K2649 THERMOSTAT



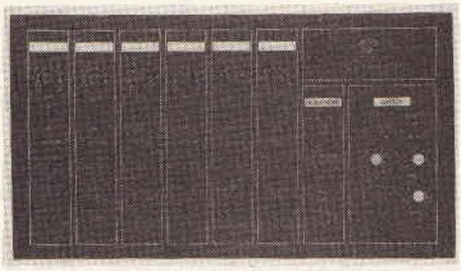
K4000 STEREO TUBE AMPLIFIER



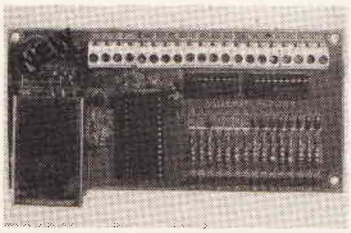
K2668 DUAL STEREO VU METER MODULE



K2659 MORSE DECODER



Professional mixing panel



15 CHANNEL INFRARED RECEIVER

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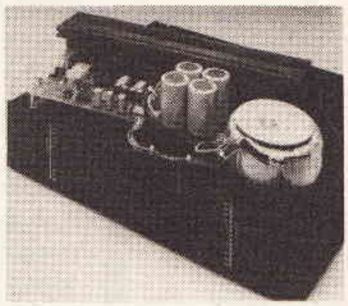
K4010 300W MOSFER AMPLIFIER

TEMPERATURE SENSOR WITH LED DISPLAY



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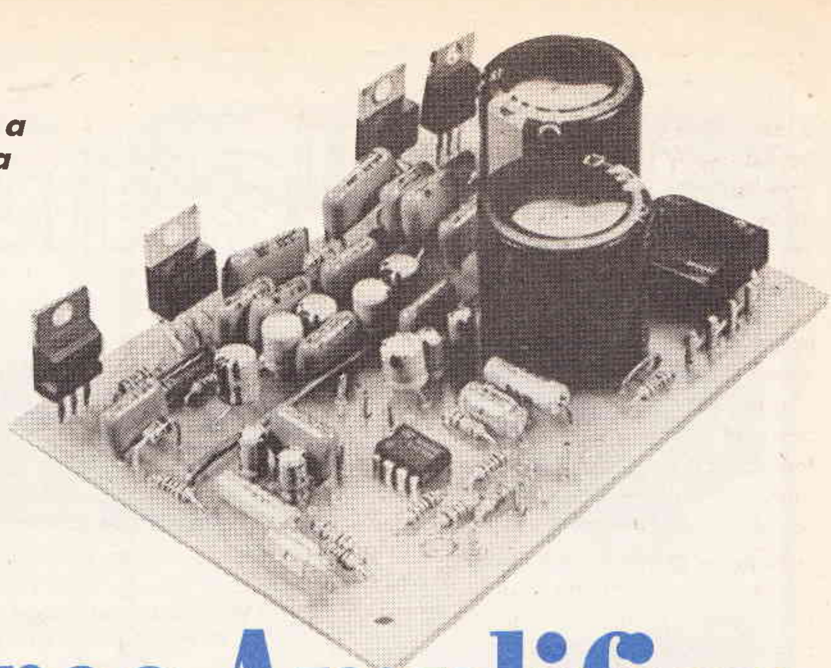
VISA

This amplifier can fit into a small space yet delivers a power and quality out of proportion to its diminutive size by Dave Bradshaw.



ETI Cover PCB Project

Chip Stereo Amplifier

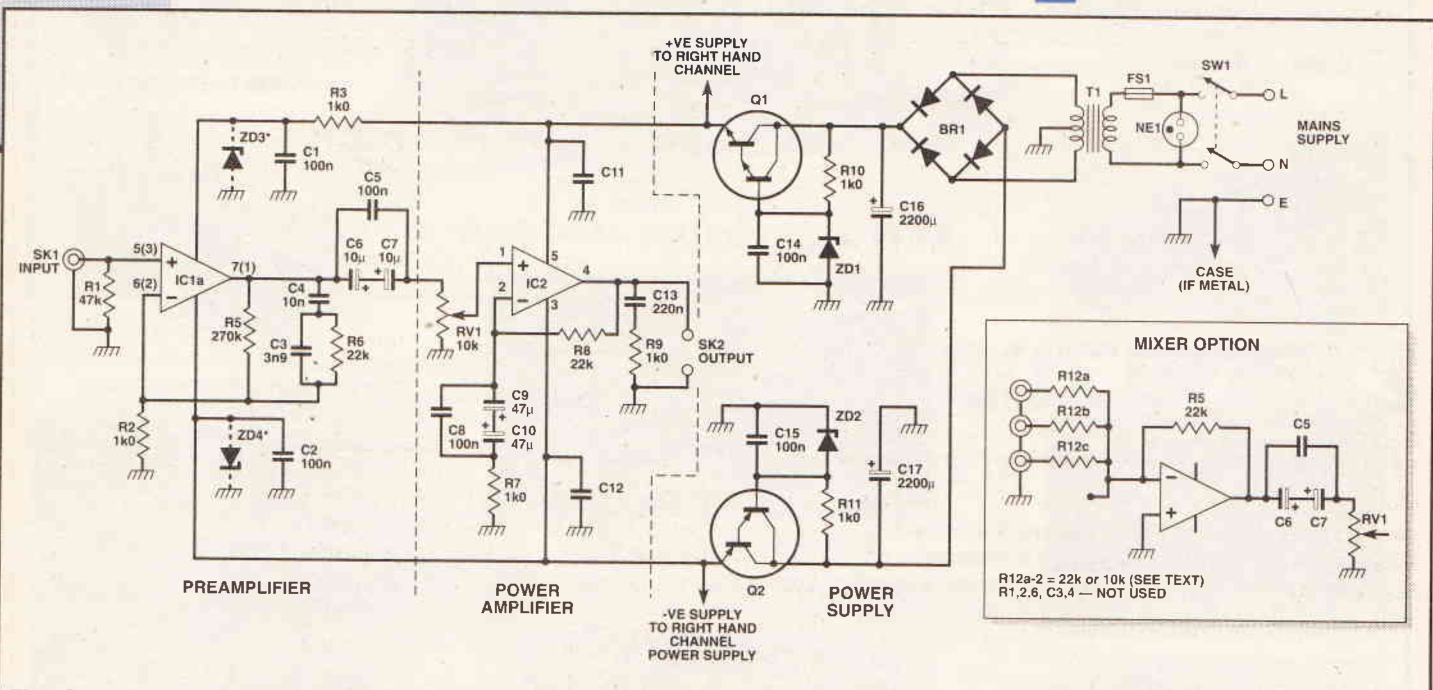


Fig.1 Amplifier circuit. The other audio channel is not shown, but the pre and power amplifiers are identical (all the component numbers have 100 added to them to distinguish them, except SK1 and IC1 which are split between the two channels).

This project is a straightforward application of the TDA2030 audio power amplifier IC. In its basic form it delivers 8W RMS per channel, which is ample to fill a medium sized room. A higher power version, using LM1875s can give 15W per channel, and a bridge version will give 20W or more into 8R.

The novelty of this amplifier lies not in the audio circuitry —it's all very standard —but in the use of a simple regulated supply for the power amps. John Linsley Hood's designs gave me the idea for using a regulated supply with standard power amp IC, but reviving low-cost amps with meaty power supplies is a technique ETI has been advocating for some time.

I have been using the basic version of this amp as an alternative to my normal hi-fi for two years (when I get exiled from the sitting room), and it gives a very good account of itself. More recently, my pride and joy transmission line loudspeakers were also banished on the grounds that they are too large, and despite their profligate inefficiency, the 8W amp produces more than enough noise through them to make my presence felt round the house. Disco level it isn't, but it's ample for my listening levels whether it's Mahler or Seal who is pushing them there voice coils.

In the most basic version, besides the on/off switch, there is just one control —the volume. It's easy enough to add a switch to allow different sources to be used. The balance and tone controls on my normal amplifier remain untouched for long periods, so I did not include them. To get the same effect as a balance control you can use a split volume control.

The amp was designed before compact disc became so universal. If CD or tape is all you use, you can leave out the RIAA stage. However, most of us will still have some vinyl disc we want to play, and the base of a record deck makes a handy case provided the transformer will fit in. Using the amp with other inputs requires mounting the volume control off-board and adding a selector switch.

Circuit

The circuit of just one channel of the amplifier, along with the full circuit of the power supply, is shown in Figure 1. (With circuits of stereo amplifiers and the like, it is usual to show just one channel if the other is the same.) The circuit is in three sections: the preamplifier, around IC1a, which takes the output from the pick-up, amplifies it and corrects for frequency. response; the power amplifier, which makes the signal large enough to drive a loudspeaker; and the power supply and regulators.

The circuit is described in detail in 'How it works', so I won't woffle on here. One point to note is that I use three capacitors for coupling where others might use one, at C5/6/7 and C8/9/10. A single electrolytic capacitor used here would have an evens chance being the wrong way round if there is any DC voltage, so two are used back-to-back. An unpolarised capacitor is added to compensate for the small inductance electrolytics have, and which can affect higher frequency audio signals. Capacitors are so cheap it seems pointless to skimp, even when the results may be negligible.

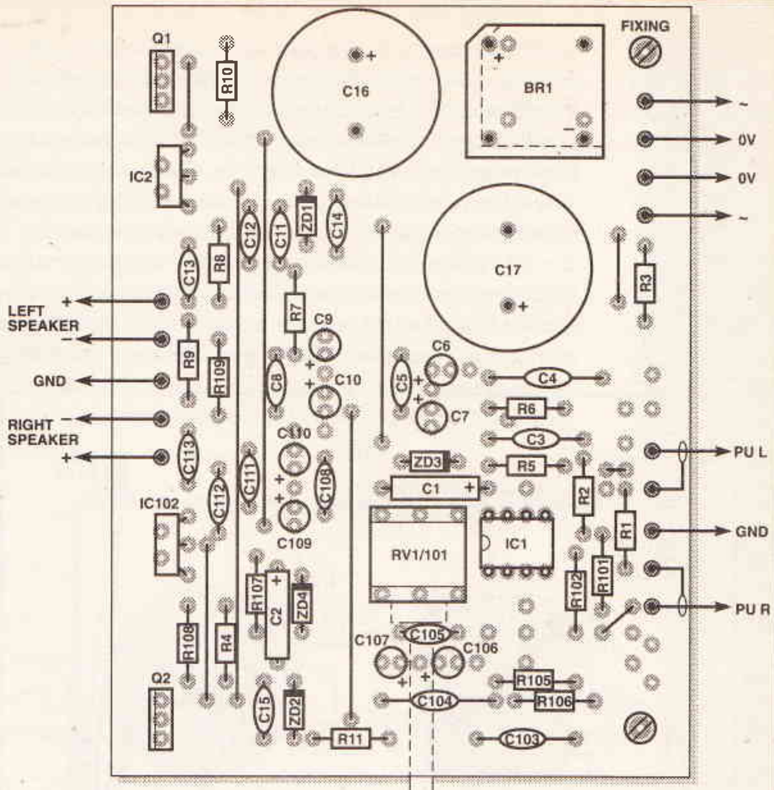


Fig.2 Overlay diagram for the PCB of the stereo amplifier.

HOW IT WORKS

In the preamplifier, one op-amp from the dual TL072 op-amp is used for each channel. This corrects for the recording preemphasis, where high frequencies are boosted relative to the bass ones following the RIAA (Recording Industry Association of America) standard. There are two sets of frequency selective components in the feedback loop, C3 and R6, and C4 and R5. The values of these components are selected to meet the RIAA requirements.

Ideally, there should be no DC voltage present at the output of the preamplifier, but op-amps are not perfect so blocking capacitors C5/6/7 are used to avoid any DC being passed on.

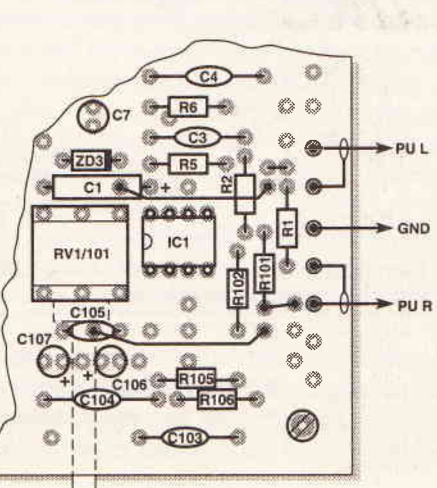
The power amplifier IC2 is of the 'super op-amp' type. For audio frequencies, its gain is fixed at 22 by feedback resistors R7 and R8. For DC, capacitors C8/9/10 disconnect R7 and turn the circuit into a voltage follower; this ensures that there can only a tiny DC voltage across the output. Loudspeakers can be damaged by DC voltages of around a volt. Capacitor C13 and resistor R9 prevent the amplifier from turning into an oscillator which can happen if it is presented with a very reactive load, such as a typical loudspeaker!

The power supply uses a very simple regulator circuit, but this part of the circuit is largely responsible for giving the amplifier such a respectable sound. Because the amplifier will occasionally draw currents over 2A, 78xx and 79xx regulator ICs could not be used, and higher current regulators are rather expensive. R10 and ZD11 provide a stable 15V, provided the voltage on the smoothing capacitor is a volt or two above this. C14 minimises the noise on this voltage. Q1 and Q2 are Darlington transistors connected as an emitter follower, so the output voltage at its base will be 15-1.2 = 13.8V, whatever current is asked of it, provided the ripple voltage on the reservoir capacitors does not drop below about 16.5V — if using alternatives to the basic circuit, see the main text for details of making sure that this does not occur. The circuit of the transformer, bridge rectifier and smoothing capacitors C16 and 17 is a standard arrangement for a dual supply.

Another design point is that I have opted for a dual supply so that the speakers can be directly coupled to the power amplifier outputs. This increases circuit complexity, but cutting out the output capacitor is well worth the extra trouble.

Construction

Care must be taken in the construction of this project because it uses the mains. If basic rules are not followed, there is the danger of electric shock. Particular attention must be paid to the housing and wiring of the mains section of the project (up to and including the transformer).



STRAIGHT THROUGH OPTION

Fig.2a

In the prototype, the amplifier and transformer were built into the base of a record deck; alternatively, the amplifier can be housed separately, and I would recommend using a metal case to help with heat dissipation and to provide an earthed container for the circuitry. Make sure the case you choose is large enough to fit all the components comfortably, with room to do the interwiring.

Mounting the volume control (RV1a and b) on the PCB simplifies construction, but may not always be practical or desirable if you want to use several inputs. The extra circuitry needed to do this is shown in Figure 2.

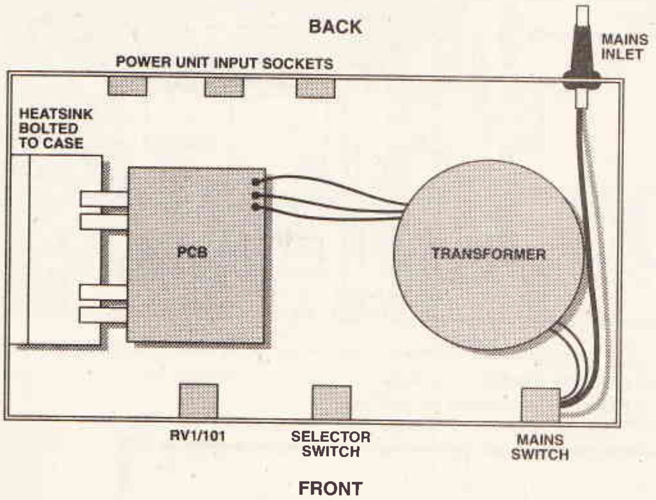


Fig.3 Suggested internal lay-out if a metal case is used for the project.

Use the PCB to gauge the position for its own mounting holes before assembling any components onto it (this is something I almost invariably forget to do myself, and it usually results in bent and broken components that I have to replace).

Assemble the PCB, inserting and soldering into position first the wire links, PCB pins, then resistors, capacitors and finally semiconductors. You may have some problems fitting in C4 and C104, since some types are rather large, so fit these last over the top of surrounding components, being careful not to short leads together. Do not make the leads too short on Q1, Q2, IC2 and IC202, so you can fit them to the heat sink. Two different sizes of rectifier bridges can fit on the PCB.

If the volume control is to go on the PCB, it should be the last component fitted; if it is to be mounted off-board, then pins should be soldered into its place for leads at the same time as the other PCB pins.

Once you have completed the PCB and checked carefully for mistakes, assemble the other parts into the case. Allow good clearance for the screws used to bolt the transistors and ICs to the heat-sink or metal case, as there must be no electrical contact, and special insulating kits must be used.

Final Assembly And Testing

Wire up the mains side of power supply first, keeping carefully to the circuit diagram as a mistake could be costly. In particular, check switch connections to ensure it doesn't short the live to the neutral, and double check connections to the transformer making sure you have wired the transformer correctly.

If your transformer is a laminated type, solder wires on to the terminals to make connections. Toroidal transformers usually have flying leads, ie wires already connected; if these are not long enough, use a connector block designed for the mains to connect wires long enough to reach the mains switch. You may have to wire two separate primaries in series — instructions with the transformer should be followed carefully. Cover any exposed connections to the mains live and neutral using heat-shrink sleeving. If using a metal case, attach the mains earth to the case using an earthing solder tag; this is very important.

The mains lead should be firmly clamped; there are special clamps available for this, or you can improvise (on the prototype a clamp was made using two screws and some hardboard). A reasonably strong pull should not move the cable.

Once the mains wiring is complete, check that none of the secondaries are shorted together or to the primaries, apply the mains and switch on. If the transformer shows any sign of distress — smoke, getting hot, continuous loud humming — switch off immediately and look for the fault. If all appears well, check the voltages on the secondaries with a multimeter switched to the appropriate AC voltage range. Switch off.

If your transformer has two separate secondaries, you need to check which way they should be connected — one way round will lead to their voltages cancelling, the other will not. The transformer instructions should make it clear which way round secondaries should be wired. If they don't, connect a jumper lead between two leads or terminals from separate secondaries, and attach the multimeter leads to the other two ends of the secondaries, then switch on. You should either have twice the normal secondary voltage or nothing at all. Switch off and disconnect the mains. If you had twice the voltage, the two ends connected together can be permanently connected to the 0V connection on the PCB; if you have nothing at all, move one end of the jumper and try again.

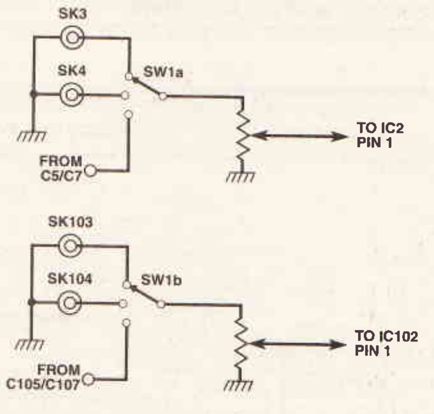


Fig.4 Circuit diagram and wiring of a front panel switch to allow different inputs.

Attach the heat-sink to the transistor and power amplifier ICs, using the insulator kits (if the insulators need silicone gel, leave it off for now) and check with a multimeter switched to a resistance range that there is no connection between the transistors or ICs and the heat sink. (If you are using just a short length of aluminium to attach to a metal case, you do not need to attach it to the case for the moment.) Attach the volume control to the board using lengths of wire, if it is to be mounted separately.

After checking yet again that everything is in its correct place, reconnect the mains and, keeping well clear of the board, switch on and immediately off, then disconnect the mains (there is a very small risk that one of the large capacitors may explode if connected the wrong way round). Using your multimeter switched to a low DC voltage range, check that there is about 0.5V across both C16 and C17, the correct way round for the capacitors' polarities; this will drop away when the multimeter is applied. If there is no voltage, the rectifier may be wrongly connected, the fuse blown or some fault in the soldering.

If all is well so far, reconnect the mains and switch on; check the voltages across C16 and 17, which should both be about 20V (23V with a 17V transformer). Connect the multimeter negative lead to the common input at the base of the two capacitors and with the probe of the positive lead, measure the voltages around the positive regulator circuit. You should find about 15V across the zener diode ZD1 and 14V or slightly under at the emitter of Q1, the output of the regulator. Attach the positive lead of the multimeter to the common point and probe around the negative regulator, checking for corresponding values.

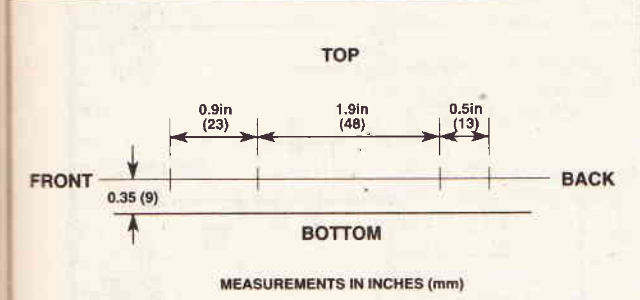


Fig.5 Position of drill holes in the heat sink, in millimetres. Holes are 5mm (or near) in diameter.

While doing this, check on the temperatures of the power transistors and the power ICs; if they get more than warm, or if any of the voltages are seriously out, switch off immediately. Be cautious when checking temperatures, as hot metal bits can give a nasty burn. Check around the rest of the board for overheating. Next check the voltages at the loudspeaker outputs and at the output of the preamp, pins 7 and 1 on IC1; these should be zero or very close. Also the inputs should have no voltage on them.

If all these checks are OK, switch off, and connect loudspeakers to the outputs for them, and switch on again. There should be no sound from the loudspeakers except perhaps some low frequency mains hum, which will vary according to the volume control setting. Touching one or other of the inputs to the preamp with a finger or screwdriver tip should audibly increase the hum on the channel touched. Carefully check that the power ICs and transistors do not get very hot — they should get a little warm.

The final check before completing assembly is to apply a normal input signal to the amplifier from a record deck or other good quality source; the amplifier should give a good sound from the loudspeakers. Be careful not to let the power ICs or transistors over-heat if you are not using the full heat-sink.

Final assembly depends on the case being used. All signal wiring, except to the loudspeakers, should be done with audio quality screened cable, and any remaining wiring should be of good quality stranded lead. Some points are particularly applicable to metal cases. Make sure that none of the PCB tracks are shorted to the case. The sockets for the input and output should be insulated

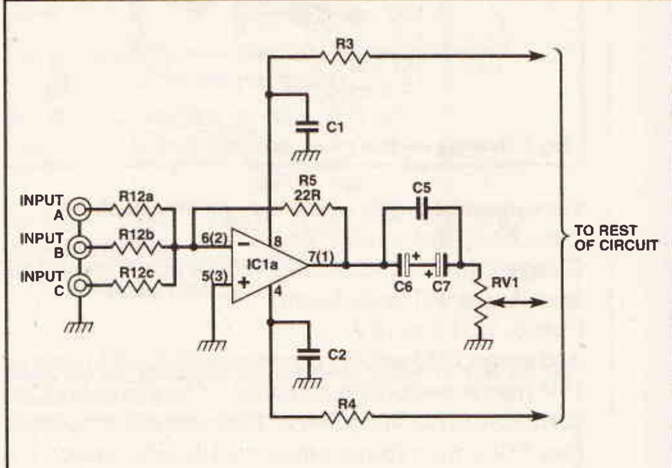


Fig.6 Circuit modifications to use the preamp as a mixer.

from the case — use appropriate versions of sockets. The circuit common has to be earthed to the case at just one point — and this may have to be moved to get the best results. For non-metal cases, connect the circuit earth directly to the mains earth. Make sure there are no earth loops — loops of wire connected to the common line. In this project, the most likely point is in connections to and from the volume control and input selector switch (if fitted). The screens to these wires should be earthed by one route only. The power transistors and ICs should be mounted on the heat sink using an insulating mica or plastic washer (a thin smear of silicone gel is needed between semiconductor cases, the washer and the heat-sink for the mica washers). Tighten the mounting screws firmly and re-tighten then after several hours of use.

Options and Mods

You will probably have noticed that there are a few extra holes and tracks on the PCB to allow some variations on the basic circuit.

Different power amp IC: the most straightforward mod is to use a different power amp IC. The LM1875 is a higher quality, lower distortion device than the TDA2030, and can be used as a direct replacement in the basic circuit. This is may be worth doing if you intend using the amp with a half-decent CD player.

You can get more undistorted power out of the LM1875, up to about 15W is feasible here, but this requires raising the supply voltage (the 2030 can go up to 14W but the distortion increases markedly). To do this: increase the current capability of the transformer (if you can — there doesn't seem to be many suitable transfor-

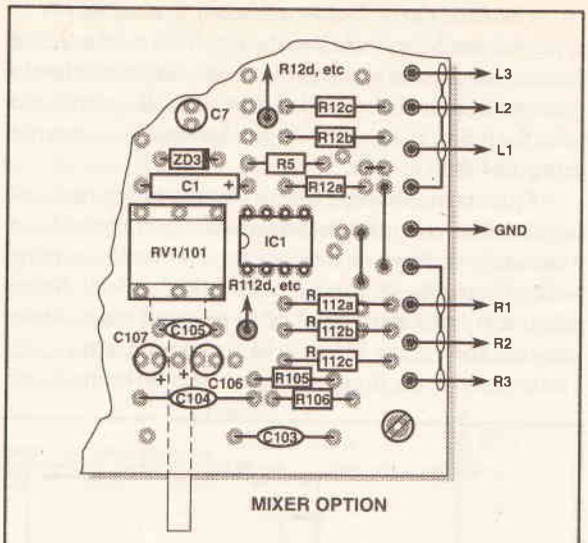


Fig.7 Overlay for the mixer option.

mers around, though, so you may get away with 2A).
Use a 4A bridge rectifier for BR1
Change C16 and 17 to 4,700μ (check that the type you have chosen will fit the board)
Change ZD1,2 to 18V
Add zeners ZD3 and 4 to keep the supply to IC1 down to 15V (this is particularly important if you have used an alternative to the TL072 for IC1 because many op-amps have 15V as their absolute maximum supply voltage); C1 and 2 become 10μ 25V axial electrolytics.
Increase R8 to 33k (optional; this increases the gain of the power amp stage slightly)
Reconsider the size or positioning of the heat sink; with 15W power output per channel, the heat output will be pushing towards 20W depending on the transformer and other factors, so good heat dissipation is needed. If the heat sink is in an enclosed area, the power ICs are likely to get rather hot, and although they will not get damaged (they are thermally protected) the distortion when they do shut down is alarming. Transistors Q1 and Q2 are not protected, and may be damaged.

Mixer Option

If you don't need an RIAA input (or you have a better RIAA stage you want to use) then you could consider making the preamp act as a mixer. The circuit mod to make a simple 3-input mixer is shown in Figure 6, and the overlay modifications are shown in Figure 7. Extra input resistors can be added off the PCB to allow many more inputs.

Making the preamp a mixer removes the need for a selector switch; all you have to do is turn on whatever signal source you want to use and it comes through. My favourite pre-amp is set up this way, it saves so much fiddling about with the selector switch.

For those with magic ears, the mixer option makes the amp overall invert the signal, and you may prefer to connect your loudspeakers accordingly.

Bridge Option

With a little bit of adaptation, the op-amp can be used as a bridging inverter: the same signal is fed to both channels, but one is inverted with respect to the other, and a single loudspeaker is connected across the two power amp outputs. The power output per channel is increased, but two entire amplifier boards are needed for stereo.

This can theoretically deliver up to 60W (using the higher power options above) into an 8R load, but current restrictions mean that probably only an undistorted 40W is available.

The circuit modification needed for this option is shown in Figure 8. This mode was not thought of when the board was being designed (shame!) so it requires a slight 'fudge' on the PCB, ie adding two resistors on the underside (Figure. 9). An extension of this idea would be to feed the board via a balanced line, so that the entire power amplifier could be mounted next to the speaker.

One further possibility I will throw out as an idea only is to use the preamp area as an active filter, use one power amp to drive a bass unit and the other to drive a HF unit, in a two unit loudspeaker (ie what is often incorrectly called an active loudspeaker).

Fault Finding – Basic Unit Only

The amplifier produces a large amount of hum: Possible causes include the circuit and case being connected at an inappropriate point —usually the best point would be at the volume control -or there may be a hum loop, or a completely missed or bad earth connection —possibly on one of the capacitor leads. Alternatively, a fault which prevents one or both of the regulators working might lead to a bad hum. Solving hum problems can often involve a lot of experimentation.

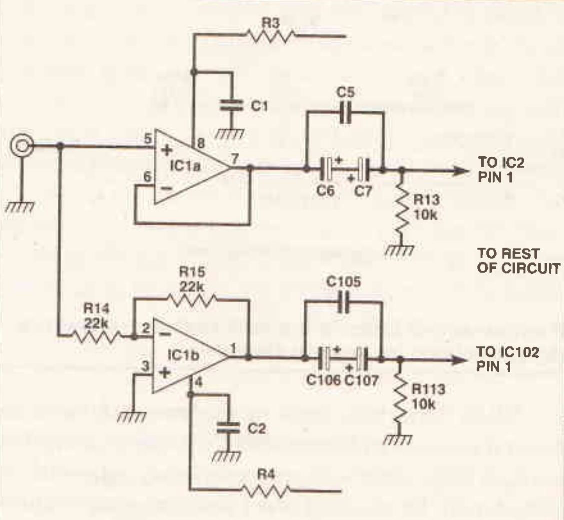
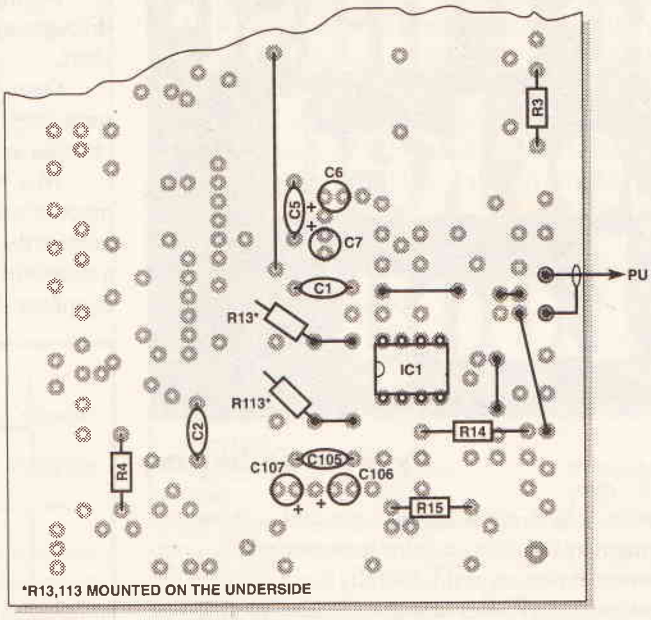


Fig.8 Circuit mods for the bridging option.

