ETI

ELECTRONICS TODAY INTERNATIONAL

TOMORROW'S TECHNOLOGY TODAY

FREE PCB & SCHEMATICS DESIGN PACKAGE TO RUN ON YOUR PC PART 2

6 SUPER PROJECTS TO BUILD

GIVE SIGHT TO YOUR ROBOT

BUILD AN AUDIO FREQUENCY SIGNAL GENERATOR

IMPROVED POWER SUPPLIES

PROGRAMMING EPROMS

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RADIO REVISITED

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March 1994 £2.25

BEST VALUE Argus SPECIALIST PUBLICATION

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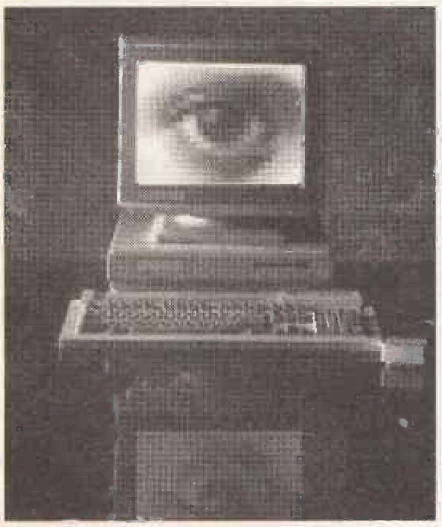
March 1994



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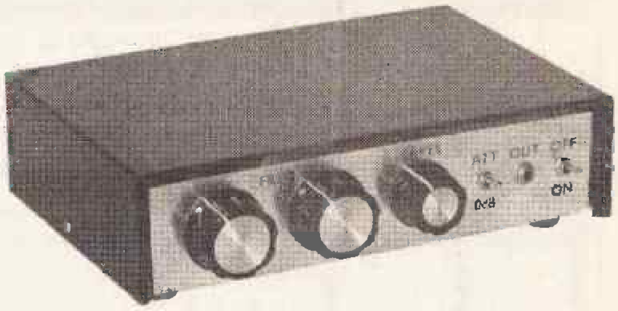
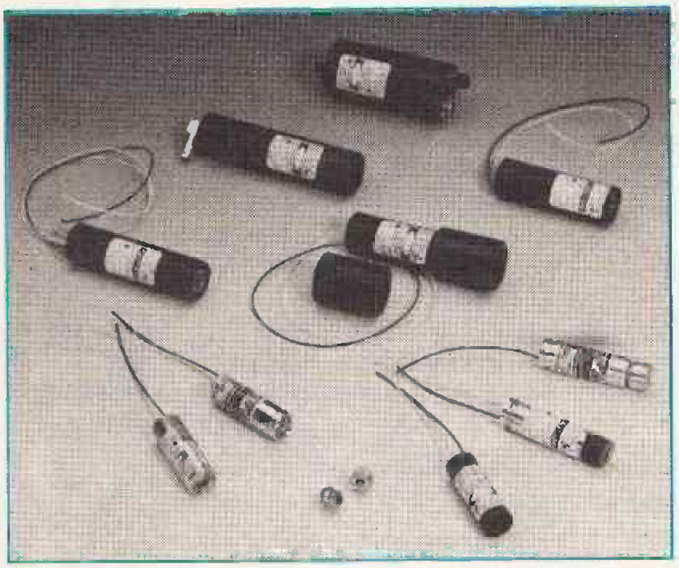


Regulars

Free with this issue: Part 2 of the LAYO1 PCB schematics and design software package and a powerful cross assembler, to enable readers to write software for ETI's microprocessor projects - see page 9 for details

ETI NEWS



Miniature Lasers

Miniature laser specialists Imatronic is offering a new range of semiconductor laser diodes aimed at OEM users. This highly reliable range of miniature and compact laser diode modules includes the semiconductor laser, collimating optics and drive circuitry packaged neatly into a rugged anodised aluminium housing. Modules are available in the visible range (635nm/650nm/670nm) and near infra-red (820nm), plus other wavelengths and power options.

The applications for which these modules are designed include industrial alignment systems, process control, medical diagnostic equipment, robotic control, range finding, inspection equipment, particle sizing, target designation, speed detection and bar code readers.

For further information contact Imatronic on 0635 550477.

Designers kit slashes cost of 8bit micro development

Mitsubishi has just launched a comprehensive low cost microcontroller designer's kit, the DK8. Costing just £249, the kit is available from Mitsubishi distributors and comes as a complete system that is quickly and easily connected to an MS-DOS PC or compatible, with a text editor.

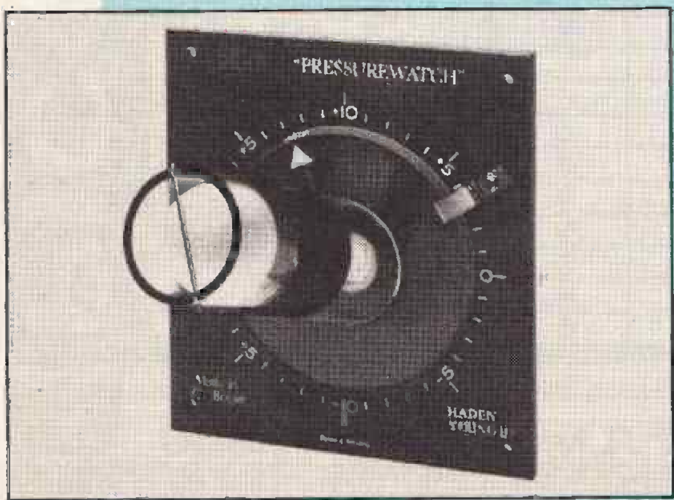
The DK8 kit comprises a designer's board with a DB8Mon Debug monitor, together with the Mitsubishi SRA74 structured relocatable assembler and communications software. A 5V power supply, serial cables and 9 to 25 way adaptor, plus all manuals, are also provided.

The designer's board is based around a M37451 8bit microcontroller chip. In operation, the device runs in microprocessor mode and an I/O expander, mapped to page zero, preserves the I/O the ports used as data and address busses. On board 32Kb of EPROM and battery backed RAM provide ample space for user software. Two decoded chip selects are provided, enabling further I/O expansion if required.

The designer's board features 56 I/O lines, together with eight 8bit analogue to digital inputs, two 8bit digital to analogue outputs and one 16bit PWM output. As well as the host bus interface, three 16bit timers and a serial port with RS232 drivers and baud rate generator are also provided, together with six external and eight internal interrupts.

For more information contact Mitsubishi on 0707 276 100.

Differential pressure indicator

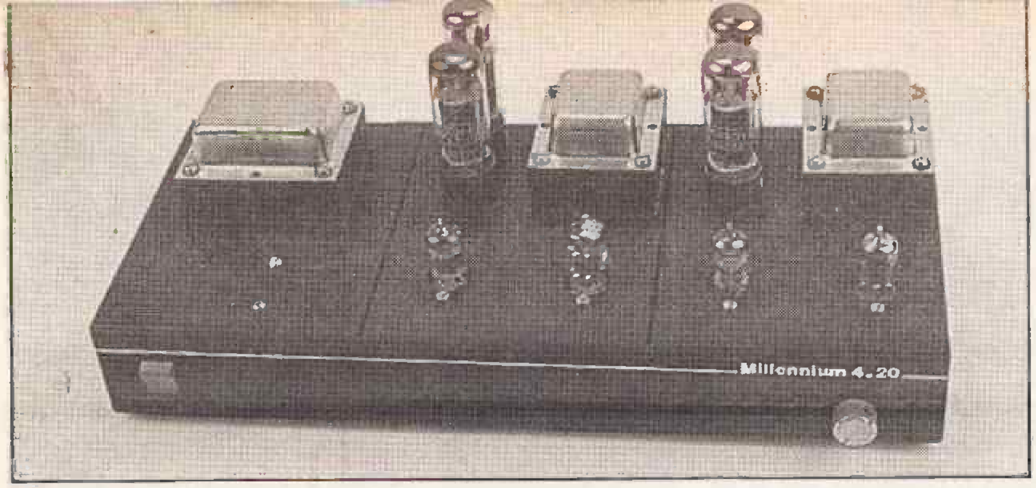


The Haden Pressurewatch is a brand new concept for indicating the existence of a differential pressure in clean rooms and in extraction systems such as fume cupboards. It has been invented and developed by Haden Young Ltd, part of the BICC group.

It contains red and green fluorescent indicators which change from green to red on the failure of the system to maintain the required pressure differential. The change over point can be set without any need to know the actual pressure differential.

The standard unit can be adjusted to default over the range 2- 16Pa approximately and specials will be available for different ranges to suit specific requirements. It can also be used to check negative pressure between adjacent areas. It is entirely self powered and reliable.

For further information contact Alert Products on 0948 880627.



Valve Power Amplifier Kit from Maplin

Maplin Electronics has launched a valve power amplifier kit, the Millennium 4-20. This amplifier is, according to Maplin, guaranteed to turn any capable domestic stereo system into something special, emitting a wonderfully gutsy bass even at low volume, together with 'an extra something' in the mid and treble ranges.

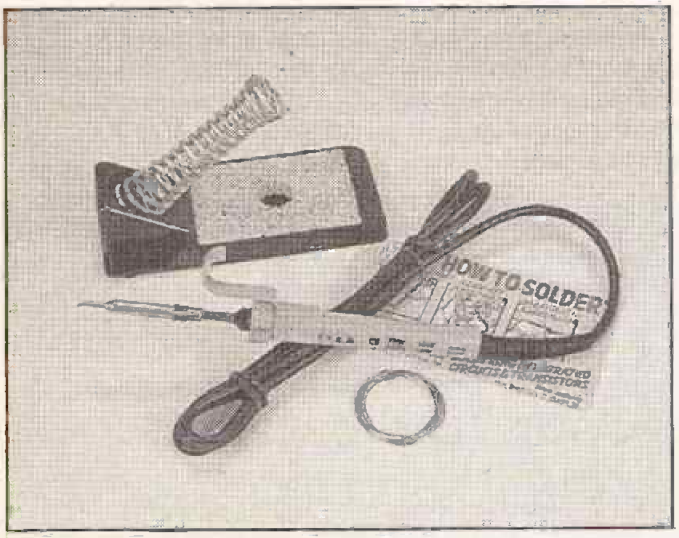
Closely resembling Mullard's 520 design of the early sixties, the amplifier benefits hugely from the quality of modern components. Modern materials have produced transformer cores that are half the size of twenty years ago, yet with better specifications. High speed capacitors achieve a competent, even sparkly, HF performance and 1% metal film resistors help push the S/N ratio to nearly 90dB, making a nonsense of the myth that valve circuits are inherently noisy.

Most commercial, ready made valve amplifiers are classed in the high power, Hi-Fi end of the market, and at this giddy altitude prices may begin at £1200, or even £1500 and increase from that point upwards. The Maplin Millennium route did not aim for 40 or 50W designs, but settled for a more practical (in terms of cost and home usage) stereo 20W design.

In order to help spread expenses whilst putting the unit together, the complete system has been organised into just two separate kits. In this way each kit can be bought and built as and when funds permit, as opposed to a large financial outlay at the beginning. The kits comprise one complete mono amplifier module and a power supply as a separate module. To complete the total stereo power amplifier, two identical amplifier kits, together with the PSU will be required. The PSU is able to supply a pair of amplifiers, but it can also cater for a mono version.

A single mono amplifier kit costs £74.95, the PSU kit £49.95 and the complete stereo kit £179.85.

For more information contact Maplin on 0702 554161.

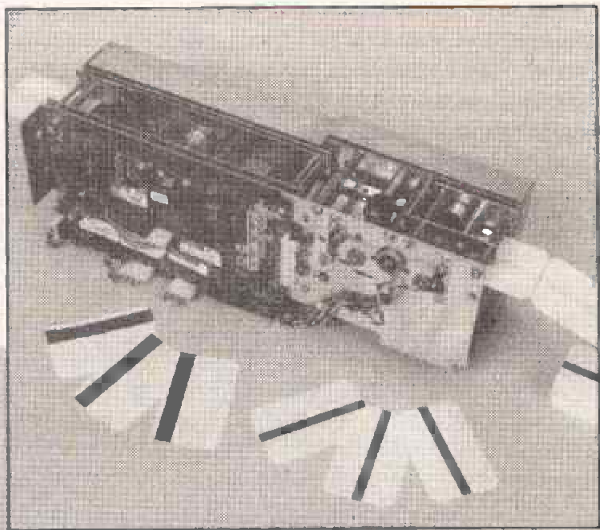


New High Quality Soldering Iron

Maplin Electronics has launched a new high quality soldering iron kit, the SK5. It is ideal for both expert and the beginner. The kit comprises a 17W 240V type CS soldering iron for light electronics work, a soldering iron stand ST4 with tip cleaning sponge and a coil of solder. It is all neatly packaged with full instructions on how to use and the art of soldering.

The kit is available until the 28th February at a special offer, £2 off the normal price of £13.95.

For further information contact Maplin on 0702 554161.



New Magnetic Card Readers

From Phi Ticket Systems of Pinner in Middlesex, comes a range of compact self contained magnetic card readers for use in a range of different equipment, ranging from access and parking control applications to ticket-validation. These readers feature built in microprocessors to control all functions such as Read, Write, Encode, Cut and Print and only require an external low power DC supply. Communication with external devices is over an RS232 link.

For more information contact Phi Ticket Systems Ltd on 081 866 2871.

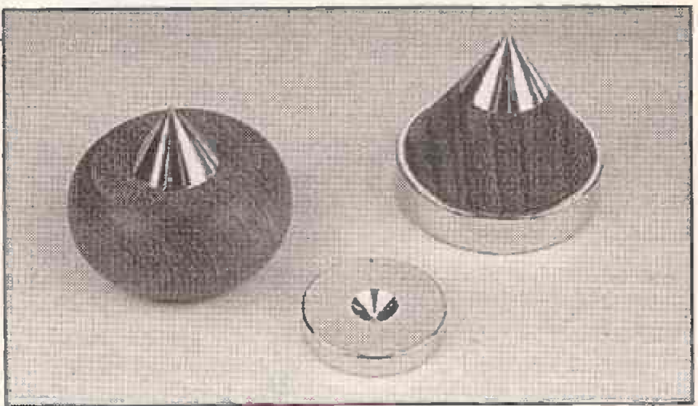
Magneto-resistance

Giant magneto-resistance is a recently discovered effect that dramatically amplifies the response of magnetic sensors. Scientists at Argonne National laboratory have achieved a record for giant magneto-resistance in iron-chromium films.

The Argonne group recorded a value of 150%, up 30% from the previous record. Whilst the underlying physics that results in these high values is not fully understood, studies of the new system suggest that the magneto-resistance could easily be raised to 200%.

Structured as a superlattice, the film was built with alternating chrome and iron layers, about 1,100 angstroms thick, sputtered onto a magnesium oxide substrate. Previous attempts to use magnetron sputtering to build iron-chromium magneto-resistance films have produced mediocre results because of the propensity of the deposited layers to form into polycrystalline domains. Previous records have been set with sputtered cobalt-copper films and iron-chromium films deposited with molecular beam epitaxial methods.

Anti-acoustic mountings



High quality audio equipment, such as CD players, tape decks, turntables and speaker cabinets, is frequently supported by special sharp pointed conical mountings. The theory behind the use of such mountings is that the smaller the contact area between the base of the equipment and the supporting surface, the less the music will be affected by feedback and resonance.

Such conical mountings are in fact a very simple but effective way of improving performance by reducing subfrequency vibration and are a must for every serious Hi-Fi enthusiast. A range of such conical mountings is now available from Maplin and consists of a conical support accompanied by a metal disk with central indentation for the point of the cone to rest upon.

There are three different types available. The first is a gold plated brass cone on a sandal-wood base having a low sympathetic vibration characteristic and is intended for use with items not exceeding 10Kg in weight. It come as a set of six cones and six bases (price £19.95 for the six), three of which would be used for the CD or record player and three for the amplifier. In use, the cones are inverted with their bases carrying the bottom panel of the unit, while the points rest upon the metal discs protecting the supporting surface.

The second type (£49.95 for a set of six) is a composite gold plated brass and sandal-wood cone which is suitable for speaker cabinets up to 20Kg in weight. The third type (£59.95 for a set of six) is the same as the second but has fixing screws so that the cones can be physically attached to the base of the speaker cabinet.

For further details contact Maplin on 0702 554161.

64Mbit DRAMs from TI and Hitachi

Texas Instruments and Hitachi have started releasing samples of their jointly designed and developed 3.3V 64Mbit dynamic random access memory integrated circuit. The two companies have previously jointly developed a 16Mbit DRAM and are currently considering joint development of a 256Mbit DRAM.

The 64Mbit DRAM has a 0.35micron feature size (a human hair is 75 microns wide) and a single one of these chips could store the equivalent of 2,800 typed pages of text. The chip has been initially organised as 8Mbit x 8 with a 60 nanosecond or less access time. Fabricated using CMOS technology, its memory cells each measure 1.65 square microns and are designed with advanced stacked capacitors. The chip will be available in 500mil wide packaging.

This chip is expected to become a standard component in the next generation of PCs and workstations.

For further information contact Hitachi Europe on 0628 585000.

Light Probe

A new light probe is designed to enter spaces as small as 3/8in in diameter and has brightness enhancing features. A heat and shatter-resistant frosted cover shrunk onto a Jiffy Super Light Probe diffuses the light of the halogen bulb to eliminate shadows. The light illuminates a 190 degree arc, allowing it to be used as a flashlight as well as a probe. Pins connect the socket, extension tube, and handle to prevent twisted wires that can lead to short circuits.

Two battery holders enable the probe to be used with different Makita rechargeable batteries. Unlike the Makita holders, which cover the entire length of the battery, the Jiffy holders are short and use a quick release catch to hold the batteries securely in place. The shorter holders can be moulded as a single piece, rather than two. And by not covering the length of the battery, one holder can accommodate both available styles of 9.6V battery. A 12V Super Light Probe, also available, can be run from a vehicle cigarette lighter or through a 120V to 12V transformer, for bench use.

Lights are used by drug enforcement officers to inspect hollow panels of cars, boats, and planes for contraband or bombs. They are used by locksmiths to help in opening locked cars, by auto and truck mechanics and in plant maintenance. The battery holders are also used separately to permit Makita batteries to power radio remote controllers.

The probe produced by AAA Products International, Dallas, Texas.