The amplifier produces only limited output volume: Are you using the right sort of cartridge? The amplifier will not work with expensive moving coil cartridges, without a preamp or step-up transformer, or with ceramic cartridges, which would probably give too great an output leading to distortion. Are the speakers unusually unresponsive — try out the amplifier with another pair if possible. Does a signal from a cassette deck, applied to the auxiliary input (or to the top of the potentiometer) give an adequate output —if it does, there is some fault in the preamplifier, if not, then the power amplifier is faulty. The gain of the power amplifier can be increased slightly by increasing R8/108 or decreasing R7/107, but this will make a relatively small difference. **The amplifier picks up radio signals:** This is a very common problem. If it is just from the occasional passing taxicab or police car, its probably not worth bothering with, but if it is from radio stations (a particular problem in summer evenings) some caution is necessary. The loudspeaker leads are acting as a radio antenna, and some part of the amplifier is acting as a radio signal detector. The standard solution is to wind both loudspeaker leads in the same direction round a ferrite ring. This doesn't always work, and again, the best solution is to experiment.



BRIDGING OPTION

Fig.9 Overlay mods for the bridging option; note that R13 and 113 are mounted under the board.

PARTS LIST

RESISTORS (all 1/4W or more, 5% or better)

R1,101	47k
R2,102	1k0
R3,4,10,11	1k0
R5,105	270k
R6,106	22k
R7,107	1k0
R8,108	22k
R9,109	1R0
RV1/10	10k dual (stereo) potentiometer, logarithmic track (not miniature if it is to be mounted on the PCB)

CAPACITORS

C1,2,5,8,	100n 15V or more working voltage, any sort
105,105	that will fit the PCB
C3,103	3n9 5% or better tolerance, preferably polyester or polystyrene but a tolerance of 5% or better is most important
C4,104	10n 5% or better (same comments as for C3)
C6,7,9,10,14,15,	10µ 25V or higher single-ended electrolytic
106,107,109,110	
C13,113	220n, any sort that will fit
C16,17	2,200µ (or 4700µ see text), 25V or higher electrolytic, single-ended leads

SEMICONDUCTORS

IC1	TL072 dual op-amp
IC2,102	TDA2030 or LM1875 power amplifier IC
Q1	TIP122
Q2	TIP127
ZD1,2	15V 1W zener diode (see text)
ZD3,4	15V 400mW zener diode (not used for basic version — see text)
BRI	50V 2A bridge rectifier

MISCELLANEOUS

T1	15-0-15V (or 17-0-17V) 2A mains transformer
FS1	500mA anti-surge fuse with mount
NE1	mains neon light (or part of SW1)
SW1	double pole mains switch, to choice
SKI	stereo disc input socket dual phono socket or similar (not needed if amplifier mounted in base of record deck)
SK2	stereo loudspeaker output connectors (or two singles)
SK3,4,5	stereo input sockets, if required; dual phono or similar
SW2	Input selector switch, 4 pole 3 way (if needed)

Audio screened cable; case PCB; PCB mounting pillars; heat-sink (thermal coefficient 2.5/W or lower, depending on usage); TO66 transistor mounting kits, four of; small quantity of silicone grease (if needed); case to choice; knobs for controls; wire, solder, heat-shrink sleeving.

BUYLINES

All components are widely available except the 3n9 5% capacitor C3 which may be a little harder to find. One point to watch is the size of C4, as some 10n 5% polystyrenes are very large and may be difficult to fit on the board. Paradoxically, we found that 1% types were smaller. Watch also the size of C16 and C17, a maximum diameter of 1" (25mm) is allowed for. Now you've got the PCB, what are you waiting for?

If you are interested in this and other projects by Dave Bradshaw, readers might like to note, the ETI Book of Electronics (ISBN 0-85242-928-2) published by Argus Books will very soon be available.

The Phase Locked Loop

By Mark Robinson

Imagine you've got a square wave and you want to divide it by two. Easy, a quick look through the component cataloeues yealds literally hundreds of variations on the counter/divider IC. But what if you wanted to multiply it by two? Chances are your search through the catalogues would be less fruitful, although there is an IC which will do the job, along with FM, AM and FSK demodulation, frequency translation and signal regeneration. It's called the Phase Locked Loop, and it's as versatile to the user of frequencies as the op-amp is to the user of voltages.

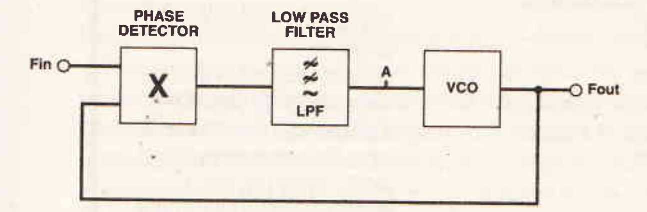


Fig.1 Block diagram of basic PLL

The Basic Loop

The PLL in its most simple form is shown in Figure 1. We'll look in detail at phase detectors later, but for now consider it as a box whose average output voltage depends on the phase difference between its two input frequencies. The Low pass filter (LPF) is usually a simple RC type, although this is not always the case as we shall see later.

Consider the PLL initially with no input, a voltage of V_a at joint A, and an output frequency of f_o. Now apply a frequency f_i, which is lower than f_o, to the input. The phase difference between f_o and f_i is constantly changing and the output of the phase detector will oscillate at the difference frequency f_o-f_i. Provided that this frequency is low enough to pass through the LPF it will be superimposed on V_a as a small amplitude ripple.

This ripple causes the output frequency to 'wobble' around f_o. When the output frequency is brought closer to f_i it varies more slowly because the difference frequency is lower. Hence the ripple on Point A is asymmetric and the average voltage is now lower than V_a. This causes the VCO output frequency to move towards f_i, until eventually they are equal. At this point the PLL is said to be 'in lock'.

Figure 2 shows how the voltage at joint A varies throughout this process, which is called the capture transient.

Once the PLL is in lock the output frequency will track any changes of input frequency, Provided the changes are slow enough for the lock to keep up.

Well, we don't seem to have improved much on a piece of wire so far. Bear with me though because there's more to this than meets the eye. But first we need to define a couple of technical terms, and take a closer look inside the phase detector.

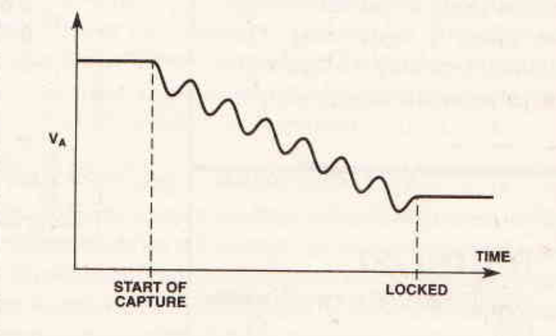


Fig.2 The PLL Capture transient

Capture and Lock Range

In the previous description of the capture transient, the assumption was made that the difference frequency was low enough to pass through the LPF. If it isn't then there will be no ripple on V_a and the VCO output will not change. This means that there is only a limited range of input frequencies, called the capture range, which will cause the PLL to lock. Suppose that a PLL is locked onto an input frequency f_1, which suddenly chances to a new frequency f_2. The PLL will only lock onto this new frequency if it falls in the range;

$f_1 - \frac{1}{2}f_c$ to $f_1 + \frac{1}{2}f_c$

where f_c is the capture range. It is fairly easy to see that f_c defends directly on the cutoff frequency of the LPF.

Once the loop is locked it will track slow changes in frequency over the full VCO range, which is called the lock range. Just how fast the input has to change before it becomes a 'sudden' change again depends on the LPF cutoff frequency. In all the integrated circuit PLLs the centre frequency and lock range of the VCO is selected by hanging various resistors and capacitors off the relevent legs of the IC, according to the design equations on the data sheet.

Phase Detectors

There are two types of phase detector used in PLLs, imaginatively named type I and type II detectors.

A type I phase detector consists of a four quadrant multiplier. I proved that the average output of a multiplier depends on the phase between its inputs when looking at lock-in amplifiers in the past (Ref. 1) (although for lock-ins it's not a desirable property because it means we have to keep fiddling with the delay control to maximise the signal).

If the inputs are digital square waves then the phase detector can be simplified to an exclusive-or gate. A care-

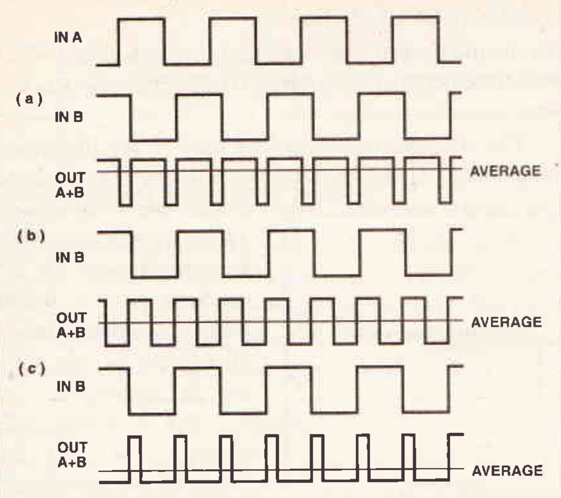


Fig.3 The action of an Exclusive 'OR' phase detector a)45° b)quadrature c)135°

ful look at Figure 3 should convince you that the duty cycle (mark-space ratio), and hence average level, of the output depends upon the phase difference between the inputs. An interesting point to note from Figure 3 is that the output frequency is double the input frequencies, which is consistent with the device acting as a multiplier.

One major failing of PLLs using type I detectors is that they have a tendency to lock onto and multiple of the input frequency which falls within the capture range (even if that multiple isn't present as a harmonic in the input signal). They also run into trouble if the duty cycle of the input is not close to 50%. Also, since the output of these detectors is oscillatory, there will always be some residual ripple on the LPF output. This causes jitter on the output of the VCO. Their big plus point is a very good immunity to noise on the input.

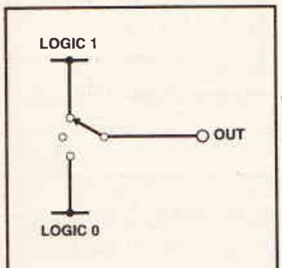


Fig.4 The switching (type II)phase detector

The type II detector is an edge sensitive device, which must be provided with squarewave inputs. It can be considered as a three position switch as shown in Figure 4. It works like this; a falling edge on the 'signal input' causes the switch to move one position upwards (ie towards the positive rail) unless it is there already, in which case it stays there. Similarly, a falling edge on the 'feedback input' causes the switch to move one position downwards. The net result of this is that when the phase of the signal leads that of the feedback, the phase detector will source pulses of current to the LPF capacitor, and sink current from it when the feedback leads the signal. These current pulses either charge or discharge the capacitor until the VCO output is at the same frequency as, and in phase with, the input. When this is achieved the phase comparator output is effectively open circuit.

Unlike the type I detector, the output pulses from the type II detector disappear completely when the loop is in lock, so there is no residual ripple on the LPF output, and the VCO output is rock steady.

Another nice feature of type II detectors is that the capture range is equal to the lock range and not restricted by the LPF. This is because the current pulses to or from the LPF will always charge or discharge the filter capacitor to the correct voltage eventually, the LPF time constant only determines how long it takes to get there. In fact, for type II detectors the LPF is acting more like a sample and hold, storing the required VCO input voltage until the detector tells it that it should be different.

	Type I	Type II
Input duty cycle	50% optimum	Irrelevent
Lock on harmonics?	Yes	No
Noise performance	Good	Poor
Ripple	High	Low
Capture range	Less than VCO range	Full VCO range
Phase difference when in lock	90°	0°
Frequency when out of lock	Centre freq. of VCO	Minimum freq. of VCO

Fig.5 Main difference between type I and type II phase detectors.

Probably the only bad points about type II phase detectors is their poor noise rejection, caused by spurious spikes on the input being regarded as part of the signal, and the difficulty of interfacing them to non-square waveforms.

The important differences between the two types of phase detector are summarised in Figure 5.

The Low Pass Filter

As we have seen, the LPF performs two functions. It averages the output of the phase detector and it restricts the rate at which the VCO input can change, providing the 'flywheel' effect that gives the loop its excellent noise immunity. Since it also dictates the maximum rate of change of input frequency that the loop can keep up with, the choice of cutoff frequency is a compromise between noise immunity and the bandwidth of the loop.

The simple RC filter is fine for most PLL applications, but a loop using it is not guaranteed to be stable under all conditions. Applying all the theory developed for closed loop control systems (like op-amps and oven thermostats) tells us that for a given lock range, you must keep the bandwidth above a certain threshold otherwise the loop may be unstable. If this seems unusual (after all a wide bandwidth is normally a desirable property, so who would we want to minimise it?) remember that all the PLL's noise performance comes from its narrow bandwidth. You have probably seen op-amps which have a minimum usable gain (called decompensated op-amps) —it all comes from the same theory. A good rule of thumb is to keep the -3dB frequency of the filter above about one fiftieth of the lock range. All is not lost if your application requires a loop that could be unstable though. Simply replace the filter with a pole-zero type like the one shown in Figure 6. Start by making R2 about one fifth of the value of R1 and trim it for stability over the whole lock range. For the perfectionist (ref-

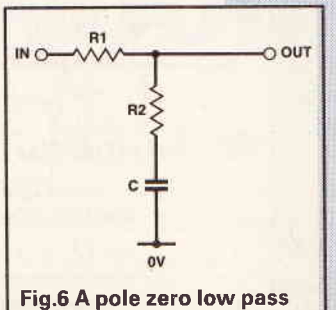


Fig.6 A pole zero low pass filter.

erence 2) gives a method of calculating the optimum values of R1, R2 and C using theory similar to that of pole-zero compensation for op-amps.

Uses of the PLL

Now that we have our complete theory of PLLs lets see how it's applied to make the PLL do something useful.

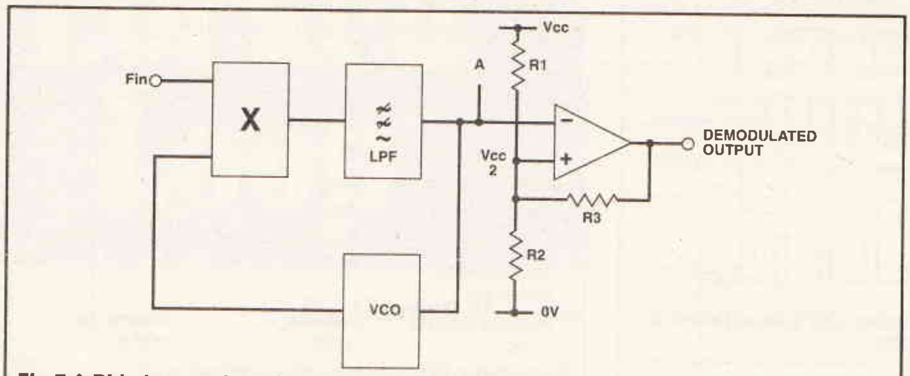


Fig.7 A PLL demonulator for FSK signals

Signal Regeneration

One interesting point about PLLs is that there is no rule which says that the input and output waveform need to be identical. This means that it is perfectly reasonable to lock a nice, friendly sinewave onto some horrible input shape. Not only that, but the 'flywheel' effect provided by the LPF smooths out noise and discontinuities in the input signal, providing signal to noise ratio improvement. In fact the input could disappear completely for about one LPF time constant without the VCO even noticing. When your modem is trying to receive a signal that has travelled half way around the world this is a feature you'll particularly appreciate.

As was pointed out in (Ref. 1), an improvement in signal to noise ratio is always accompanied by a reduction in bandwidth, and in this case the bandwidth of the channel is reduced to the cutoff frequency of the LPF.

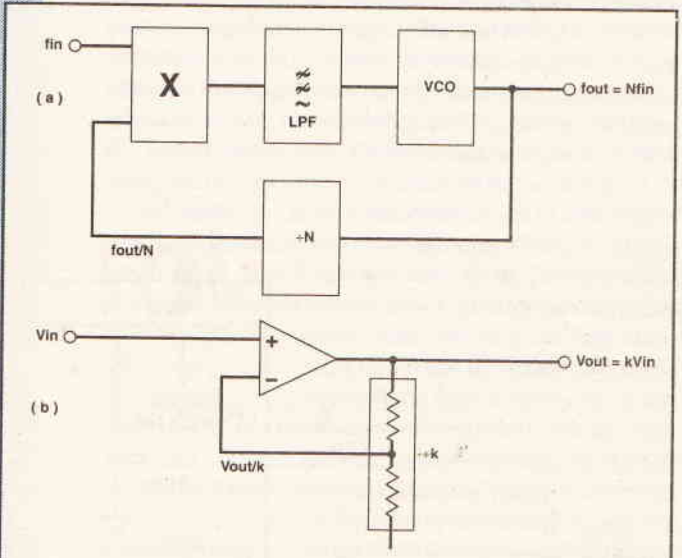


Fig.8 a) A PLL frequency multiplier and b) an op-amp voltage multiplier

FM Demodulation

FM demodulation is an inherent function of the PLL, since the voltage at the output of the LPF is proportional to the input frequency.

PLL FM demodulators are used in top flight hi-fi tuners because they can be more linear than ratio or quadrature detectors. They are more expensive though, because of the need to have a linear VCO and a phase detector capable of operating at high frequencies.

The VCO is arranged so that its centre frequency is equal to the IF frequency and its lock range is larger than twice the maximum deviation frequency of the signal (10.7MHz and 75kHz respectively for broadcast FM). The audio bandwidth is determined by the -3dB frequency of the LPF.

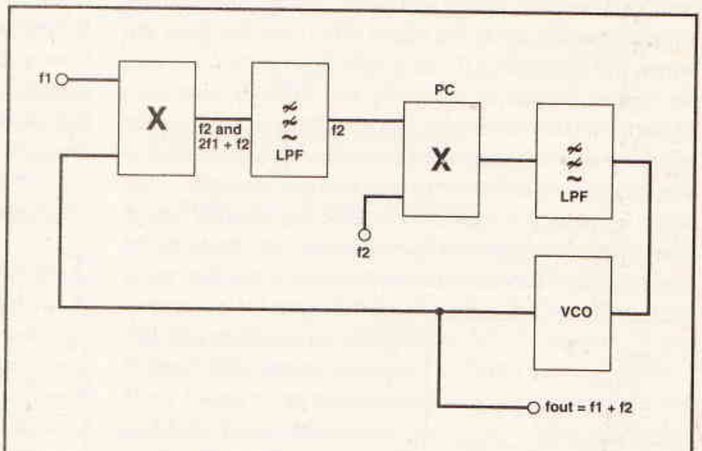


Fig.9 A PLL Frequency translator

Frequency Shift Keying

Frequency Shift Keying (FSK) is a form of digital FM modulation used by modems, computer cassette interfaces and the like to Interface digital signals to audio channels. The two digital levels are represented by different frequencies, which can be decoded using the circuit of Figure 7. The loop is arranged so that the two input frequencies cause voltages at Point A close to the maximum and minimum levels (usually +Vcc and 0v), and a comparator is used to detect which level is present.

The high noise immunity of the PLL reduces demands on signal processing and error correction circuits, but again there is a compromise between bandwidth (ie transmission speed or Baud rate) and noise immunity.

Frequency Multiplication

Frequency multiplication is where the similarity between PLLs and op-amps is most apparent, as Figure 8 shows. This circuit finds uses in frequency synthesis and regeneration (for example generating the 38kHz stereo

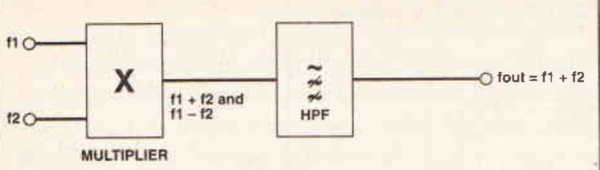


Fig.10 The cynics frequency translator

subcarrier from the 19Hz pilot tone in broadcast FM and generating clock signals locked to the mains for integrating ADCs). The project which accompanies this article uses a PLL frequency multiplier to extend the useful range of a bench frequency counter.

Frequency Translation

There are a number of ICs available which take a reference frequency and generate a range of frequencies related to it (the HD44015 and MC145151 series are typical examples). They are designed for use in multichannel radios, to allow all the local oscillator frequencies to be generated from one crystal.

These ICs use a combination of frequency dividers and a rather esoteric variant of the PLL called a frequency translator, shown in Figure 9.

The job of this circuit is to produce an output frequency equal to the sum of its two input frequencies, f_1 and f_2. The best way to show this is to assume that the output frequency is at f_1+f_2 and then show that this is a stable state. So, if that is the case then the multiplier will be generating sum and difference frequencies at

$$(f_1+f_2)-f_1=f_2$$

and

$$(f_1+f_2)+f_1=2f_1+f_2.$$

Now, if LPF1 passes the difference frequency but rejects the sum frequency then the inputs to the phase comparator are at the same frequency and the loop is stable.

When using this circuit it is best to make f_2 the lower frequency in order to maximise the separation of the sum and difference frequencies.

The more cynical readers are probably wondering why go to all the trouble when the circuit of Figure 10 would do just as well. Let's consider an example.

Suppose we have a 10kHz signal which we want to translate by 100Hz. The multiplier in Figure 10 would produce frequencies of 10100Hz and 9900Hz, whereas the PLL version produces frequencies of 20100Hz and 100Hz. In the first case it would be virtually impossible to separate the two frequencies, but even a simple RC filter performs admirably in the second case. Even if the sum and difference frequencies are well separated, the circuit of Figure 9 offers better noise immunity, and is not bothered by harmonics (the simple multiplier will only work well with good clean sine waves).

AM Demodulation

The 'synchrodyne' AM detector outlined in Figure 11 is the ultimate in high performance AM demodulation,

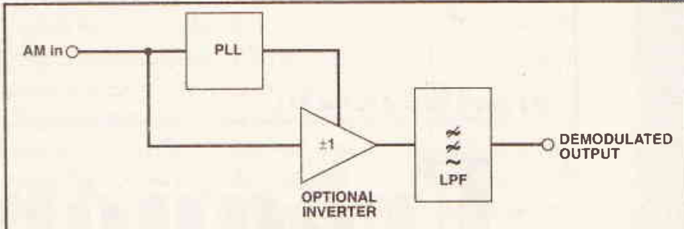


Fig.11 High Quality PLL AM detector

offering vast improvements in linearity over conventional diode detectors.

The PLL generates a squarewave reference phase locked to the carrier frequency. The optional inverter is a device which has a gain of either +1 or –1 depending upon the control signal, which in this case acts as a synchronous rectifier as described in (1) (I make no apology for referencing my own article so much: somebody has to.)

Conclusions

Hopefully, this article will have provided an insight into some of the more popular applications of the PLL. I have avoided detailed circuit diagrams and design equations in this overview because specific details depend upon which of the many PLL or PLL based ICs is used. However, there is a mini-project accompanying this article based around the popular 4046 PLL from the 4000 series CMOS family which includes a detailed explanation of the design process.

References

1. *Extracting signals from Noise* M. Robinson ETI July 1991
2. *The Art of Electronics* Horrowitz and Hill Cambridge University Press 1989

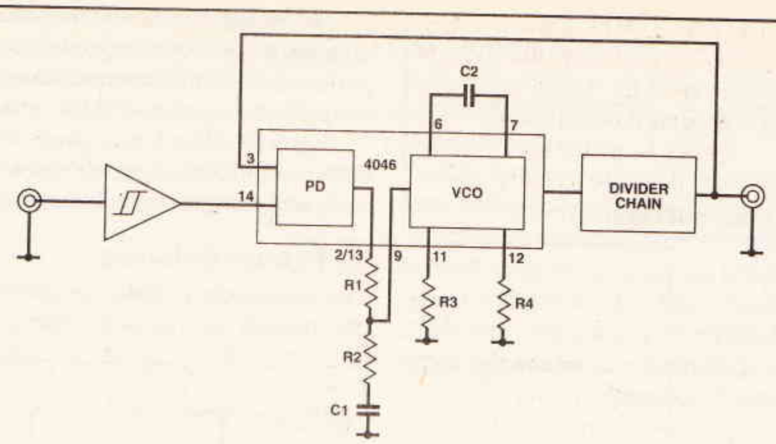


Fig.1 Basic circuit of the PLL

Frequency Meter Range Extender

by Mark Robinson

The digital frequency meter (DFM) works by counting the number of cycles of the test frequency that arrive during a known period (called the gate time). If the gate time is made precisely one second then the count will give a direct reading in Hz.

The problem with this though, is that no matter how precise the gate time (and ovenised crystals can be very precise) the reading can only be accurate to ±1Hz. At 1MHz this amounts to an error of only 1ppm, but at 1kHz it's up to 0.1% and at 1Hz you might as well not bother.

The obvious solution is to count for longer: counting for 10 seconds gives a resolution of 0.1Hz, 100 seconds gives 0.01Hz resolution and so on. There's limits to how far we can take this though, to get 0.1% at 1Hz would take nearly 17 minutes and even the most saintly wouldn't have the patience to wait for 1ppm. Few commercial DFMs have a date time longer than 100 seconds, and most stop at 10 seconds.

This is where this project comes in. What it does is multiply the input frequency by 10 or 100, increasing the DFMs resolution 10 or 100 times without needing lengthy date times. The circuit is also useful when measuring low frequencies on oscilloscopes, since it obviates the need to use the low timebase speeds, with their associated flicker.

Presentation

The presentation of this project will be different to the usual ETI format since it is intended to follow up the article on PLLs. For this reason more time will be spent discussing the design philosophy and less on construction details. Although no PCB layout is given the circuit is not too difficult to construct on stripboard, or even on breadboard as and when it is required.

Design Procedure

The circuit is designed around the CMOS 4046 PLL, which is ideal for low frequency digital applications. It contains both exclusive-OR and type II phase detectors, a VCO and an open drain source follower to buffer the filter output. With a 9V power supply the VCO can reach about 1MHz, although the 74HC version can manage 15MHz.

The basic circuit we are going to use is shown in Figure 1, all we need to do is decide what the component values are going to be.

The first decision to make is the frequency range of the VCO. Since there's little to be gained from multiplying frequencies greater than lkHz, it seems reasonable to set the maximum output frequency to about 10kHz This would give maximum input frequencies of 1kHz on the x10 range and 100Hz on the x100 range, Ideally the low end should go down to DC.

Looking at the data sheet tells us that the VCO frequency range is determined by the following equations;

$$f_{min}=1/(R_4C_2)$$

$$f_{max}=1/(R_3C_2)+f_{min}$$

Missing out R_4 altogether makes f_{min} as low as possible, and then R_3 100k and C_2=820pF gives us an f_{max} of about 12kHz.

A capture range this large introduces a couple of problems. First, all frequencies below 6kHz have at least one harmonic within the capture range, which rules out the type I phase detector. It wouldn't be a good idea to use a type I detector anyway, because we can't be sure of the input duty cycle and the residual ripple could cause trouble for the DFM. The second problem is that we have to be careful about stability, and a pole-zero filter is pretty much essential. With that in mind, let's now turn to the filter design. What we want from the filter is a long time constant to reduce jitter and noise sensitivity. However, since the device is designed to replace the 10 second gate time, a time constant (and hence settling time) longer than this rather defeats the object. A compromise of 4 seconds was used in the final design.

Circuit description

The complete circuit diagram of the DFM range extender is shown in Figure 2. IC1 amplifies the input ten times, and biases the input to IC2a to half rail. An AC coupled amplifier is used, but the large capacitors ensure a cutoff frequency of less than 1Hz. The input impedance is about 500k.

After shaping by the schmitt trigger IC2a the signal is applied to the PLL, whose operation has been described previously, R6, R7 and C3 are the filter components and R8, C4 select the VCO range. The multiplied output appears on pin 4.

prefer to build it on breadboard as required, or dedicated LF people could build it into an existing DFM. Whatever construction method you use., remember that the CMOS chips are static sensitive and take the usual precautions.

Testing is simple enough, connect the unit to your DFM or 'scope and apply a frequency of about 100Hz to the input. Check that the frequency is multiplied by 10 and 100.

If there's no response first check that a signal is reaching IC3 pin 14, if not check the input amplifier and IC2. If that's OK., temporarily disconnect pin 9 of IC3 from the filter and connect it to the wiper of a pot between 0v and 9v. Check that as the pot is turned a variable frequency between 0 and 12kHz is generated on pin 4. If not, check the circuit around IC3 for mistakes or poor joints. Check also that a divided frequency is available on pin 3, suspect IC4 if this is not the case. If the circuit seems sound, you may have despatched one of the chips with static. If this is the case, replace the duff device and remind yourself to be more careful next time.

Finally ensure that LED1 is lit when a frequency in range is applied (up to 1kHz on the x10 range, or 100Hz

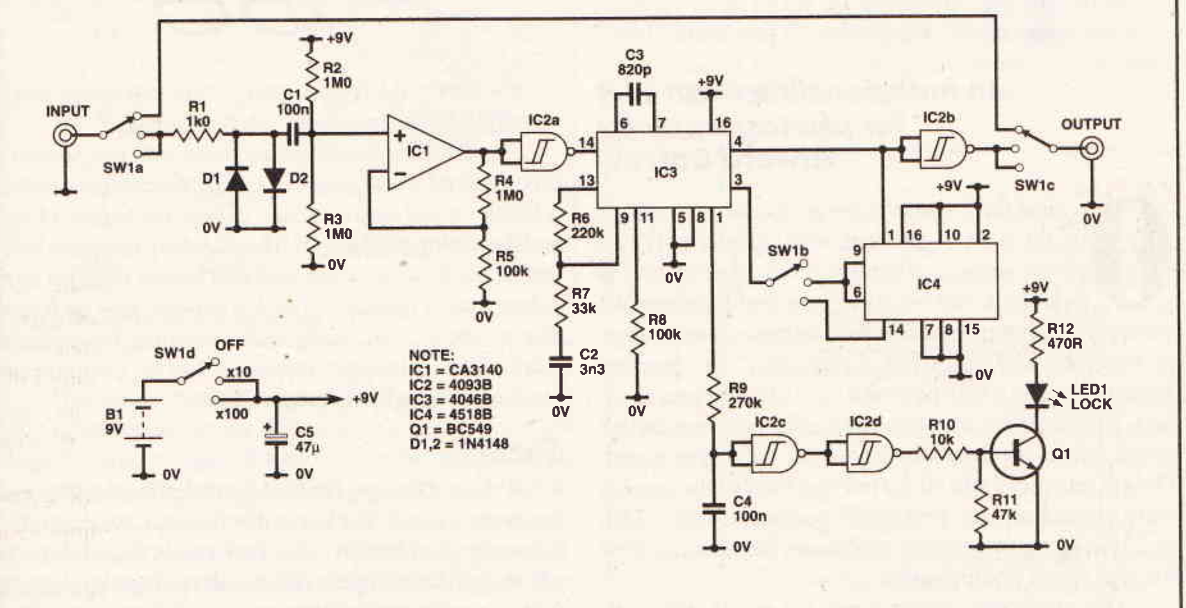


Fig.2 Circuit diagram of the PLL LF range extender

on the x100 range), but extinguished when the input is removed, or taken out of range.