The ETI Cover Disk

This month's cover disk includes Part 2 of the Layo1 PCB design and schematics package PLUS a powerful Cross Assembler package, which allows one to write assembly language programs for all the popular 8bit microprocessors, using your PC

A great many ETI readers are now building and designing projects which include microprocessors. But the use of microprocessors brings with it the problems of writing assembly language software to perform the desired control tasks. In this month's and last month's issue of ETI we have included a project for building a Z- 80 processor system which could form the heart of many a project.

But how can one write Z-80 assembly language software without a Z-80 development system and associated assembler? The answer is to use a cross assembler and do it on a standard PC. The program included on this month's disk is just such a cross assembler, and is called TASM.

TASM is described as a table driven cross assembler for the MS- DOS environment. Assembly source code written in the appropriate dialect can be assembled with TASM and the resulting object code transferred to the target microprocessor system via PROM or other mechanisms.

TASM supports a wide range of popular microprocessor families, they include: **6502, 6800/6801, 6805, TMS32010, TMS7000, 8048, 8051, 8080/8085, Z-80** and users who feel so inclined can even build their own tables to allow TASM to assemble code for other microprocessors.

TASM is, in fact, a very versatile assembler. It supports powerful expression parsing (17 operators), supports a subset of the C pre-processor commands and has extensive macro capability. Output can be in any one of four object file formats (Intel hex, MOS Technology hex, Motorola hex and binary). It also has features in support of PROM programming such as preset memory and contiguous blocks.

The documentation which comes with TASM is extremely comprehensive. However, documentation for the microprocessor you intend writing software for is something which you will have to acquire separately.

In order to use TASM, the source code must be written using a text editor. The source code format should correspond to the standard for the processor, details on which can be obtained from the processor's documentation. Once the source code has been written it should be saved as an ASCII file. It can then be run through TASM.

The syntax used by TASM can be quite complex, but is fully detailed in the documentation and also displayed if we try running TASM without any parameters. As a simple example, if we are writing a 6502 program saved as a text file called TEST.SRC, we can assemble it using the following command sequence: **TASM -65 TEST.SRC**

If there are any errors in the assembly code listing, the assembler will list them. It is then back to the editor to correct them before reassembling.

Layo1 - Part 2

This issue contains the concluding part of the Layo1 PCB design and schematics package. On this month's disk are the schematic output drivers, the PCB output drivers, the PCB design rule checker and a comprehensive set of self running tutorials. All these, together with the programs on last month's disk should enable any reader to start designing professional looking PCBs on his or her PC.

As we noted last month, this is a shareware version of a popular commercial program. This version is limited to 1000 commands, which in practice means designs with about 200 pads and 800 tracks, sufficient capacity to design almost any one of the PCBs used in ETI projects. It will run on any IBM PC or 100% compatible, with mouse, EGA graphics and running DOS 3.1 or later

Readers who have already installed Layo1 on their PC will find the tutorial package particularly useful since it demonstrates how various operations are performed in a way that is far better than any documentation.

The way that Layo1 works and the basic theory behind the operation of PCB design and schematics layout programs, was included in last month's issue of ETI. The operation of the output drivers and the design rule checker was also covered. Any reader who did not get a copy of last month's issue can still get one from ETI's Back Issues Dept, the cost is cover price, £2.25, plus 60p P&P, and you will receive both the magazine and the free cover mounted disk for this price. The address to send your cheque or P.O. to is ETI Back Issue Service, Argus House, Boundary Way, Hemel Hempstead, Hertfordshire, HP23 7ST.

Installing TASM

To install TASM on your computer, you will first of all need to decompress it. There is a special decompression program to do this.

Firstly, create a directory to store TASM, thus: MD ASM and then enter that directory and copy the following two ETI cover disk files to it:

PKUNZIP.EXE 2362.ZIP

Then decompress the files by running PKUNZIP, thus: PKUNZIP C:\ASM\2362.ZIP the result is a decompressed collection of files including TASM and all the documentation (ignore the comments in the documentation about having to unzip the documentation, since it has already been done!).

There is a copy of a very comprehensive manual included on the disk, which be can viewed directly or printed out using a word-processor (don't forget to give your printer plenty of paper before doing this!).

The version of TASM included on the ETI disk was kindly supplied to ETI by the Public Domain and Shareware Library of Winscombe House, Beacon Rd, Crowborough, Sussex, TN6 1UL. Tel. 0892 663298. This company is able to provide a very wide range of useful shareware and public domain programs, many of which will be of interest to ETI readers.

TASM is a shareware product, which means that if you like it and intend using it regularly, then it is only fair that you pay something to the authors. Full details of who the authors are and how to pay them is included in the documentation.

Installing Layo1 - part 2

To install these additional Layo1 programs on your computer there is a special Install program to simplify the procedure. All you need to do is insert the disk into the appropriate disk drive and access that drive, then simply type: INSTALL. A windows type menu system will then be displayed and the various messages will lead you through the installation procedure.

There is a copy of the manual on disk and this can be printed out either from Layo1 or by loading it into Word. Also included in Layo1 and its documentation are details of how to register your copy of Layo1 and the prices and ordering details for the full versions of this program.

Prices for Layo1 Commercial Versions.

Level 1 - has a design capacity of 4000 commands	£95
Level 2 - has a design capacity of 10000 commands	£295
Level 3 - has a design capacity of 20,000 commands	£565
Level 4 - has a design capacity of 65,000 commands	£995

All prices are exclusive of VAT at 17.5% For educational establishments there is a discount of up to 40% and on all products there is a 30 day money back guarantee.

All versions of Layo1 are available from: **Baas Electronics bv, Rijksstraatweg 42, 3281 LW Numansdorp, The Netherlands. Tel. +31 1865 4211. Fax +31 1865 3480**

SOME POPULAR BARGAINS

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TAPE MOTOR BY EMI, 2 speed & reversible, **£2,** Order Ref 2P70
¼HP 1000RPM, £8, Order Ref 8P7
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3" 4 OHM TWEETER, £1, Order Ref 433
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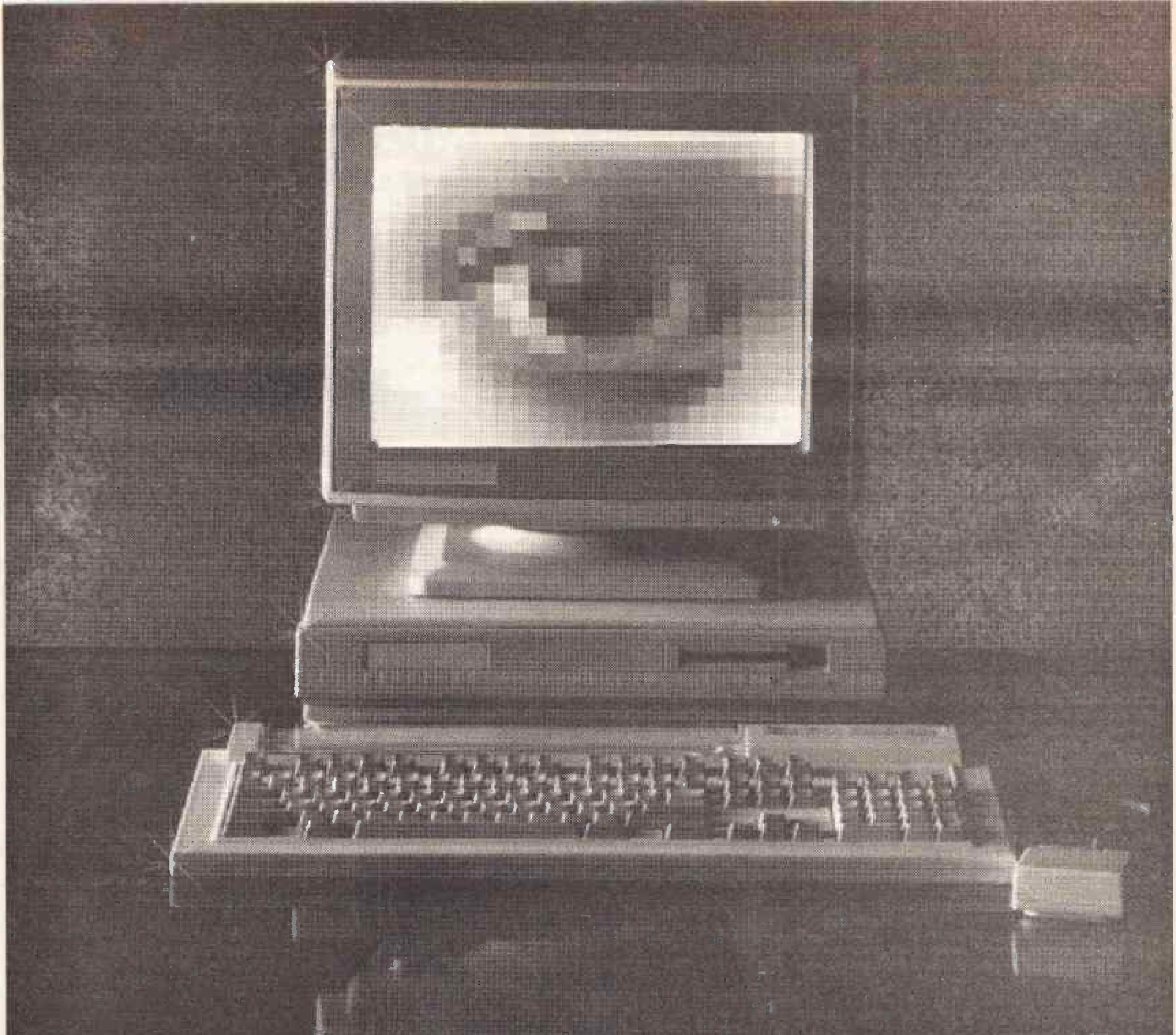


Machines that see

Can we learn from nature and create machines that can see and visually understand the world around them?

The eye is our window onto the world around us. Through this window we learn about the world, about the objects in it, their relationship to each other, their behaviour and their function. For most of us vision is something we take for granted, but without it life can be very difficult.

What applies to us humans, also applies to the intelligent machines which are now being built. If such machines are to find out about the world around them they need to be able to see it. They need to touch it, hear it and be able to learn to recognise familiar object, to discover the basic rules which govern existence in that world.

Sensory systems, in particular vision, for machines has long been a subject of considerable interest to researchers in the field of artificial intelligence. The approach taken by these researchers has, however, tended to one or other of two distinct paths. There are those researchers who will simply input an image using a video camera and then attempt to do all the image recognition and analysis by computer software and there are those who are seeking to build systems which more closely model the biological eye. It is the work of this latter group of researchers, who can broadly be described as neural cyberneticists, that we will be looking at in this article.

The biological model

The biologist can give us plenty of examples of vision systems from all sections of the animal kingdom. These range from the extremely simple photoreceptors found in single celled animals, through the compound eyes of insects to the highly complex human eye. We may not want to model these systems exactly but they do give us some ideas about how the problem can be tackled.

There is not much that we can learn from simple single celled and small multicellular organisms since their light receptors are very rudimentary. They are primarily used to allow the organism to move towards or away from a light source, the direction being dependent upon the feeding habits and behaviour of the animal. There is no suggestion that such optical sensors are used to build up an image of the environment around the animal.

Probably the simplest true image sensors that are of interest to neural cyberneticists are those found on molluscs and on arthropods, such as insects and crustaceans. These optical sensors are designed to not just detect light but also to perform simple image analysis. They can detect the polarisation of light to provide some form of direction finding with respect to the sun. They can also perform motion detection for finding prey and as a warning of predators. They also provide sufficient image analysis to enable a flying insect to identify a leaf and then land upon it.

An insect does not see an image in the same way that a camera does, in fact it is doubtful that an insect can see any sort of image in the sense that we can see an image. An insect has two compound eyes and in most cases a number of single eyes. In an ant, for example, each compound eye consists of about 1200 individual optical elements or ommatidia, each of these elements having its own lens and optical sensor.

But not all the sensors in an ant's compound eye are the same. Some are sensitive to polarised light, some to ultraviolet radiation, both of which are used to help the ant navigate. Others are sensitive to colour, or to motion. All of these signals from different types of sensors are combined by the nervous system of the ant to provide it with all the visual information that it needs to survive.

If we were to use electronics to model part or all of an insects visual system we would have a system that consisted of a lot of separate optical sensors, each comprising of a lens and perhaps a colour filter, or a polarising filter, to screen out unwanted light radiation. The desired part of the light spectrum, or polarisation direction, is then measured by a sensor, such as a standard photodiode. Depending on what is being measured, the output from this sensor could be a simple on/off voltage, or a variable voltage.

It would be up to a controlling computer program to decide what each input meant and how it would affect overall system behaviour. Thus, a simple mobile robot could be built which had a liking for blue light, or blue coloured objects and an aversion for red light and red coloured objects. Or one that would search for and follow any light coloured marks painted on the floor. This is visual input, but not image input.

From the standpoint of neural cybernetics, this distinction is very important. In other words an image, as we humans understand it, is not necessary in order to provide a rudimentary level of optical and visual information. Thus the concept of using polarised sunlight to navigate could be adopted in the design of a mobile robot, without the robot actually being able to see where it is going.

Although the eyes of insects and other lowly forms of animal life can provide some interesting design ideas, the neural cyberneticists' main interest lies primarily in the single lens camera type eye found in amphibians, reptiles, birds, mammals and, of course, man. The single lens eye is much more generalised in its function than ommatidia of an ant and it is primarily designed to input and process visual data in the form of images of the external world.

Much of the early work in this area was done at the Massachusetts Institute of Technology by people like J Y Lettvin on amphibian vision. He showed how the eye of an animal like a frog actually worked, an analysis which has enabled the neural cyberneticists to build models of the optical system of not just the frog, but also of higher level animals such as cats and even the human eye.

In a frog's eye, the single lens focuses an image of the world onto the retina, a surface built up from thousands of individual light receptors and their associated nerve cells. Each of the receptors in the retina detects a small part of the focused image and the associated nerve cells perform an initial level of processing on the perceived image, then transmit this data via the optic nerve to the brain, for further analysis.

The result of this pre-processing is the generation of four specific types of information about the image being perceived. The first type if information is described as net dimming and is a measure of how much an image has dimmed when compared with the previous image. The second type of information is moving edge data, concerned with motion at the periphery of objects in the image field. The third type of information is sustained contrast data, telling us the size and shape of objects in the visual field by describing edges of optical contrast. Lastly, there is net convexity data, which tells us the speed and direction of small moving objects within the image field.

These different types of pre-processing image data are all generated by the horizontal layer of nerve cells which link each photoreceptor. It is this linkage which allows the frog's eye to perceive images rather than the collection of optical data inputs in an insect. This horizontal layer acts as a neural network which allows each receptor to influence, and be influenced by, its neighbouring receptors.

The silicon eye

By the mid 1980s biologists and neuroscientists knew enough about the much more advanced mammalian eye and its associated nerves and synapses to be able to accurately model the processes which takes place. Simultaneously, electronics had advanced to a level where it was possible to duplicate the behaviour of any neural process. From this convergence of two separate areas of development was born a number of projects to build a silicon retina, the sensory portion of an eye on a single silicon chip, that would behave much like its biological analogue and act as a possible basis for future machine vision systems.

Probably the most promising work in this area is being done at the California Institute of Technology under the auspices of veteran AI researcher and the man behind much of the development of modern methods for digital VLSI, Carver Mead. His team has already built silicon models of biological structures, including a silicon retina and a silicon ear.

The silicon retina consists of an array of light sensors, each covering a small portion of the image area, an area known as a pixel. With just a single pixel it is possible for the system to detect changes in lightness and darkness, and even movement of an object across the field of vision, but impossible to detect any image. To identify simple shapes such as the letters on this printed page, we need an array of at least 64 pixels, an array of at least 256 pixels to actually read the text, and 1024 pixels or better for very limited image recognition and scene analysis. The Caltech team's latest silicon retina has over 2500 pixels.

Each of the pixels in the Caltech silicon retina has three parts; the photo receptor, the horizontal cell connections and a bipolar cell. The receptor has a photosensitive element that outputs a current proportional to the number of photons it absorbs. The receptor also has a feedback loop which amplifies the difference between the instantaneous current output by the sensor and its average level over a long period. The output voltage from the photosensor is thus proportional to the logarithm of the light intensity. There is also a feedback loop between the horizontal connections and the receptor, the function of which is to change the sensitivity to areas of uniform intensity.

The individual pixel circuits are linked by the horizontal cells. The Caltech silicon retina's receptors are arranged on a hexagonal grid pattern and the horizontal links thus form a hexagonal network. The six horizontal links between each pixel and its neighbours consist of six identical variable resistors and capacitors.

Each node in the horizontal network thus has a voltage which represents the spatially weighted average of the receptor inputs to the network. This means that the effective area of the image over which the signals are averaged can be changed by simply changing the resistor values in the horizontal links.

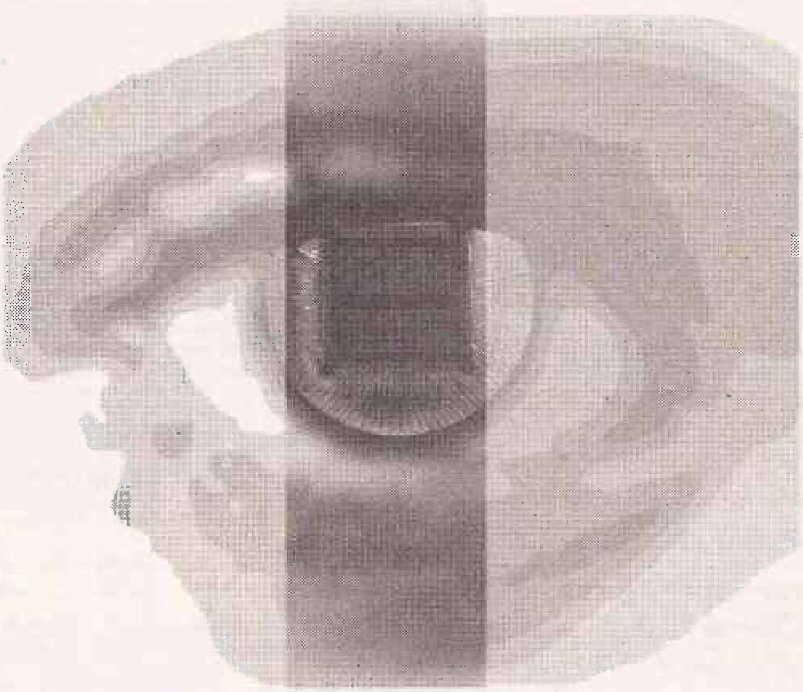
The final component in the silicon retina is the bipolar cell. This is an amplifier which has the function of determining the voltage difference between the photoreceptor to which it is attached and the corresponding node in the horizontal network.