IC4 is a dual decade counter which is used to divide the output by either 10 or 100, depending upon the setting of SW1. The third position of SW1 is used to remove the power and bypass the circuit.

Pin 1 of the 4046 is labelled the 'phase pulses' output, and provides a waveform whose mark-space ratio depends on how far the look is out of lock. Internally, this signal is used to control the type II phase detector, but the designers thought it useful enough to bring it out to a pin of its own. In our case, the signal is averaged by R9, C5 and used to drive an 'in lock' indicator, LED1.

Construction and Testing

As mentioned earlier, I don't intend to present detailed construction information for this project. The circuit is relatively straight forward, and can be easily built onto stripboard, The occasional user of low frequencies may

Conclusion

The aim of PLL article and project has been to show that designing around PLLs is not difficult, and can solve some tricky circuit problems. If you're into decoding signal transmissions (modems, FSK, RTTY, CW and so on) then PLLs are a godsend.

There are books filled with terrifying maths about PLLs, and some designers will frown on the cut and try method, insisting that the maths is essential. Admittedly, for high performance applications cut and try might not be good enough, but for less critical circuits (particularly when using the 4046) perfectly good results can be obtained as long as you're careful.

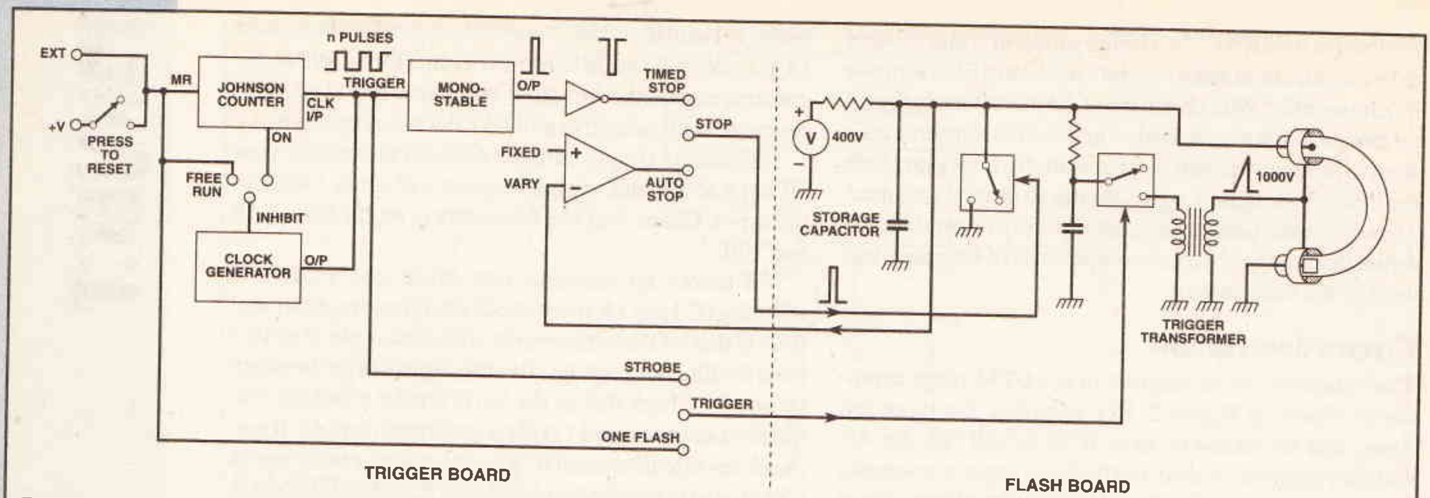


Fig.1 Block diagram of flash unit

Xenon Flash Trigger

An indispensible flash unit for photography by Edward Barrow

On most flash units the range of control available by the user is minimal, with usually only two power settings catered for. All other control is automatic and access to information about the control lines difficult to come by. The main disadvantage of commercial flash units is that they are purpose designed to give a high powered flash of fairly long duration. To make them simple to use usually only one shutter speed can be used, usually called the flash sync speed. Only at this speed will all the moving parts of the camera work in synchronism. This speed is usually a 60th, 125th or 250th of a second at the maximum, which is too slow for high speed photography.

This two-board project covers the area that lies outside of the domain of commercial flash units. A Xenon tube produces the light output with three basic switchable power settings. But to broaden the range of control a thyristor is also used to switch the power to the tube off. Using mains power fast recycle times can be obtained and so fast powerful strobes obtained.

A separate board has been built to trigger the tube. Firstly it allows the Xenon tube to be used as a strobe by repeatedly triggering it. This allows movements to be recorded on one exposure. The number of flashes can be set or just left to free run. Of course the frequency of these flashes is presettable.

This board also controls the power and output duration of the flash. Five output durations are catered for; 2µs, 10µs, 100µs, 1ms, 10ms, all of which are switchable. Alternatively a feedback arrangement can be used to turn off the Xenon tube after ⅔ of its light power has gone. This is useful as it is the remaining ⅓ that accounts for the longest part of the flash, usually called afterglow, and by removing this a clean fast flash is obtained.

No direct interfacing is required with the camera as this is a stand alone project. Usually the camera's shutter is left open and the flash used as both the source of light and the timing mechanism. The exposure time thus being that of the flash duration, and this allows very fast equivalent shutter speeds so fast movements may be frozen. The strobe is particularly useful for time lapse photography where multiple exposures can be taken on one picture showing the passage of time.

Theory

A full block diagram, Figure 1, has been included to ease this section along. The key to this circuit is understanding the workings of Xenon tubes. In the main these tend to be a U shaped tube of glass filled with the inert gas, usually Xenon, see Figure 2. There are other inert gases such as Helium, Argon, and Krypton, but Xenon is preferred as the light it emits has almost an identical spectral content to daylight. This fact is very important in colour photography to retain accurate colour balance when using daylight compensated film. Inert gases also need to be used to prevent reaction with the internal wires as the combination of high currents and temperatures make gases particularly reactive.

There are three connecting wires to the tube each with its dedicated function. The first connection is the cathode which is recognised by a small plate attached to it inside the glass tube. This plate is usually coated with a small amount of a reactive metal such as Barium. The metal acts as an electron donor, and as we know when metals react they donate electrons so the more reactive the metal the better it is at donating. Barium is used in preference to more reactive metals such as Sodium and Potassium as it has a much higher boiling point and so its lower volatility keeps it on the cathode where it should be and not on the walls of the tube. More will be said about the function of electrons in the process of light production later.

The other connection at the end of the tube is the anode which is just a piece of wire. The middle wire is attached to the outside, secondary anode. This is usually just a flat piece of metal wrapped around the outside of the tube near the anode and cathode.

To operate the tube firstly a primary high voltage source must be present across the anode and the cathode (-), this is usually in the range of 300 to 400 volts for small Xenon tubes. This voltage in itself is not great enough to cause breakdown of the tube under normal conditions. A much higher one, around 3000 volts would be required to do this. Nothing will happen until the secondary anode is momentarily raised about 4000 volts above the cathode. This trigger pulse causes the resistance of the tube to fall to about 1 ohm and a flash of light is then produced.

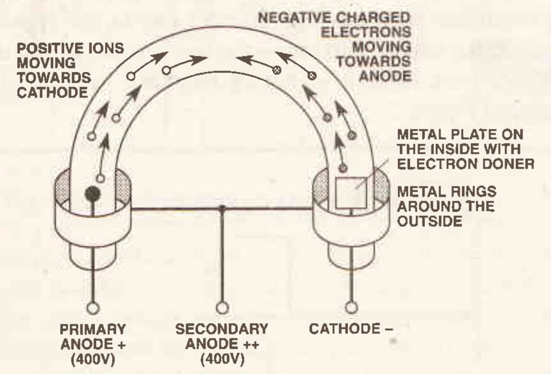


Fig.2 Xenon Flash Tube detail

The actual mechanism that produces the pulse of light is an avalanche one. When the secondary anode is triggered with a high voltage, the Xenon gas inside the tube is momentarily ionised. This is particularly stressful for an inert gas whose electron structure makes it extremely stable, and unwilling to forego any of its electrons. It's the generation of these ions that allows conduction across the tube, starting the avalanche process. Electrons from the cathode especially the electron donors collide with other Xenon atoms stripping them of some of their electrons. The movement of both the ions and their electrons across the tube conveys charge and generates an electric current. Once started the primary voltage source provides the main power to continue the process of striping of electrons. The current causes the gas to glow by a simple heating process, rather like a tungsten filament bulb. The difference being that the specific heat capacity of the gas in this tube is very small and the current flowing through it very great, so the gas heats up and cools very quickly. A series of curves have been drawn in Figure 3 which show the voltage, current and light output for a typical tube.

The primary voltage source in most circumstances is a capacitor charged up to around 400 volts. Thus the energy transfer is fixed at $\frac{1}{2}CV^2$. But more importantly the impedance of the voltage source is very low, and so very high momentary currents are obtainable. It is the level of the current that determines the output power and duration of the flash. With a resistance of 1 ohm when conducting, currents can be as high as 400A are demanded, something which conventional power supplies could not achieve.

As a result, very careful consideration is required when choosing capacitors. In particular attention must be paid to the value of the capacitor's series inductance. As odd as this may seem most capacitors have some series inductance, and some have quite large amounts due to the shape of their design. The worst of these are the ones that are rolled up in a can, this means all electrolytic and some polyester capacitors. Unfortunately electrolytics are the only capacitors that can deliver large capacitance with low volume especially at high voltages. The only other way is to parallel lots of smaller layered polyester capacitors. As we all know if we try to change the current flowing through an inductor, the inductor does all in its power to resist this by altering the voltage at its terminals. So when we suddenly call upon the capacitor to generate current the inductance attempts to stop this raise in current and thus causes a sense of inertia in the performance of the capacitor. In simple terms the rise and fall times of the capacitor will be slow, causing low light output and long afterglow. The representations in Figure 4 show this point for a charged capacitor when the switch is closed.

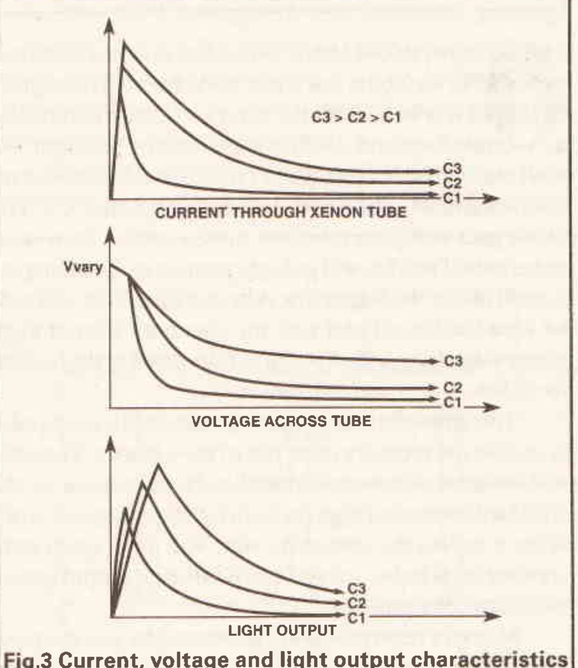


Fig.3 Current, voltage and light output characteristics of tube

The rise time can be increased by using a smaller capacitor, which will give you a smaller flash. Or using a layered capacitor. The problem of afterglow is easily remedied by the use of a thyristor to discharge the capacitor after the bulk of the power has been drained from the capacitor.

A trigger transformer is used to generate the required 4000V pulse using a small amount of the primary voltage as a source. A thyristor is used to switch the transformer on electronically, allowing smaller voltages to control the switching process.

The overall power source is the mains which is bridge rectified and used to charge the capacitor.

The strobing operation was built around a ten stage Johnson counter. A timing diagram has been included to explain its workings (Figure 5). Suppose we start when the power has just been switched on. At this point all the counters outputs are low, thus the diode D1 will be reversed biased and so it can be left out of the equation. The input of the invertor IC4a will also be low thus its output will be high. With this combination the NOR gate

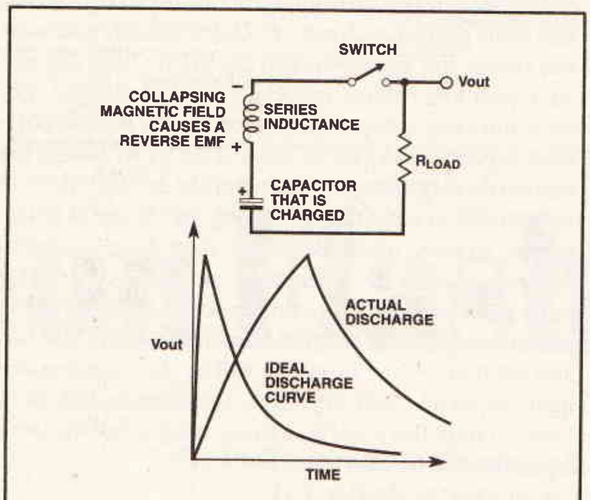


Fig.4 High voltage discharge arrangement

created out of an OR gate IC5d and an invertor IC4b will have one of its inputs low while the other will be high, so its output will be low. As the invertor IC4a is configured as a simple feedback oscillator eventually its output will start oscillating. The frequency of this will be dependant on the variable resistor RV1 and the capacitor C5. The NOR gate will pass on these pulses until n have been generated. Then On will go high, permanently forcing the output of the NOR gate low. Also the diode D1 will now be forward biased and pull the oscillator's input high, hence stopping oscillation. Now the output of the oscillator is low.

This state of affairs would remain until a reset pulse is sent to the memory reset pin of the counter. Then On will be driven low and immediately the output of the NOR will be forced high (as both its inputs are now low). After n pulses the stationary state will arise again until another reset pulse occurs. The NOR gate output generates the strobe pulses.

Memory reset pulses are generated by either a push switch or an external signal which are both ORed and then pulse converted. Please note that the free-run operation is achieved by inverting the output of the former OR gate before pulse conversion and using this as an On output. So for example when this mode is selected, and the switch SW1 is pressed the clock oscillator will be enabled and stopped when it is released.

To obtain accurate timing of the flash duration a monostable was used, a full timing diagram from start to finish was included in Figure 7. This is triggered by either the strobe clock generated above, or the push switch/external source combination generated by the OR gate IC5b. After triggering, this monostable produces a single pulse of a duration set by a timing resistor and capacitor. The output is used firstly to trigger the Xenon tube, but more importantly it is used to turn off the tube after the set time. This is done by inverting the signal and pulse converting it. Thus a pulse is generated after the monostable's output returns low after the set time period. This pulse is used to trigger the thyristor that grounds the primary storage capacitor on the flash tube board.

If the alternative mode is selected, again the Xenon tube is triggered by either of the combinations selected by SW3. But the tube is now turned off after two-thirds the primary storage capacitors energy is expended. This is easily done using a comparator to monitor the voltage across the capacitor in question. The comparator's positive input is a fixed representation of a third of the full charge level, while the negative one is a representation of the actual state of the capacitor. So normally before triggering, the output of the comparator is low (the positive being less than the negative). But when the Xenon tube is triggered the negative input voltage starts falling until it reaches the third way level then the output of the comparator will switch to high. It is this output that is pulse converted and used to trigger the thyristor to turn off the Xenon tube. Again a full timing diagram is included this time in Figure 7.

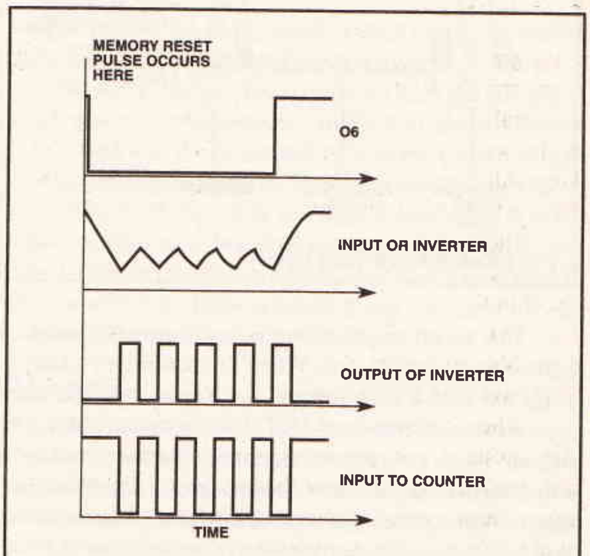


Fig.5 Timing waveforms

Construction

The tracks on the flash board were made using quite heavy copper due to the high voltages and currents involved. When soldering use lots of solder to give good contacts. Do not under any circumstances omit the fuse from the mains circuit. This is very important as this board is running directly off the mains and this is your only form of isolation. Common sense prevails when mounting the components. The small ones like resistors go in first then thyristors and the transformer, finally the external components.

The bridge rectifier BR2 should be a high voltage high current variety, eg W004. Use wire wound resistors for R22 and R23, 2 watt varieties should be sufficient as the currents are not constant but only instantaneous. As the storage capacitors were large they were mounted

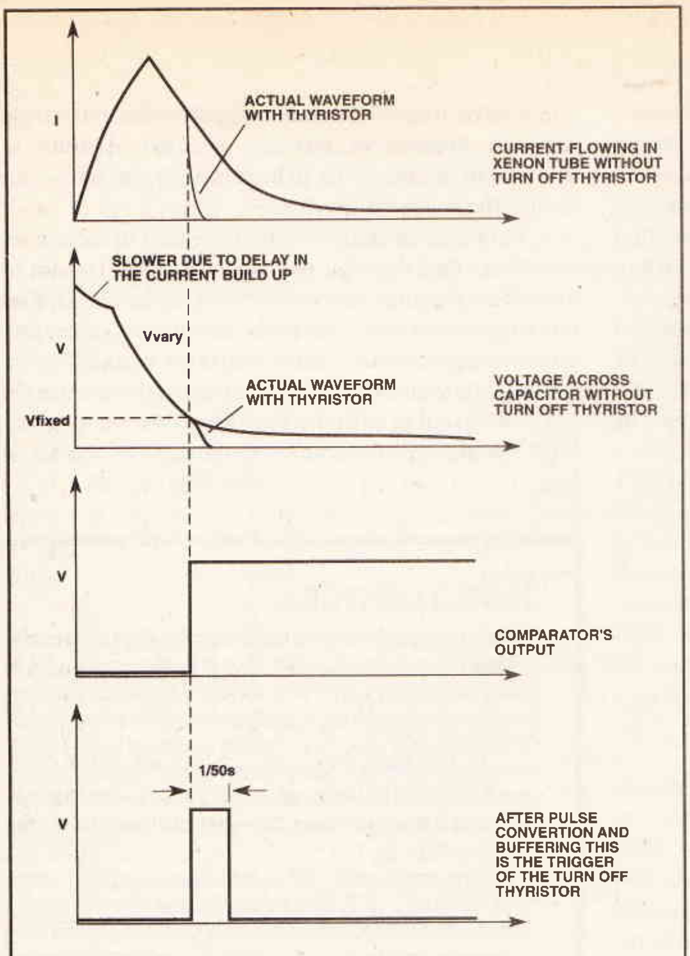


Fig.6 Timing diagrams for thyristor

external to the board and heavy wire used for connection to the board and the switch. Don't be tempted to use very large value capacitors as these will shorten the life of your Xenon tube and may even destroy it on the first go.

Check that you have wired the trigger transformer the right way round, ie the thick wire is the primary and the thin the secondary. Any mistakes here and you will have to foot the bill for a new one. Thyristors have definite polarities and must be put in the right way or else they don't work, so stop, think and consult your data book.

When it comes to mounting the Xenon tube some fore-thought is needed especially when choosing a suitable box. In the prototype I mounted a mirror behind the tube so as to obtain the maximum amount of light on the subject. This is important to bear in mind if you are using the smallest capacitor setting which doesn't give out much light anyway. The mirror I used was convex, with a short focal length. This is useful for macro photography as it allows the light to be focused on one small spot. It is also useful to fit a piece of frosted plastic over the tube to act as a diffuser.

The second board is more standard. Again resistors and small bits first, then larger bits. I used IC sockets on this board which is useful when using CMOS ICs, which you should handle with the usual caution. The regulated power supply is included on this board and is quite simple. An external transformer was used to step down the mains.

Testing

Before I start I must warn you to exercise extreme caution when testing the flash board. You are dealing with some high voltages and so the old rule from the days of valves applies; only work with one hand behind your back, using well insulated probes. This means you cannot set up a circuit through your body by holding both a high voltage line and ground at the same time. Secondly the storage capacitors, do exactly what they say and store charge, even after the power has been switched off. Before you start poking around make sure there is no residual charge, the best way is to touch a screw driver across the two terminals, if it is charged you should see a spark. All in all, this board is very simple, not much can to go wrong, except the thyristors being reverse connected. Or the electrolytics have their polarities back to front.

When ready select a storage capacitor and switch on the power to see if there is about 350 volts DC across it. If you do not have a high voltage meter, then check the VARY line. It should read 3.5 volts. Next momentarily touch a 12 volt supply line across the trigger line and the ground line. The Xenon tube should flash at full power. Do the same for the other two storage capacitors. Each one should give a different flash intensity depending on the size of its capacitance.

If you have problems switch off the power, discharge the capacitor then start looking. If you find that the tube flashes only once after powering up, then you may have chosen a thyristor with a small holding current. What is happening is that after the first triggering R29 is providing enough current to keep the thyristor in its conducting state, so it never switches off and allows C17 to recharge. The easiest solution is to use a more powerful thyristor, as this also increases the holding current.

No draconian measures are required for the second board as it is a low voltage one. Firstly check the power

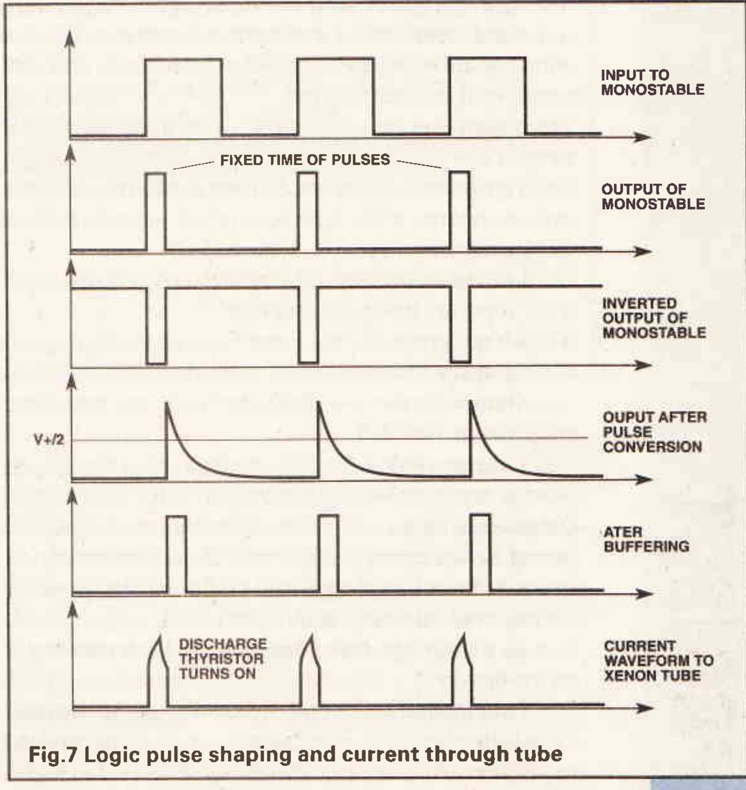


Fig.7 Logic pulse shaping and current through tube

supply is supplying power to the correct parts of the circuit. Test the oscillator is working by selecting the freerun mode, and pressing SW5. Monitor pin 13 on IC1, when its pressed it should start pulsing, with the frequency dependant on VR1. If you are having problems check that both R4 and R5 are in place, as these tie the OR gate's inputs low. Also the polarity of D1 may be wrong.

Still monitoring pin 13, select a set number of pulses from SW1, and press SW5. Problems here could arise from a reset pulse not getting through to the memory reset pin, pin 15. An oscilloscope should alert you of any problems here.

To test the monostable again select freerun on SW1 and strobe on SW3. Monitor pin 3 on IC2 with an oscilloscope while pressing SW5. You should see a series of fine pulses whose width varies with the resistor selected by SW2. Also check the output of IC5c. It should also be a series of pulses all of the same width.

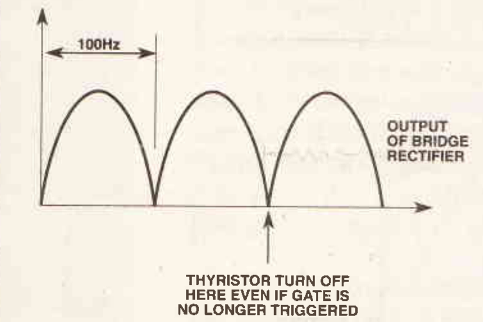


Fig.8 Thyristor characteristic

The comparator can only be tested by connection to the flash board. After connection select one step with SW3 and change the mode on SW4. Then observe pin 7 on IC3 while pressing SW5. Every time the Xenon tube flashes, the output line should go high, turning on the thyristor. Also LED 2 should flash on. If there are any problems look at the VARY and FIXED input lines, they should preform to their names. Again check that IC5c's output is a series of fixed width pulses.

In Use

Before jumping feet first and wasting a roll of film, stop and think what you are actually trying to achieve. The first thing is to select which storage capacitor to use. Here are some points to bear in mind;

The distance of the subject away from you. The further away it is the more power you need. Remember that light obeys an inverse square law, ie if you double the distance you get a quarter of the light. So don't try to get flash filled pictures of the moon.

The smaller capacitors will give high speed flashes with faster recovery times, but less light.

If you want to use the low power setting for high speed photography, then remember to use high speed film to compensate for the low amount of light, try something greater than 400ASA.

The usual way to use this unit is to set up the camera in a dark room and while leaving the shutter open triggering the flash. This is easily done by putting the camera in B setting, now the camera's shutter is open when the shutter button is depressed. I use a cable release to do this while the camera is mounted on a tripod. Most cable releases have a lock facility, so you don't have to keep your finger on the button.

The disadvantage of this method is that you have to by-pass the camera's metering and so you are flying blind so to speak. So some experimenting is needed to ascertain the light output of each setting before the unit is used seriously. Remember you can use the aperture to increase or decrease the light getting to the film, even though the shutter is left open.

To use the strobe, firstly set the speed to record the movement and then the number of flashes. Try not to overkill on the speed or the number of the flashes used on one exposure as this leads to the burning out of the picture in any region where there is no movement. If you are using the strobe on a human figure then it is best to use the full power setting with the flash duration set to 10ms. High speeds are not necessary as movements are not so fast.

HOW IT WORKS

On the flash board a simple power supply was made using a bridge rectifier to convert the mains to a DC voltage. Because the source is the mains, its voltage rises and falls every 1/100th of a second. This means the storage capacitor may take longer to charge as it needs to wait for at least one peak. So bear this in mind when you are choosing the speed of strobing and the storage capacitor to use. A resistor R22 was included to prevent large currents flowing when the unit is switched on, or when the strobe facility is used on the highest power setting. The present value limits the current to a maximum of 2A.

Another isolating resistor, R23, is used to again limit currents in the latter part of the circuit to 1A. There is a choice of three storage capacitors. I used a 4(1-3) way rotary switch to select the capacitor, with all 4 parts of the switch used in parallel so as to reduce the effective resistance of the switch. This is important as it is the ability of the capacitor to provide current quickly and in large quantities. This ensures fast bright flashes.

The thyristor used to end the flash (TH1) was obviously of the high power variety, handling around 10A RMS. Being RMS, they can handle even higher instantaneous currents, so discharging the capacitor should be no problem. Trigger currents for these varieties are usually in the region of 20mA. Once triggered, thyristors remain in the conducting state until the current flowing through them falls below what is called their holding current (usually around 35 mA for such devices). As the source of power is the mains, the power waveform looks like Figure 8, so the thyristor should turn it self off when the mains power cycle falls to zero.

The trigger transformer used runs on about 200V so a voltage divider was used to drop the supply to this level. This charges a capacitor C17 which holds the necessary charge to trigger the tube. The other end of the capacitor is tied to ground via the primary of the trigger transformer. Another similar thyristor is used to trigger the tube. This is done by the thyristor grounding the positively charged end of the capacitor (C17), thus causing a sudden current to flow from the other end of the capacitor through the primary of the transformer. The result in the secondary is a pulse of about 4000V.

A voltage divider with a ratio of 1.3:100 was used to generate a usable signal to tell the state of the storage capacitor (VARY line), this feeds the negative input of the comparator. A second voltage divider with a ratio of 1:100 with also a smoothing capacitor generates the fixed half charge signal (FIXED line) for the positive input of the comparator.

Turning to the second board, there are two ways of triggering this cir-

If you are going to use the unit for macro work try using a convex mirror as mentioned before to focus the light on the subject. I also mount the unit on a small tripod when doing this as this allows accurate setting up and good control of the positioning of the flash unit. Exercise some common sense and do not point the unit in the direction of the lens as you will either get silhouettes or a blank white print. Keep the unit on the same side as the camera so it only picks up reflected light.