The behaviour of a silicon retina

The Caltech team started work on their silicon model of a mammalian retina in the early 1980s and their retina has now been through about 20 versions in its evolution. What has surprised the researchers is how closely the behaviour of the silicon retina mimics that of the biological original.

Thus, the silicon retina will adapt itself to an image which remains stationary for a reasonable period, the network will gradually adapt the image away. However, just like the human eye, if a blank screen is suddenly placed in front of the adapted retina, it will display a negative after image. The same effect that we get if we stare at a bright light and then look at a blank wall.

Indeed, the researchers made some interesting discoveries that their silicon retina was subject to many of the same optical illusions that we perceive. For example we see a grey square as being darker when placed on a white background than when it is placed upon a dark background, the Caltech silicon retina sees the same illusion. The silicon retina also sees the illusion of apparent bright and dark bands adjacent to a transition from a light to a dark area, the so called Mach bands. Similarly, it also perceives grey spots at the intersections of a grid of white lines, the Herring grid. The appearance of these optical illusions and a host of other visual quirks of the human eye in the Caltech silicon retina shows that the electronic model of the biological retina is pretty accurate. It also shows how important the image processing done by the retina is.



Another enormously important conclusion to come from this research is that it demonstrates the enormous power of analogue computing in neural networks. Normally designers would have converted sensor input to digital form and then worked digitally, only transferring it back to analogue form when necessary. But neurons are, nevertheless, analogue devices and can singly and in networks perform analogue computation, indeed in the form of the human brain they make up the most efficient and most powerful information processor known.

Analogue computation has been almost totally eclipsed by digital computing over the last twenty years, but perhaps it is now time to take another look. It takes a lot of processing time and a lot of silicon space to convert analogue voltages into digital form, then process that data and reconvert it. An analogue computational circuit could do the same thing in less time and with a much smaller usage of silicon. Indeed, as the Caltech silicon retina demonstrates, analogue computational techniques can perform tasks which would be very difficult if not impossible to do digitally.

Perhaps the supercomputers of the future will be partly analogue and partly digital?

Future development

As we have seen, scientists are already a long way down the path towards developing viable machine vision systems. The silicon retina is just one component, although probably the most important one. Another component is the development of pattern recognition systems, which can further process the data from the silicon retina. Such systems might also be based on neural networks and will be able to recognise familiar objects irrespective of orientation, distance, lighting conditions, etc.

With silicon retinas that have a resolution perhaps a hundred times that of the current Caltech chip and chips that work in pairs to give binocular vision and hence distance information, real machine vision is a possibility within the next decade or so.

And what about man, will we see the bionic eye of the Six Million Dollar Man? Well scientists at the Duke University Eye Centre in Durham N.C., are well advanced in research work aimed at implanting a silicon retina into the eye of blind people (in particular those with retinitis pigmentosa) so that they will have some sensation of light and dark and eventually complete image sensing.

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PROJECT

Radio Revisited

Raymond Haigh shows how to build a low cost, high quality FM radio which has the look of yesteryear.

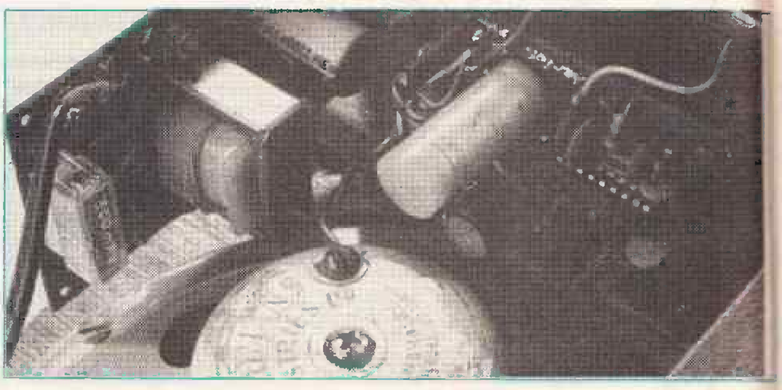
Transistor portables are probably used for most domestic radio listening but, unless they are in the luxury class, plastic cabinets and tiny speakers can result in rattles and inferior audio quality. Even their most impressive attributes - very low power consumption and extreme portability - are not too relevant in a domestic situation where a mains supply is available and where they are usually left in one location, perhaps the kitchen or dining room, for much of the time.

Most home constructors can provide some form of wooden cabinet and a speaker of reasonable size at little or no cost and many will already have suitable items cluttering up the workshop. The problem is one of finding a low-cost, high-quality radio tuner/amplifier combination that does not involve complicated alignment and setting up procedures. The circuit described below meets all of these requirements. Comprising only two IC's and a handful of external components, there are no alignment problems and adjustment of the single tuned circuit is extremely simple.

Design Considerations

For a high quality, interference-free signal, the choice has to be VHF, FM radio. Most of the BBC's services are transmitted in this mode and commercial stations further extend the range of news and music programmes available. Confining reception to the VHF broadcast band does not, therefore, seriously limit programme choice, especially having regard to the niche this radio is going to fill. However, it does eliminate all signal frequency switching and it greatly reduces complexity and cost. It also makes the choice of an interesting FM radio IC, introduced by Philips a few years ago, particularly appropriate.

This IC, the TDA7000, brought the advantages of solid-state integrated circuitry to an economical FM receiver design developed at the close of the valve era. Featured a number of times in electronics magazines during the early 60s, all of the IF transformers were eliminated by the use of a very low IF, typically 150kHz, which was determined by the RC couplings between the valves. Variable tuning was provided only to the oscillator stage which was often run at the second or third harmonic of the signal frequency in order to improve stability. Detection was carried out by a double-diode pulse counting circuit and AFC was usually applied to the oscillator. The audio signal from the TDA7000 IC is typically 75mV, more than enough to drive most small power amplifier ICs. An undistorted output of 1W is quite adequate for an ordinary domestic radio, especially when a reasonably sensitive speaker is used and a TBA820M is accordingly an ideal choice for this application.



Mains operation is much more economical than battery power supplies. The additional outlay on components will be more than recovered after a few weeks' steady use and the mains connection lead can increase signal pick-up, improving the action of the telescopic aerial by acting as the second element of a dipole.

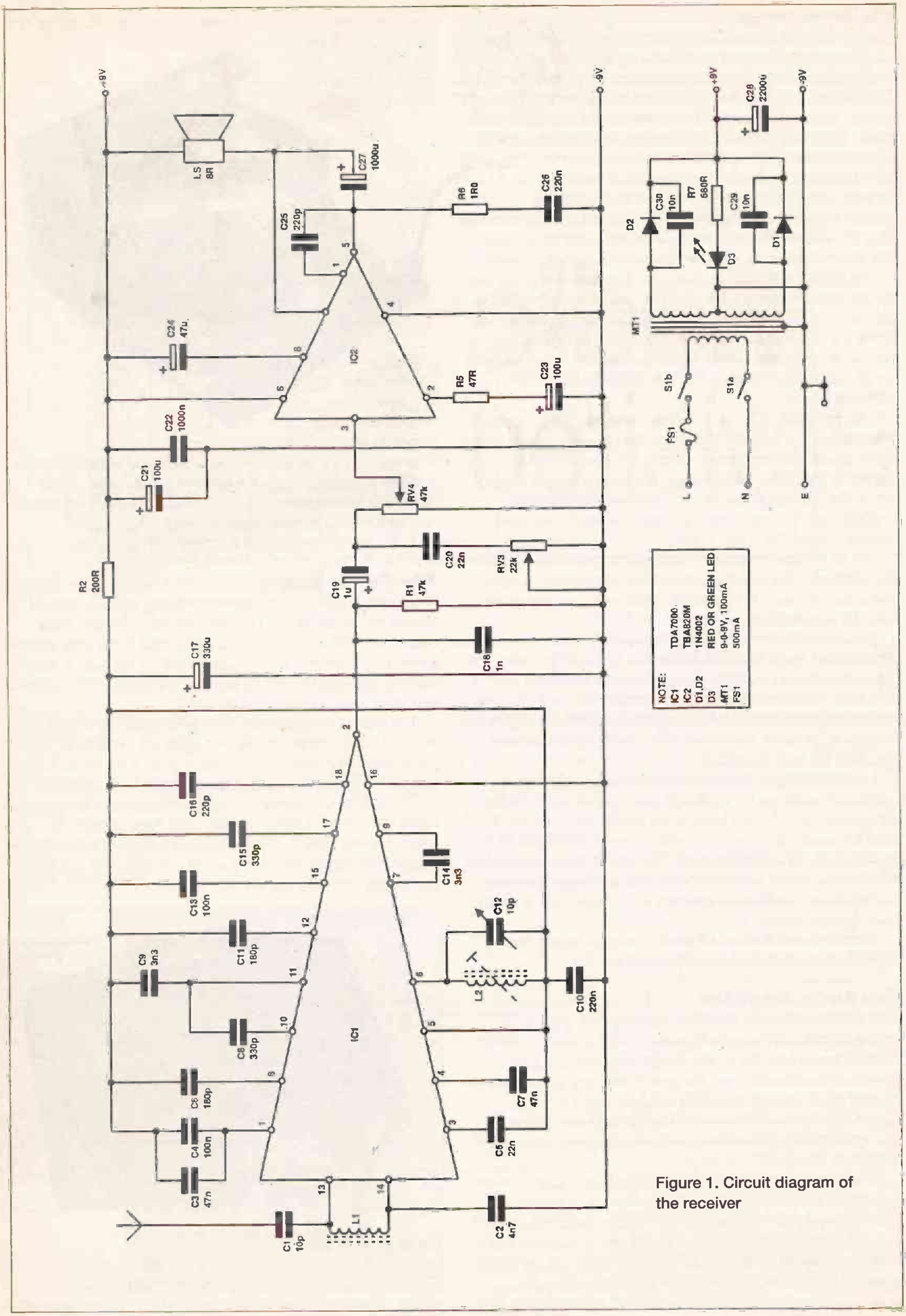


Figure 1. Circuit diagram of the receiver

FM Tuner Stage

The full circuit of the receiver is given in Figure 1 and a function diagram for the TBA7000 is shown in Figure 2.

Signals collected by the telescopic aerial are applied to pin 13 of IC1 via C1. Inductor, L1, is wired across the input of the IC and comprises a few turns of wire threaded through a ferrite bead. There is nothing to be gained by tuning this non-critical coil as it is heavily damped by low-value resistors within the chip. During the development of the receiver, alternative input circuits were tried, including connecting pin 13 to a tapping on a tuned coil and the provision of an RF amplifier stage, but they were not found to offer any real advantage over the simple arrangement shown in Figure 1.

The oscillator coil, L2, is connected between pins 5 and 6 of the IC. With this design, the oscillator runs at signal frequency, plus an IF of approximately 70KHz. Minimal stray capacitances (there are no trimmers) thus permit coverage of the required frequency range with a 10pF variable capacitor, C12. The tuned circuit is set to the centre of the VHF broadcast band by adjusting the core of L2.

Capacitors C6, C8, C9, C11, C14, C15 and C16, together with resistors on the chip, determine the receiver's IF and shape its response. Two capacitors, C3 and C4, are connected in parallel to permit the exclusive use of small, ceramic components (the required 150nF is not a readily available ceramic capacitor value). They combine to mute spurious responses, including unwanted image signals.

The IC contains circuitry to inject inter-station-noise. C5 on pin 3 activates this function, which is discussed later. Simply delete the capacitor for completely silent tuning, or reduce its value for a softer hiss.

Capacitor C7 eliminates IF harmonics at the output of the demodulator stage. It also fixes the time constant for locking the frequency locked loop (FLL) and influences upper audio frequency response. The recommended value is 10nF, but this had to be increased to 47nf on prototype receivers in order to completely eliminate spurious signals. The reduction in treble response is hardly noticeable.

Most of the signal shaping and processing circuits are 'grounded' at RF via the positive supply rail and supply decoupling capacitor, C10, is crucial to the stability of the device. It must be located as close as possible to pin 5. The mixer is decoupled by C2, and R2 and C17 provide a measure of supply line isolation for the entire front end. With prototype receivers, any significant reduction in the value of C17 gave rise to modulation hum problems.

After de-emphasis by C18 and R1, the output from the TDA7000 is coupled to the audio stages via C19.

The Audio Amplifier

A simple top-cut tone control, comprising C20 and R3, is connected across the volume control, R4, the slider of which is taken to the input pin of the TBA820M power amplifier. Feedback resistor, R5, sets the gain of the device. The value chosen gives an input sensitivity of about 25mV for 1W output. This deliberately errs on the high side and constructors who find the gain excessive can increase the value of this resistor to 100 ohms.

One of the loudspeaker leads is connected to supply positive in order to minimise external component count (a resistor and electrolytic capacitor are saved). The value of feedback capacitor, C25, has been chosen to give a frequency response which is more or less flat up to 20kHzand, as the radio is to be mains powered, ripple rejection capacitor C24 is included in the circuit. Any tendency to instability is curbed by connecting the Zobel network, comprising R6 and C26, across the output, and by including HF bypass capacitor, C22, which must be located close to pin 6 of the IC.

The tuner/amplifier combination has an extended bass response and constructors who wish to try a large speaker in a cabinet of suitable size will find that the value of output coupling capacitor, C27, is big enough to fully exploit this. It can be reduced to 470µF, without any audible drop in bass response, when a 130 or 150mm speaker is fitted in a small cabinet.

The Power Supply

The power supply is quite conventional with a centre-tapped transformer arranged in a bi-phase, full-wave rectifier circuit. Capacitors C29 and C30, connected across the rectifier diodes, prevent modulation hum and C28 smoothes the output. A 35V working type was chosen for the smoothing capacitor in order to ensure good ripple current handling.

The receiver is completely silent in the absence of modulation and this increases the risk of it being left switched on and connected to the mains supply after station close-down. LED indicator, D3, and its supply dropper, R7, help to avoid this.

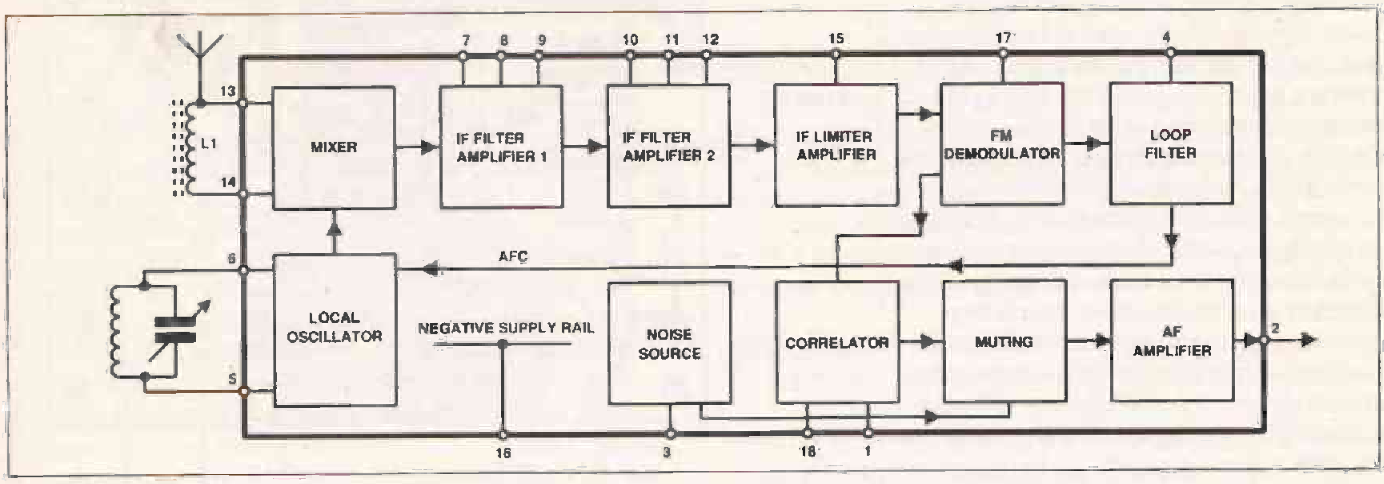
Connecting the transformer core and secondary windings to mains earth and the fitting of a low-value fuse on the PCB where it is less likely to be tampered with, helps to maximise the safety of the equipment. Mains on/off switches, S1a and S1b, are ganged with tone control, R3.

How it Works

Local oscillations combine with incoming signals in the TBA7000 mixer to produce an IF signal of approximately 70KHz. This signal is fed through two amplifier stages, around which are arranged a fourth order low pass and a first order high pass RC filter. The signal is then processed by an IF limiter/amplifier stage and a quadrature detector. Conversion gain of the mixer and the gain of the three IF amplifier stages, is high, and the sensitivity of the receiver is at least as good as that displayed by most commercial FM portables.

Because of the low IF frequency, IF deviation has to be limited to ±15kHzin order to prevent distortion. This is achieved by a frequency locked loop (FLL) system in which the output from the detector is made to shift the oscillator frequency in inverse proportion to the IF deviation caused by the incoming signal. This loop also affords a high degree of automatic frequency control (AFC).

Figure 2. Block diagram of TDA7000



The internal circuitry of the chip is arranged to ensure suppression of AM signals and to provide a measure of automatic gain control (AGC). Correlator and muting systems suppress the images which would otherwise be a problem because of the low IF. They also suppress inter-station noise and provision is made for reinstating this in order to simulate the tuning action of conventional FM receivers.

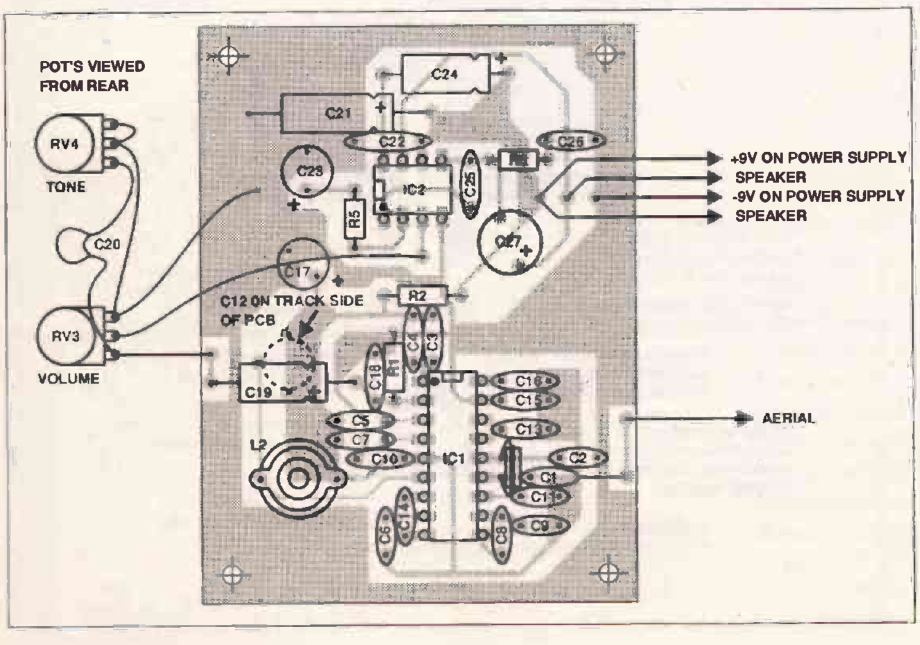
Audio amplification is provided by IC2 and power for the complete receiver is supplied by a conventional, unregulated, mains unit.

Construction

All of the components, with the exception of R3, R4, C20, D3, the loudspeaker and a telescopic aerial, are mounted on printed circuit boards. A separate board is used for the power supply in order to give more freedom in assembling the receiver and to enable constructors to dispense with the mains unit and use batteries, should they so wish.

The component side of the receiver PCB is given in Figure 3 and the foil side in the PCB foils section at the rear of this issue of ETI. Holders were used for mounting the ICs on the prototype board as this makes substitution checking of the devices an easy matter. Vero pins were inserted at all of the lead-out points and at the three connection points for C12. The pins for C12 must, of course, project on the foil side of the board. They prevent the copper tracks being pulled from the board and also enable the position of C12 to be adjusted slightly to align it with its spindle bush.

Figure 3. PCB component side



L1 is three turns of 26swg, or similar, enamelled copper wire threaded through a small ferrite bead. Trim the wire leads close to the bead, scrape away the enamel and thoroughly tin the bared copper before attempting to solder it into position on the PCB.

Tone and volume controls, R3 and R4, and a bush for the spindle extension to C12, are mounted on a small plywood or paxoline control panel. This panel also carries the telescopic aerial and the LED on/off indicator, the receiver PCB being mounted on stand-offs beneath it. The photographs show the method of assembly adopted for the prototype receiver.

The tuning capacitor, C12, is a plastic film dielectric 10pF trimmer and a spindle and control knob have to be attached to its slotted head. Figure 5 shows how this is done. Scrap spindle, cut from R3, is drilled at one end to receive the brass head of the trimmer, which should be a firm push fit into it. Mount the PCB in position, carefully aligning the trimmer with the spindle bush in the control panel, then pass the spindle through the bush and secure it to the trimmer head with a dab of Superglue. This procedure ensures the correct vertical alignment of the spindle, which is otherwise difficult to achieve. It is not easy to form a dead-centre hole in the end of the spindle, but a very close approximation is possible with a little care. If the first attempt is not good enough, try again at the other end of the spindle. If this is not satisfactory, remove the end section and have another go. Scrap spindle from R4 can always be pressed into service should the spindle from R3 become too short.

This tuning arrangement, which costs pence rather than pounds, has proved completely satisfactory. It is smooth, noise free, reliable and not prone to microphony. The small effort required to produce such a cost-effective system is certainly worth while.

The power supply is assembled on its own PCB. Details of component placement are given in Figure 4 and the copper foil side of the board is shown in the PCB foils section at the rear of this issue of ETI. Again, Vero pins ease off-board wiring and the mains cable should be restrained where it leaves the cabinet, to prevent it being detached from the PCB by rough handling. The leads which connect the power supply PCB to S1a and S1b should be tightly twisted together, to minimise ac fields which could be picked up as hum by the audio circuits.

The Cabinet

The style and details of the cabinet are very much matters of personal taste, but sealed enclosures should be avoided as they reduce speaker efficiency and create a dull, 'boxy' sound (hi-fi speakers based on this principle rely on special drive units and powerful amplifiers to achieve good results). The photographs accompanying this article show the vintage style cabinet produced by the author. The controls are mounted on the top and a large vent is formed in the base. The 210 x 130 x 260mm

Figure 4. Power supply PCB component placement

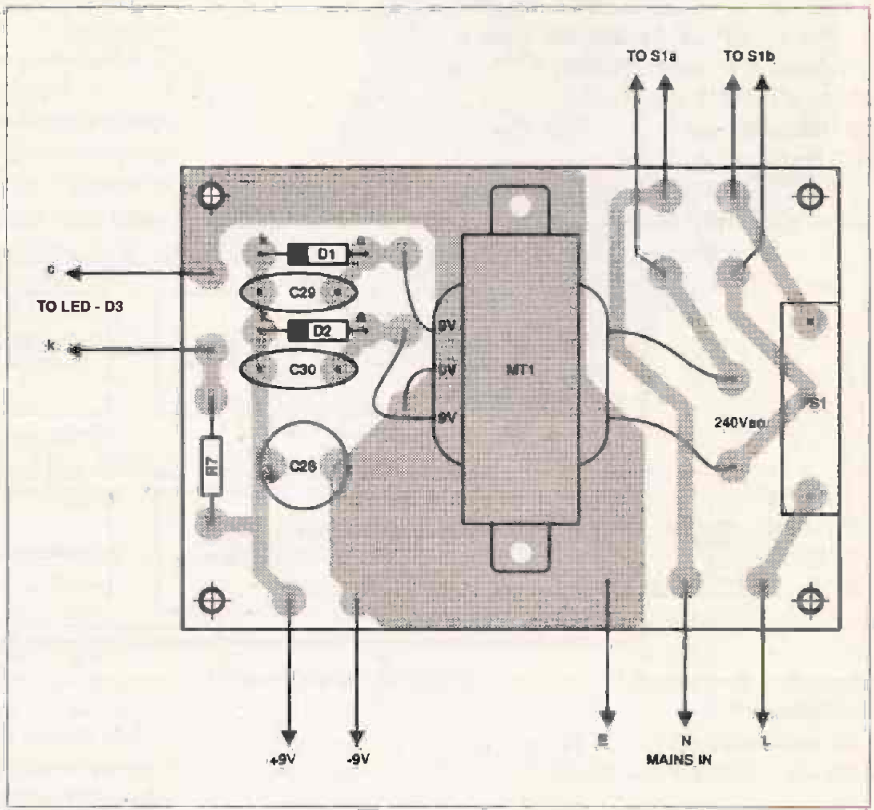
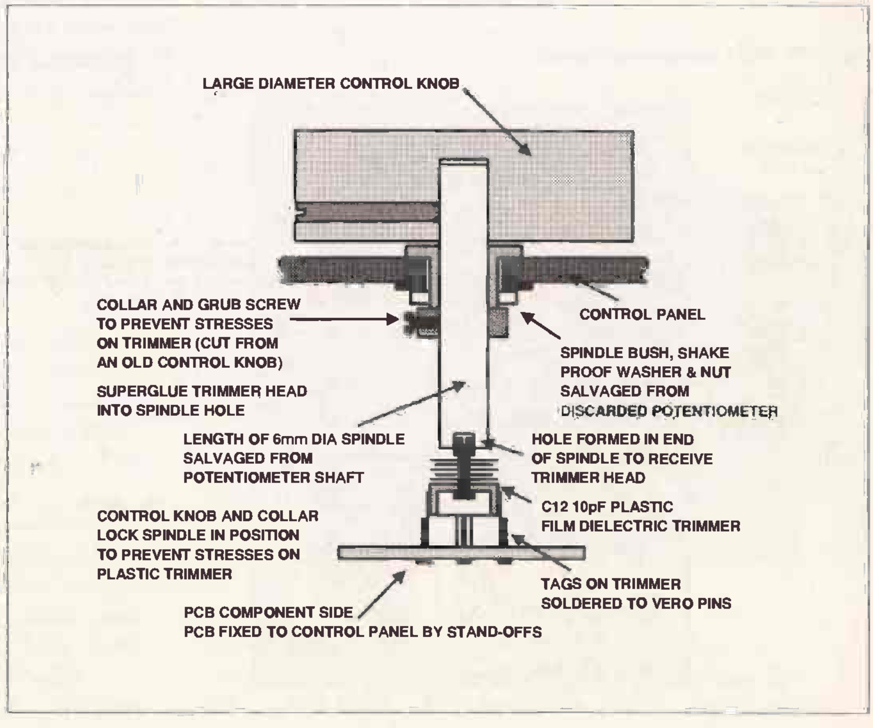


Figure 5 Sketch section through spindle attachment for tuning capacitor



cabinet, which houses a 160mm diameter speaker, is formed from 6mm thick hardwood panels, glued and pinned together.

Quality of reproduction is pleasant and particularly clear.

Setting Up and Using the Receiver.

The initial adjustment and testing of the receiver is best carried out before the various parts are mounted in the case.

Check the PCBs for defective joints and bridged tracks. Check the ICs, diodes and electrolytic capacitors for correct placement and, if all is in order, connect the power supply to the mains and switch on. Remember that the power supply PCB carries exposed mains wiring and it can be lethal if it is handled carelessly. Constructors who are uncertain of their ability to commission mains powered equipment should consider using batteries.

Set the ferrite core of L2 so that it projects 2mm above the top of the former, connect about 1 metre of wire to the aerial pin, advance the volume control until the inter-station hiss is audible, then search for a transmission with tuning capacitor, C12. If no signals are heard, adjust the core of L2 and rotate C12 again. If the specified Toko coil has been used, only a slight adjustment of the core will be needed to centre the receiver on the VHF broadcast band. The ferrite core is extremely brittle and the correct trimming tool must be used.

The low-value tuning capacitor and strong AFC eliminate the need for a slow-motion drive. A large diameter knob on the spindle of C12 will, however, make tuning the receiver easier. Fix a pointer to the knob and calibrate the receiver by marking the settings for the local BBC and commercial stations on the control panel.

The action of the tuning control differs from that of conventional receivers, having a less critical, softer feel. The control should be rotated slowly until the circuit locks on the desired transmission. It will then probably need turning back very slightly to centre the tuning. AFC hold is quite strong and, once lock has taken place, the setting of the dial pointer becomes relatively broad. The pointer should, however, be centred as carefully as possible or interference pulses may drive the circuit out of lock and result in the 'loss' of the signal. Activating the internal noise generator simplifies the correct tuning of the receiver, as the pointer can be set mid-way between the two positions where the inter-station hiss starts. Moreover, accidentally tuning through a station is less likely with the noise generator operational.

The potential across C28 should be of the order of 11V under no-output conditions. This will fall to approximately 8.5V when music is being reproduced at loud volume. Provided the receiver has been correctly tuned, the AFC system will prevent this voltage swing having any effect on reception. Quiescent current consumption is approximately 15mA rising to about 30mA with speech at normal volume. Battery operation is, therefore, perfectly feasible and a 9V pack of AA or larger cells is recommended. A 4 ohm loudspeaker will enable the audio IC to deliver more power when 9V battery supplies are used.

BUYLINES

The TDA7000 IC is retailed by Maplin and the Toko coil is available from Maplin, Cirkit and Bonex. The remaining components can be obtained from a variety of sources. An inexpensive loudspeaker is recommended and suitable types can often be salvaged from old television receivers. A bush for the tuning spindle can be obtained from a discarded volume control.

PARTS LIST

Resistors (all 0.5W, 5%)

R1	47K
R2	200
R3	22k lin' potentiometer with double pole switch
R4	47K log' potentiometer
R5	47
R6	1
R7	680

Capacitors

C1	10pF ceramic
C2	4n7 ceramic
C3, C7	47nF ceramic
C4, C13, C22	100nF ceramic
C5, C20	22nF ceramic
C6, C11	180pF ceramic
C8, C15	330pF ceramic
C9, C14	3n3 ceramic
C10, C26	220nF ceramic
C12	10pF plastic film dielectric trimmer
C16, C25	220pF ceramic
C17	330µF 16V electrolytic, radial lead
C18	1nF ceramic
C19	1µF 63V electrolytic, axial lead
C21	100µF 16V electrolytic, axial lead
C23	100µF 6V electrolytic, radial lead
C24	47µF 16V electrolytic, axial lead
C27	1000µF 16V electrolytic, radial lead
C28	2200µF 35V electrolytic, radial lead
C29, C30	10nF ceramic

Inducters and Transformers

L1	see text
L2	Toko type S18 moulded RF coil with ferrite core, 0.230uH, 5 1/2 turn winding, colour-coded green. Toko part No. 301SS-0500MT1. Mains transformer: sub-miniature type. Primary to suit mains voltage. Secondary 9-0-9V, 100mA.

Semiconductors

IC1	TDA7000
IC2	TBA820M
D1, D2	1N4002
D3	Red or green LED

Sundries

Small ferrite bead, anti-parasitic type
18 pin and 8 pin holders for ICs
PCB type fuse holder and 500mA fuse
Telescopic aerial
Loudspeaker, 8 ohm for mains operation, 3/4 ohm for 9V battery version.
One large and two small control knobs.
Materials for printed circuit boards, Vero pins, hook-up wire, solder; nuts, bolts and screws
Mains lead and plug
Spindle bush for tuning control (see text)
Cabinet or cabinet constructing and finishing materials

74LS SERIES

74LS00	0.10
74LS01	0.10
74LS02	0.10
74LS03	0.10
74LS04	0.10
74LS05	0.10
74LS07	0.38
74LS08	0.10
74LS09	0.12
74LS10	0.10
74LS11	0.10
74LS12	0.10
74LS13	0.17
74LS151	0.25
74LS14	0.21
74LS15	0.11
74LS20	0.11
74LS21	0.11
74LS22	0.11
74LS24	0.32
74LS26	0.11
74LS27	0.11
74LS28	0.11
74LS30	0.11
74LS32	0.12
74LS33	0.12
74LS37	0.13
74LS38	0.13
74LS40	0.13
74LS42	0.22
74LS44	1.60
74LS47	0.50
74LS48	0.45
74LS49	0.61
74LS51	0.11
74LS54	0.11
74LS55	0.13
74LS73	0.20
74LS74	0.15
74LS75	0.21
74LS26	0.21
74LS77	0.42
74LS83	0.34
74LS85	0.34
74LS86	0.22
74LS90	0.24
74LS91	0.50
74LS92	0.29
74LS93	0.24
74LS95	0.38
74LS96	0.46
74LS107	0.25
74LS109	0.25
74LS112	0.25
74LS113	0.25
74LS114	0.25
74LS122	0.32
74LS123	0.32
74LS125	0.27
74LS126	0.21
74LS132	0.28
74LS133	0.24
74LS136	0.21
74LS137	0.62
74LS138	0.23
74LS139	0.25
74LS145	0.57
74LS147	0.86
74LS148	0.69
74LS153	0.27
74LS154	0.70
74LS155	0.24
74LS156	0.24
74LS157	0.20
74LS158	0.24
74LS160	0.31
74LS161	0.31
74LS162	0.31
74LS163	0.31
74LS164	0.29
74LS165	0.47
74LS166	0.52
74LS168	0.58
74LS169	0.52
74LS170	0.65
74LS173	0.55
74LS174	0.23
74LS175	0.23
74LS181	1.46
74LS182	1.56
74LS183	1.56
74LS190	0.24
74LS191	0.23
74LS192	0.28
74LS193	0.38
74LS194	0.38
74LS195	0.23
74LS196	0.23
74LS197	0.23
74LS221	0.35
74LS240	0.31
74LS241	0.31
74LS242	0.31
74LS243	0.31
74LS244	0.31
74LS245	0.32
74LS247	0.31
74LS249	0.65
74LS251	0.23
74LS253	0.34
74LS256	0.50
74LS257	0.23
74LS258	0.23
74LS259	0.48
74LS260	0.28
74LS266	0.14
74LS273	0.31
74LS279	0.24
74LS280	0.85
74LS283	0.48
74LS290	0.23
74LS293	0.23
74LS295	0.57
74LS298	0.62
74LS299	1.16
74LS322	1.56
74LS352	0.76
74LS353	0.86
74LS365	0.23
74LS366	0.26
74LS367	0.25
74LS368	0.27
74LS373	0.31
74LS374	0.31
74LS375	0.33
74LS377	0.31
74LS378	0.61
74LS390	0.24

4000 SERIES

4000	0.15
4001	0.15
4002	0.15
4006	0.30
4007	0.15
4008	0.29
4010	0.21
4011	0.14
4012	0.14
4013	0.15
4014	0.28
4015	0.29
4016	0.16
4017	0.23
4018	0.25
4019	0.17
4020	0.29
4021	0.29
4022	0.31
4023	0.15
4024	0.20
4025	0.15
4026	0.39
4027	0.17
4028	0.27
4029	0.26
4030	0.16
4031	0.69
4033	0.54
4034	1.22
4035	0.29
4040	0.27
4041	0.29
4042	0.20
4043	0.26
4044	0.29
4046	0.29
4047	0.23
4048	0.29
4049	0.18
4050	0.18
4051	0.23
4052	0.23
4053	0.23
4054	0.54
4055	0.28
4060	0.29
4063	0.27
4066	0.16
4067	1.79
4068	0.14
40160	0.30
40162	0.31
40173	0.34
4069	0.18
4070	0.15
4071	0.19
4072	0.16
4073	0.16
4075	0.16
4076	0.29
4077	0.16
4081	0.14
4082	0.16
4085	0.26
4086	0.25
4089	0.54
4093	0.14
4094	0.25
4095	0.54
4097	1.17
4098	0.30
4099	0.36
4502	0.36
4503	0.30
4508	0.87
4510	0.24
4511	0.27
4512	0.29
4514	0.71
4515	0.76
4516	0.29
4518	0.25
4520	0.24
4521	0.81
4526	0.38
4527	0.37
4528	0.38
4529	0.42
4532	0.30
4534	2.18
4536	0.98
4538	0.35
4541	0.29
4543	0.44
4555	0.33
4556	0.32
4560	1.16
4566	1.93
4572	0.23
4584	0.22
4585	0.31
4724	0.68
40106	0.29
40109	0.48
40161	0.31
40163	0.40
40175	0.34