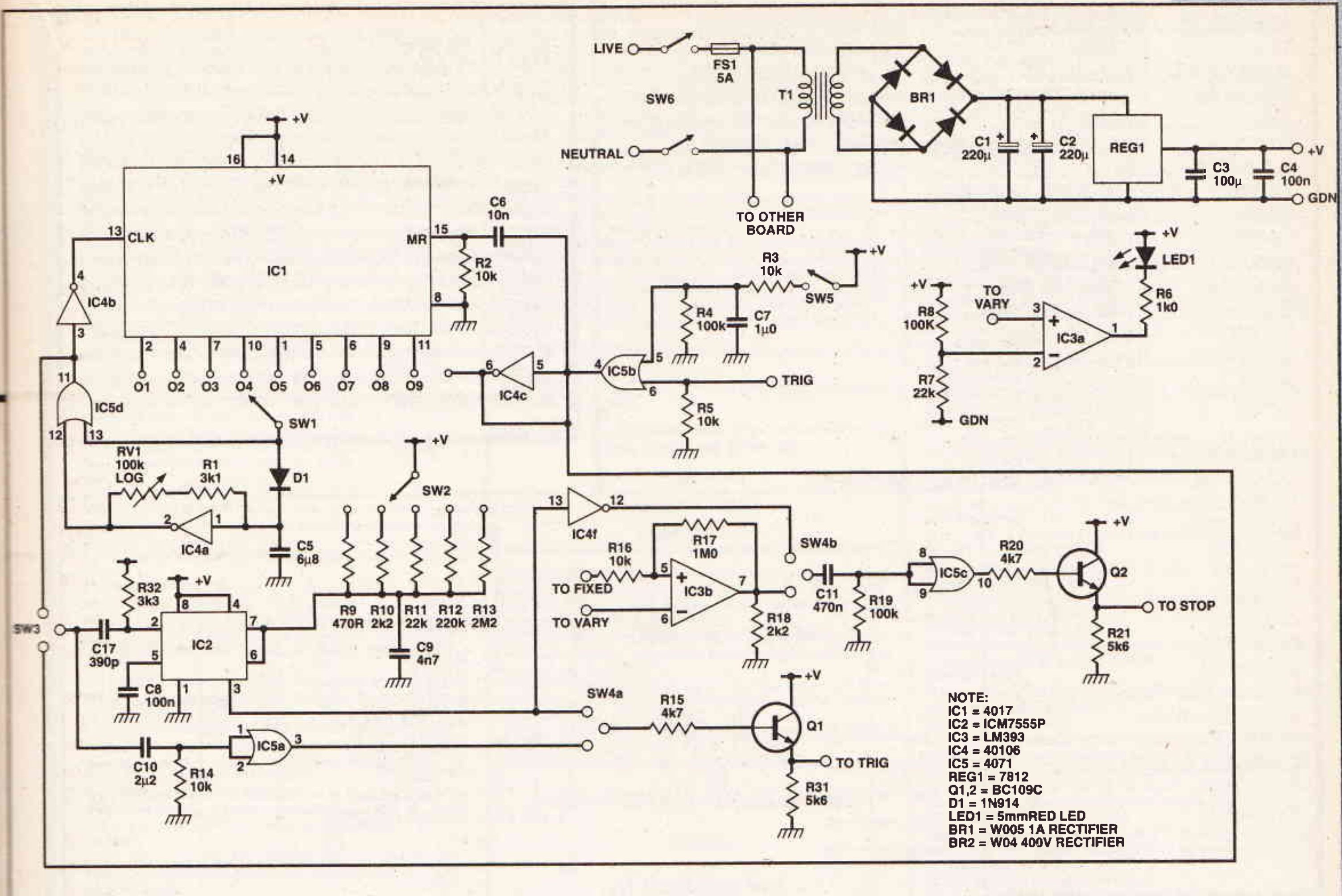


Fig.9 Xenon flash triggering circuit

cuit. Using the switch SW5 which is debounced firstly, or an external digital source via the input line. Both of these feed an OR gate. There is an oscillator built around the invertor IC4a has been designed to operate within a frequency range from 30Hz to around 1Hz, and is set by RV1. This sets the frequency of strobing.

The monostable was built using the CMOS version of everybody's favourite timer chip, the 555. After receiving a trigger pulse on pin 2 the output, pin 3, goes high for the preset period of time. Here the timing capacitor (C9) is fixed and its the resistor value that is variable, here selected by SW2. Each of the values have been chosen to give the flash durations mentioned before in the specifications.

The comparator used to monitor the storage capacitor has some added positive feedback to ensure clean, fast switching. Also note that its output is an open collector and so needs a pull up resistor for normal working. Before connection to the thyristor on the other board the output of the comparator was pulse converted by C11, R19. The time constant for this combination was chosen so as to generate a pulse of 20ms width. This should be enough to allow the thyristor to discharge the storage capacitor. The pulse convertor was buffered by a spare OR gate IC5c before a final buffering by a transistor to raise the output current switching to around 20mA for the thyristors. Note that the output to the trigger thyristor was also buffered by the same means.

The spare comparator on the LM393 was used to display the state of the storage capacitor. It uses the VARY line to illuminate a LED when the capacitor's charge falls below half its peak value.

This board is driven by a small mains 12V power supply. A 1A regulator being used to stabilise the smoothed output of the rectifier BR1.

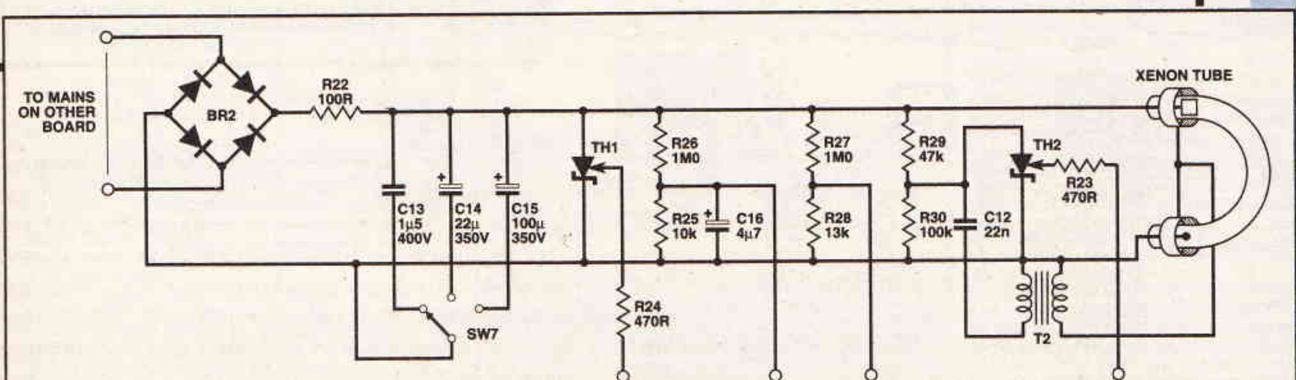


Fig.10 Power supply for flash tube

PARTS LIST

RESISTORS
R1=3k1
R2,3,5,14,16,25=10k
R4,8,19,30=100k
R6=1k
R7,11=22k
R9,23,24=470R
R10,18=2k2
R12=220k
R13=2M2
R15,20=4k7
R17,26,27=1M0
R21,31=5k6
R22=100R
R28=13k
R29=47k
R32=3k3

CAPACITORS.
C1,2 =220µ ELEC
C3=100µ ELEC
C4,8=100n POLY
C5=6µ8 TANT
C6=10n POLY
C7=1µ TANT
C9=4n7 POLY
C10=2µ2 TANT
C11=470n POLY
C12=22n POLY 350 VOLTS
C13=1µ5 POLY 400 VOLTS
C14=22µ ELEC 350 VOLTS
C15=100µ ELEC 350 VOLTS
C16=4µ7 TANT
C17=390p POLY

SEMICONDUCTORS
Q1,2 BC109C
D2=5mm RED LED
IC1=4017 10 STAGE JOHNSON COUNTER
IC2=ICM7555P CMOS 555 TIMER CHIP
IC3=LM393 DUAL COMPARATOR
IC4=40106 HEX SCHMITT INVERTORS
IC5=4071 QUAD OR GATES
BR1=W005 1 RECTIFIER
BR2=W04 400V RECTIFIER
TH1=10A THYRISTOR
TH2=10A THYRISTOR
REG1=7812 +12 VOLT REGULATOR

MISCELLANEOUS
FUSE 1= 5A Fuse
TR1=12V 6VA TRANSFORMER
TR2=4000V XENON TUBE TRIGGER TRANSFORMER
SW1=10 WAY ROTARY SWITCH
SW2=5 WAY ROTARY SWITCH
SW3=SPDT MINIATURE TOGGLE
SW4=SPDT MINIATURE TOGGLE
SW5=PUSH TO MAkE SWITCH nOn LOCkING
SW6=DPDT MINIATURE TOGGLE
SW7=4(1-3WAY) ROTARY SWITCH

BUYLINES

All the main stream components are available from most suppliers. A few of the others may need a little hunting around to find. The high voltage capacitors are not too common especially the large values. Maplin do however have a small range of high voltage electrolytics. Remember the higher the voltage rating the better, so do not be inhibited to use 600 volt ones. Most suppliers stock some breed of high current thyristors and most are housed in standard packages. Maplin also stock a range of Xenon tubes and suitable transformers, but their transformer packages vary from the Tandy one I used so you may have to alter the PCB layout to suit. When choosing a Xenon tube study the data given. Look especially at the maximum flash rate at maximum power, usually this lies in the range from about 1 per second to 60 per second. A faster one is best for strobing, while slower ones usually give larger amounts of light output. The guide for the amount of light is maximum energy per flash, usually given in Watt seconds or Joules.

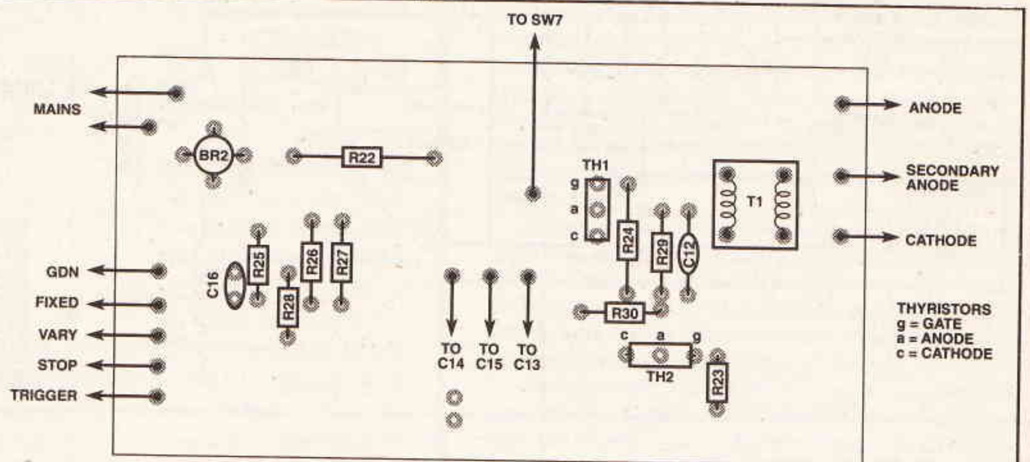


Fig.11 Component overlay of Xenon tube supply

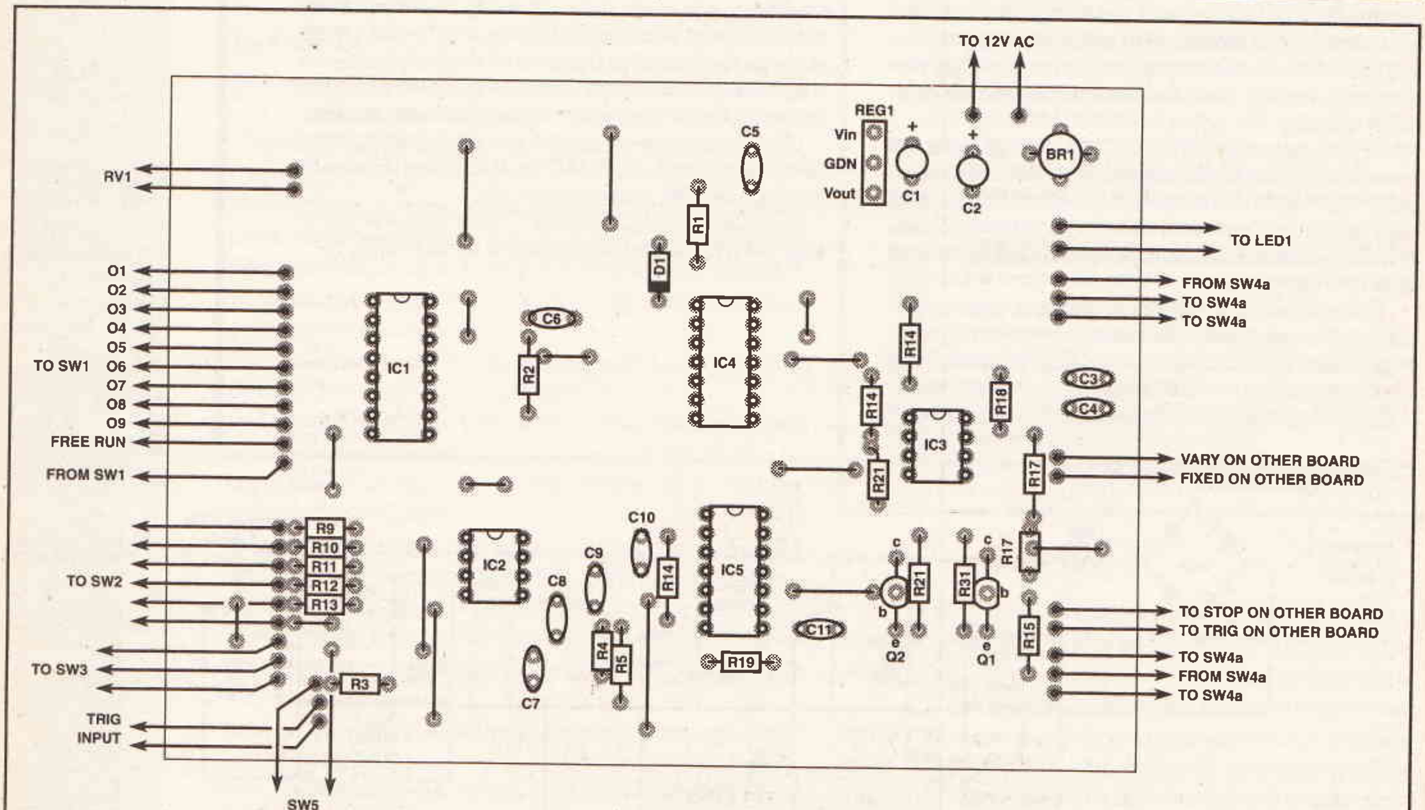


Fig.12 Component overlay of main board

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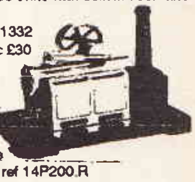

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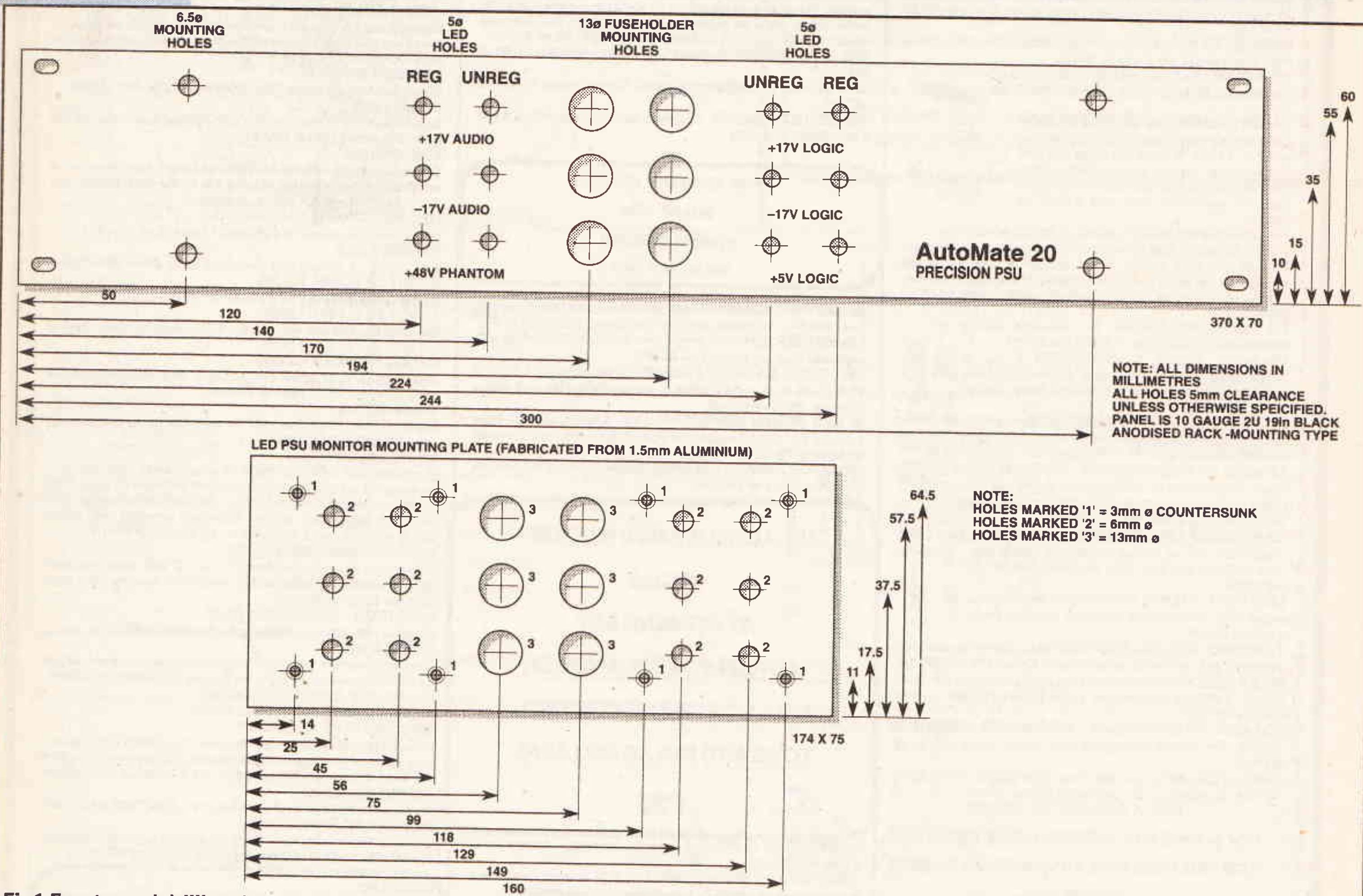


Fig.1 Front panel drilling diagram/LED PSU monitor mounting plate

It's time for detailed power supply construction from Mike Meechan.

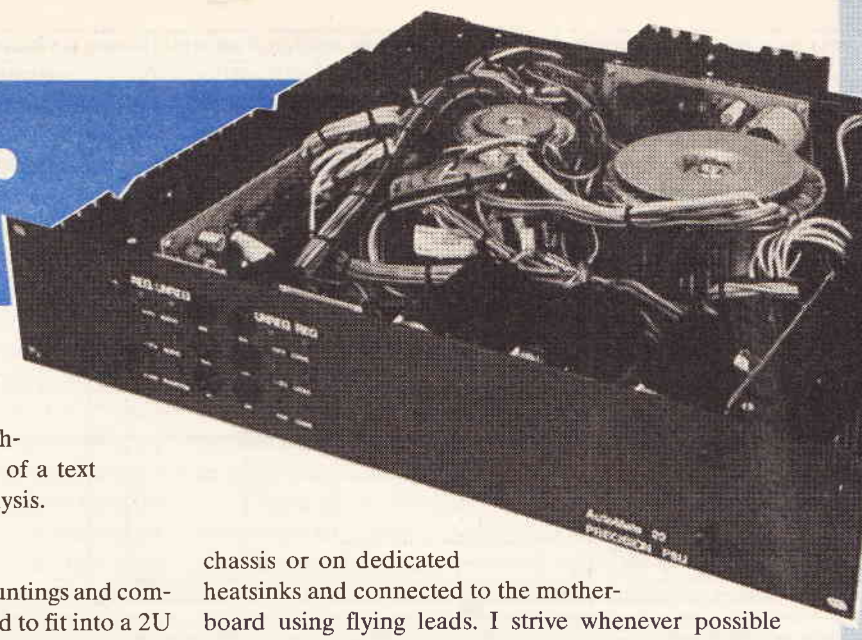
Last month's issue, on the cover of this very respectable magazine, revealed all.

What? No, not us, silly. The AutoMate 20. The most comprehensive mixer project ever published in an electronics magazine.

To briefly recap. So far, in the preceeding two parts of the saga, we've covered noise in the microphone preamplifier stages, choice of methods of amplification open to us, pros and cons of both, and which of the two will be included in this particular design and why. In last month's instalment, we discussed the power supply unit, the features and performance which should be expected of it when it is to be used in a pro-audio, high quality application, the importance of conservative design, protection circuitry, mains safety and good regulation.

This month, we move onto the more constructional aspects of the design. I know that in Part 1 I was most emphatic in stating and then reiterating at choice moments throughout the text that it would be wiser not to attempt ANY construction until all of the main parts had first been published. Although we will, in fact, discuss at some length the intricacies of the mechanics of the construction of the Power Supply Unit, this sound advice still holds true and at present, no construction should be attempted. As a way of explanation, I should mention that the text and diagrams of the AutoMate series in its entirety will occupy some one hundred pages or so. Thirty or so pages of this total are of a constructional or unit calibrating/setting-up nature which, even to the most deviant of our readers — the type who would wish the whole article in a single issue — would prove somewhat daunting and definitely off-putting. It is more logi-

e Mixer



cal to adopt this more structured approach and to discuss the construction of each module as it is presented. It will also provide some much-needed comic relief from the ardours of a text based purely on theory and circuit analysis.

Power Supply Constructon

The boards, heatsinks, transformer mountings and component placings have all been optimised to fit into a 2U high rack mounting case. The particular one that I used was custom-designed (ad-man speak for home-made!) and so was absolutely perfect as far as internal and external width and depth dimensions were concerned. Commercially-produced cases may need some dimensional fine-tuning and trimming. For everything to fit as neatly and compactly as in the photgraphed prototype but so long as the case is no smaller than that specified, there should be no problems in fitting all of the components and wiring into the casing in a secure and workmanlike manner. Refer to Figures 1, 2 and 3 for the dimensional details.

Keeping The Right Connections

It is an unfortunate by-product of high power or high current design that, for reasons of cooling, heatsinking, or simply because of the sheer physical size or bulk of the components use in this type of circuitry—toroidal transformers, massive smoothing capacitors, rectifiers and other power semiconductors — some of the necessary circuitry must be mounted off-board, perhaps on the chassis or on dedicated heatsinks and connected to the motherboard using flying leads. I strive whenever possible within my designs to both minimise the number of different PCB's which must be interconnected —damn, I've let slip yet another trade secret—and furthermore, to reduce as much as possible the components which are mounted remotely from the PCB. In this way, at least one source of error (qv interconnection wiring error) is eradicated as much as humanly possible. It also means that circuit performance is standardised and the unit should perform as per the specification sheet, being independent of the vagaries introduced because of inductance of an uncontrolled sort or instability caused by the constructor using non-conformist or downright bad-practise interwiring techniques which the designer is unable either to anticipate or eliminate.

The Author Is Led Astray

What I am trying to say is that the proliferation of very high power components intrinsic to this design has meant, sadly, that I have had to deviate from this ideal philosophy and specify that many parts of the circuit are mounted either within the chassis but off-board or on

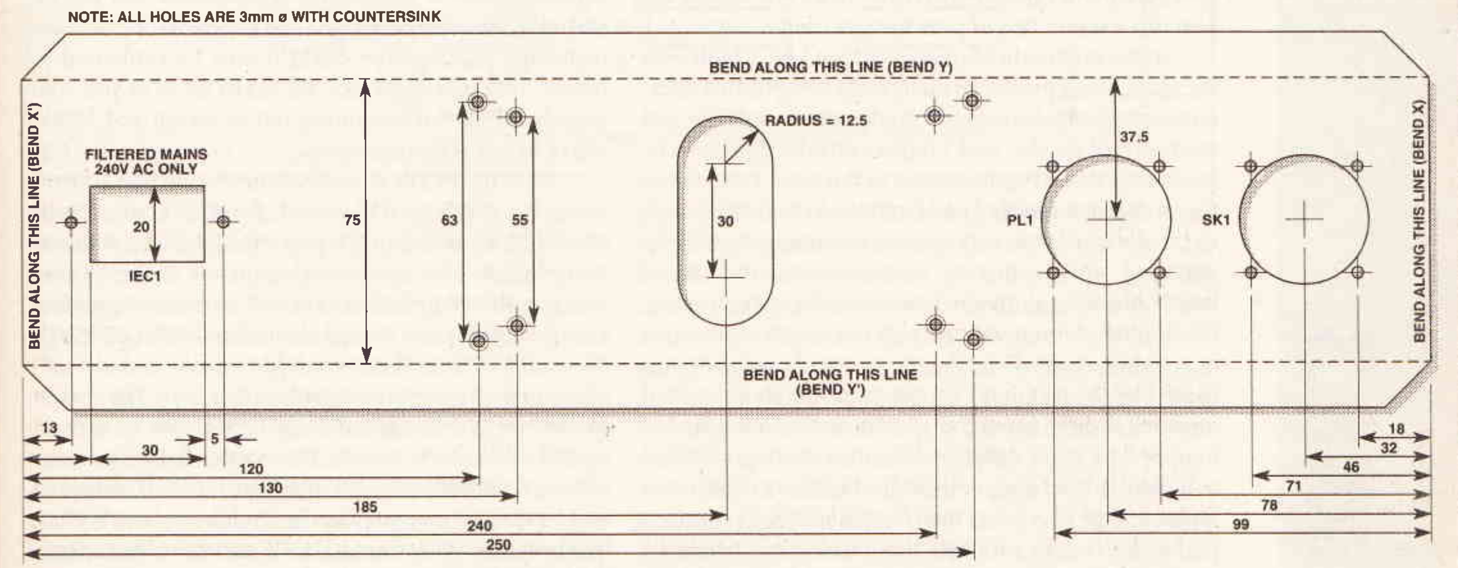


Fig.2 Chassis rear panel drilling details

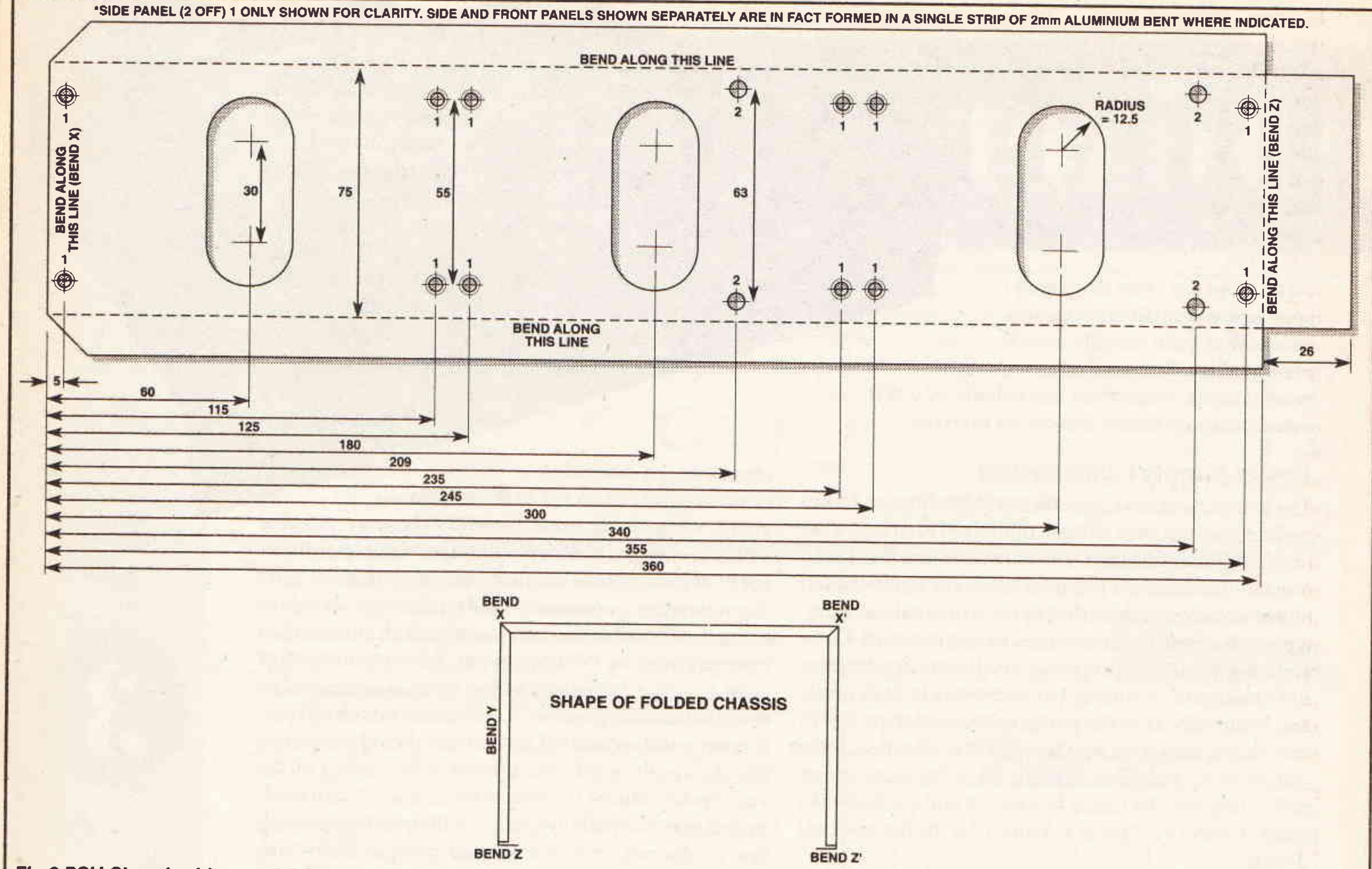


Fig.3 PSU Chassis side panel drilling details

heatsinks which are bolted to the outside of the rack-mounting casing. The pass and crowbar transistors alone —14 in all —with their three connections each account for some 42 connections. There are also 17 connections on each of the PCB's as well as fuseholders, capacitors, bridge rectifiers etc. It is easy to see that the wiring loom very quickly and very easily becomes complicated with much scope for error during its creation, errors which are very messy and expensive to correct and will obviate the need for another flex of your flexible friend.

In the multitude of projects which I have built over the years, I have produced many quite complicated interconnecting cableforms and I think quite reasonably, and modestly, of course, that I might consider myself to be somewhat above beginner level in this field. I was therefore somewhat shocked and humbled to find that even I, as the designer, was very quickly becoming thoroughly confused when using my time-honoured method of interconnecting different boards (using a preformed, colour-coded loom with enough tail length to ensure a neat termination). The primary source of confusion was caused by the fact that I almost immediately exhausted my stock of different-coloured wire and therefore had to have two or more different functions sharing identical colours. (Thicker gauge wire is produced in a much more limited range of colours then its thinner gauge counterpart and it is quite probable that I had at my disposal a much more varied selection than might be available to the average home constructor).

Consequently, I was forced to adopt a new and as it transpired, infinitely more satisfactory method. Within reason, colour-coding was still used but the new approach to the problem entailed working through the interconnections on the netlist on a one-by-one point to point wiring basis rather than try to untangle and decipher a preformed loom as before. Each wire followed a parallel path to those on a similar route, or with similar source or destination components and PCB's, and only once the connection was proven to operate correctly and satisfactorily could it then be cable-tied to others. This may seem like old hat to those of you who already utilize this technique, but to myself and others who had not, it is a revelation.

All of the PCB's should be constructed first according to the overlays of Figures 4, 5 and 6. Components should be mounted in the prescribed fashion which is according to size, resistors (except the high-powered types) mounted first, then zeners, IC sockets, capacitors etc. Having said this, though, capacitors C203, 204, 303, 304 and 107 should all be left to one side and not soldered to the appropriate boards at this time. The reason for this will be discussed when the time comes for us to set up and calibrate the boards. The emitter-ballasting resistors are mounted some distance from the PCB surface so that cooling air may circulate around the resistor bodies. The heatsinks (which are 1.1°C/W and more than adequate for the purpose) house all of the power semiconductors (and the high power current-sensing resistor for the foldback limiting circuitry which is mounted on the reverse side ie inside of the case). They are drilled using either the diagrams or a TO3 drilling template —a TO3 mica washer does the trick nicely —as a constructional guide. Use heatsink paste (Thermasil or equivalent) and mica washers and ensure that insulation between all transistor leads, casings and heatsink is absolute —be wary of burrs caused during the drilling operation which can puncture the washers and cause shorts which are both difficult to see and therefore difficult to track down and rectify.. The heatsinks are secured to the sides of the casing using M3 mounting hardware as per the photograph and diagrams. This particular type of heatsink is actually manufactured in a size exactly twice that which we require and must therefore be cut carefully in half using a hacksaw. Again, your friendly, local sheetmetal supplier will most likely have a power hacksaw which will make a much neater job with minimal wastage —the two parts must be identical in size —and with none of the blood, sweat and tears associated with a task of this nature when it is carried out using the relevant handtools. They will probably do this for the price of a round of beers, but with the price of ale fast approaching the two pound mark, it works out somewhat more expensive than a similar exercise carried out during the course of the Nightfighter project! Once more, if I haven't already made myself quite clear on the subject, the complexity of the unit means that one and only one board c/w ancillary components should be built and tested at a time. It really is to court disaster to bolt everything together and then hope that it will work first time when power is applied. Shroud all pins and adhere to the recommended wire gauge when making all interconnections and colour coding of the wires. This will be shown in Figure 7 next month. The interconnection table —netlist —of Figure 8 aids the construction immensely as I have already said. The temptation to use thinner gauge wire must be resisted at all costs as it would compromise the overall performance of the whole unit. On the first constructional 'pass', use wire of a longer length than at first seems necessary as the boards must first be bench-tested before the leads are de-soldered and the PCB's fitted into the chassis. The flying leads are then trimmed to length, passed through the chassis leadout holes (which should be grommeted to prevent chafing) and then carefully re-soldered to the appropriate terminals. The use of TO3 transistor-mounting sockets makes for a very professional- looking semiconductor installation. It also means that any blown semiconductors — perish the thought —can easily be removed and replaced. If you do use these (Parts Number and associated supplier in the Parts List) be warned that they are manufactured from a thermosetting plastic such as Bakelite or phenolic and as such are somewhat brittle and intolerant of any serious deformations of shape. I found this to my cost (38p) when I tried to tighten one which was not quite parallel to the surface of the heatsink and it shattered into so many pieces! Be warned!

I have made provision on the PCB for the larger, heavy current carrying solder pads to be of a size such they they can be drilled out to accomodate M2 screws. These are bolted to the board and then soldered underneath. In this way, the wires carrying the large currents can be terminated with M2 solder tags which provide a much better arrangement for connecting these heavy-duty wires than mere 1mm terminal pins. (As a point of interest, if there exists out there any manufacturers/distributors of heavier duty terminal pins than those just mentioned, could they please make themselves known to me as I will have definite need of such items in a later project). However, because of their size, the solder tags will be very close to one another with the obvious potential for damaging short circuits and so the solder tags, too, should be sleeved and a check made for isolation between each of the neighbouring connections. Be wary of dry joints when tinning or soldering the 2.5mm wires — the joint is only to be assumed to be properly made when the heat conducted through the plastic insulation of the wire is just too much to bear on human flesh! A wooden clothes peg or other non-conducting gripping implement will be found to be an invaluable friend at moments like these. Double check all of these connections very thoroughly as none of the high power semiconductors or the smooothing capacitors will take very kindly to wrong polarity voltages being applied to them and any mistakes

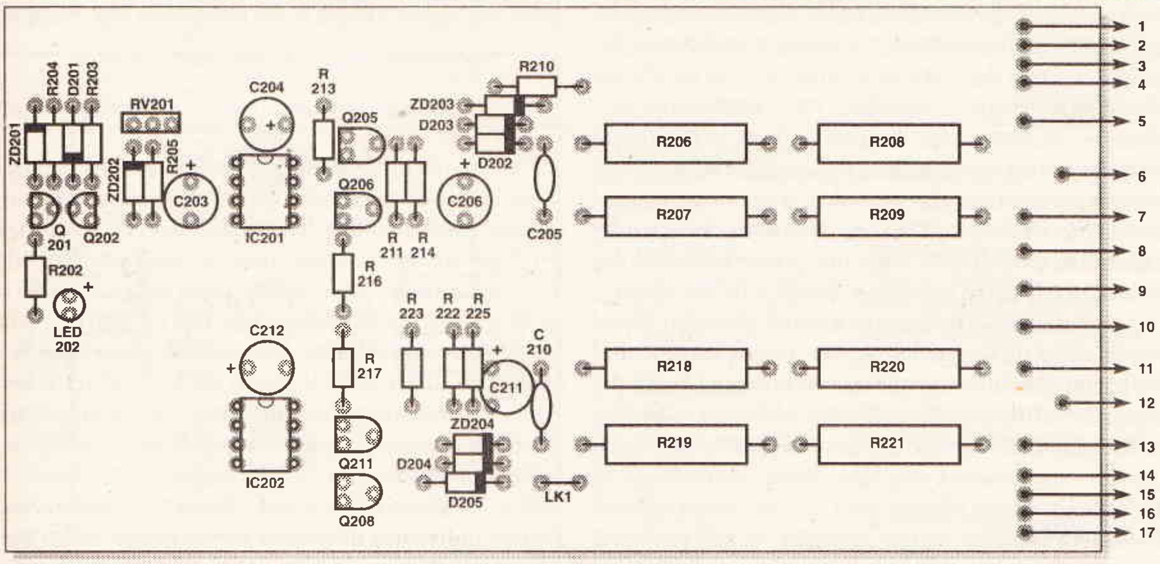


Fig.4 Precision +17,-17V Bipolar PSU component overlay

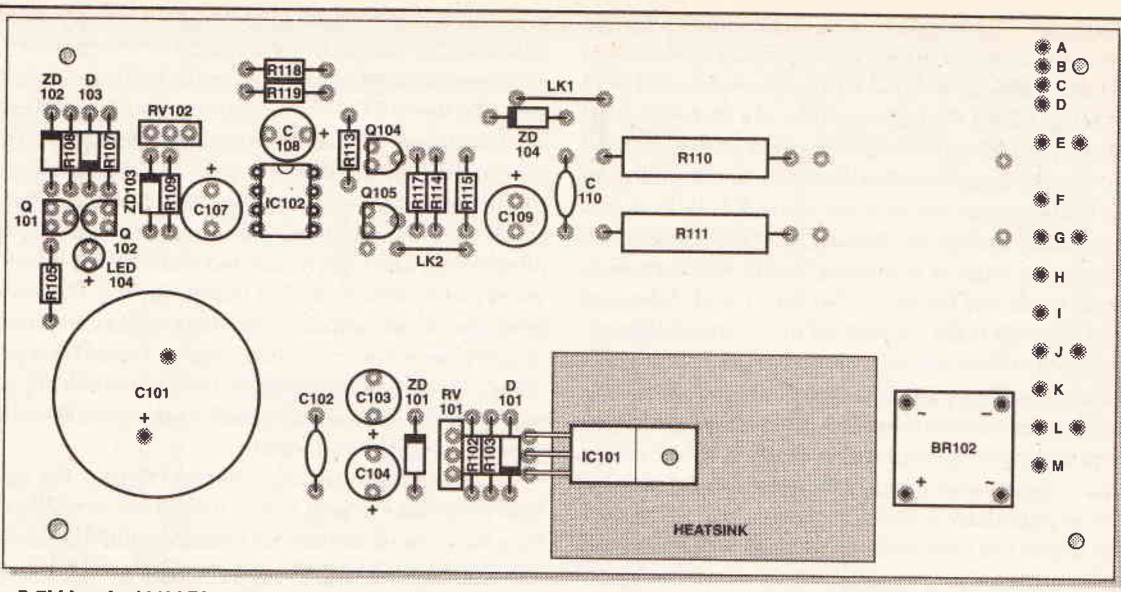


Fig.5 5V Logic /48V Phantom power PSU component overlay

will prove both catastrophic and expensive —power supply units of this size and capacity self-destruct, Mission Impossible-style, with great panache, fervour and an abundance of costly and spectroscopic pyrotechnics! Both the primary and secondary flying leads from the transformers are terminated in different ways. With both sets of wires, any enamel must first be scraped carefully from the wire. The primary wires connect to a shrouded and enclosed terminal block which distributes all of the mains voltages inside the unit. This method of mains distribution within the unit is in accordance with recent recommendations which state that TWO deliberate operations — which require the use of tools — should be necessary before any surfaces containing mains energy hazards are exposed. The secondary leads must be terminated with sleeved 1/4" Lucar style spade receptacles which then plug directly onto the Bridge Rectifiers (or onto the PCB in the instance of the 48V power supply).

Adhere rigidly to the wiring layout provided as it is proven to be stable and hum-free —others may not and any serious deviation is at the individual's peril. I used the expensive EP series of connectors, which are manufactured specifically for high current audio (normally loudspeaker connections) and bear some resemblance to XLR types, being latching and almost indestructible. These aren't mandatory requirements but they provide a secure and fail-safe means of power connection but all of this great spec. is at the expense —no pun intended —of quite appreciable extra cost. Two, four-way chassis-mounting connectors facilitate connection to the mixing console, a male and a female being used so that no errors may occur through mis-plugging of the corresponding connectors. The female type is used for the connector which carries the 48V supply —this means that the pin carrying this higher voltage connection cannot inadvertently be touched. Other connectors may be used but be wary of using those which will create a rear panel populated with more plugs than a typical Terry Wogan show! The Neutrik "Spaekon" is a good second choice, although, as it is intended for high power speaker connections, is manufactured only in single sex chassis mounting and free versions.

Prior to connecting the unregulated supply to any of the boards, ensure that all is well concerning the transformer/rectifier/smoothing capacitor section with respect to correct polarities etc. This advice cannot be over-emphasised.

The sound pressure level reading of a 22,000µ capacitor exploding because it has been connected round the wrong way has to be heard to be believed! Toilet paper sales rise in proportion to the size of this SPL reading.

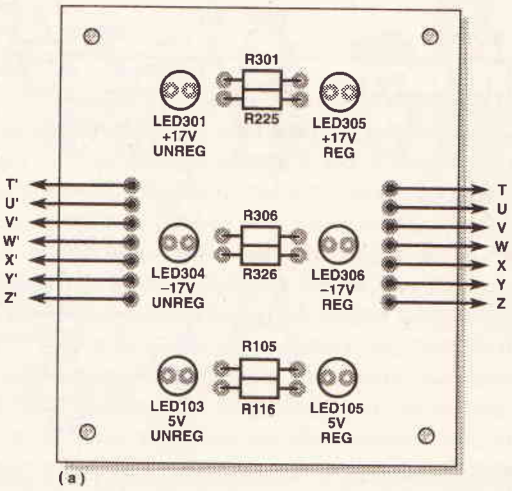


Fig.6a LED PSU monitor (+17/-17V switching 48V phantom)

Apply power and check for the presence of approximately +22V on C201 and −22v on C207. Disconnect power and go and make a coffee while the smoothing capacitors discharge completely. The charge stored on these is sufficient, in a short circuit load condition (soldering iron inadvertently touched between the two terminals) to weld said implement or a medium-sized screwdriver across the terminals.

Once this has occurred, then and only then should any connections be made to the PCB to be tested. Solder the plus and minus connections to the board, as mentioned previously, and the 0V connection too. At this

PROJECT

point in the proceedings, no other connections are necessary. Re-apply mains power and check for the presence of +6.2V on pin 3 of the IC socket of IC201, +22VDC on pin 7 of this socket and 0V on pin 4. Also check for -22VDC on pin 4 of IC socket 202 and for 0V on pin 4. If all is well in these respects, switch off power and wait, as before, for the capacitors to discharge. Insert both of the error amplifier IC's, respecting correct orientation, and connect one MJ11016 NPN pass transistor and one MJ11015 PNP pass transistor. These need not be fitted to sockets as they will be used throughout the testing of each of the three power supply PCB's. Again, ensure that the base, emitter and collector connections do not become transposed or that NPN and PNP are connected to the wrong supplies. The attached pinout table

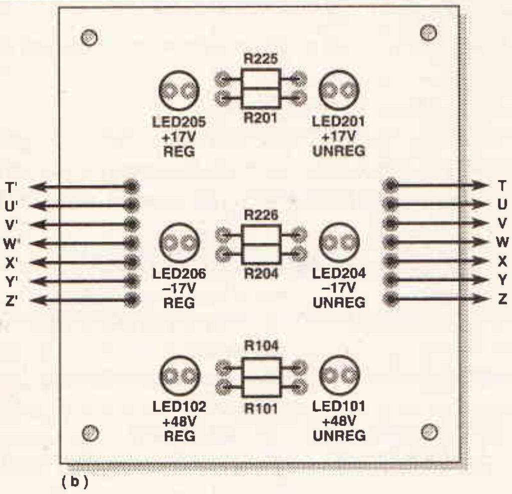


Fig.6b LED PSU monitor (+17V/-17V audio, 5V Logic)

lists all of the PCB connections and rigourous and careful heed should be paid to this. Finally, makethe connections to the high power finned and heatsink-encapsulated foldback limiting sense resistors, R212 and R224.

Now, reapply mains power and if eyebrows remain intact and unscorched, and there are no smells of burning or evidence of semiconductor misadventure, check the voltage on pin 8 of the board. If all is well, it should lie somewhere in the region of 10-18V and again, if a 'scope is available, there should be no visible signs of ripple on the waveform. Pin 10 should also be producing a regulated output voltage of equal and opposite (negative) magnitude — because of the tracking function — and again, there should be no discernible evidence of ripple.

With a proper trimming tool or a very fine bladed screwdriver, adjust multi-turn preset PR101 until the output voltage on pin 8 is exactly 17.00V. The negative rail outputted on pin 10 should have tracked this adjustment exactly and should of course be —17.00V.

Power can now be disconnected and after the discretionary capacitor-discharging time has elapsed, capacitors C203, 204, 212, 107 and 108 and which were omitted on the first constructional 'pass' at the board can now be inserted. They were not included first time round because of the time-lag effect which they produce between mechanical adjustment of the voltage-setting trimmer pot and evidence of the movement having any electrical effect on the output voltage. During prototyping and whilst they were fitted to the PCB when adjustments had still to be done, I found it almost impossible to set the output voltage to the correct value because the overdamped response meant that it hunted too slowly around the mean value for it ever to become correctable. You may be wondering why they were fitted at all. Their inclusion in the circuitry enabled me to squeeze yet another few dB's of noise and hum rejection from the output. The only slightly unfortunate consequence of their existence is the fact that this time-lag effect is apparent under normal operating conditions after the mains power to the unit has been initialised. In simple terms, 'this means that the outputs take some tens of seconds to stabilise to the full 17V output. If this is a problem in any applications, I am presently developing a relay circuit which will only enable the output sockets once ALL of the rails are at their correct nominal values. The by-product effect of this is, of course, that if ANY of the rails should fail, for whatever reason, all supply voltages are disconnected from the desk. I guess this is no bad thing in just about every conceivable circumstance, but it does introduce extra cost, complexity and another auxilliary item which can fail.

As you might have guessed, all of the above instructions refer to the bipolar audio or switching boards. I do not intend to go into any great detail about the procedure to be followed in the testing and setting up of the 5V/48V board. The 5V board uses circuitry identical in just about all aspects to the +17V board. Substitute 10V for the unregulated voltage figure, +3.1V for the precision reference voltage and +5V for the output. The setting of the +48V supply simply entails adjusting RV101 for an output of 48V.

Last month, when I explained the circuit operation,

Fig.8a NETLIST 1

5V LOGIC/40V PHANTOM - BOARD CONNECTIONS

Pin	Designation	Wiring Route
A	Unreg 9V DC input	520b (BR102,+connection)
B	Q103 Drive output	Q103 base connection
C	Over voltage sense O/P drive	Q106 base connection
D	Over voltage sense I/P	501 (EP4 way chassis socket Pin 3)
E	Sens resistor O/P	519a (R112 current limiting sense resistor I/P)
F	Non connected	–
G	Q103 emitter O/P	Q103 emitter connection
H	Feedback voltage I/P	519b (R112 current limiting sense resistor O/P)
I	0V	527 (star earth)
J	45V AC input	516b (45-0-45-0/50VA transformer secondary)
K	+48V DC reg out	510a (48V phantom fueseholder), 510b-507 pin 1, 510b-506 (LED PSU monitor board audio, Pin V)
L	+48V DC unreg out	506 (LED PSU monitor board audio, Pin Z[1])
M	45V AC input	516b (45-0-45-0/50VA transformer secondary)
–	Q103 collector	525a (15,000μ, C105 smoothing cap, +ve pin)
–	Q106 collector	507 (chassis plug Pin 3)
–	Q106 emitter	527 (star earth)
–	517a (Toroid 3 primary)	518 (mains terminal block)
–	517b (Toroid 3 secondary)	520a (BR102 I/P)
–	520b (BR102 O/P tve)	525a (C105[1] smoothing cap positive) – 514 (LED PSU monitor switching pin)
–	520b[1] (BR102 O/P ve)	527 (star earth)
–	519b (R112 output)	513a (5v logic fueseholder I/P) – 513b-501 (switching socket, Pin 3) 513b-514 (LED PSU monitor switching pin)
–	516a (Toroid 2 primary)	518 (mains terminal block)

*Other connnections – Toroid 2, 3 electrostatic screen connection to 535 (chassis earth)

Note: 5**a is an input, 5**b is an output, a and b are positive and negative connections to bridges and capacitors etc.

Fig.8b NET LIST 2

AUDIO +/-/+V PRECISION PSU (Part No505)

Pin	Designation	Wiring Route
1	Unreg +22V DC input	503a (+22V DC shrouded terminal block)
2	Q203, Q204 base Drive O/P	Q203 base connection, Q204 base connection
3	Q207 over voltage base O/P	Q207 base connection
4	+overvoltage sense I/P	507 (4 way audio chassis plug, Pin 4)
5	+sense resistor send	502a (R212 current limiting resistor in)
6	Q204 emitter return	Q204 emitter connection
7	Q203 emitter return	Q203 emitter connection
8	+sense resistor return	502b (R212 current limiting resistor out) also; 502b-508a (+17V audio fuseholder I/P); 508b (fuse O/P) - 507 (chassis plug-pin 1) 508b (fuse O/P) - 5006 (audio red PSU monitor board, pin T)
9	0V	527 (star earth)
10	-sense resistor return	504b (R224 current limiting resistor out) also; 504b-509a (-17V audio fueseholder I/P); 509b (fuse O/P) - 507 (chassis plug pin) - 509b (fuse O/P - 506 (audio LED PSU monitor board, pin U)
11	Q209 emitter return	Q209 emitter connection
12	Q210 emitter return	Q210 emitter connection
13	-sense resistor send	504a (R224 current limiting resistor in)
14	- overvoltage sense I/P	507 (4 way audio chassis plug; pin 1)
15	Q212 overvotage base O/P	Q212 base connection
16	Q209, Q210 base drive O/P	Q209 base connection, Q210 base connection
17	Unreg - 22V DC input	503b (-22V DC shrouded terminal block)
–	Q203 collector	503a (+22V DC shrouded terminal block)
–	Q204 collector	503a (+22V DC shrouded terminal block)
–	Q209 collector	503b (-22V DC shrounded terminal block)
–	Q210 collector	503b (-22V DC shrounded terminal block'
–	Q207 collector	507 (4 way audio chassis plug, pin 4)
–	Q207 emitter	527 (star earth)
–	Q212 collector	507 (4 way audio chassis plug, pin 1)
–	Q212 emitter	527 (star earth)
–	526a (toriod 201 prim)	518 (mains shrouded terminal block)
–	526b (toriod 201 sec.1)	521 (BR 201+bridge I/P)
–	526b' (toriod 201 sec.2)	522 (BR 202-bridge I/P)
–	521b (BR 201+ve O/P)	523a (C201+ve) - 503a (+22V DC shrouded terminal block - 506 (audio LED PSU monitor board - pin X); 532a (C201+ve) - + 22V DC switching shrouded terminal block - (switcing LED PSU monitor board - pin T)
–	521b (BR 201 -ve O/P)	527 (star earth)
–	523b (C201-ve O/P)	527 (star earth)
–	522b (BR 202 +ve O/P)	527 (star earth)
–	522b' (BR 202 -ve O/P)	524b (C207 -ve) - 503b (-22V DC audio shrouded terminal block) 514 (switching LED PSU monitor board pin U)
–	522b (BR 201 +ve O/P)	527 (star earth)
–	524a (C207 +ve O/P)	527 (star earth)
–	Toriod 201 electrostatic screen	535 (chassis earth)

I mentioned that the unit had a quite exemplary noise performance. This is of great importance but it should not be forgotten that any well-designed audio circuitry should have the inbuilt capability to operate in such a way that the noise and performance in many other aspects is as independant as possible of supply line fluctuations, noise etc although it is obvious that to eradicate these components, too, from the supply rails can only be advantageous. Modern IC's and circuit designs alleviate many of the problems which used to occur in discrete component designs of yore since the power supply rejection ratios of these discrete configurations were much worse by an order of magnitude.

It was somewhat remise of me not to include the other parts of the specification of the power supply which are equally important to the overall performance of the system. I also neglected to detail some of the other factors and considerations which have to be understood before a workable high performance design can be realised in practise. Only in this way can it be seen just how good the comparative performance of the PSU really is when placed alongside units of a similar genre.

As a slight aside — and probably because up to a point, I see the power supply unit only as a small but nonetheless necessary and important part of the mixer project — it was only when someone mentioned to me that with some slight modification, the unit could be configured as a stand-alone laboratory standard PSU and featured as a project in its own right that I realised two things.

1 Just how much time and effort I actually put into the design and construction

2 How good the design was.

With this in mind, I think that some slight indulgence is permissible, and so to conclude this month's part of the series, I shall explain by way of a tutorial some of the

Fig.8c NET LIST 3

SWITCHING +/-17V PRECISION PSU (Part No534)

Pin	Designation	Board/System Interconnections
A	Unreg +22V DC input	523a (+22V DC switching shrouded terminal block
B	Q303, Q304 base Drive O/P	Q303 base connection, Q304 base connection
C	Q307 + overvoltage base O/P	Q307 base connection
D	+ overvoltage sense I/P	501 (4 way switching chassis socket - pin 4)
E	+ sense resistor send	531a (R312 current limiting resistor in)
F	Q304 emitter return	Q304 emitter connection
G	Q303 emitter return	Q303 emitter connection
H	+ sense resistor return	531b (R312+current limiting resistor out); also 531b-511a (+17V switching fueseholder I/P); 511b (fuse O/P) - 501 (chassis SKT-1) 511b (fuse O/P) - 514 (switching LED PSU monitor board, pin X)
I	0V	527 (star earth)
J	- sense resistor return	533b (R324-current limiting resistor out) also; 533b-512a (-17V switching fuseholder I/P); 512b (fuse I/P) - 501 (chassis S pin 1); 512b (fuse O/P) - 514 (switching LED PSU monitor board, pin)
K	Q309 emitter return	Q309 emitter connection
L	Q310 emitter return	Q310 emitter connection
M	-sense resistor send	533a (R324 current limiting resistor in)
N	—overvoltage sense I/P	501 (4 way switching chassis socket; pin 1)
O	Q312 overvoltage base O/P	Q312 base connection
P	Q309, Q310 base drive O/P	Q309 base connection, Q310 base connection
R	Unreg -22V DC input	532b (-22V DC shrouded terminal block)
–	Q303 collector	523a (+22V DC shrouded terminal block)
–	Q304 collector	532a (+22V DC shrouded terminal block)
–	Q309 collector	532b (-22V DC shrouded terminal block)
–	Q310 collector	532b (-22V DC shrouded terminal block)
–	Q307 collector	501 (4 way switching chassis skt - pin 4)
–	Q307 emitter	527 (star earth)
–	Q312 collector	501 (4 way switching chassis skt - pin 1)
–	Q312 emitter	527 (star earth)

MISCELLANEOUS CONNECTIONS

529a (mains in, live)	528a (mains fuseholder); 528b (fuse out) - 518a (mains terminal block)
529b (mains in, neutral)	518b (mains terminal block, neutral)
529c (mains in, earth)	535 (chassis earth)
506, pin W'N (0V PSU mon)	527 (star earth)
514, pin W (0V PSU mon)	527 (star earth)
530a (ground lift switch)	527 (star earth)
530b (ground lift switch)	535 (chassis earth)

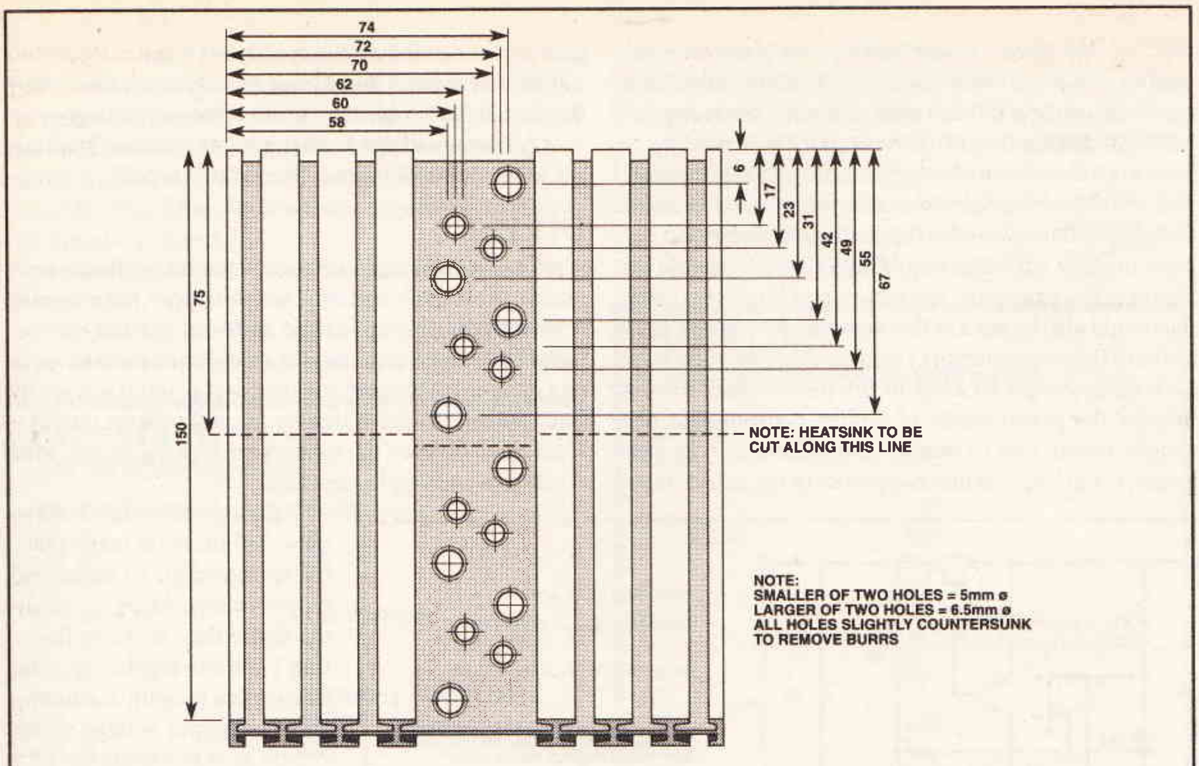


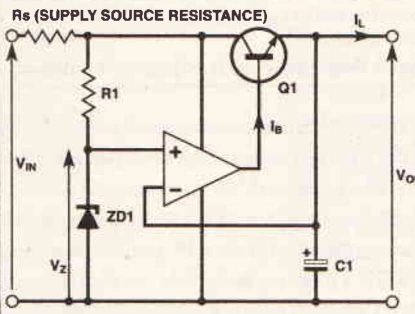
Fig.9 PSU Heatsink drilling details

important terms and specifications which have to be understood when striving to design a good specification. We'll look at the specs and how they can be determined mathematically and then gradually work up through the various types of regulator in order of increasing complexity, until the last design will produce ripple rejection, line and load regulation and noise figures around those of the AutoMate supply. In this way, it will become more readily apparent to the reader some of the features of design which both increase cost and expenditure.

Aha! Money, you say. A very important criteria in this design and it keeps coming back to us again and again like a bad penny! With the power supply, I was more aware than ever of this aspect and the fact that the determining factor, I think, in whether audio enthusiasts and musicians will wish at the end of this series to build their own AutoMate mixer will depend on cost in comparison to ready-built units. If we can quickly return to something which I said in part 1, there seems recently to have been a disheartening trend in the major pro-audio commercial sector to produce, much to my personal dismay, an ever-increasing number of budget-priced mixing desks. These come complete with a bewidering array of good features (limited mute and automation facilities among them) and are ideally suited to those among the musical fraternity who like to retain as much of their hard-earned cash as possible. Whether this is because of the global recession of the past few years is open to conjecture —cynics may speculate that the only way in which the manufacturers' of consumer luxuries can shift the goods in the present-day financial climate is to produce equipment which is excellent value for money. Personally, I'm inclined to believe that it is not out of some well-intentioned (but misguided) philantropic urge that they do this!