74HC SERIES

74HC00	0.13
74HC02	0.13
74HC03	0.13
74HC04	0.13
74HC08	0.13
74HC10	0.13
74HC11	0.13
74HC14	0.17
74HC20	0.13
74HC27	0.13
74HC30	0.13
74HC32	0.13
74HC42	0.25
74HC73	0.25
74HC74	0.18
74HC75	0.18
74HC76	0.18
74HC85	0.25
74HC86	0.18
74HC107	0.10
74HC123	0.32
74HC125	0.22
74HC126	0.21
74HC132	0.24
74HC133	0.25
74HC138	0.24
74HC139	0.24
74HC151	0.24
74HC153	0.24
74HC154	0.37
74HC157	0.27
74HC158	0.25
74HC160	0.31
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74HC162	0.24
74HC163	0.24
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74HC173	0.31
74HC174	0.24
74HC175	0.24
74HC192	0.46
74HC193	0.39
74HC194	0.35
74HC195	0.31
74HC240	0.34
74HC241	0.35
74HC242	0.35
74HC243	0.45
74HC244	0.33
74HC245	0.48
74HC251	0.27
74HC253	0.27
74HC259	0.33
74HC266	0.24
74HC273	0.33
74HC280	0.35
74HC299	0.59
74HC354	0.41
74HC356	0.43
74HC365	0.31
74HC366	0.31
74HC367	0.24
74HC368	0.24
74HC373	0.34
74HC374	0.33
74HC390	0.43
74HC393	0.31
74HC423	0.35
74HC533	0.41
74HC534	0.41
74HC563	0.45
74HC564	0.45
74HC573	0.41
74HC574	0.41
74HC640	0.60
74HC643	0.71
74HC646	1.09
74HC648	1.09
74HC688	0.46
74HC2002	0.33
74HC4017	0.31
74HC4020	0.37
74HC4040	0.38
74HC4049	0.26
74HC4050	0.25
74HC4060	0.39
74HC4075	0.15
74HC4078	0.15
74HC4511	0.39
74HC4514	0.79
74HC4538	0.39
74HC4543	0.65
74HC7266	0.25

LINEAR ICs

AD558	0.65
AD562	19.50
AD574	14.90
AD7501	0.80
AD7541	8.20
AD7581	8.75
AM2147-70	4.99
AM2167	4.99
AM25LS07	1.50
AM25LS374	1.80
AM25LS377	1.90
AM25S05	19.99
AM25S07	4.99
AM25S08	3.99
AM25S10	4.99
AM27S20	1.99
AM27S29	8.99
AM27S37	4.99
AM27S45	4.99
AM27S49	18.99
AM2841	8.75
AM2901	28.99
AM2918	4.50
AM2952	8.99
AM2955	8.99
AM29818	4.99
AM29822	8.99
AM500	9.60
AM7910	14.50
AM7911	8.99
AM8035	8.99
AM9122-25	2.78
AM9122-35	9.99
AM9150-35	14.99
AM91L12	4.99
AM91L22-45	9.99
AM92L44	8.99
AM9551	8.99
AMPAL16H	15.00
AMZ8120	12.99
CA3046	0.35
CA3080E	0.49
CA3081	4.99
CA3130E	0.73
CA3140E	0.38
CA3240E	0.99
CA3290	1.35
CNY51	2.99
CNY71	1.40
D2125H-2	2.50
D2147	9.30
D2148	7.75
D4016C-5	7.50
D416C	1.80
D8041	12.99
D8048C-127	5.5
D8155	18.99
D8251	8.99
D8253C-2	10.19
HD465D8255.	12.50
D933-1	6.80
DAC0800L	14.99
DF320ADJ	5.80
DG128	1.75
DG189	5.80
DG190AP	3.80
DG308	2.80
DP8304	5.20
DP8308	3.75
DS8838	3.75
H104D	6.80
H117	2.80
H11A2	9.50
H11C4 (OPT)	1.99
H148	5.75
H157	1.75
HD45505	6.99
HD46505	5.50
HD46850	9.75
HD63A03	8.99
HM6116P-2	0.98
ICL7106	4.85
ICL8038	3.05
ICM7555	0.29
ICM7556	0.78
IH5025	6.50
IH5029	5.25
IH5033	5.75
IM6403	7.60
IMS1400.35	3.99
IM1600.45	13.99
IT132	15.99
KR2376	8.99
KR3600	19.50
L165V	1.83
L272M	1.64
L293E	3.16
L295	5.99
L297	4.90
L298	4.84
L3299975	14.80
L3377426	12.99
L4312679	14.30
L5400491	2.45
L7140273	22.99
L8221464	2.80
LF351	0.28
LF353	0.30
LF356	0.56
LM13600	0.68
LM1458	0.16
LM2917	1.98
LM301	0.29
LM307	0.80
LM311	0.34
LM318	0.79
LM324	0.21
LM334Z	0.79
LM335Z	0.89
LM338	4.95
LM339	0.21
LM340	1.20
LM348	0.30
LM358	0.18
LM360	4.75
LM380	0.76
LM381	2.29
LM386	0.39
LM3900	0.68
LM3909	1.12
LM3911	1.74
LM3914	1.99
LM3915	1.99
LM393	0.18
LM566	1.10
LM567	0.55
LM710	0.80
LM711	0.80
LM725	4.80
LM741	0.14
LM747	0.36
M4027	1.98
M5L8251	5.50
M5L8253	5.99
M5L8282	5.70
M65C51A	24.99
MAR8041	12.00
MB700	3.99
MB701	5.99
MB81461	3.99
MB8404	5.48
MB8416	5.40
MC10231	5.99
MC14049	1.20
MC1416	5.99
MC14502	2.99
MC14520	0.79
MC14541	0.96
MC14572	5.99
MC1458	0.28
MC14584	4.99
MC1488	0.45
MC1489	0.67
MC1545	5.99
MC1741	0.50
MC3302	0.58
MC3340	1.18
MC836	0.99
MC848	2.99
MCA230	3.99
MCM2114	13.45
MCT276	1.99
MDP1403	6.50
MDP1603	0.48
MF10CN	2.85
MK3881	3.50
MK4096	9.87
MK4801	8.99
MK4802	9.99
MM57109	9.75
MOC3021	1.50
MOC8050	1.99
MP7684	14.99
MR9735	14.99
B0C39	19.99
MV8870	16.99
N282	1.45
N428	3.60
NE5532	0.56
NE5534	0.47
NE555	0.14
NE556	0.28
NE565	0.94
NE566	0.94
NE567	0.35
NE570	2.35
NE571	1.95
NE572	3.20
P4C150	7.75
P4C198	13.99
PAL10L8	14.99
PAL16R4	8.75
PAL20L10	4.22
PBL3717	2.99
PC725	7.50
PCF0450	7.25
RC4558	0.31
RC8202	8.99
RM8263	12.99
SAA1027	1.98
SAK115	12.50
SBA5089	4.99
SL486	1.86
SL490	2.35
SL652	1.99
SL90159	14.99
SM8516	3.99
SN7420	0.75
SP705	0.89
STL106A	4.99
SY2128	8.75
TBA120S	0.61
TBA810S	0.49
TBA820M	0.25
TC5504	1.99
TC5517	19.50
TCA965	3.90
TCM5091	3.50
TDA2030	0.84
TDB01570	4.99
TDE2608	8.99
TEA1001	5.75
TIL111	1.80
TIL112	5.50
TIL119	2.60
TL061	0.33
TL062	0.39
TL064	0.43
TL071	0.30
TL072	0.33
TL074	0.44
TL081	0.31
TL082	0.32
TL084	0.44
TBA120S	0.61
TMM2016	24.99
TMS320C	9.99
UA1489	2.90
UA723DC	0.52
UA747	0.55
UA749	1.60
UA78S40	1.10
UA9636	3.70
UA9667	0.48
UDN2982	2.38
UHP400	4.99
UHP402	5.90
ULN2002A	0.60
ULN2003A	0.24
ULN2004A	0.39
ULN2803A	0.44
ULN2804	1.55
ULN3008	6.99
UM82C11	6.99
UPB8212	6.99
UPB8286	2.60
UPB8287	3.99
UPB8288	7.40
UPD2114	1.75
XR2206	3.95
Z086810P	3.99
Z80A CPU	0.99
Z80ACTC	1.35
Z80BCTC	1.95
Z80BS10	2.45
Z8530	4.50
ZN414Z	0.77
ZN416E	1.14
ZN423	0.92
ZN425E	3.48
ZN426E	1.96
ZN427E	6.34
ZN428E	5.14
ZN435E	4.35
ZN448E	6.58

TRANSISTOR

AC125	0.30
AC126	0.29
AC127	0.29
AC128	0.28
AC176	0.34
AC187	0.35
AC188	0.36
AD142	1.80
AD161	0.78
AD162	0.85
AF124	0.78
AF126	0.46
BC107	0.12
BC107B	0.13
BC108	0.11
BC108B	0.13
BC108C	0.14
BC109	0.13
BC109C	0.14
BC140	0.24
BC141	0.26
BC142	0.30
BC143	0.33
BC147	0.33
BC148	0.33
BC149	0.11
BC157	0.11
BC158	0.11
BC159	0.11
BC160	0.29
BC169C	0.16
BC169C	0.16
BC171	0.11
BC177	0.17
BC178	0.17
BC179	0.17
BC182	0.07
BC182L	0.07
BC183	0.07
BC183L	0.07
BC184	0.07
BC184L	0.07
BC212	0.07
BC212L	0.07
BC213	0.07
BC213L	0.07
BC214	0.07
BC214L	0.07
BC237B	0.08
BC238B	0.08
BC308B	0.08
BC327	0.09
BC328	0.09
BC337	0.09
BC338	0.09
BC477	0.33
BC478	0.33
BC479	0.33
BC517	0.19
BC547B	0.07
BC548B	0.07
BC549B	0.07
BC557B	0.07
BC558B	0.07
BCY70	0.20
BCY71	0.19
BCY72	0.19
BD115	0.49
BD131	0.36
BD132	0.36
BD135	0.19
BD136	0.19
BD137	0.19
BD138	0.19
BD139	0.22
BD140	0.23
BF180	0.30
BF182	0.30
BF185	0.30
BF194	0.18
BF195	0.18
BF196	0.19
BF197	0.19
BF198	0.19
BF199	0.19
BF244B	0.27
BF256B	0.27
BF257	0.32
BF258	0.35
BF259	0.32
BF337	0.35
BFR40	0.38
BFR80	0.38
BFR81	0.38
BFX29	0.28
BFX84	0.30
BFX85	0.30
BFX87	0.43
BFX88	0.43
BFY50	0.28
BFY51	0.25
BFY52	0.27
BFY53	0.46
BFY55	0.46
BFY56	0.46
BSX20	0.26
BSX29	0.52
BSY95A	0.46
BU205	1.39
BU206	1.40
BU208	1.55
MJ2955	0.75
MJE340	0.35
MJE520	0.44
MJE521	0.59
MJE3055	0.84
MPSA05	0.27
MPSA06	0.27
MPSA12	0.27
MPSA56	0.17
MPSU06	0.55
TIP29A	0.30
TIP29B	0.30
TIP29C	0.31
TIP30	0.31
TIP30A	0.31
TIP30B	0.30
TIP30C	0.30
TIP31A	0.30
TIP31B	0.30
TIP31C	0.31
TIP32A	0.30
TIP32B	0.30
TIP32C	0.31
TIP33A	0.65
TIP33C	0.71
TIP34A	0.68
TIP34C	0.74
TIP35A	0.99
TIP35C	0.99
TIP36A	0.99
TIP36C	0.99
TIP41A	0.35
TIP42A	0.35
TIP120	0.37
TIP121	0.34
TIP122	0.36
TIP141	1.05
TIP142	1.05
TIP147	1.10
TIP2955	0.59
TIP3055	0.60
ZTX107	0.17
ZTX108	0.17
ZTX109	0.17
ZTX300	0.16
ZTX302	0.19
ZTX341	0.22
ZTX500	0.14
ZTX501	0.22
ZTX502	0.22
ZTX504	0.22
2N2219A	0.27
2N2222A	0.15
2N2369	0.23
2N2484	0.24
2N2646	0.57
2N2904	0.24
2N2904A	0.24
2N2905	0.20
2N2905A	0.20
2N2906A	0.20
2N2907	0.19
2N2907A	0.19
2N2926	0.14
2N3053	0.26
2N3054	0.83
2N3055	0.55
2N3442	1.32
2N3702	0.09
2N3703	0.09
2N3704	0.09
2N3705	0.09
2N3706	0.09
2N3773	1.68
2N3819	0.26
2N3866	0.99
2N3903	0.09
2N3904	0.09
2N3905	0.09
2N3906	0.09
2N4026	0.16
2N6027	0.33

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4.7UF 25 VOLT	0.07
10UF 25 VOLT	0.07
10 UF 63 VOLT	0.08
22UF 35 VOLT	0.08
47UF 10 VOLT	0.08
47UF 16 VOLT	0.09
47UF 25 VOLT	0.06
47UF 35 VOLT	0.08
100UF 16 VOLT	0.09
100UF 25 VOLT	0.09
100UF 63 VOLT	0.12
220UF 16 VOLT	0.10
220UF 25 VOLT	0.11
470UF 16 VOLT	0.19
470UF 25 VOLT	0.22
1000UF 16 VOLT	0.28
1000UF 25 VOLT	0.35
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2200UF 25 VOLT	0.52
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7812	0.23
7815	0.23
7905	0.25
7912	0.25
7915	0.25
78S05	0.37
78S12	0.37
LM323K	1.95
LM317T	0.43
LM200	0.78
LM723	0.34

IC SOCKET

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20 PIN	0.15
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IN4001 10 PACK	0.22
IN4002 ..	0.23
IN4003 ..	0.24
IN4004 ..	0.25
IN4006 ..	0.26
IN4007 ..	0.27
1N4148 ..	0.22
IN914 5 PACK	0.20
1N4149 ..	0.40
OA47	0.95
OA90	0.40
OA91 ..	0.45

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1.3W	0.07

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27,33,47,56,68
82,100

THE FOLLOWING COST 0.07 P EACH.VALUES PF
120,150,180,220
270,330,390,470
560,680,820
1N,1N5,1N8,2N2
3N3,3N9,4N7
6N8,10N,20N
100N

P/STYRENE

ALL AT 0.06P EACH VALUES IN PF.
47,56,68,82,100
120,150,180,220
270,330,390,470
560,680,820,1N
1N2,1N5,1N8
2N2,2N7,3N9
4N7,5N6,6N8
8N2

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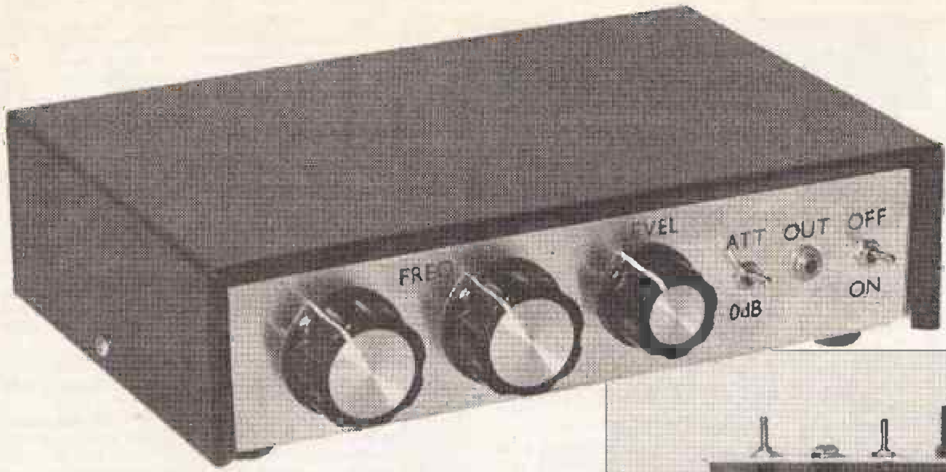
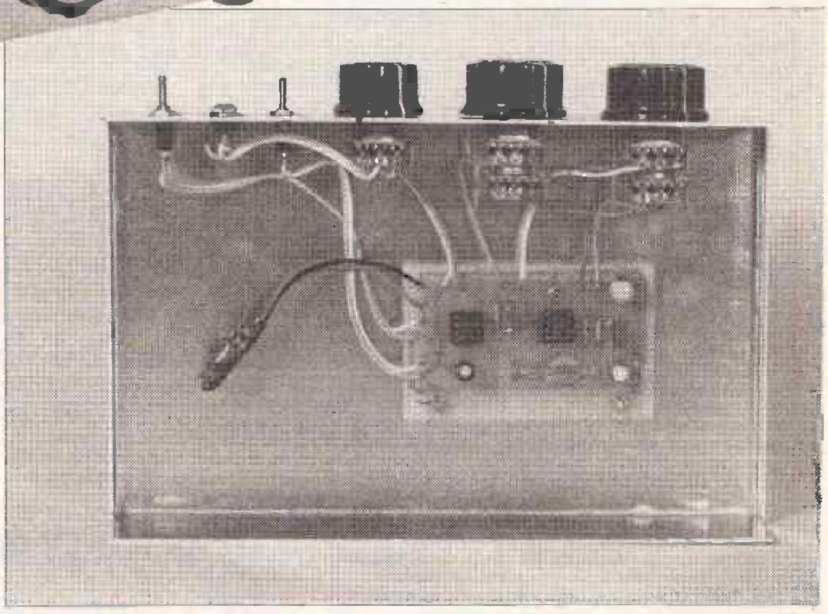




Audio Signal Generator

Construct this useful piece of test equipment from Robert Penfold

An audio signal generator is an essential item of equipment for anyone involved in the designing, building, or testing of audio equipment. It is by no means crucial, however, to have an elaborate signal generator with all the frills and something much more basic will suffice, provided its basic level of performance is adequate.

The unit featured here is a simple battery powered generator which covers the full 20Hz to 20KHz audio band in a single range. It is important that the output level of an audio generator is consistent over the full frequency range, so that frequent manual trimming of the output level is unnecessary. This generator uses thermistor stabilisation which gives no significant variation in the output level from one end of the audio range to the other.

Thermistor stabilisation contributes little noise or distortion and the output signal is an extremely pure sine wave. Using high quality operational amplifiers in the circuit should give a total noise and distortion level that is well below 0.1%, at any output frequency. The output purity is more than adequate for most critical applications, such as checking the frequency response of a notch filter and distortion measurement. It is substantially more than adequate for general purpose testing, such as measuring voltage gain and general frequency response testing. The maximum output level is approximately 3V peak-to-peak (just over 1V r.m.s.). The output level can be controlled using a continuously variable attenuate and a -40dB switch is also provided.