It does, however, serve as a timely reminder that the designs offered within this journal must compete successfully with similar commercial designs. It should be said, though, that we don't start this commercial race on an equal footing —hark back to my meanderings about bulk-buying et al in Part 1. Bearing in mind that the author of the article does actually want some of you out there to build the machine, I think it appropriate that in the places where economies CAN be made without adversely affecting performance, I mention the fact.

The power supply is a good case in point and an excellent place to start. (It is for this reason that I shall go on to explain the processes involved in the design of PSU's, since this will then provide the building blocks for anybody wishing to make economies to start by constructing their own design). I have to state at this juncture



FOR CORRECT OPERATION VCE ≥ 3V

EQUATION (1) $\Delta I_Z = \dfrac{\Delta V_S}{R1}$

USING DYNAMIC IMPEDANCE FOR ZENER DIODE ΔV_O,

EQUATION (2) $\Delta V_O = \Delta V_Z = \Delta I_Z Z_D$

EQUATION (3) $\Delta V_O = \dfrac{\Delta V_{IN} Z_D}{R1}$

EQUATION (4) $\Delta V_{IN} = I_{L(MAX)} R_{SOURCE}$

EQUATION (5) $\Delta V_{OUT} = \dfrac{I_{L(MAX)} R_{IN} Z_D}{R1}$

EQUATION (6) $Vro = \dfrac{Vrs\, Z_D}{R1}$

EQUATION A

$$\text{LINE REGULATION} = \frac{(\Delta V_{OUT} \text{ FOR } \pm 10\% \ V_S \text{ CHANGE}) \times 100\%}{V_{OUT}}$$

EQUATION B

$$\text{LOAD REGULATION} = \frac{(\Delta V_{OUT} \text{ FOR } \Delta I_{L(MAX)}) \times 100\%}{V_{OUT}}$$

EQUATION C

RIPPLE REJECTION = 20 LOG [Vrs/Vro]

(Vrs = SUPPLY RIPPLE)
(Vro = OUTPUT RIPPLE)

Fig.10 Circuit model 1 Simple voltage follower regulator

that, yes, the mixer —in its smallest form, of course —will operate adequately well using a 78/79 series monolithic regulator-centred PSU so long as a wary eye is kept on current consumption of the unit. For those wishing to save a not insubstantial amount of the old folding stuff, and who know outright from the onset of construction that they will never wish to upgrade the unit beyond say, eight module capacity, this MIGHT be the way to go. Smaller, less expensive capacitors and less hefty toroidals could also be used in this instance. As a purist, but a purist of the pragmatic sort, I cannot advocate or endorse such an approach so early in the proceedings since it impairs the performance of a large console with one simple action, and in one fell swoop to boot. In later issues, it will become more apparent to the reader that I have had to go to some quite extraordinary lengths to squeeze the last dB into the noise spec or crosstalk spec or any number of other measurable parameters of audio fidelity and so, quite frankly, it seems a shame to forego a truly revelationary audio experience by penny-pinching in the area of the PSU. I might qualify this sweeping statement by saying that I am not so long in the tooth that I cannot remember fretting in the local shop, anxious that my meagre £30 wouldn't be enough to pay for the miserable little bag of assorted passive components being offered to me! It also depends on whether or not the mixer is to be used in a totally analogue environment. If it is judged that some sort of digital recording or playback equipment may at some time be connected to the console, (and this is somewhat surprisingly the case, with increased amateur usage of CD and DAT for mastering processes), it is as well to remember that this domain is rather good at showing up any deficiencies in analogue circuitry. These deficiencies, otherwise masked by the inherently noisier performance of outboard analogue equipment, become glaringly and embarrassingly obvious when subjected to a stream of digits. I mentioned this aspect in the "Introduction to Audio Mixers" series some months ago.

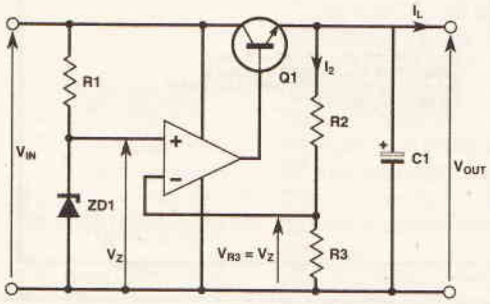
Anyway, without further ado, and as the Orientals say in my native Scotland, "Read on Macduff!

DIY PSU

A perfect voltage regulator should output a voltage which remains absolutely constant, with no ripple, regardlees of both supply — input -voltage and load current fluctuations. Real regulators always exhibit some output ripple so a measure of the performance of the circuit is given by three measurements which we can make on the circuit — these three defined parameters are line regulation, load regulation and ripple rejection.

Equations 1 to 3 show these definitions as mathematical relationships of input and output voltage. More explicitly, the figure derived from Equation 1 for line regulation, Vout defines as a quantity the fluctuation in output voltage which occurs as a consequence of a specified amount of fluctation —normally ±10% - on the supply voltage, V_{in}. It is expressed as a percentage of normal DC output (V_{out}). Load regulation is the inherent ability of the regulator to maintain a constant output voltage regardless of changes in load current (I_{load}). The load current change is from zero to the full rated output current capability of the circuit and load regulation (V_{out}) is expressed as a percentage of the normal output voltage.

Ripple rejection is a measure of the ratio between the amount of ripple present on the input to the regulator and the attenuated version of the ripple which is superimposed on the output. It is typically quoted in the form of x dB's of ripple rejection.



EQUATION (7) $V_{R3} = V_Z$

EQUATION (8) $V_O = V_Z \dfrac{(R2 + R3)}{R3}$

EQUATION (9) $\Delta V_O = \dfrac{\Delta V_Z Z_D}{R1} \times \dfrac{R2 + R3}{R3}$

LINE REGULATION, LOAD REGULATION AND RIPPLE REJECTION CALCULATED AS PER FIXED OUTPUT REGULATOR

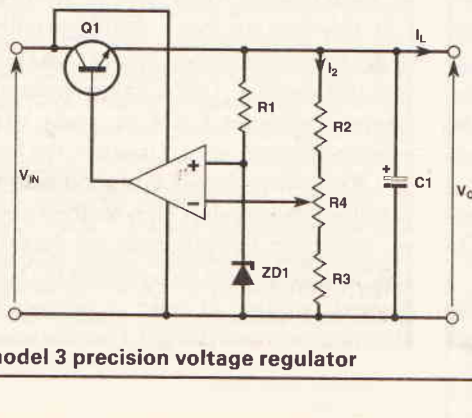
POTENTIAL DIVIDER R2 AND R3 MAKES $V_{OUT} > V_{IN}$

Fig.11 Circuit model 2 Regulator with adjustable output

Straight From The Drawing Board

Figure 10 shows the very simplest regulator circuit. The inclusion of C1 across the output terminals helps to improve the current sourcing capability of the circuit under transient load conditions and it is typically of a value in the order of 50-100μ.

The voltage follower configuration means that V_{out} will remain as close to the voltage, V_z, present at the non-inverting terminal of the error amplifier.



EQUATION (10) $\Delta V_{OUT} = \dfrac{\Delta V_{IN}}{M} \quad \dfrac{R2 + R3 + R4}{R3}$

EQUATION (11) $V_{R1} = (V_{OUT} - V_Z)$

EQUATION (12) $I_B = \dfrac{I_L}{h_{FE}}$

Fig.12 Circuit model 3 precision voltage regulator

PROJECT

Zener current fluctuation I_z must first be calculated. The current must fluctuate because V changes as V_{in} changes. Differences in the zener output voltage mean that there must also be corresponding changes in V_{out}. I_z is calculated from Equation 1. Next we must calculate V_o using the spec. figure for the zener dynamic impedance and Equations 2 and 3.

Line regulation can then be calculated for a 10% change in V_{in}.

Calculating the load regulation requires that we know the value of the sorce resistance of the rectifying and smoothing network feeding the circuit. We can then calculate using Equations 4 and 5 the drop in V_{in} when the load current changes from zero to I max.

Substituting V_o due to the change in load current into Equation B yields the load regulation value. We are now able to calculate ripple by substituting V_{in} with V_{ri} and V_{out} with Vro in Equation 2. These values then plugged into Equation C gives the ripple rejection.

PARTS LIST

µ±17V PRECISION POWER SUPPLY

RESISTORS (All ¼watt, 1% unless otherwise stated)

R201,215	1k8
R202, 203	470R
R205	120k
R206-209,218-221	R1 5W Wirewound
R210,223	1k5
R211,222	15k
R212,224	0R33 25W High Power Heatsinked
R213	220k
R214,225	1k0
R215,226	1k5
R216,217	10k
RV201	10k vertical multiturn preset

CAPACITORS

C201,207 (Common to both ±17V Precision PSU's)	22,000µ, 56V Cerafine Audio Grade Electrolytic (MAPLIN Part No. FA20W)
C202,208 (Common as stated above)	100n polyester
C203,204,209	100µ, 25V electrolytic
C205,210	470n polyester
C206,211	470µ, 25V electrolytic

SEMICONDUCTORS

IC201,202	TL071
Q201,205,206	BC549C
Q202,208,211	BC559C
Q203,204,205	MJ11016
Q209,210,212	MJII015
D202,203,204,205	1N4003
ZD201,202	1N821 Precision Zeners (RS Components Part No. 283-097)
ZD203,204	16V, 1W3 Zener
LED201,203,204,205,206	0.2" Yellow LED
LED202	0.1" Green LED
BR201,202 (Common to both ±17V precision PSU's)	25A, 400V High power Bridge Rectifier

MISCELLANEOUS

T201	500VA 15-0-15-0 Toroidal Transformer (Newmarket Transformers Tel 0638 662989 for details)
2 off I.1C/W Heatsinks	(RS Components Part No.401-807 6 off T03 transistor sockets, covers)

(Farnell Part Nos. 170-030, 170-131 1mm ,2.5mm connecting wire of various colours, 4BA screws, M3 mounting hardware (nuts, bolts, washers, threaded spacers), M2 nuts, bolts and solder tags, insulating sleeves, cable ties, 20mm panel mounting fuseholders, PCB's (2 off ±17V Precision Power Supply type for audio and switching, 1 off LED PSU Monitor type and double all quantities of components in semiconductor, capacitor and resistor sections).

PARTS LIST

5V LOGIC SUPPLY/48V PHANTOM POWER SUPPLY

RESISTORS

R101,104	5K1
R102	Ik8
R103	240R
R105,106,107,115	470R
R108	820R
R109	56k
R110,111	0R1 5W Wirewound
R112	0R5 25W High Power Heatsinked
R113	33k
R114	4k3
R116	330R
R117,118	10k
RV101	500R vertical multiturn preset
RV102	10k vertical multiturn preset

CAPACITORS

C101	4700µ 63V electrolytic (RS Part No. 106-265)
C102	100n Polyester
C103,107,108	100µ 63V electrolytic
C104	100µ 63V electrolytic
C105,106	6800µ 25V electrolytic (RS Part No. 105-688)
C109	470µ 25V electrolytic
C110	470n Polyester

SEMICONDUCTORS

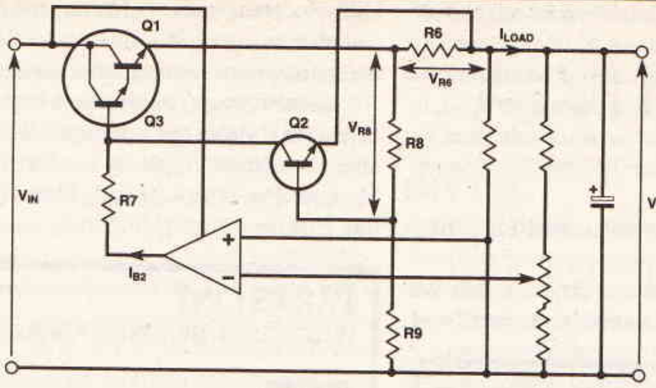
IC101	LM317T
IC102	TL071
Q101,104,105	BC549C
Q102	BC559C
Q103,106	MJ11016
D101,102,103	IN4002
ZD101	45V, 1W3 Zener
ZD102,103	1N821 Precision Zener (RS Part No. 283-097)
BR101	6A, 200V Bridge Rectifier
BR102	25A, 200V High Power Bridge
LED101,102,103,105	0.2" Yellow LED
LED 104	0.1" Green LED

MISCELLANEOUS

T2 (Newmarket Transformers 45-0-45-0 50VA Toroidal) , T3(Newmarket Transformers 9-0-9-0 50VA Toroidal), M2 nuts bolts and solder tags M3 mounting hardware, 1 and 2.5mm connecting wire of various colours 3 off 5x20mm panel mounting fuseholders and insulating boots, 1 off 48V Phantom Power Supply/5V Logic PCB and I off LED PSU Monitor PCB, I.IC/W Heatsinks, Veropins, cable ties, T03 transistor sockets and covers, RS Components 9.9C/W finned heatsink (Part No. 401-964).

MISCELLANEOUS TO COMPLETE THE POWER SUPPLY UNIT

IEC Mains filter (RS Part No. 210-263), IEC Insulating boot, 3 way and 4 way shrouded terminal block (RS Part Nos. 424-563 and 425-869), 5×20mm panel mounting fuseholder and insulating boot, 2U rack mounting case, 4 Way EP Style connectors, RS Components (Chassis Plug 460-317, Free plug 460-250, Chassis Socket 460-288, Free Socket 460-222)



IN SHORT CIRCUIT SITUATION, $V_{OUT} = 0$

EQUATION (13) $\therefore V_{RG(ISC)} = I_{SC} \times R6$

DURING NORMAL OPERATING CONDITIONS, WHEN $I_L = I_{MAX}$

EQUATION (14) $V_{R8} \approx \frac{V_{OUT} \times R8}{R8 + R9}$

FOR Q2 TO TURN ON, V_{R6} MUST EQUAL

EQUATION (15) $I_{L(MAX)} R6 = V_{BE} + V_{R8}$

AT ELEVATED TEMPERATURES, $V_{BE} \simeq 0.5V \therefore V_{R8} \simeq 0.5V$

$\therefore I_{L(MAX)} R6 = 0.5V + 0.5V$

AS $I_{SC} R \simeq 0.5V \quad I_{L(MAX)} = 2I_{SC}$

IF $V_{R8} \approx 1V$ THEN $I_{L(MAX)} = 0.5V + 1V \quad I_{L(MAX)} \approx 3I_{SC}$

FOR DARLINGTON CONNECTION, $I_{B2} = \frac{I_L}{h_{FE1}\, h_{FE2}}$

Fig.13 Possible enhancements to basic regulator model- Foldback current limiting/Darlington output stage

Figure 11 expands on this simple regulator circuit of Figure 10 to give an adjustable output voltage. In this circuit, V must always equal V_z, the op-amp output moving to oppose any changes which would alter this condition. Design using equations 8 and 9. 9 shows that just as the zener voltage is amplified by the network comprised of (R2+R3)//R3 to calculate V_{out}, so any fluctuations in the zener voltage must be multiplied by this same factor.

Figure 12 shows a configuration which closely approximates the AutoMate PSU circuitry. We have already demonstrated that variations in the zener output voltage have a very marked and hence detrimental effect on the output voltage. Feeding the zener network from the regulated rather than the unregulated voltage means that input voltage variations have little or no effect on the zener voltage since as we have already seen, these fluctuations are attenuated before reaching the zener (according to Equation 10). Points to note include the fact that the op-amp output must remain at a more positive potential than V_{out}. This is made possible by powering the op-amp from the higher, unregulated input voltage.

Design is as for the simple voltage regulator circuit of Fig 10, save for the fact that V is now $V_{out} - V_z$ rather than $V_{in} - V_z$. Equation 12 show the parameters necessary to calculate Q1 base current.

Any of these circuits may be protected by adding a foldback limiting network. In calculating the potential divider and sense resistor values, remember that in a short circuit load condition, V_{out} is zero. We design so that V in a short circuit situation is of such a value that Q2 is biased on. Equations 13 to 15 show the procedure. R must first be calculated for the short circuit current, I which is desired. Next, determine the values for the potential divider resistor values, chosen so that there is necessary voltage across R8 to give the desired ratio of I_{max} to Isc.

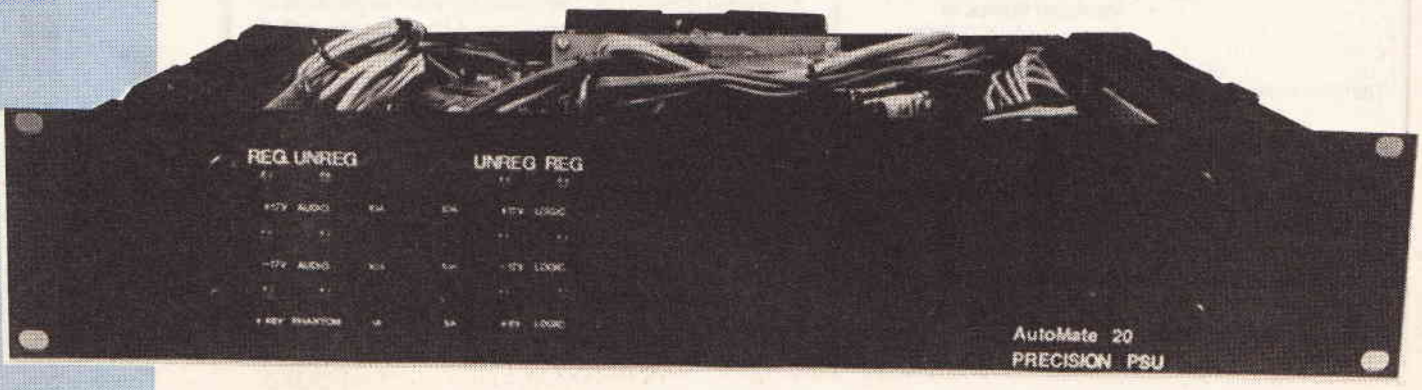
Next month we rewiew the long-awaited return to the input stage circuitry, with a lengthy (and hopefully illuminating) discussion on grounding, together with Figure 7 the interconnection diagram which could not appear this month owing to lack of space.

References

Operational Amplifiers: Applications, Trouble-shooting and Design (DC Voltage Regulators) —David A. Bell (Prentice Hall)

A Practical Introduction to Electronic Circuits (Power Supplies and Power Control) —Martin Hartley Jones (Cambridge University Press)

The Art of Electronics (Power Supplies and IC Voltage Regulators) —Horowitz and Hill



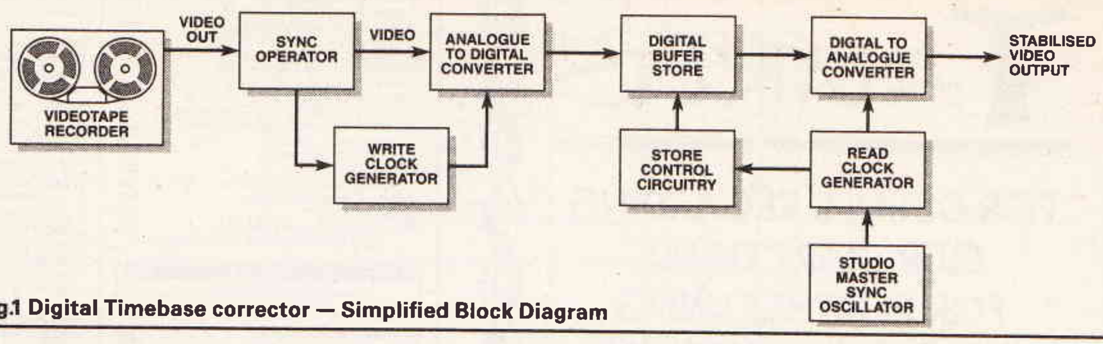


Fig.1 Digital Timebase corrector — Simplified Block Diagram

2

Digital Television

Digits in studios

A View of the Future by James Archer

In part one of this series we discussed how the coming of the digital video recorder has revolutionised studio operating techniques by allowing programme makers to create images from many different generations of recordings, without the build up of noise and distortions that would occur with any analogue recording machine. In other studio areas too, digital techniques have been used for many years, primarily because they allow the programme makers to do things that are very difficult or even impossible to achieve by normal analogue means. Until recent times, however, each piece of digital processing equipment was used for a particular purpose, and operated quite separately from any other pieces of digital equipment; since the signal path was essentially analogue, the analogue signals at the input of each piece of digital processing equipment had to be converted into digital form and then, after undergoing the digital processing, had to undergo yet another conversion, from digital back to analogue. As we mentioned earlier in the series, repeatedly passing signals through 'codec' stages can degrade the signal quality.

The Time Base Corrector (TBC)

One of the first pieces of digital studio equipment to be used regularly was the time base corrector (TBC), a digital store of from 3-16 television lines, which was vitally important in making the analogue helical scan videotape recorder into the universal studio tool that it has become. Since television signals require extremely close timing specifications to be adhered to, videorecorder mechanisms are subject to enormously stringent requirements if these timings are to be achieved. In essence, all videorecorders make use of electronics to compensate for the unavoidable mechanical tolerance errors inherent in the operation of such machines. Small variations in the speed of the tape and of the head rotation, due to mechanical tolerance limitations, might merely cause annoying 'wow' and 'flutter' on an audio recorder, but on a videorecorder could render television pictures unwatchable as the synchronisation mistimings cause picture breakup and jitter. A timebase corrector reads a few lines of the picture at a time into a digital store, and subsequently reads the information out of the store at a time which is precisely determined by the accurate synchronisation signals used throughout the rest of the studio. How much memory is actually needed to overcome the various timing errors that can occur will depend upon the actual setup used. Timebase correctors can also include 'dropout compensators', which are again based around stores which are capable of holding several lines of a television

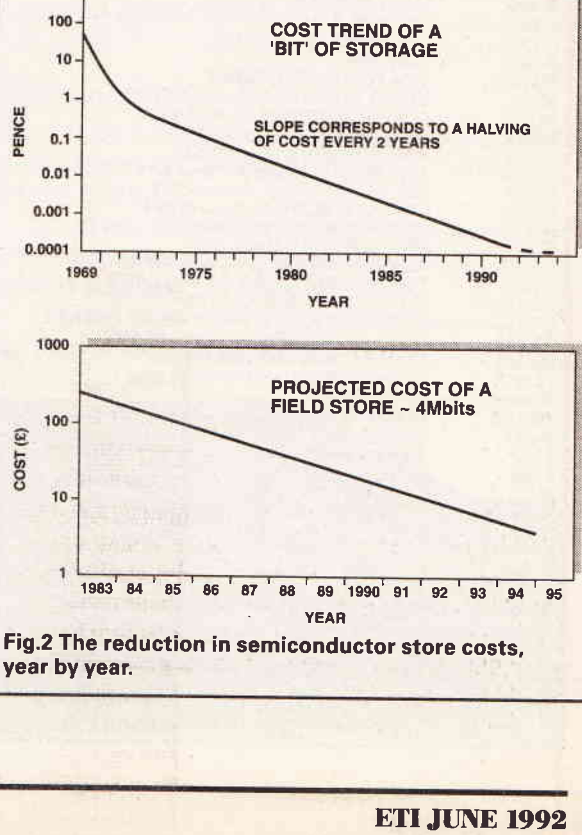


Fig.2 The reduction in semiconductor store costs, year by year.

ETI

picture. Should a dropout occur, where the playback head does not deliver a particular part of a picture, perhaps because a particle of oxide has momentarily lifted the tape from the head, the previous television line that has been stored is read out again, so filling in the 'hole' that the dropout would otherwise have made in the picture. In practice, more sophisticated techniques are used, based on interpolation between several stored lines, to more effectively replace the missing parts of the picture.

In the early days of digital technology the cost of the actual storage was high, so that it made a significant difference to the cost of a TBC whether three lines or 16 lines of storage were provided, but as storage costs fell because semiconductor manufacturers managed to squeeze more and more bits on to individual chips, it became realistic to build equipment which could store one or more complete television picture frames, the digital frame store.

The synchroniser

Ever since television broadcasters began to bring together signals from several sources to assemble a complete television programme in the studio, there have been problems in ensuring that the timing of the individual source pictures remained within tolerance. Just imagine the problems involved in combining pictures from several outside broadcast sources with pictures generated in the studio — a discrepancy of only a few microseconds between the various picture timings would inevitably lead to the viewer seeing the picture break up every time that a switch to a different non synchronous source was made, which could be dozens of times during the average Saturday afternoon sports programme.

Before the advent of frame stores, complex arrangements were required, which allowed the master oscillator in the studio to be locked to the synchronising signals incoming from the remote source, a process known as 'gen-locking'; life became enormously complex for the studio engineers when gen-locking was used to synchronise more than a couple of sources. An alternative system called 'Natlock' was used with multiple remote programme sources, whereby the timing of the incoming signals was compared with that of the studio synchronisation pulse generators, and correction signals were sent from the studio along telephone lines to the remote sites, where the timing of the synchronising signals was adjusted to precisely match that of the studio signals. The digital frame store overcomes all these problems and makes life very much easier. In essence, digital frame stores can be used to hold one or more frames of the incoming picture signals from the various sources, and these pictures can be read out of the store whenever required, at a time which is controlled by the synchronising pulses from the studio master oscillator. All the sources are therefore automatically re-timed so that they are fully synchronous, and this use of the digital frame store led to its being called a 'synchroniser'. As well as the main memory store, the synchroniser consists of processing circuitry to cope with the incoming video and synchronising signals, needed to determine the manner in which the incoming signals are written to the store. The output from the store is controlled by the reference synchronisation signals, typically from the studio master oscillator. Note that the output from a synchroniser will be delayed with respect to the input, since we are effectively asking the equipment to store the picture frame until the time is appropriate for it to be displayed, which is when the synchronising pulses are synchronous with those of the studio output. Passing a picture through several synchronizers, which could happen as video signals are distributed around a national network of studios, as happens in the UK Channel Three system, could lead to these delays building up so much that the pictures are no longer in 'lip-sync' with the sound, and the broadcasters have to take care to ensure that appropriate steps are taken to avoid this. Digital audio delay units are available from several manufacturers which can delay up to eight channels of digital audio and any associated time code signals, to match the video delay in the system. The delay can be adjusted in terms of fields, milliseconds, or samples, and many units can cope with the various digital audio sampling frequencies that are normally used in broadcasting, 48kHz, 44.1kHz, and 32kHz.

Fig.3 The digital synchroniser

Digital Video Effects

The basic storage components of the synchroniser can however be used for other purposes, and it is the structure upon which all digital video effects equipment is built. As a simple example, once a picture frame has been digitised and stored, the output of the store could easily be used to provide a freeze frame effect, and with the application of various complex computer based processing techniques a wide range of different effects can be produced, albeit at a much increased equipment cost.

The frame store is essentially a computer store, using digital random access memory (DRAM) to provide millions of individual storage boxes, with one box for each picture element.(There could be a box for the luminance value of each picture element and another for the colour or chrominance value.) The process of scanning a television picture along a line and line by line would be equivalent to counting along the individual boxes of the store. We would have no problem in understanding that the ones and noughts in a computer memory could be shuffled about as required, could be added to, subtracted from, or multiplied by a particular factor, and so it is clear that once the numbers representing the characteristics of each element of a picture have been placed in their proper positions in the frame store, we need not necessarily read them out of the store in the same order as we placed them in the store, which occurs when using the frame store as a synchroniser.

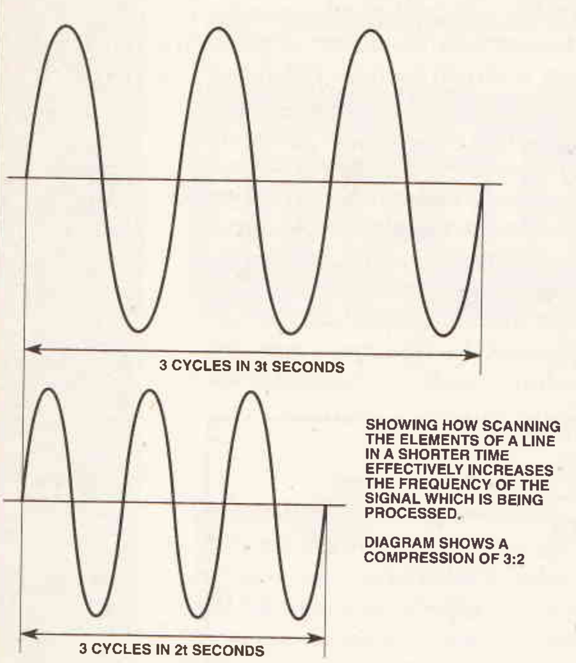


Fig.4 Showing how scanning the elements of a line in a shorter time. i.e. by speeding up the counters. the frequency of the signal is effectively increased.

Simple Special Effects

Reversals

If we decide to read out from the store in the reverse order to that in which the values of the picture elements were inserted into the store along each line, then we will obtain a simple 'special effect' —the picture would be reversed horizontally. Similarly, if we reverse the order in which we count out the lines made up from the elements of the store, we will obtain another special effect —the picture will be reversed vertically.

Picture Shifts

Just as it would be possible to add a fixed number to each of the values in a computer store, we can add a fixed offset to each of the addresses in our frame store, resulting in the picture being shifted, horizontally, or vertically, or in both directions, as we choose. This forms the basis of a whole range of other special effects.

Changing the picture size

In essence we could make the picture emerging from the frame store smaller than the one which went in simply by increasing the speed of the horizontal and vertical counters which control the readout from the store. We could make the picture bigger by simply slowing down the counters. Unfortunately, real life is not so simple and we must carry out other processes as well. When we reduce the picture size by speeding up the counters we are making the picture pixels physically smaller on the screen. So being scanned in a shorter time, the signals will effectively be at a higher frequency than they were originally.

Readers will remember from the sampling theory explained in the first part of this series that digital signals must normally be sampled at a rate of at least twice the highest frequency contained in the signal, the so-called Nyquist criterion. The digital signal we are dealing with has already been sampled at a frequency appropriate to a certain number of picture elements occuring during a whole line period, and since we have speeded up the clocks controlling the readout from the store we will now have a situation where the Nyquist criterion is no longer satisfied —we are no longer sampling at twice the highest frequency. The result is known as aliasing, a situation where the excessively high frequencies are converted into lower frequencies, which show up as objectionable patterns on the picture. To prevent this, we must, filter the video signal to remove all components that would end up above the Nyquist frequency before we attempt to reduce the size of the picture from the store. Any other geometric transformations or translations of the image will similarly need appropriate filtering to be applied to the signal, and digital filters, which generally consist of strings of fairly simple digital delay circuits, adders and multipliers, can be designed so that they can rapidly change their characteristics to suit the nature of the signal to be processed. The necessary changes must take place within approximately one sample period if distortions are not to be noticeable. The characteristics of the available filters, such as their bandwidth and the amount of physical displacement or offset which will be provided, may be stored in 'look-up tables' to minimise the calculations required for each effect. It is worth noting that the construction of suitable filters using analogue circuitry would be extremely difficult, because of the requirement that the filters must be able to change their characteristics very quickly. This may not seem a very dramatic example of the advantages of digital technology over analogue, but in practice turns out to be extremely important.

We have seen that the frame storage part of the DVE equipment needs some form of complex controller in order to provide the multiplicity of video effects that are nowadays required by even the least imaginative of programme directors, and since the frame store is effectively a computer store, it seems logical that the control should be specially written computer programs or algorithms, operating in microprocessor chips. The picture stored in the frame store can then be addressed pixel by pixel, and the control programme can calculate the new position (i.e. the address in the frame store) of every pixel when the necessary mathematical operations have been carried out on the picture, whether the aim is to wrap the picture around a 'Coke' can, or to perform an electronic zoom in which a tiny part of the original picture is magnified to fill the screen. If the amount of zoom or magnification is excessive, the resulting picture will be of lower resolution than the original, in the same way that an excessively enlarged newspaper photograph will show up the gaps between the dots from which it is made. Since the digital filter characteristics can be precisely controlled, the equipment can be considered as completely transparent when no special effects are being called for; the picture can be compared and accurately registered with the original source picture having passed through a digital video effects machine.

Some other digital effects are obtained by straight manipulation of the signal as it is converted from analogue to digital form. As an example, if an insufficient number of quantising levels is used to represent the original analogue signal, 'contour lines' can be seen between areas of picture of differing brightness. When this happens accidentally, the effect is usually called 'contouring', but when the effect is wanted, and is deliberately sought by the producer, it is usually called 'posterisation', after the photographic technique that provides a broadly similar effect. Other electronic effects are 'solarisation', where the number of bits used to describe the colour signals is deliberately reduced, and 'pixelisation', in which groups of contiguous picture elements are replaced by rectangles of uniform brightness and colour. Digital video effects machines offer a wide range of other special effects, some of which could, with difficulty, be achieved by analogue means, but their digital implementation is generally far more satisfactory, and results in better quality pictures. Some effects are self expanatory, such as the 'swinging gate', 'flips' and 'tumbles'. Other typical effects are:

Spotlight effect —a special effect in which one part of the picture, often circular in shape, is made much brighter than the rest.

Negative effect —the normal image signal is replaced by another signal such that the instantaneous levels of the luminance signal are inverted symmetrically about a median grey level.

Complementary picture effect —the effect on a colour picture where colours are replaced by their complementary colours, i.e. those whose chrominance vectors are 180° out of phase on the PAL vector diagram.

Smoothing —the effect on an image in which the neighbouring values of the luminance signal are replaced by a single value. The same process may be carried out for chrominance signals.

Inset, or picture in picture —the effect where one or more small digital pictures or parts of pictures of predefined shapes are displayed inset into the main picture, and can be moved around at will. This effect is very difficult to achieve by analogue means, because it is hard to maintain the synchronisation of each of the different pictures.

Border effect —a special effect in which only the edges of a televised object are highlighted.

Outline effect —an effect in which only the edges of a televised object are reproduced.

Routing and Distribution of Digital Signals

We saw in the first part of this series that in studios we are likely to have to deal with two different kinds of digital signals, component digital, where we need to treat luminance and colour difference signals separately, and composite digital, where we are dealing with digitised PAL

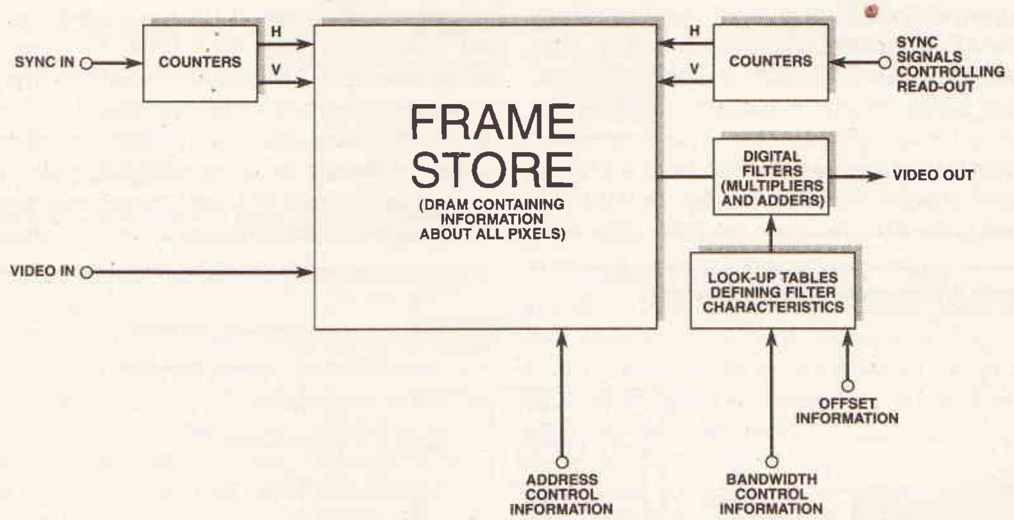


Fig.5 A simple Digital Video Effects generator

Scrolling —images appear to move, one after the other, sideways across the screen, or to roll smoothly upwards and downwards.

Mirror effect —the television screen is divided, so that part of the screen carries an image which is a symmetrical copy of the image appearing on the other part.

Teletrack — a special effect in which the successive images of a moving object, a tennis ball, for example, are highlighted, and the path traced by the object appears superimposed upon the picture.

signals in which the colour and luminance can be carried together simply along one wire.

Just as CCIR recommendation 601 specifies the sampling standard for digital component video, an associated world standard, CCIR recommendation 656, specifies the interface standard which is to be used for interconnecting equipments which use digital component signals. It specifies that the luminance and colour difference components should be routed in parallel, in byte-wide form, that is eight bits at a time for each component, plus clock signals, the luminance and chrominance components being interleaved by time division multiplexing. The bits of the digital code word that are used to describe the digital signals are transmitted in parallel by means of eight pairs of conductors, and each carries a multiplexed stream of each of the component signals Cb, Y, Cr, Y, in turn. The eight pairs also carry ancillary data that is time multiplexed into the stream of data during the video blanking intervals, and a ninth pair of cables carries synchronous clock signals at 27MHz. To connect all these signals 25 pin D-connectors are used, and the wiring between the various pieces of equipment in a studio is therefore very bulky and inconvenient, and the length of the multicore or twisted ribbon cables that can be used is restricted.

In a typical high quality studio post-production area there will be several different types of component digital equipment, including digital effects generators, a digital vision switcher, a digital graphics or paintbox unit, and perhaps three digital videotape recorders. Imagine the complexity of interconnecting a system something like that shown in Figure 7 when 25-way cabling is used to interconnect equipment using the three component signals, and remember that it is not unknown for the bulky cable connectors to be pulled out of their sockets, or for some of the connections to be less than perfect, a situation that leaves the maintenance man in something of a quandary if he believes the old adage that digital signals either work or don't! In an analogue PAL environment vision switchers and studio routing switchers have the relatively simply task of switching single co-ax cables between various sources, but it soon becomes clear that trying to do the same with 25 way cables and connectors is far from simple — even a plug in 'patch-panel' is difficult to build and maintain, and multiple pole switching units are horrendous in their complexity. If interconnections are too long, which effectively means more than a few tens of metres, timing differences can occur between the different data bits making up the parallel signal strands, due to cable propagation errors, with the result that the different bits of the data stream do not arrive at the next piece of equipment at the same time. If interconnections longer than about 50 metres are to be used, equalisation can compensate for such delays, so that the data will be received correctly, and the standard includes a suitable equalisation curve.

Serial Distribution

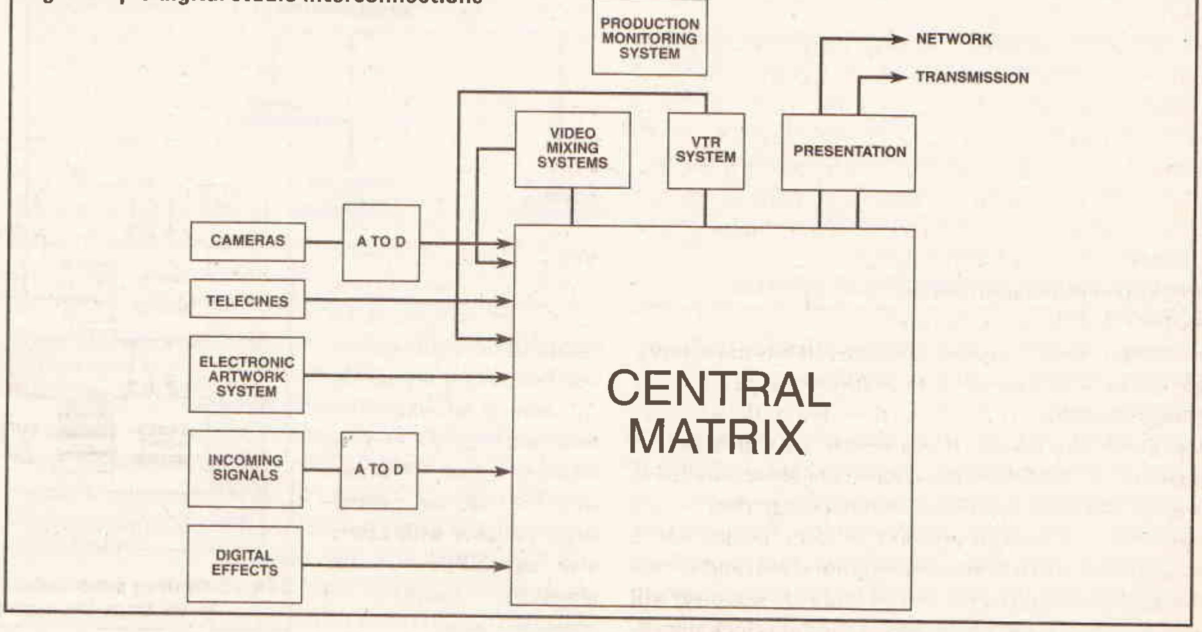
When CCIR recommendations 601 and 656 were being drawn up, the disadvantages of multi-wire parallel distribution and the advantages that a single wire serial system would give were well understood, and an 8 bit parallel to 9 bit serial strategy was actually worked out, but the data rate of around 250Mbit/s that was needed made it quite difficult to build practical equipment at reasonable cost with the technology available at the time (1983). The multiplexed data stream of 8 bit words is thus transmitted over a single channel in serial form as a series of 9-bit transmission words, and in order to make recovery of this data easier at the receiver, the data stream is subjected to additional coding and spectral shaping before transmission. Although some serial digital equipment was made to suit this standard, and arrangements were made for the signals to be carried either over 75 ohm coaxial

WIRING FOR 25-PIN 'D' CONNECTORS USED FOR PARALLEL DIGITAL COMPONENT SIGNALS

PIN NUMBER	SIGNAL	PIN NUMBER	SIGNAL
1	CLOCK A	14	CLOCK B
2	SYSTEM GROUND	15	SYSTEM GROUND
3	DATA 7A (MSB)	16	DATA 7B
4	DATA 6A	17	DATA 6B
5	DATA 5A	18	DATA 5B
6	DATA 4A	19	DATA 4B
7	DATA 3A	20	DATA 3B
8	DATA 2A	21	DATA 2B
9	DATA 1A	22	DATA 1B
10	DATA 0A	23	DATA 0B
11	SPARE A-A	24	SPARE A-B
12	SPARE B-A	25	SPARE B-B
13	CABLE SHIELD	—	—

Fig.6 Wiring for 25 pin D connectors used for parallel digital components signal interconnections

Fig.7 Simple digital studio interconnections



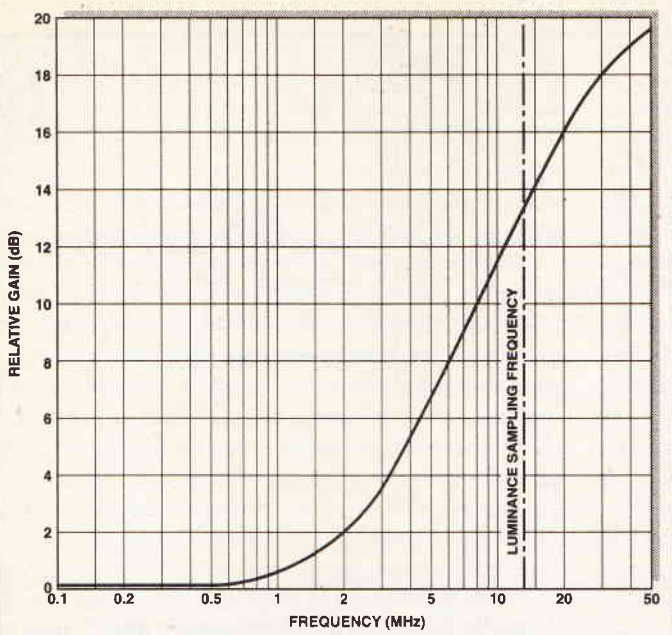


Fig.8 Equalisation characteristic curve for parallel data (CCIR recommendation 656)

The output from the serialiser chip is suitable for direct transmission over very short distances, such as between boards in individual switcher boxes, for example, but another chip is required to feed these signals around the studio coax cables, this second chip acting as both a line driver amplifier and simple distribution amplifier.

A complementary de-serialiser chip is also available, which takes in the scrambled serial data that comes along a coaxial cable, and from this it recovers the necessary clock timing and data synchronisation signals, which allow the data to be descrambled and decoded into parallel form.

Equalisation Built-in

Since the cables along which the serial signals have been sent will unavoidably attenuate the high signal frequencies more than the lower ones, some form of frequency response levelling, known as equalisation, is needed if the data is to be decoded with the minimum of errors. Foreseeing this problem, the designers of the Sony chips built in cable equaliser circuitry that can correct both the high frequency and low frequency responses of a typical studio distribution circuit.

cable or fibre optic cables, it was never really supported by manufacturers. This should come as no surprise when I tell you that a single serialiser/de-serialiser took up about a four inch high section of a 19 inch standard equipment rack, which meant that the racks required for a typical inter-studio multi-input/output switcher would have taken up a small room!

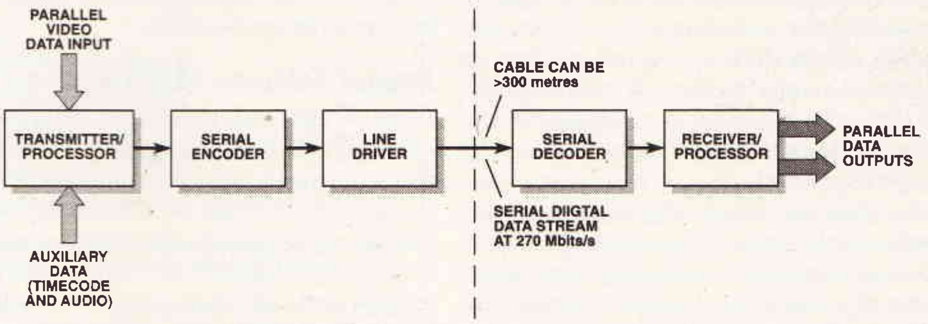


Fig.9 The basic elements of a serial/parallel interface system

Serial distribution only really became practicable in about 1990, when Sony and other manufacturers perfected the design of a single chip which can take in an 8/10 bit parallel digital data stream consisting of the video data and embedded ancillary information, and convert it to an extremely high speed serial digital bitstream. The maximum bit rate involved is obtained from;
13.5MHz luminance sampling rate
+6.75MHz B-Y sampling rate
+6.75MHz R-Y sampling rate
i.e. 27MHz total sampling rate times 10 bits per sample, which gives a total of 270 Million bits per second, 270Mbit/s. There is also the option of using the serialiser for digital composite (PAL) signals, in which state it operates at 177Mbit/s. The data is actually scrambled as it is serialised, to provide a better energy distribution throughout the spectrum, so that data 'peaks' which could cause interference, are smoothed out, and so that the decoding equipment in the eventual de-serialiser will have a better chance of recovering the data clock signals.

A Routing Switcher On A Chip

In addition to designing and building chips for the digital serial interface, Sony have developed a chip which can act as the central element of a routing switcher for these digital serial signals, so that equipment in different studio areas can easily be interconnected. A single crosspoint chip provides 16 sources and 16 destinations, requiring 256 crosspoints, and four of these remarkable chips can be arranged on a printed circuit board to make a 32 by 32 routing switcher. Several such cards can be stacked to give 256 inputs and 256 outputs, providing a switcher with extensive capabilities in the absolute minimum of physical space.

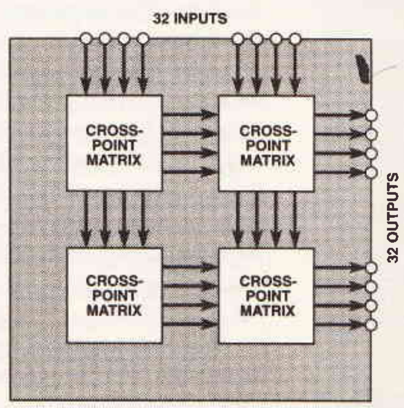


Fig.10 Routing switch matrixes in chip form (Sony Broadcast)

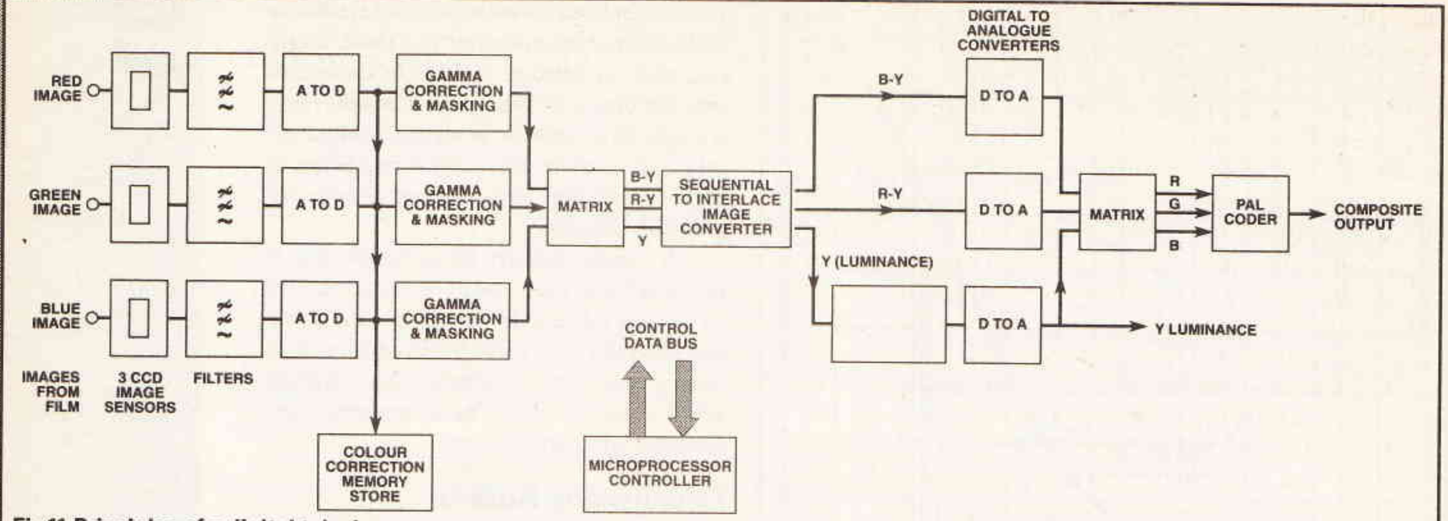


Fig.11 Principles of a digital telecine

Audio As Well!

In any television broadcast environment it will be necessary to deal with audio signals as well as video, and the Sony serial digital interface and its associated chipset has enough capacity to carry not only a single channel of video, which can be composite for the D-2 recorder standard or component for the D-1 recorder standard, but also channels of high quality digital audio and some Vertical Interval Time Code (VITC) signals which enable individual fields to be identified for automatic computer editing. Provided that the studio is only ever dealing with audio and video signals which are married together, as would be the case in a typical modern playout centre, the serial digital system has enormous advantages; all video and audio signals can be carried on a single co-axial cable and can be switched with ease; a truly marvellous example of the advantages that the digital approach can bring. This very simple arrangement cannot be used for more creative studio areas where audio and video signals need to be treated separately, and so there is a standard format for digital audio signals that has been defined by the American Audio Engineering Society (AES) and the European Broadcasting Union (EBU). This AES/EBU specification defines a balanced signal format rather like the RS422 standard that computer buffs will be familiar with. The audio is sampled at 48kHz, and a single cable can then be used to carry a serial digital data stream that carries left and right hand audio channels (20 bits) plus 4 auxiliary bits, synchronising information, and channel status information.

Distributing audio around studios as a serial digital data stream also provides the somewhat unexpected advantage that it is no longer possible to interchange left and right hand audio channels by wrong cable connections, which happened more frequently with analogue systems than many studio operators would like to admit! Now that digital recorders and players are readily available, signals can be distributed in digital form throughout the studio centre.

No system is perfect and once we get away from analogue audio signals and use a serial digital data stream, some new problems do occur with audio signals that we have not had to worry about before. Although the specification for the serial data stream has taken care of any relative timing errors, the digital signals will all need to use a standard master timing clock if glitches or clicks are to be avoided when switching between different sources, and special arrangements will need to be made to deal with the timing of audio signals coming from external sources. Effectively, the move to digital distribution means that we must take similar steps to those that we have always needed to synchronise television pictures, and re-synchronising and re-clocking are processes that are used to cope with digital audio signals from sources external to the studio centre.

Digital Telecine Machines

In spite of all the talk that goes on about electronic video recording replacing film, there is still a great deal of television programme material originated on film, and the amount actually seems to be increasing as new formats like 'super-16' can easily provide widescreen pictures for the latest generation of 16:9 aspect ratio receivers. For many years the standard means of converting images on film to video signals has been to use a 'flying spot' telecine machine, where the film is moved continuously past a specially bright cathode ray tube displaying a bright raster pattern. The light from the raster passes through the film and colour separation equipment, before landing on photoelectric detectors which register the amount of red, green, and blue light from the film at any instant. In order to provide an interlaced picture for normal transmission, the raster is made to move very quickly about the cathode ray tube, jumping to one position to scan the first field, and then moving rapidly to another position, where it scans the frame again to provide the second video field — the so-called 'hopping patch' technique. This type of telecine works very well, but requires very precise mechanical and optical alignment if perfect pictures are to be obtained, and for this reason the introduction of digital techniques to telecines has proved a boon.

The latest telecines have replaced the cathode ray tube and its complex scanning arrangements with a lamp which provides a thin slit of light across the width of the film. A row, sometimes two rows, of charge coupled device image sensors or photo detectors, are placed across the film path, so that as the film is moved through the machine the picture is automatically scanned a line at

TV

a time, the outputs from each of the sensors, typically 1024 in each of the rows, being read sequentially via shift register circuitry into a frame store. Notice that the film is not being scanned in an interlaced manner, but sequentially, line by line, for all the 575 lines that make up the picture. The interlaced picture that is required by the normal TV system is then generated by reading alternate lines from the frame store. Strictly speaking, each of the charge coupled devices that make up the line array is an analogue device, the amount of charge which it contains being directly analogous to the amount of light passing through any particular pixel of the film image onto the sensor. The signals from the line sensors are then converted to digital form before being processed in a whole series of digital adders and multipliers to ensure that the contrast, gamma, and colour of the resulting images are correct. Although the actual picture signals from such a telecine need to be coded using only the standard eight bits per sample used in CCIR recommendation 601, in order to avoid mathematical rounding errors and to achieve the necessary accuracy, 11-bits per sample are used for much of the internal processing, with up to 13 bits per sample being used for some of the critical colour masking and gamma correction stages. Luminance and chrominance information from each line of the picture is digitised separately and stored, and it is then possible to produce 'freeze frame' effects from the store, and to provide pictures at different speeds from slow-motion to fast forward and reverse. The digital images can be stretched and compressed to provide displays from different aspect ratio films, including the very wide aspect ratio 'Cinemascope' type, and the variable speeds which can be produced allow the producer to speed up or slow a film in order to fill a particular programme slot. Incredibly, viewers will not notice changes of a few percent in the running speed of the film, as long as the pitch of the audio is corrected so that the viewer's ears cannot detect the change.

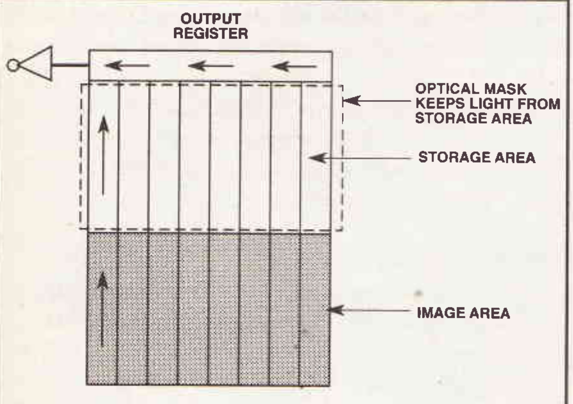


Fig.12 Principles of a CCD camera image sensor chip

Digital Cameras — Not Yet!

There is no device more essentially analogue than a television camera, since its basic purpose is to provide electronic signals which are analogous to the amount of light falling on each part of the image which is to be transmitted, but digital control of the complex circuitry that modern cameras contain has made them far easier to line up and adjust than they used to be. Once adjustments can be made digitally it is a short step to putting those digital adjustments under the control of a microprocessor, and many modern cameras can now automatically align themselves and adjust their grey scales and colour balances to match those of other similar cameras in the studio. These tasks would traditionally take up several hours of the working day of a skilled studio technician, and digital control of cameras has gone a long way towards improving the efficiency of many studio centres.

Although we have said that the output from a camera tube is bound to be analogue, the coming of charge coupled device (CCD) image sensors has enabled camera manufacturers to adopt digital techniques, rather like those used in the telecine machines that we discussed in the previous section. The major difference is that the CCD image sensors used in cameras consist of not just one line of CCDs, but of a whole twodimensional rectangular array of such devices, upon which the complete image may be focused, and the really clever part is that all the elements, perhaps as many as half a million, are manufactured as part of a single silicon chip.

Whilst there are several different techniques used in such cameras, each having its own advantages, one of the simplest to understand is the 'frame transfer' device, originally marketed by RCA. The first thing to notice is that the chip has to have a relatively large area in order to have the image from the camera optics focused upon it, and this leads to difficulties in manufacture. The smallest blemish occurring in the silicon during the production of the chip will give rise to permanent marks on the pictures produced from such a chip, and so the manufacturing yield of such chips will necessarily be low, making broadcast quality chips expensive. This may well be counteracted, however, by the many advantages that chips have over vacuum-tubes; they are smaller, lighter, more robust, and resistant to shock and vibration, as well as requiring much less power, especially since there are no heater supplies needed, and no complex scanning coils to be driven with heavy currents.

The image is focused on the top part of the frame transfer chip, so that each of the many thousands of elements making up the chip surface area takes up a charge which depends upon the brightness of the particular picture element or pixel. The bottom half of the frame transfer chip is kept in darkness, and during the vertical blanking interval, between the 'scanning' of each field, all the charges from the CCDs in the imaging area are rapidly transferred to the lower part, which acts as a storage area. Each individual CCD element in the imaging area not only stores the charge resulting from its own particular pixel, but must also act as an analogue shift register, transferring the charges from the cells above it through to the storage area. During the time during which the transfer of the charges is taking place from the imaging area to the storage area no light must be allowed to reach the chip, or the amounts of charge describing the image will be changed. To ensure that the chip is kept in darkness during the switching period a special shuttering mechanism has to be incorporated into the imager.

The signals are read out from the storage area via a shift register, and the resulting signals can then be processed digitally. Other designs of CCD image sensor use storage areas positioned next to each photosensitive area of the chip. This means that the area of the chip which is available to receive light is smaller than with the frame transfer device, so that the sensitivity of the chip at low light levels is worse. Makers of this type of chip, usually known as interline transfer chips, claim that this disadvantage can be more than counteracted because of the fact that the photosensitive elements do not have to act as their own storage elements as well, which makes for far more efficient charge transfer.

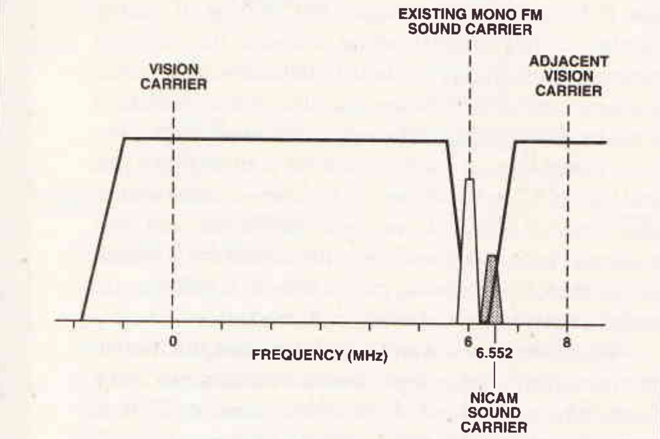


Fig. 13 Baseband spectrum of UK TV system I, showing limited space for an extra sound signal

The simplest CCD cameras have a single light sensor chip, with colour being obtained by a clever arrangement of colour stripe filters and digital processing, but such arrangements cannot produce the quality or the sensitivity required of a broadcast camera, so that most broadcast cameras utilise three separate CCD image sensors, for the Red, Green and Blue components of the image which are obtained from conventional optical dichroic mirrors or prisms.

Other Digital Studio Tools

The introduction of digits to studios has brought with it the capability to provide excellent quality graphics systems, which can digitally produce everything from TV company logos to on-screen clocks, which although they appear to have analogue displays, complete with moving seconds hands, produce the effect in a completely digital manner. The wide range of digital electronic paintboxes that are now available have given creative directors the chance to obtain an unlimited number of graphics effects, and this equipment can be used to 'paint' completely electronic pictures which have no equivalent in the real world. Although there were electronic caption generators long before digital television days, digital caption generators can provide a vast range of different colours and typefaces which can be shaded, shadowed, or filled from any other digital signal source, and the quality of the digitally produced images is superb, being virtually noise free and with crisp well-defined colours.

Solid State Image Storage

Digital still-image stores have now become a useful tool in almost all newsrooms. A still frame can be captured from any source, and stored on a computer hard disk for virtually instant recall at any time in the future. In the 'olden days' of television, all of ten years ago, studios would have stocks of thousands of 35mm photographic slides, which had to loaded by hand into the slide trays that were then placed in the automatic, but very electro-mechanical slide scanners of the day. These days hundreds of 'digital slides' can be stored on hard disk, with thousands more being stored on computer back-up tapes for easy access.