Wien Oscillator

This design, in common with virtually all high quality audio sine wave generators, is based on a Wien oscillator. Figure 1 shows the circuit for a Wien network. In the present application the most important property of this circuit is that, at a certain frequency, it provides zero phase shift between the

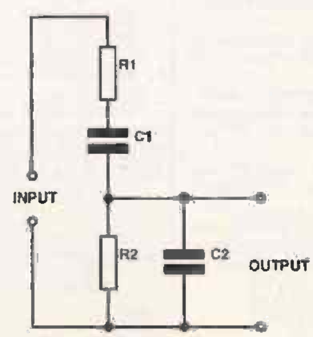


Figure 1. The Wien network circuit

input and output of the circuit. It is only at this frequency that zero phase shift occurs. The zero phase shift frequency is given by the formula:-

Frequency = 1/6.283 C R Hertz

In practical Wien networks, R1 and R2 normally have the same value, as do C1 and C2.

In a Wien oscillator circuit the Wien network is used to provide positive feedback over an amplifier. Of course, the feedback is only fully positive at the zero phase shift frequency. In days gone by the amplifier was usually a discrete type, but these days it is invariably an operational amplifier. Figure 2 shows the basic configuration for a Wien oscillator, based on an operational amplifier. R1, R2 and C2 are merely needed for biasing purposes. R4 and Th1 are the negative feedback network that sets the closed loop voltage gain of the amplifier. We will consider the purpose of Th1 in detail at little later. C4 is merely an output coupling capacitor. C2, C3, R3 and R5 are the Wien network.

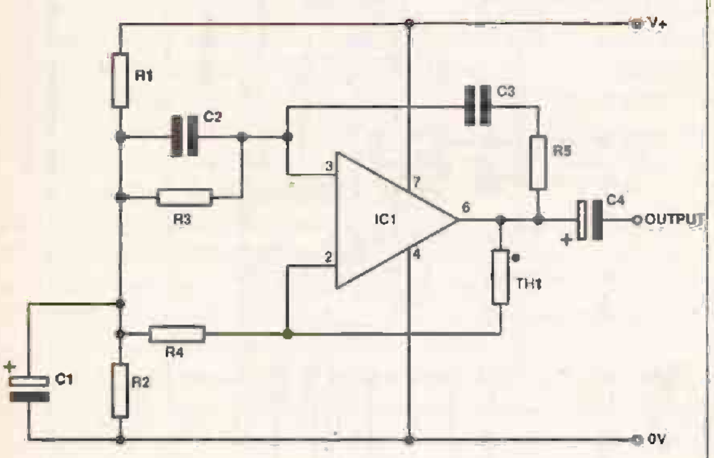


Figure 2. The Wien oscillator configuration

There is a loss of about 10dB through the Wien network at the frequency where zero phase shift occurs. In order to produce oscillation the amplifier must have a voltage gain that at least compensates for the losses through the Wien network. In other words, it must have a voltage gain of about 10dB, or three times. The circuit then oscillates at the zero phase shift frequency. In order to obtain a good quality sine wave output it is essential for the closed loop voltage gain of IC1 to be stabilised at a suitable level.

On the face of it there is no problem if the gain is accurately preset using a multi-turn trimpot as one element of the negative feedback network, but in practice this does not work very well, since variations in the loading can necessitate minor adjustments in the feedback network to maintain a stable output level. Also, in a signal generator application either C2 and C3, or R3 and R5 must be made variable, so that the output can be set at the required frequency. Changes in the values of these components also require minor adjustments in the closed loop gain in order to maintain a stable output level.

Unfortunately, even a very slight lack of gain is sufficient to quell oscillation. The slightest excess of gain results in the output level steadily increasing until clipping occurs, resulting in a massive amount of harmonic distortion on the output signal. In a signal generator application some form of automatic gain control is needed, in order to maintain a consistent output level and provide an output signal which has a low distortion level.

Some form of field effect transistor (fet) can be used as the gain control element in the feedback circuit, but a drawback of this method is that a fet does not provide pure resistance. Consequently, the distortion introduced by the fet is likely to be far higher than the distortion level of the oscillator itself, giving a relatively low level of performance. A self heating thermistor is a more popular choice. It has the advantage of simplicity and it should produce a very low distortion level as it does provide pure resistance, or something very close to it anyway. The main drawback of a self heating thermistor is that it is relatively expensive. However, considering the level of performance it provides, a good self heating thermistor should

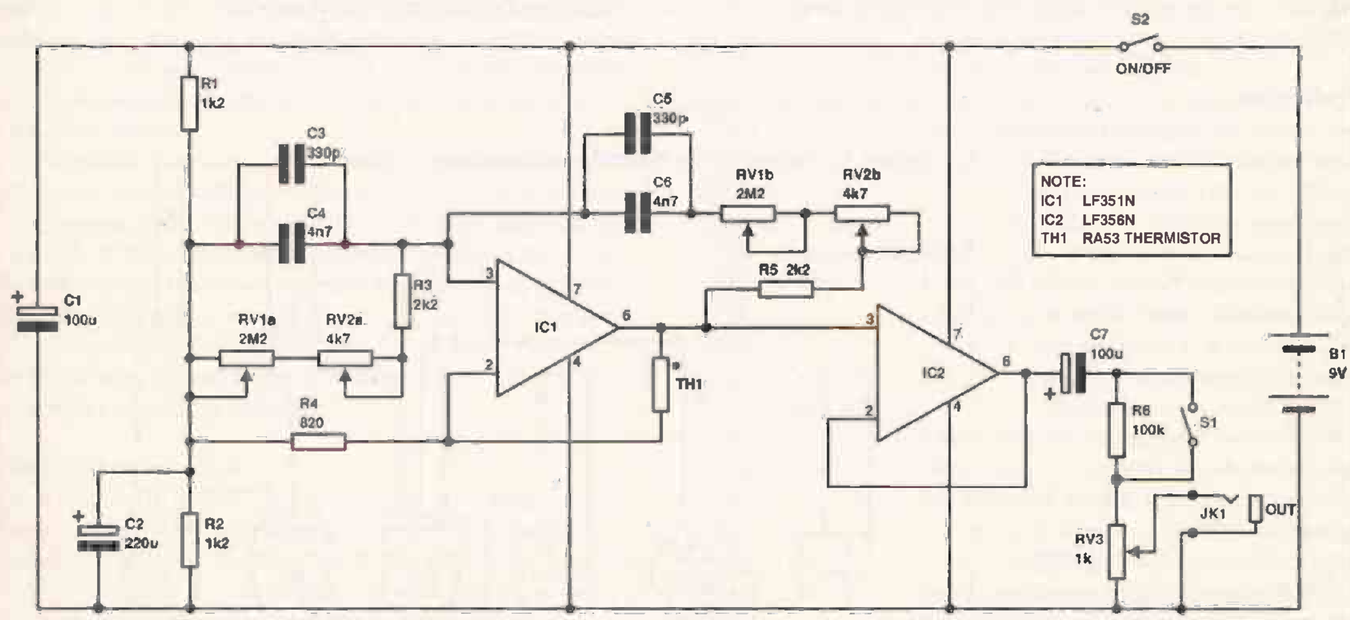


Figure 3.The A.F. Signal Generator circuit diagram

be considered cheap at the price.

The way in which the thermistor stabilises the output level is very simple. Initially the thermistor is cold and, as it is a negative temperature coefficient type, it has a high resistance. This gives IC1 a high closed loop voltage gain and the circuit oscillates strongly. This strong oscillation produces large current flows through the thermistor, which rapidly heats up. Its resistance then drops, as does the closed loop voltage gain of IC1. Oscillation then dies down to a low level, the average current through Th1 decreases and its resistance rises. The closed loop gain of IC1 rises and stronger oscillation is produced.

This cycle of events repeats itself a few times, with the output level gradually stabilising at an intermediate level. At high frequencies, the output level stabilises very rapidly, but at low frequencies it can take a few seconds for the output signal to settle down properly at a consistent amplitude. However, provided a high quality thermistor is used, once the output signal has stabilised it will remain at the same level despite changes in loading, etc.

Circuit Operation

Figure 3 shows the full circuit diagram for the audio signal generator. The Wien oscillator is based on IC1 and it closely follows the configuration described previously. In order to obtain a suitable capacitance value for the Wien network it is necessary to use two capacitors wired in parallel (C3 - C4 and C5 - C6). Each resistive element consists of a fixed resistor in series with two variable resistors. VR1 is the main frequency control, while VR2 is used for fine tuning the output frequency. VR2 is especially useful when setting high output frequencies, where control via VR1 is rather coarse. Th1 is the self heating thermistor. This is the usual RA53 type, which is sometimes sold as an R53. These two devices seem to be identical, and this circuit will certainly work using either type.

IC2 is simply used as a buffer amplifier at the output of the unit. This feeds into a volume control style output attenuator (VR3). The output signal is fed to VR3 via attenuation resistor R6 when S1 is set to the open position.

This reduces the output level by about 40dB (i.e. it reduces the output level by a factor of approximately 100). The output level can then be varied from zero to about 30mV peak-to-peak using VR3.

Options

The circuit can be powered from a small 9V battery such as a PP3 and the current consumption is about 8mA. However, if the unit is likely to receive a lot of use it would be more economic to use a higher capacity battery such as six HP7 size cells in a plastic holder. If very high performance is important, it is better to use a higher supply voltage, such as an 18V supply provided by two 9V batteries connected in series. The operational amplifiers will give better performance with an 18V supply. Also, with a higher supply voltage, the circuit seems to stabilise more rapidly after large readjustments of the frequency control. Unfortunately, doubling the supply voltage virtually doubles the current consumption as well. This makes it essential to use high capacity batteries if an 18V supply is used.

If high performance is not essential a couple 741Cs are adequate for IC1 and IC2. Much better noise and distortion performance is produced using a couple of good quality Bifet devices such as the specified LF351N and LF356N, or a couple of LF351Ns will work well if the LF356N proves to be difficult to track down. Using these devices, the noise and distortion is so low that it requires some good quality test gear to find it. However, if you require the ultimate in super-fi

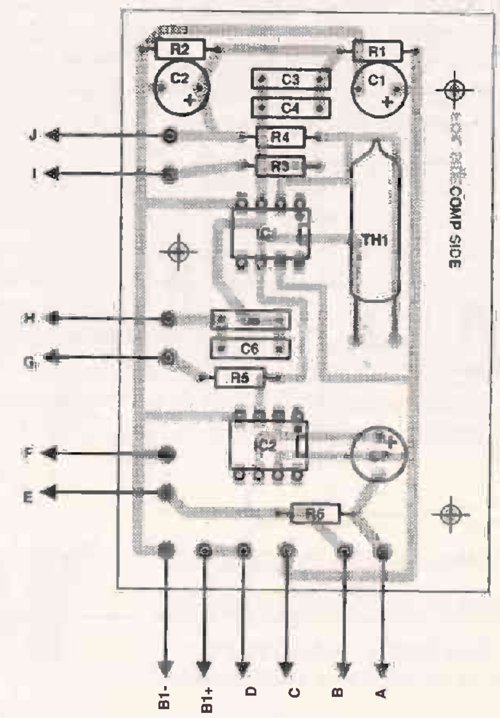
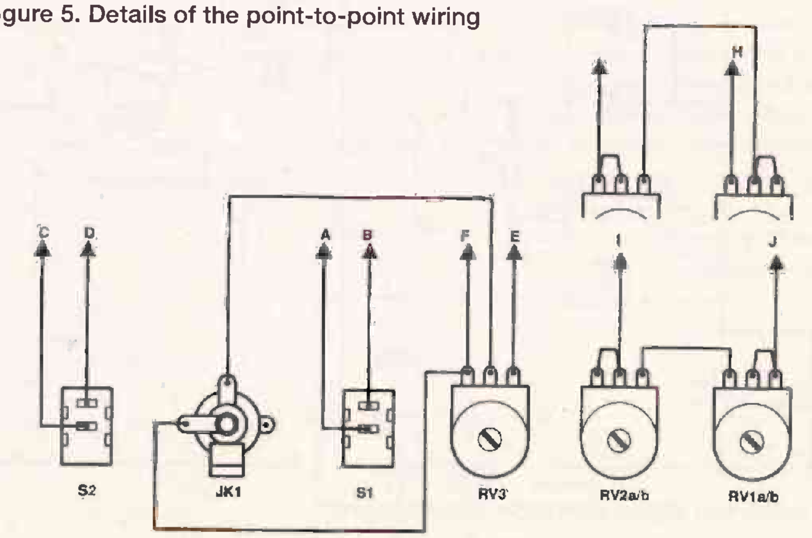


Figure 4. The printed circuit overlay

Figure 5. Details of the point-to-point wiring



performance, two high grade bipolar audio operational amplifiers should be used. I found that the NE5534A works very well in this circuit.

Ideally VR1 should have an anti-log law, but a dual anti-log potentiometer of the required value is unlikely to be obtainable. A linear type can be used, but will provide logarithmic, not linear, scaling. Alternatively, VR1 can be a log potentiometer connected in reverse (i.e. clockwise rotation gives reduced output frequency). This gives something approximating to linear scaling and makes frequency adjustment at the high end of the range much easier.

Construction

Details of the printed circuit board component layout are provided in Figure 4. None of the suggested operational amplifiers are static sensitive devices, but I would still strongly urge the use of holders for both integrated circuits. C4 and C6 must be miniature printed circuit types having 7.5mm (0.3in) pin spacing if they are to fit onto the board easily. They should have a tolerance of 5% or better. The RA53/R53 thermistor is a fairly expensive component and it has a glass encapsulation. Accordingly, it should be handled carefully. It is mounted horizontally on the printed circuit board and it is a good idea to fix it to the board using a small piece of Blue-Tak, rather than simply leaving it to flap around. Fit single-sided solder pins to the board at the places where connections to the controls, etc., will eventually be made.

The prototype is housed in a medium sized metal instrument case. This provides far more space than is needed for the circuit board and battery, but a case having a reasonably large front panel is needed in order to accommodate the controls and output socket. Ideally the unit should be used with a frequency meter to monitor the output and act as a digital frequency readout. Many digital multimeters now have audio frequency ranges which can be used for this purpose, or a digital multimeter plus the frequency meter adaptor described in a previous article could be used.

If the generator is to be fitted with a calibrated frequency scale, use a case having a very large front panel so that a long scale can be marked around the control knob of VR1. A large diecast aluminium box used upright is probably the best choice. The control knob should be a large type fitted with a long pointer. Even with a long and carefully calibrated scale, frequency accuracy is likely to be far less precise than that obtained using some form of frequency meter to provide a frequency readout.

The general layout of the unit is not critical. Figure 5 shows details of the hard wiring and should be used in conjunction with Figure 4 (e.g. point A in Figure 4 connects to point A in Figure 5). A 3.5mm jack socket is used at the output of the prototype, but this can be changed to a coaxial type, a BNC socket, or any type of socket that is apposite for this application. It is assumed in Figure 5 that VR1 will be a reverse connected log potentiometer and that VR2 will be a linear type connected for normal operation.

Testing and Use

It is preferable to check the output of the unit using an oscilloscope. This will show whether or not the output waveform, the output level and the frequency coverage are correct. If access to an oscilloscope is not possible, monitor the output using an amplifier and loudspeaker, or even a crystal earphone will suffice. For most people the lowest output frequencies will be inaudible, as will the highest output frequencies. In between these two extremes it should be possible to hear a wide range of audio tones. A sine wave signal has a very pure sound which is easily distinguished from other sounds. Any harshness on the output signal at low to middle frequencies indicates that there is some sort of constructional error and that the output signal is being clipped. Check that the output level controls enable the volume of the tone to be varied in the appropriate manner.

When using the unit for frequency response measurements, remember that it takes a short while for the output level to stabilise, particularly when output frequencies below about 100Hz are involved. At high frequencies the circuit should stabilise almost instantly. The output impedance is quite low, but the generator can only supply output currents of up to a few milliamps. It will drive all normal preamplifiers, power amplifiers, mixers, etc., without any problems, but do not expect it to drive an 8ohm loudspeaker with a high quality 1V r.m.s. sine wave signal! Bear in mind that the top end of the audio range can only be achieved with VR2 set at minimum resistance. When setting low output levels (less than 30mV peak-to-peak) S1 should be set to the -40dB position. Accurately setting the required output level using VR3 is then very much easier.

PARTS LIST

Resistors (all 0.25w)

R1	1k2
R2	1k2
R3	2k2
R4	820R
R5	2k2
R6	100k

Potentiometers

VR1	2M2 log dual gang carbon
VR2	4k7 lin dual gang carbon
VR3	1k lin carbon

Capacitors

C1	100µ 25V radial elect
C2	220µ 16V radial elect
C3	330p ceramic plate or polystyrene
C4	4n7 polyester 5% or better
C5	330p ceramic plate or polystyrene
C6	4n7 polyester 5% or better
C7	100µ 16V radial elect

Semiconductors

IC1	LF351N
IC2	LF356N

Sundries

S1	SPST sub-min toggle
S2	SPST sub-min toggle
B1	9V (PP3 size - see text)
JK1	3.5mm jack socket
Th1	R53 or RA53 thermistor
	PCB, metal instrument case about 200 x 125 x 50mm, three control knobs, battery connector, two 8 pin DIL holders, solder pins, wire, solder, etc.

PROJECT

Paleface Minor Guitar Amp

Part 3

Time to put together this small amp with a big sound. Design and construction by Dave Bradshaw

There are many different ways that you can build this project. I am going to describe the way I built it (leaving out the bits I got wrong, of course) and point out the main choices you might take along the way.

The chassis is made out of two pieces of aluminium U-channel bolted together. The valves and transformers mount on the tops of the U-sections, while all the other components mount on the inside. The preamplifier goes in the front section, and the power amplifier and power supply in the rear. The chassis mounts upside-down (i.e. valves and transformers hanging downwards) in the top of the loudspeaker cabinet.

Three PCBs hold most of the components, but the valves are mounted separately. Putting the valves on the PCBs generated too many complications and some combo units with valves mounted on PCBs have a reputation for being unreliable, because the solder joints on to the sockets tend to crack.

Choices, Choices

Before you begin construction, decide which options you are going to build. The most important decisions are:

Stand-alone Unit or Combo?
Which (if any) of the mods and options?
Which controls and inputs do you want on the front panel? In particular, you must decide if you want a 'mid' control.
What controls and connections you want on the rear panel? An alternative to wiring the loudspeaker permanently to the output is to have an output jack. You may also want to put the FX out and FX return sockets on the rear panel.