The introduction of digital optical disks has provided considerable advances in still store technology, simply because a single optical disk can store, typically, up to 1600 PAL images, or a corresponding number of component digital pictures, and autochanging 'jukeboxes' can allow 50 disks to be accessed rapidly, allowing any one of 80,000 or more still images to be retrieved quickly. Optical discs are slower than standard magnetic hard discs when it comes to retrieving pictures, but powerful menu-driven search and database management software allows for fast keyword searches and wildcard searches which can identify a wanted disc from several thousands within about 3 seconds, which is adequate for the requirements of most studios. This type of optical disk, known as a WORM (Write Once, Read Many times) has a very large capacity, but as the name suggests,

A modern camera using CCD chips

once images have been recorded the disk cannot be over-written with new images, only added to. Another type of disc is also available, the MO (Magneto-Optical) design, and although this does allow for images to be erased and re-recorded, the capacity of such discs is currently limited to about 400 images.

For the very fastest access to still images, completely solid-state 'RAM disks' can be used, consisting of semiconductor random access memory stores which have enough memory to store a few tens of pictures, each of which can be accessed within milliseconds. Cost is the only real limitation to this technology, and most still store systems offer a combination of different storage techniques to match the requirements of the customer.

Digital slide-storage units frequently offer the operator a 'Polyphoto' display, on which she can see perhaps fifty small pictures on a screen at once, instantly selecting the one that is needed for transmission at the press of a button or by touching the appropriate part of the screen with a light pen. In addition to the advantages of making it much easier to find any particular still picture, rather than having to sort tediously through a slide library, the 'digital slides' do not suffer from dust, and they cannot be finger-marked! Optional extras to the digital slide files offer the capability of being able to edit the digital pictures, perhaps to remove an ugly gasholder from the background of the picture, or even to electronically touch up the faded highlights of an ageing blonde superstar.

Monitoring Digital pictures.

In the analogue world, television signals can easily be monitored at various points along the programme chain, subjective assessments of picture quality being made on a picture monitor and objective measurements taken by means of an analogue waveform monitor and appropriately calibrated graticules. It is not possible to plug a picture monitor into a digital bitstream, (well, if you do you, will not see much of a picture!) so every time we need to know what pictures are like in our digital studio we must tap off some of the digital bitstream and feed it to a digital to analogue convertor, the output then being connected to a standard analogue picture monitor. Kits are now available to provide analogue studio monitors with interfaces for serial and/or parallel digital connections, and these work well and are simple to fit, although they do cost several hundred pounds.

The cost of adding digital/analogue convertor kits to all monitors can make the idea prohibitive, but there are now personal computer based adaptors available, which provide a cheaper method of monitoring the digital pictures. These usually consist of plug-in boards for PC compatible machines, and special computer based test equipment also allows quantitative measurements to be taken on the digital signals. In practice, however, the difficulty in actually being able to look at digital pictures for monitoring purposes is not as important as it might seem, because the complete digital signal chain in the studio is far less likely to give rise to errors affecting the picture quality than would be the case in an analogue environment, so you just do not need anything like as many picture monitors for quality checking purposes as you do when monitoring an analogue signal chain.

Studio output — its all change back to analogue!

We have been discussing all-digital studios with digital processing and routing of digital audio and digital video signals, but until we reach a time when we can actually transmit signals digitally over air, and we shall see in a future article that this is likely to be some years away, the final stage in the studio processing is usually to convert the digital pictures back into analogue form, so that they can be coded as analogue PAL signals for transmission over our television networks. long distance distribution of television signals between studio centres, however, or between studios and distant transmitting stations, can now be done digitally, usually using links provided by the various telecoms authorities, usually known as PTIs, that operate at data rates of between 34Mbit/s and 140Mbit/s. Since 1986 a group of experts from the CMTT, a standardisation body that specialises in long distance television transmission problems, has been developing a computer program, or algorithm, to reduce the bit rate required for the distribution of television signals digitised in accordance with CCIR Recommendation 601 from the initial 216Mbit/s down to 34Mbit/s, which is one of the lower levels of the digital distribution hierarchy used by European PTTs. The lower the bit rate, the cheaper it is to send the pictures, but the more difficult it is to maintain the picture quality. The need to reduce the bit rate from over 200Mbit/s to 34Mbit/s represents a reduction factor of about 6, and the task has by no means proved straightforward. Early attempts utilised systematic techniques which introduced distortion on many different types of picture, and the later work has concentrated on coding techniques based on the Discrete Cosine Transform (DCT). Although this technique will be described more fully in the later section on digital transmission, its essence is that the differences between successive picture frames are calculated, but since it would involve too much data to do this for each individual picture element, blocks of picture elements, typically 16 by 16, must be used. The DCT then mathematically transforms each block of pixels into blocks of mathematical coefficients, and the bit-rate can be significantly reduced. Early implementations of the technique were oniy good enough for telephone videoconferencing, because the blocks making up the picture could be fairly obvious, but further work in broadcast research laboratories showed that the techniques were not too complex for use with standard 625-line TV pictures, and the CMTT group agreed that this was the path to take, and their work has shown that good results can be achieved at 34Mbit/s, although some small distortions can be noted on certain critical picture material. This 34Mbit/s system, which is currently going through the European ETSI standardisation process, is primarily for use over inter-studio contribution links.

When digital picture transmission does eventually become economically feasible, our pictures will be able to stay in digital form from the studio source right through to the receiver, and most of the analogue to digital and digital to analogue conversion that is necessary these days will become completely superfluous, leading to even better picture quality.

In the meantime, it is important to remember that each time a television signal passes through a 'codec', that is the equipment which performs the analogue to digital and digital to analogue conversion, its quality will be slightly degraded. Good studio technique, therefore, consists of maintaining the picture in digital form for as long as possible, and in component form where this is possible, only making the conversion to analogue and to composite form when all picture editing and post-production has been completed.

Digital recording — more advantages

Yet another advantage of the change to digits in studios, an incidental one, it might seem, but one that is actually having significant effects on the design of studios, is the miniaturisation of recorders and editors that is currently taking place. The new digital half-inch format recorders that are currently being installed in many studio centres take up only a fraction of the space of their one-inch analogue predecessors. The amount of space required to store the vast libraries of tape that soon build up in any studio centre is so much reduced in the new formats that it is rumoured that some studios are being driven to use digital recorders by the demands of their ever-present accountants, who realise that if the amount of space required to store tapes can be reduced, so can the bills for running the place!

Just as the compact digital audio disc revolutionised the way in which we listen to sound, new techniques of recording moving pictures onto digital optical discs promise to eventually replace the digital tape recorder altogether. As was mentioned when we looked at still-stores, Digital optical discs of several types are now available, some of which can be recorded only once, whilst others are erasable as well. There are still some snags, such as the limited data transfer rates that can currently be achieved, and those currently on the market do not record pictures of full broadcast quality bandwidth, either for luminance or chrominance, but the convenience of disc recording, with the 'randomaccess' to any part of the disc that no tape system can ever give, could promise a bright future for digital video discs, in both studio and home.

Solid state recorders.

We saw earlier that solid state memories, commonly called 'RAM disks' can be used for still stores. The falling cost of this type of semiconductor storage is beginning to make it possible to store moving images, so that an all

INFORMATION BOX

Cons as well as pros!

In a previous section we have already discussed rounding errors, but the four major practical problems that are almost unavoidable are summarised below:

Quantisation errors

Scenes scanned by a television camera are essentially analogue in nature, consisting of a continuum of brightness levels, which effectively need an infinite number of digital brightness levels to accurately reproduce. Digital signals must be based on a finite number of brightness steps. The quantisation process that provides these steps must sometimes lead to errors, when a particular scene brightness does not fall exactly on one of the voltage steps, but somewhere in between two values. The digital value will therefore be in error compared to the original analogue value, and this error will express itself as 'noise', black and white sparkles on a picture, and background hiss on sound; the noise will be dependent on the instantaneous level of the signal. Quantisation noise can be rendered less noticeable by adding a small amount of 'dither', a rapidly varying signal whose amplitude is a fraction of that of one of the quantising steps, before the signal is quantised; this has been found to mask or conceal the effects of quantisation noise.

Convertor non-linearity

In a practical analogue to digital convertor it will prove impossible to make each of the quantising steps exactly equal in amplitude, due to tolerance mismatches in the components used, and although component integration on VLSI chips has helped enormously, under the most critical viewing conditions picture non-linearity can be seen as distortion and brightness range in some parts of the picture will not exactly match that of the original picture.

Aliasing

Since the sampling frequency must always be at least twice the highest frequency contained in the original signal if distortion is not to occur, great care must be taken when dealing with high frequency signals, if patterning is not to occur. The design of suitable filters, therefore, can be critical. Over-sampling techniques, where the Nyquist frequency is well above the upper limit of the frequency baseband, are well established for digital audio, the main advantage being that the filters do not need to be designed with such sharp cut-offs. Much higher frequencies used in video have so far rendered the technique less practicable.

Sample and hold loss

Since the quantising process involves the taking of samples at high speed, and the storing or holding of those samples for a finite time until the next sample comes along, high frequency losses can occur, often referred to as (Sin x)/x losses, because they can be represented mathematically by this formula. To overcome the effect of a reduction in the higher frequency components of a signal, the signal can be passed through a filter with some high frequency lift, sometimes an analogue filter, or oversampling techniques can be used to reduce the high-frequency losses due to the original circuitry.

solid state video recorder with no moving parts is theoretically possible. Several such devices are on the market, but their operating time is generally measured in seconds, which restricts their usefulness to postproduction and editing suites, where repeated edits can be made with no loss of video quality. The cost of such storage, and the size of the computers containing it, does mean, however, that it is likely to be many, many years before we could contemplate a solid state video recorder with a playing time of 90 minutes! Nothing seems to be impossible in our digital world, though, and some of the new bit- rate reduction and image compression techniques that are being studied could conceivably lead to the solid-state video 'Walkman' as we get into the next century. Just think of the advantages of having such a device with no moving parts, for both manufacturers and consumers.

Digital sound transmission — alongside the video signal.

At the present time, digital television sound signals, which require much lower data rates than their accompanying vision signals, are actually sent around the country hidden in the line synchronising signals of the analogue TV video waveform, a process called 'sound in syncs', and the coming of the NICAM digital sound transmission system enables audio signals to stay in digital form from studios right through to our homes, which has transformed the quality of TV sound that we can now receive.

Although digital sound signals require lower data rates than digital video signals, the bandwidth available for television signals in the UK was decided upon long before any ideas of transmitting digital audio were thought of, and so there would not be room to squeeze in a dig tal stereo sound signal if it were coded in the same way as the sound on a compact audio disc. The drawing of the baseband television spectrum shows that there is very little space available between the existing mono sound channel and the start of the next vision channel, and so some means had to be found of reducing the amount of data required to represent the two channels of a stereo sound signal, so that the resulting signal could be fitted into the limited spectrum space available.

Two channels of digital audio coded to compact disc standards would require a data rate of something over 1.4Mbit/s, since the CD sampling rate is 44.1kHz, and 16 bits per sample are used.

44.1kHz x 16bits per sample = 705.6kbit/s per channel for two channels data rate = 705.6 x 2 = 1.411Mbit/s.

Using any practical modulation technique it is not possible to fit this amount of data into the existing TV channel spectrum, and so a means of bit rate reduction and a matching modulation system were developed, initially by the BBC, the overall system being called NICAM — Near Instantaneous Companding and Multipleing. Although the keen TV salesman tries to sell the NICAM receiver as giving 'CD-Quality' sound, in fact the need to restrict the bandwidth of the audio signal does give rise to some loss of quality when compared with CD, but this will be noticeable only by 'golden- eared' purists, and the truth is that the NICAM system provides excellent quality stereo sound which is only marginally worse than that available from your CDs. The NICAM coding system manages to use a significantly lower data rate than CD, 728 Kbit/s compared with 1.411 Mbit/s, by adopting a number of different techniques.

By restricting the highest audio frequency to 15kHz, which most people find very acceptable, it is possible to reduce the sampling rate used to only 32kHz, rather than the 44.1kHz of CDs (remember that the Nyquist sampling theorem tells us that the minimum sampling frequency must be greater than twice the highest frequency contained in the original waveform). The number of bits per sample, which effectively means the number of individual audio levels that can be coded, is also reduced to 14, compared with the 16 used for CD. Even these reductions do not however reduce the bit rate enough to fit into the available bandwidth, and an 'audio masking' technique is used to effect a significant further reduction in bit rate. Audio masking is a well-known psychoacoustic effect in which when you listen to a loud sound, any other quieter sounds in the same or adjacent frequency bands become inaudible. Since these signals are inaudible, there is no point in wasting data bits by coding them, and so the remaining data bits can be used to describe more accurately the sounds that will be heard.

Prior to transmission of the NICAM sound signal the original 14- bit samples are reduced to 10 bits, the 10 bits being selected from the original 14 according to the level of the audio signal. For low level sounds only the 10 least significant bits of the 14 are transmitted, since the remaining bits, the most significant bits, would not be used because the signal is not loud enough to require them. When loud sounds are transmitted, only the 10 most significant bits are transmitted, the remaining bits, which would have described only low-level sounds, being omitted. You never get something for nothing in engineering, however, and this technique does result in some increase in noise, but if everything is done properly this noise will be masked by the audio. When your receiver tries to decode the incoming data stream it needs to be told which bits were missed from the original 14, and so each group of coded samples is accompanied by a 'range coding word' which enables the receiver to set the ten bits which it receives within the correct part of the complete 14 bit scale.

As with most digital signals, the NICAM data is very rugged and well protected against errors as it passes over the path between transmitter and receiver. The author has received excellent NICAM digital audio signals from the London Crystal Palace transmitter at locations in western Hampshire at which satisfactory reception of the pictures from the same transmitter was impossible — a good example of the benefits that digital transmission can bring.

'Spare capaqty' in the NICAM signal

Only 704 kbit/s of the available 728 kbit/s are actually used for carrying audio signals, and even when the necessary 'overhead' for control and protection of the NICAM data has been included, there are still about 11kbit/s of 'spare capacity' available for other purposes, even whilst the stereo audio is being transmitted in the main data block. Some TV companies are currently using

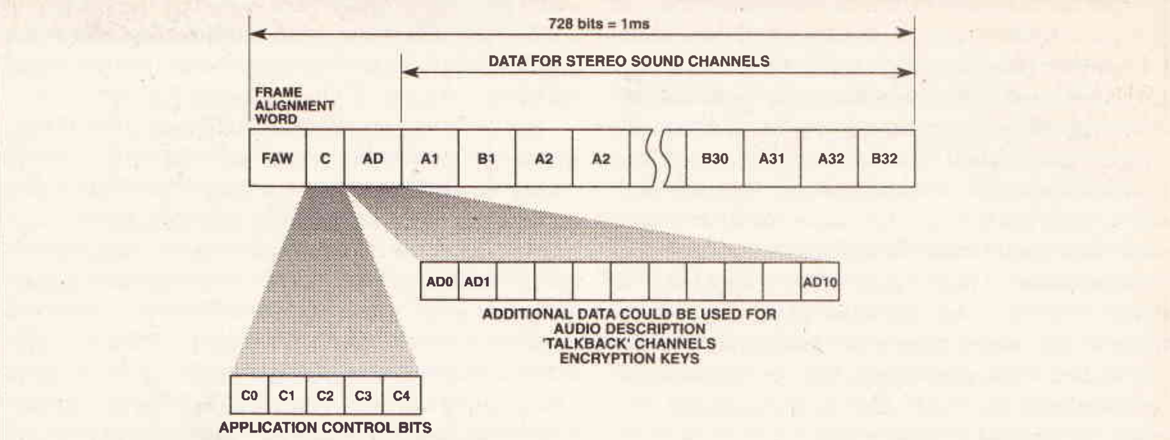


Fig. 14 The NICAM data frame showing the 'additional data bits or 'spare capacity'

these 11kbit/s to carry in-house talkback channels between studio centres and outside broadcast units, others are looking at the practicability of sending encryption control words in this space, which could be used to de-scramble previously scrambled audio signals at individual receivers making use of a subscription television network. Modern sound coding and data compression techniques might even make it possible to use the 11kbit/s to carry a third digital audio channel along with the two main stereo channels, and although the audio quality of such a system is likely to be fairly limited, research work is currently being carried out to determine the feasibility of providing an 'audio description' channel which would assist partially sighted viewers to improve their understanding of what is happening on the screen. Judging by some of the obscure plays which I have been watching on TV recently, we could all perhaps make good use of such a 'helper' channel!

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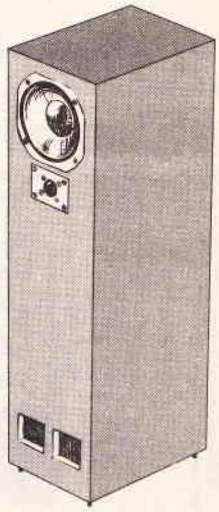

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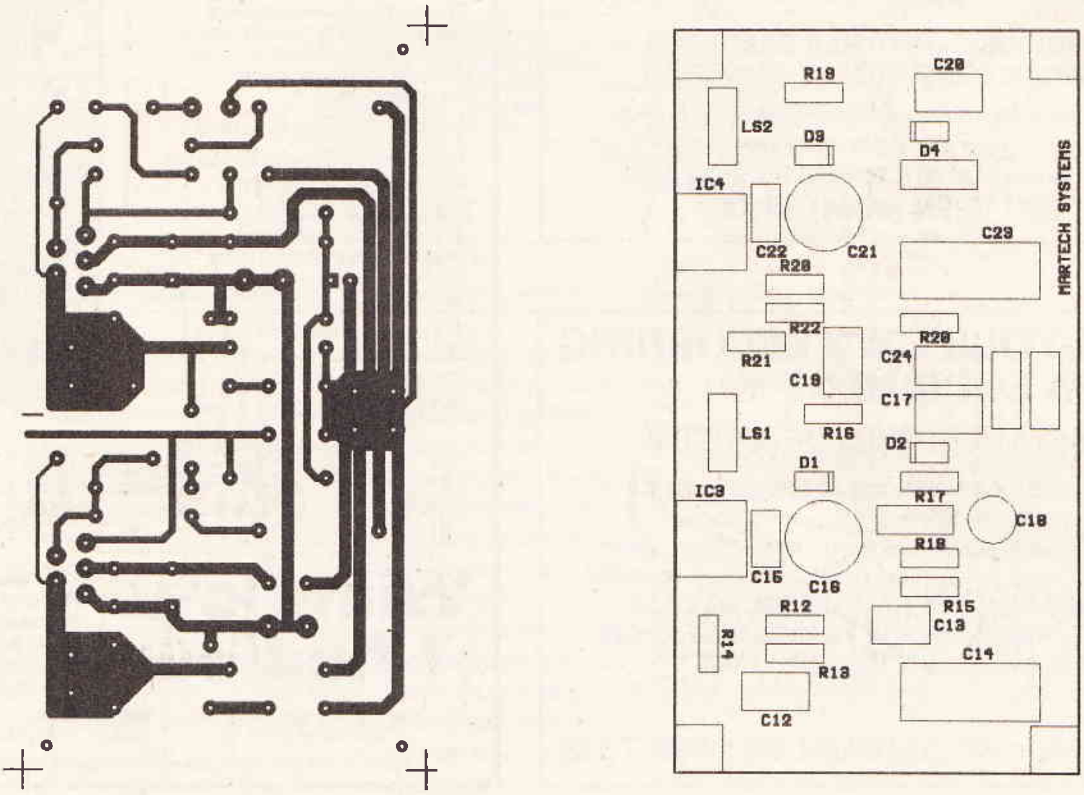
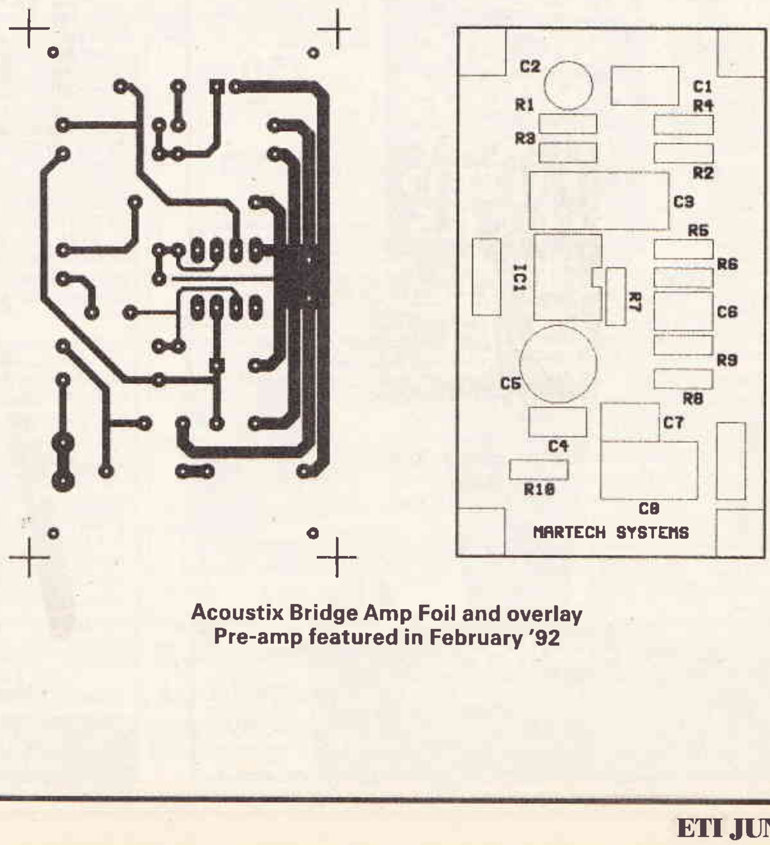


Acoustix Bridge Amp Foil and overlay
Power Amp featured in February '92

Oops!

MIDI Switcher March 1992
Fig.2 —Pins 00A of both 4 bit latches to IC7-9 should read 5 not 6. R20 the 3k3 SIL should be R28
Fig.3 —IC7,8,9,10 pins 19 should be 13
Fig.5 — Bottom left corner. The connections from left to right should be: Pins 1 and 2 =OUT Bx4. Pin 3 =OUT A1 Pin 4 =OUT A2 Pin 5 =OUT A3 Pin 6 =OUT A4
Addition to Buylines: (QL37S) is the substitute with no IC holder. The thumbwheel switch is from Maplin (cat no. JK36P)

Mains Switched Timer February 1992
Fig.1 On IC5, D3 goes to pin 5 not pin 1
Fig.2 Pin 1 and pin 15 pulses should line up with +ve edge of pin 3 pulse.
Fig.4 IC13 inputs are pins 1,2,8 not 1,2,3. the connection line P from SW3 should go to the R40/pin 1 line. The line Q from SW4 should go to the R41/pin 9 line.
Fig.6 Diode D5 is reversed.
On the topside counter driver ground plane on page 61, the clearance gap for C10 to +12V is missing on this foil only. This is placed directly above the top left hand pin of IC13 (pin 14).



Acoustix Bridge Amp Foil and overlay
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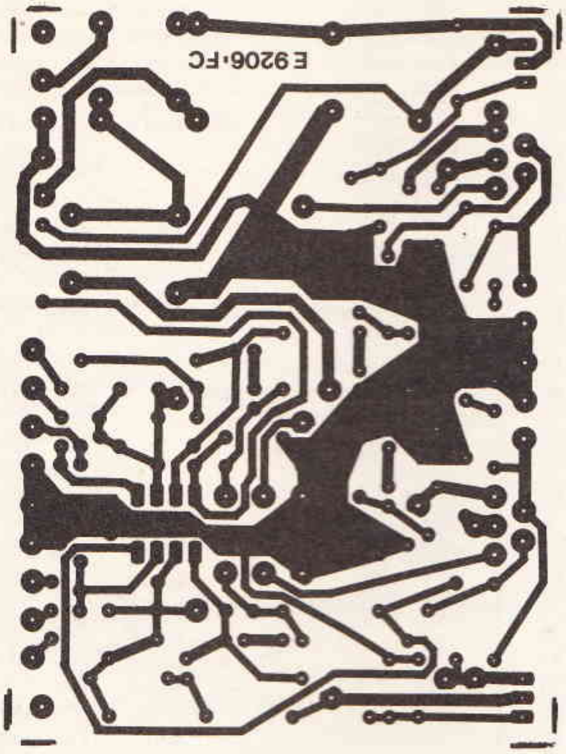
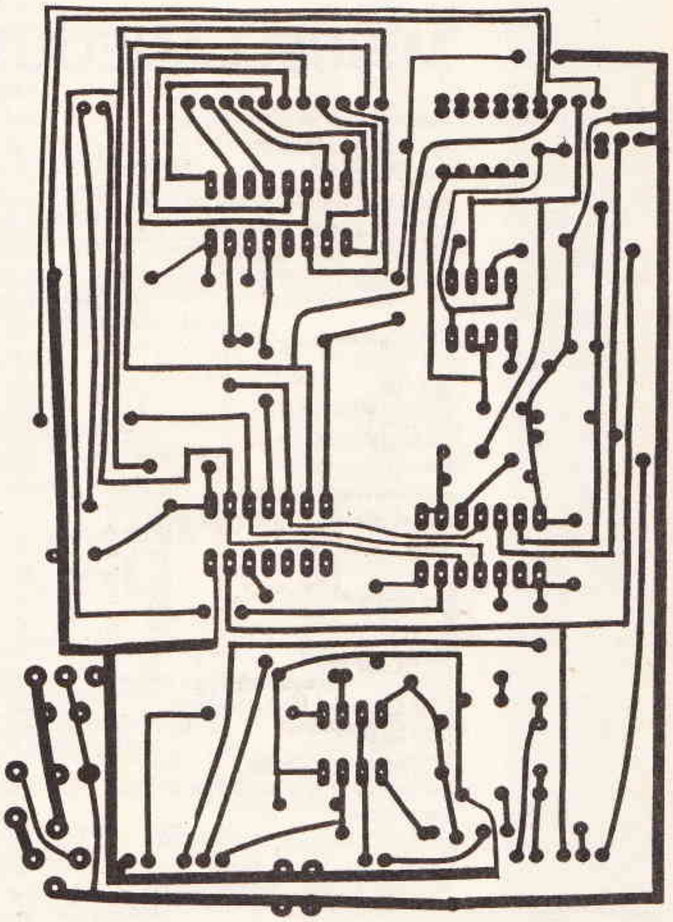
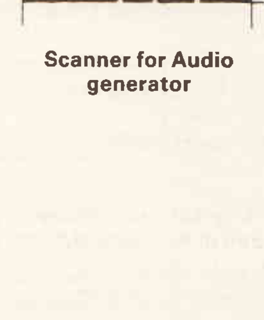


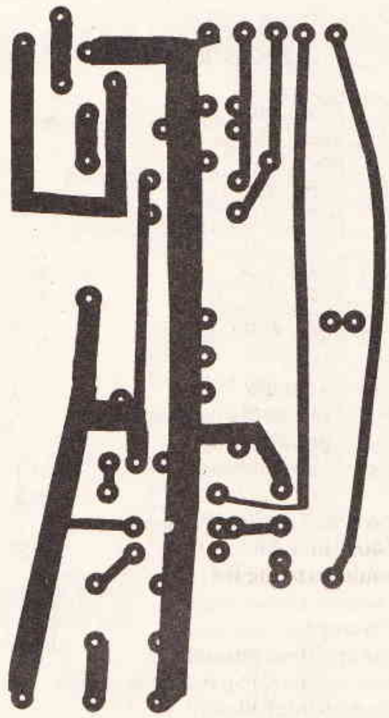
Chip Stereo Amplifier



Xenon Flash board



Scanner for Audio generator



Xenon Flash trigger board

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ISSN 0142-7229

ABC — Member of the Audit Bureau of Circulation

● Subscription rates — UK £23.40. Europe £29.50. Sterling Overseas £31.00. US Dollars Overseas $56.00.

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

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NEXT MONTH

In our bumper, action packed issue next month our cover PCB project will be a Surround sound decoder board to add to your stereo TV. Enjoy the thrill of bringing another dimension to your TV entertainment with this superb project.

Why not try out our Ultra-sonic audio sender to convey speech and music by remote control or maybe even make a Baby-bug monitor to evesdrop on your young child or anyone else for that matter. There is an alternative to the ingenious rear bike lamp featured this month — a cheaper to run economy electronic version. Together with a camera attachment and the next part in our AutoMate 20 mixing desk, these are just some of the ideas coming your way in the July edition of ETI. Out 5th June.

The above articles are in preparation but circumstances may prevent publication

LAST MONTH

The May issue featured:

A Bat Detector project
A Pond level controller
High quality Pre-amp Pt 2
Mixing Desk Pt 2
Genetic Algorithms
Digital TV Pt 1

A limited number of back issues are available from Argus Subscription Services. Address in column to left.

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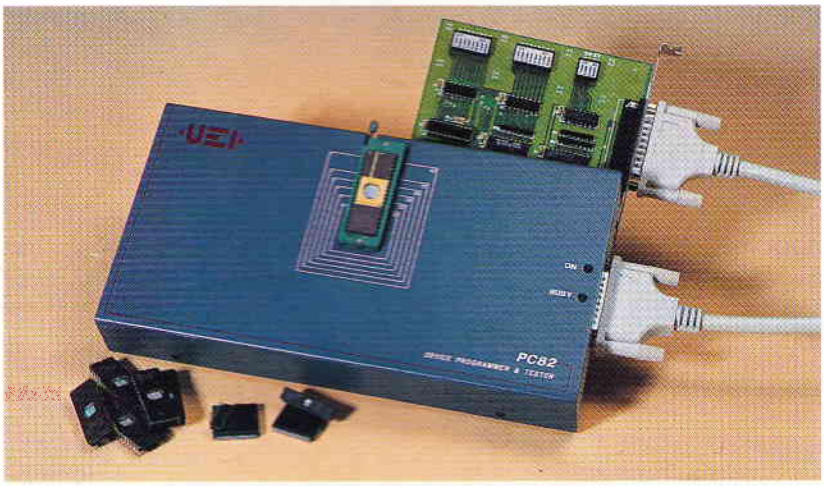

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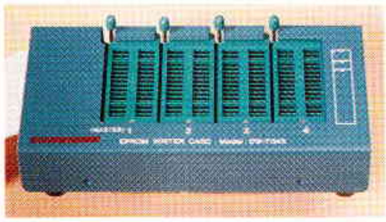

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