Speaker Choices

I recommend using a Celestion speaker to recreate the sound of classic speakers and combo units of the 60s and 70s. However, original Celestion speakers are a little hard to get hold of. Mine was kindly supplied by Wilmslow Audio, but two alternative speakers are:

The Celestion G10S-50 PE, a 10in modern loudspeaker
The Celestion Vintage 30, a 12in loudspeaker that follows the design that made Celestion's name for guitar speakers in the 1960s and 70s.

The Vintage unit is slightly warmer and more characterful, and it is also very marginally louder (by a couple of dB) than the G10S. However, it is getting on for twice the price of the G10S and quite a lot heavier.

Choosing the Components

There are a few problem items that I have identified sources for, as well as a few general points.

High voltage electrolytics: HT smoothing capacitors C4, C11, and C21-25 all have to be small enough to fit on the PCB and not stick above the chassis sides when the PCBs are mounted on their pillars. The absolutely maximum height the capacitors on the PSU board can be is 40mm and the other capacitors have to be 35mm or less, depending on the height of the PCB mounting arrangements. Incidentally, it may be cheaper to use 47{SYMBOL 109 \f "Symbol"}F for C4 and C11, and do without C20 to C22.

Non-polar capacitors: make sure you stick to the working voltages I have given. For example, even though C3 normally has

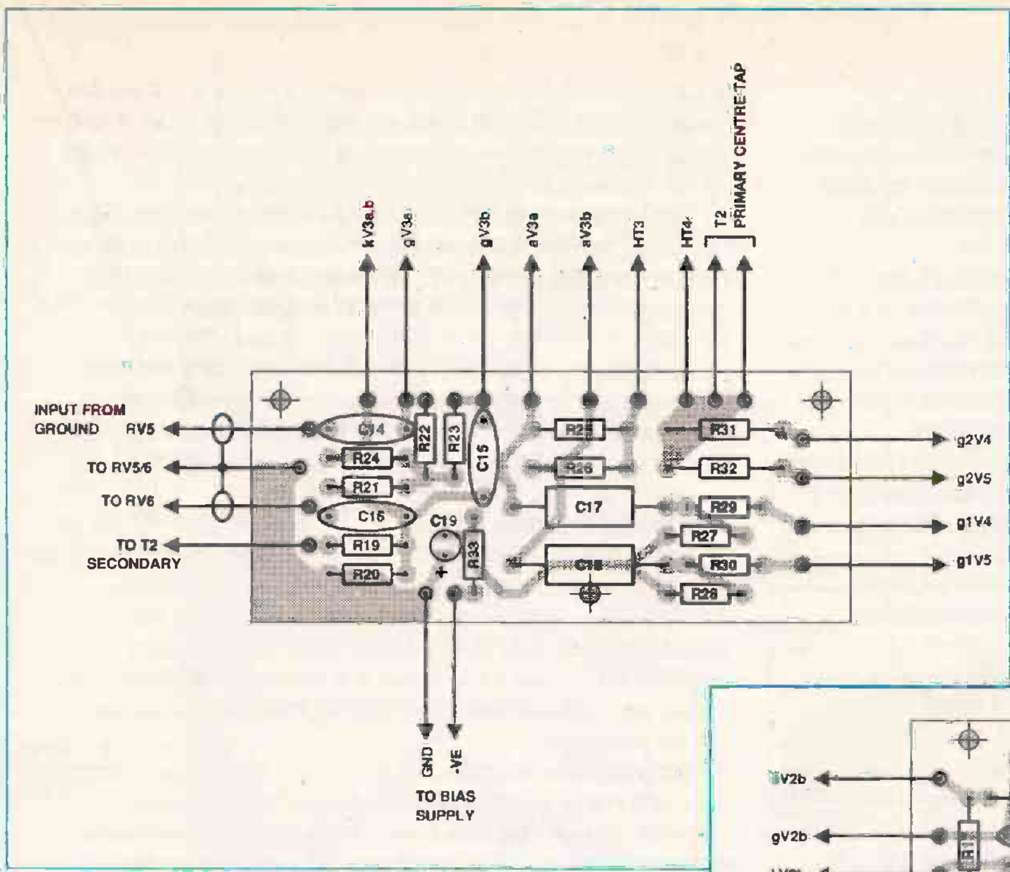
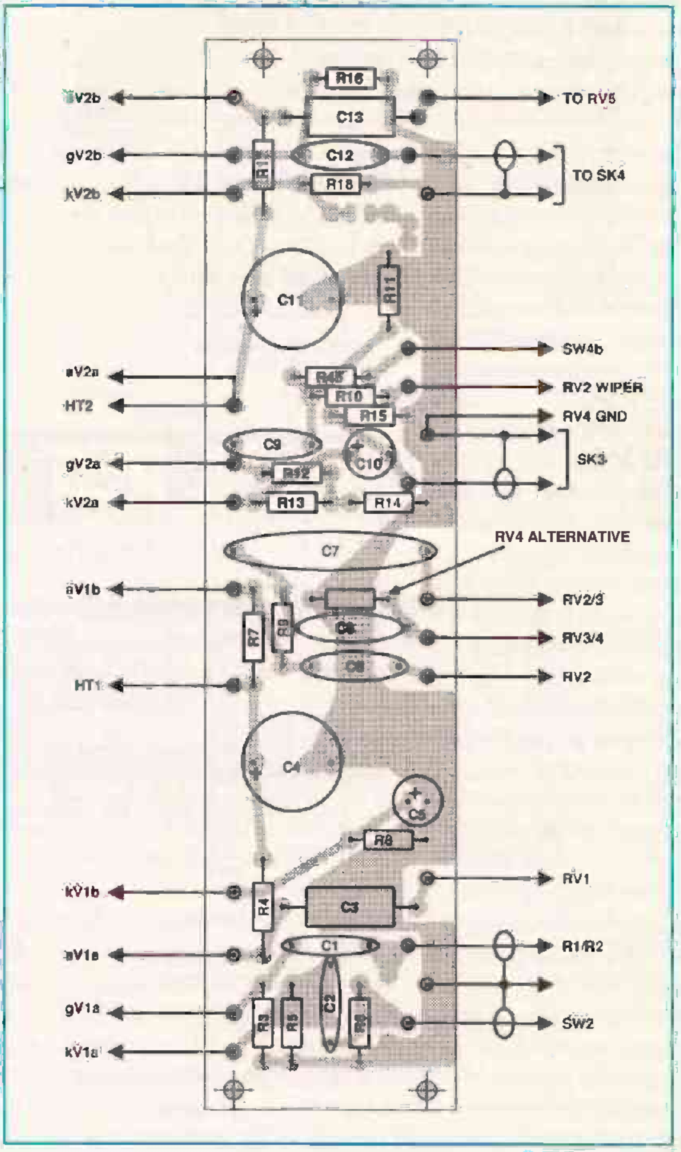


Figure 1. Component layout of power amplifier

Figure 2. Component layout of pre-amplifier



only around 170V across it, it could have as much as 360V applied if all the valves are removed. It therefore should have a 400V or higher rating.

Panelware: all the pots, connectors and switches are mounted directly onto the chassis. Some 'snap in' panelware (e.g., rocker switches) will not lodge properly in the thick aluminium of the U-channel used for the chassis.

Push-pull pots: there are potentiometers with dual pole two-way switches on them, operated by pulling out or pushing in the control spindle. I used a push-pull pot for RV1, with the switch as SW5 in the gain switching option. These pots are available in a very limited range of track resistances, but the values of R1 and R5 are not critical, they just have to be between 100k and 500k and logarithmic. Push-pull pots are hard to find, expensive when you do find them and they have splined spindles which some knobs do not fit. Also, they need a smaller mounting hole than standard pots. But they are very neat for the bright or gain switches.

Resistors: in the power supply, use a carbon or metal film 2W resistor for R40 (or two 100R 1W resistors in parallel - there's space on the PCB). Wire wound types may act as fuses, i.e. the high-current surge at switch on could 'blow' them.

Valve bases: because the chassis is quite thick, there can be a problem with the lugs on some valve bases shorting to the chassis. The valve base's sockets in the prototype, supplied by Chelmer Valves, gave no such problem (they are also available through Maplin).

Assembly Planning

The order that I suggest following is:

1. Buy the PCBs and all the electronic components you don't already have.
2. Cut the chassis sections, drill all the mounting holes for components and bolt together the chassis sections.
3. Make the case, using the unpopulated and unpainted chassis as a guide.
4. Paint the chassis front panel.
5. Assemble the electronics components onto PCBs.
6. Assemble all the electronics into the chassis.
7. Follow the commissioning section below.
8. Plug in, switch on and drown out the neighbours!

Chassis Bashing

To make the chassis, I bolted together two 15in (381mm) lengths of aluminium channel, 3in wide by 2in deep and 1/8in thick. Spend some time selecting the best side for the front panel. Choose a side with the least deep scratches and gouges, and with good edges.

Carefully plan out where the components are going to fit. Leave room for the one inch wide wooden case struts that run along the front and the sides of the chassis. The preamp valves must be mounted towards the back of their channel, the transformers must be at least an inch from the ends of the chassis and any screws in this region must be countersunk.

Ideally you should use a bench drill to make the holes for the controls, the valves and all the mounting screws. However, I managed with just a conventional power hand drill. There are some points to watch:

Centre-punch the hole centre, then drill a small pilot hole before you drill the main hole.
Be ready for the drill to 'snatch' as it begins to break through the far side of the aluminium.
Use sharp, new drill bits of the right size.
Use a proper hole saw for cutting the holes for the valve bases.

For the recommended valve sockets, you need a 7/8in (22mm) hole saw with a suitable arbour. Check that the hole saw is intended for use on aluminium, otherwise it may tend to jam or clog up. The type I used was made by Starrett and it cut very easily. Use the hole saw to cut the holes for inter-wiring between the two halves of the chassis. Use the PCBs and other components as a guide.

Bolt together the two sections of the chassis, using five (or more) 4BA, M4 or larger bolts, with shake-proof washers, spaced along the chassis. To drill holes for these bolts, drill a pilot hole in the side where you are starting from, clamp the two halves together as accurately as you can, then, using a long drill bit poking through the panel ware fixing holes, drill all the way through.

The next stage is making the wooden case, using the chassis as a guide. Once this is complete, the front panel should be filed or sanded until reasonably smooth, then spray painted. You can spray quite a thick layer of paint on in two or three goes and still get a neat result by laying the chassis on the back panel, so that the front panel is uppermost and horizontal.

To reduce the projection of the pot mounting bushes through the front panel, I made thick spacer washers from the off-cuts of the hole saw. I drilled out the centre hole then filed down the thickness. An easier alternative is to use an extra nut on the inside of the front panel.

Designing and Making the Case

The prototype case was made from >-inch mixed density fibreboard (MDF), which was screwed and glued together. If you plan to carry the case around a lot, consider using a lighter and/or thinner material. The inside width of the case has to be a good match to the width of the chassis, with a millimetre or so to spare so that the chassis can be removed easily (and to allow for the thickness of a cloth covering on the case).

If you have a good DIY shop that will cut timber to size more accurately than you can by hand, it's well worth getting them to pre-cut the panel sides for you. It's best to ask them to do this at a time when they're not very busy, i.e. not a Saturday morning!

I lined the top of the case with a thin sheet of aluminium, to increase the screening of the preamplifier. At the front, it is secured with a thin strip of moulding and nails (which the covering cloth can wrap over) and at the rear it is nailed.

Assembling the PCBs

Start by checking all the fixing holes are the right size for the bolts that must go through them. Next mount the PCB pins, then the other components. It proved easiest to finish with the large electrolytic capacitors, because assembly gets more awkward once these are installed, but before inserting any nearby components, check that they do not block the capacitors (or vice-versa).

Double and treble check the assembly of the boards; faults are much harder to rectify once the boards are installed. In particular, double check that you have wired the power supply correctly for the type of secondary on your mains transformer.

Note that if you have decided not to use a 'mid' tone control, there is a position on the PCB (labelled RV4) for the 10k resistor needed to replace RV4.

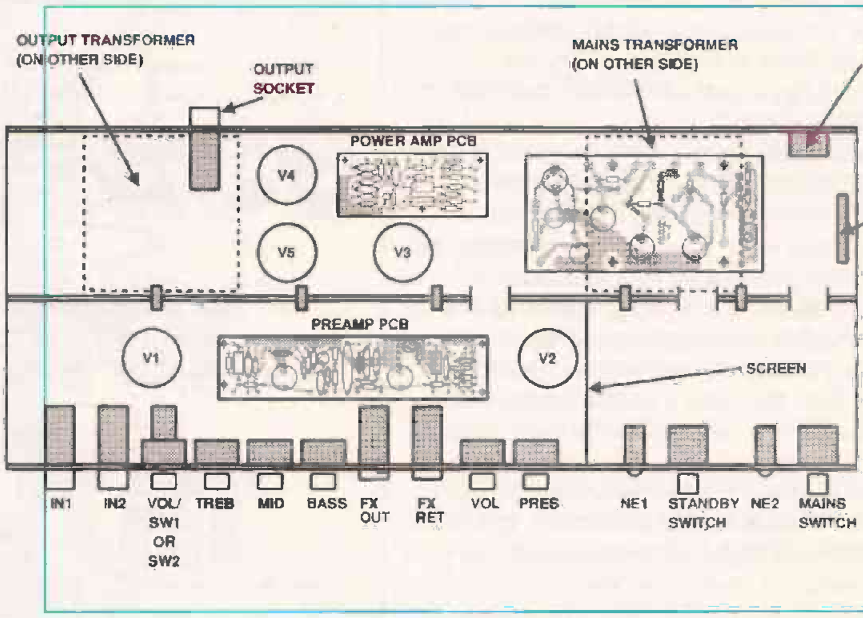


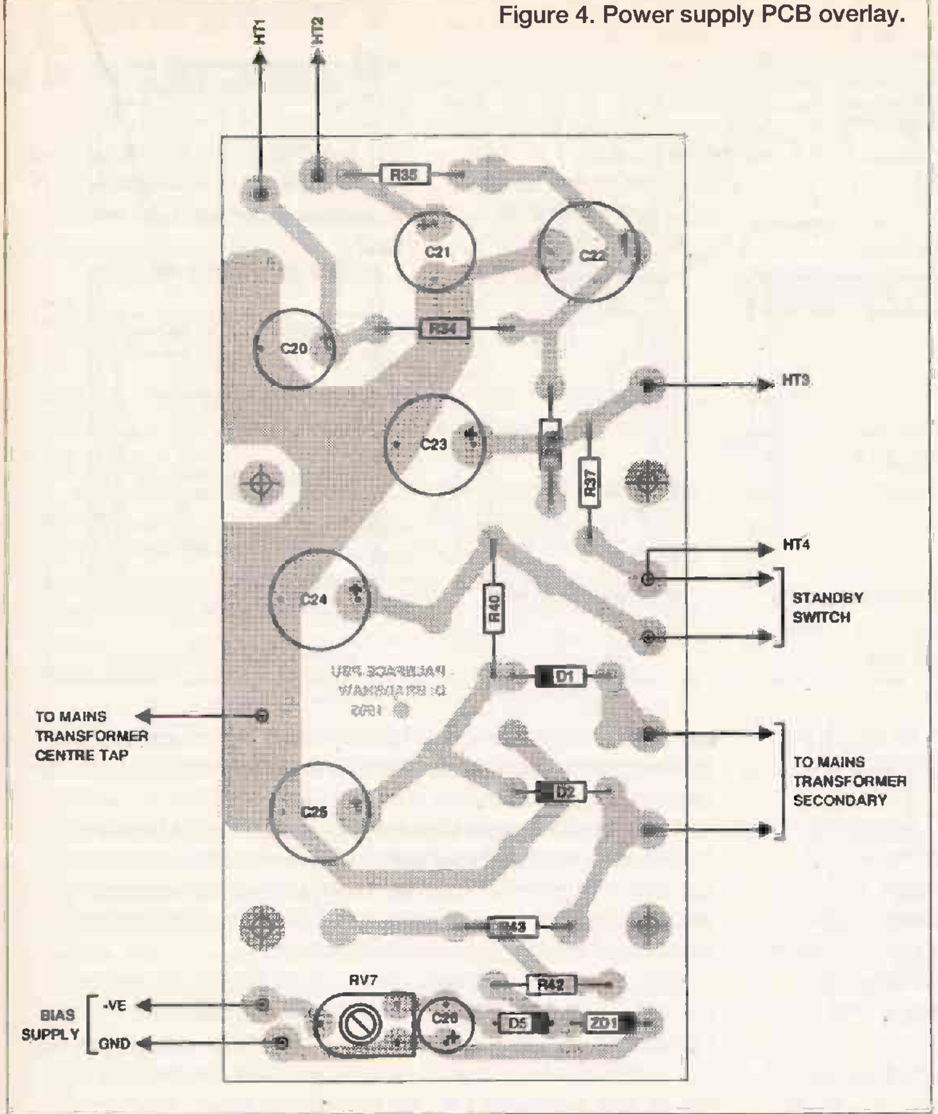
Figure 3. Board layout in cabinet

Installing the Electronics

Install the valve bases and wire together the heaters. Start from the heater supply tag strip shown in the layout diagram and, using a pair of insulated wires (rating 6A or more, solid or stranded core) twisted together, connect together all the valve heaters. In the prototype, I wired to V2, then wired one branch to V1 and another branch to V3, V5 and V6.

Locate and fix the transformers, pre-assembled PCBs, panelware (taking care not to crack off any of the front panel paint) and all other remaining components into place. Use shake-proof washers wherever possible on nuts and bolts. The preamp and power amp are mounted on 10mm insulated pillars from Maplin, but with countersunk screws for the chassis ends. The power supply sits on the transformer mounting screws and these are M4 or 4BA size.

Figure 4. Power supply PCB overlay.



Install the earth busbar. This is a length of thick copper wire that provides a very low resistance earth path through the circuit, so that signal and power supply currents can flow in the same earth path with the minimum addition to signal noise. The wire I used is a single core from mains cable (the type used for house wiring). It starts from the input and loops round to the output socket, passing and attached to the preamp and power amp PCBs, and the central pins of the valve bases, by short lengths of copper wire which also keep it in position.

Do the inter-wiring, following the diagrams associated with the PCB layouts. Wire the mains side of the power supply and the standby switch, but leave off all the connections between the power supply and the pre and power amplifiers. I found it very useful to have a good variety of different coloured hook-up wire for the final wiring. Leave off the HT1, 2, 3 and 4 connections, so that there are no high voltage connections between the power supply and the other parts of the amplifier. These are installed in commissioning.

Some points to watch are:

RV5 gets its earth from the power amplifier, not the preamp, via the braid on the screened lead.

The other panel components that require an earth get it from the PCB, not from the busbar.

The negative bias supply also gets its earth from the power amp, via one half of a twisted pair of cables (the other half being the negative supply itself). Without this earth, the negative supply will not work, so it is vital this is connected

Beware getting the connections to the valves wrong! It is very easy to reverse the cathode and anode connections to one side of the dual triode valves. This destroys the valve when you apply power.

The heater windings of the mains transformer and the output windings on the output transformer are insulated by varnish as well as a loose sheath, and you will need to carefully scrape or sand off the varnish before you can solder them. The centre-tap of the heater winding is soldered to the earth tag on the heater tag strip. The connections from the output transformer should be soldered to a tag strip or an output socket. You must leave enough spare lead length to be able to reverse the connections to either the primary or the secondary on the output transformer. The connections to the prototype transformer are shown in the table, but it's very easy to get them the wrong way round.

Table 1 Connections on the prototype output transformer

Primary	
Red	Anode, V4
White (two wires)	HT4, via the power amp PCB
Yellow	Anode, V5
Secondary	
Purple	Ground
Grey	No connection
Blue	Signal

You may find some connections (e.g. to the busbar, the heater connections and the output transformer secondary) require a higher power soldering iron, 30W or higher.

Commissioning the amplifier

In this section, we will firstly commission the amplifier, starting with power supply. Before even thinking of applying power, double, treble and quadruple check that you have assembled the electronics correctly. In particular, double-check the polarity of the diodes and the capacitors.

During the tests, I suggest you turn the power on and off by plugging and unplugging the unit from the mains. Leave the mains switch in the 'on' position for the duration of the commissioning so that the mains neon is lit whenever there is mains on any part of the project, a vital warning. I also suggest using a small wooden block about 3 1/2in long (about the same height as the mains transformer) to prop up the amplifier on a bench, so that it can sit with the components exposed without resting on the valves.

The first check is that the earth is good on the amplifier chassis. Next check that there is a resistance of a few tens of ohms (the resistance of the mains transformer primary) between the live and neutral pins on the mains plug.

For the remainder of the PSU tests, there should be no HT connections between the power supply or the pre or power amplifier and no valves should be inserted in their sockets. However, the negative bias supply can be connected.

With the standby switch off (SW2 selecting R39, not R37/38/HT4), apply, then immediately remove, mains power. Measure the voltage on C24 positive terminal. The easiest place to

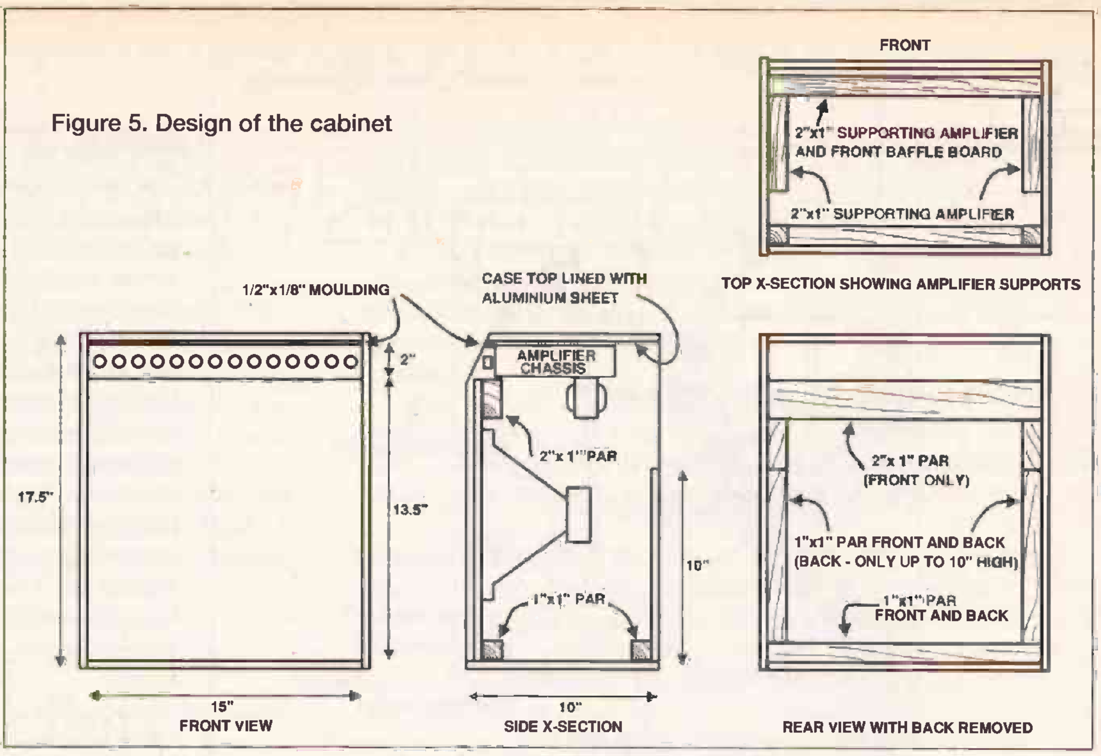


Figure 5. Design of the cabinet

get at this is on the PCB pin which is connected to the wiper of the standby switch, SW2. You should find voltages of around 300V on C24, but nothing on HT3 or 4. Depending on the option you chose for R36, there may be either nothing or up to 300V on HT1 and HT2 pins. The voltages you find depend on how quick you are and how sensitive your multimeter is. A moving coil meter will discharge the capacitors much faster than a DMM, so its readings will be much lower.

Repeat this test, but with the standby switch closed, and measure the voltage on HT3 and 4. All should be around 100V to 350V, again depending on the meter and how quick you are.

If this test is successful, turn off the standby switch, then connect the mains supply and leave it on. Watch for any component distress - resistors heating up, excessive buzzing from the mains transformer, etc. Test the HT voltages again. You should find a steady 350V or so on C24, nothing on HT3 or 4 (perhaps a few volts residual left over from the earlier test), and either zero or 350V on HT1 and 2, depending on the placing of R36.

If there is no problem, put your test prod on HT4 and move the standby switch to on: HT3 should quickly climb to around 350V, and then should carry on rising slowly but steadily. Before the voltage exceeds the rated voltage of the capacitors, switch the standby switch off and the voltage should stop rising. The voltage rise is due to the weak 'pumping' action of negative bias supply. With standby off, this is suppressed by the drain resistor, R39 (in normal conditions, current drain by the power and preamplifiers pull the voltage down more than enough).

Check the negative supply voltage. Using RV7, this should be adjustable between zero and around -15V. Set it at -12V for the moment.

Remove mains power and drain all the capacitors using a 1k resistor attached to an earthed lead. Be careful, as some of the capacitors will have more than enough charge on them to give you a nasty jolt.

Insert all the valves into their sockets. Reapply power and check that the heaters all come on. If not, go looking for the fault in the heater wiring. If all is well, remove the preamplifier valves.

Power amplifier commissioning

To set up the power amplifier, you ideally need an oscilloscope and sine wave generator, as well as your multimeter. Also very useful in any audio project is a dummy 8 ohm load; I made mine from six 47 ohm 10W wire-wound resistors in parallel, giving me a load of 7.8 ohm and a maximum power handling of 60W. You can use lower power resistors, for example 3W resistors give a maximum power of 18W which is ample for this project. However, you can just about make do with multimeter alone if you have been very careful with construction.

Using a multimeter on resistive range, check the resistances between HT3 and HT4 on power amplifier (with no connection to PSU board) and earth. You should find infinite resistance, i.e. the only connection is through the valves which are not powered up.

Disconnect feedback if already connected, that is remove the link between the output transformer secondary and R19. Connect HT3 and HT4 supplies from the PSU to the power amplifier PCB. Connect an old loudspeaker (or the 8 ohm load, plus scope if you have one) across the output.

Apply mains with standby switch off, allow two minutes for the valves to heat up, then the turn the standby switch on. Immediately start looking for any signs of component distress, components getting very hot, excessive hum from the transformer, strange noises from the loudspeaker (some mains hum would be normal) or anything else unusual, such as high frequency oscillation on the output. Switch off immediately if you see any of these signs and investigate the cause.

Assuming all is well, the first test is of the negative supply voltage at the junction of R33, C19, R27 and R28. This should be 12V, as set on the negative supply. Check round the circuit and you should find values similar to those given in the table.

Table 2: Prototype power amplifier voltages

HT3	315V
HT4	340V
V3 anode 1	217V
V3 anode 2	203V
V3 cathode 1, 2	33.5V
V4, 5 anode	334V
V4, 5 grid 2	338V

If all the voltages are fine, the next stage is to apply a signal. Note that a moving coil meter will give lower readings for the anode voltages.

If you have a scope, signal generator and dummy load, apply a 1kHz sine wave test signal to the top of RV5. Adjust the volume until you can see the onset of distortion. This should occur at an output of around 15 to 20V peak. The distortion will not be the neat clipping you get on transistor outputs, due to frequency dependent phase shifts in the transformer. In the prototype, distortion normally had the appearance of a spurious peak and trough near the zero voltage crossing on the 1kHz sine wave.

If you don't have any test gear, you'll have to improvise. For example, for a test signal use the output from a personal stereo, or anything that gives a signal of around 100mV or more. Start off with RV5 fully clockwise, and advance it clockwise until you

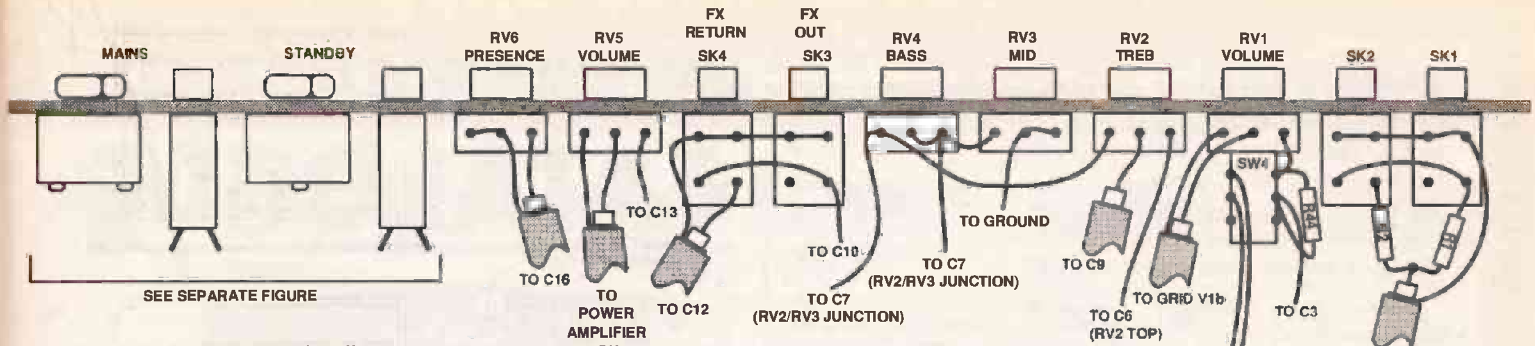


Figure 6. Front plate detail

or your loved ones can stand the din no more. The signal will not be hi-fi, but it should not sound grossly distorted up to quite high volume levels.

Move the standby switch to off, remove the mains power and then connect the negative feedback. Reapply mains, wait for a minute, then move standby to on. Either you will get a much reduced output signal or uncontrollable howling oscillation (so keep you finger near the standby switch!). If the latter occurs, the output transformer is wrongly phased and you need to reverse the connections to the primary or secondary (but not both!).

Once the feedback is OK, you should be able to get back to the same output level as before by turning RV5 further clockwise (assuming you've got enough input signal). You should notice significantly less mains hum form the output. Turning RV6 clockwise should increase the amount of high frequency signals coming through (it will slightly increase the level of a 1kHz test signal provided it is not overloading).

Finally, set the bias voltage from the power supply. If you only have a multimeter, adjust the bias voltage so that the voltage on C25 drops by around 30V when the standby switch is moved from off to on. With more sophisticated test gear, first set the bias voltage to -5V and apply enough input signal to get the maximum undistorted output signal. Then increase the bias voltage to the most negative you can have it and still get the same output with the same input signal.

The power amplifier is now working, so it's time to look at the preamp. Turn the standby to off, disconnect the mains and wait a few minutes for the voltages on the capacitors to drain away.

Preamplifier commissioning

Check that the capacitors in the power supply are fully discharged (if not, use a resistor as before to discharge them), then connect HT1 and HT2 leads between the PSU and the preamp. Switch on and look for any component distress. You may get some mains hum coming through the circuit, so turn RV1 and RV5 fully anticlockwise.

Check the voltages around the circuit, following the table below.

HT1	270V
V1a anode	170V
V1a cathode	1.2V
V1b anode	170V
V1b cathode	1.2V
HT2	267V
V2a cathode	59V
V2b anode	175V
V2b cathode	1.1V

Table 3: Preamplifier voltages

If all the voltages seem fine, it's time to apply a signal. Using the same signal source as before, apply a signal to input 1. Advance both RV1 and RV5 very cautiously. If nothing comes through, check that the tone controls are not all fully anti-clockwise, as this cuts off the signal. If nothing still comes through and you have advanced both pots all the way, it's time to check the circuit again for wiring faults. All the valve heaters are on, aren't they? Any fault should not take long to spot, as there is not a great deal to the preamp.

If all is well, remove the signal, plug in your guitar and see how the amp feels. One problem you may well have is an excess of gain, which makes the amp hard to control. I suggest considering the gain switching modification (Figure 5 in last month's article) if this is the case.

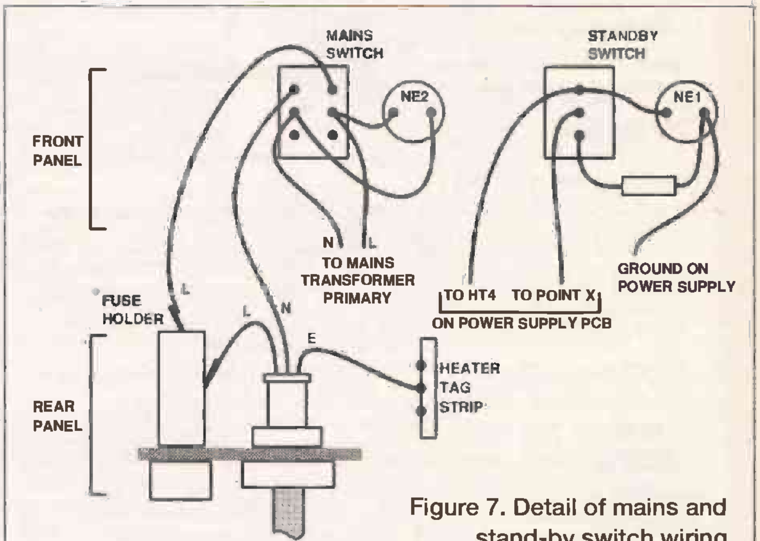


Figure 7. Detail of mains and stand-by switch wiring

Buylines

The transformers are made by E A Sowter Ltd, The Boatyard, Cullingham Road, Ipswich, Suffolk, IP1 2EG (telephone 0473 252794 or 219390, fax 0473 236188). The cost is £81.98 for the pair, inclusive of VAT and postage and packing. Each transformer is made to order, so allow 28 days for delivery. Sowter can offer many other valve transformers too, some of which (Editor permitting!) will eventually turn up in other ETI projects.

The valves used in the prototype are from Chelmer Valve Co., which advertises regularly in ETI. The output valves are a matched pair of EL84s. If you are using aluminium channel for the chassis, I strongly recommend using Chelmer's B9A sockets. Chelmer valves and sockets are also available through Maplin, but Maplin does not offer the matching service.

Celestion loudspeakers are available through Wilmslow Audio, which also advertise regularly in ETI. The Celestions can take a while to come in from the factory, but they are well worth waiting for!

The best range I could find of high voltage but compact electrolytic capacitors was at Cricklewood Electronics. Maplin has some similar capacitors, but doesn't seem able to guarantee their size. Cricklewood also stocks the 2W carbon film resistors and standard size pots with proper in shafts (I had problems with Maplin collet knobs not fitting Maplin standard pots).

The pots with push-pull switches are hard but not impossible to get. I found them in a musical instrument shop that catered for guitar customisers and builders.

Aluminium channel is available through 'heavy' hardware and metal merchants, but you may have to do some asking around to find a supplier who will sell you a relatively small amount.

All the other components are widely available.

PARTS LIST

Resistors

R1,2,14,19	47k	R3,10,12,16,22,23	1M0
R4,7,17,26	100k 1W	R5,8,18	1k2
R6,9,11,38	100k	R13	1k0
R15	220k	R17	68k*
R20	4k7	R21,33	10k
R24	470	R25	82k 1W
R27,28	470k	R29,30	22k
R31,32	100R 2W (or 220R/180R, 1W)		
R33-37	10k 1W	R35	10k or 22k 1W
R39	100k 2W (or 2 x 220k 1W)		
R40	47R 2W (or 2 x 100R 1W)		
R41	10k	R42*,43*	100k 1W
R44*	470k	R45*	22k
R46*	180R 2W (or 2 x 390R, 1W)		
RV1,5	100k panel-mounting log potentiometer (see text)		
RV2,3	220k panel-mounting linear potentiometer		
RV4	22k panel-mounting linear potentiometer		
RV6	22k panel mounting antilog (or linear) potentiometer		
RV7	100k miniature horizontal linear preset		

Capacitors

C1,2,9,12,15	100n 50V or higher
C3,13,16,17	100n 400V
C4,11,20,21,22	10{SYMBOL 109 \f "Symbol"} 375V radial electrolytic
C5	"Symbol"} 10V radial electrolytic
C6	330p (or 1n0, see 'Mods') 400V
C7	220n 400V
C8	22n 400V
C10	10{SYMBOL 109 \f "Symbol"} 100V radial electrolytic
C14	22n
C19	22{SYMBOL 109 \f "Symbol"} 25V radial electrolytic
C23,24,25	47{SYMBOL 109 \f "Symbol"} 400V radial electrolytic
C26	47{SYMBOL 109 \f "Symbol"} 25V radial electrolytic
C27	100n 500VAC

Valves and Semiconductors

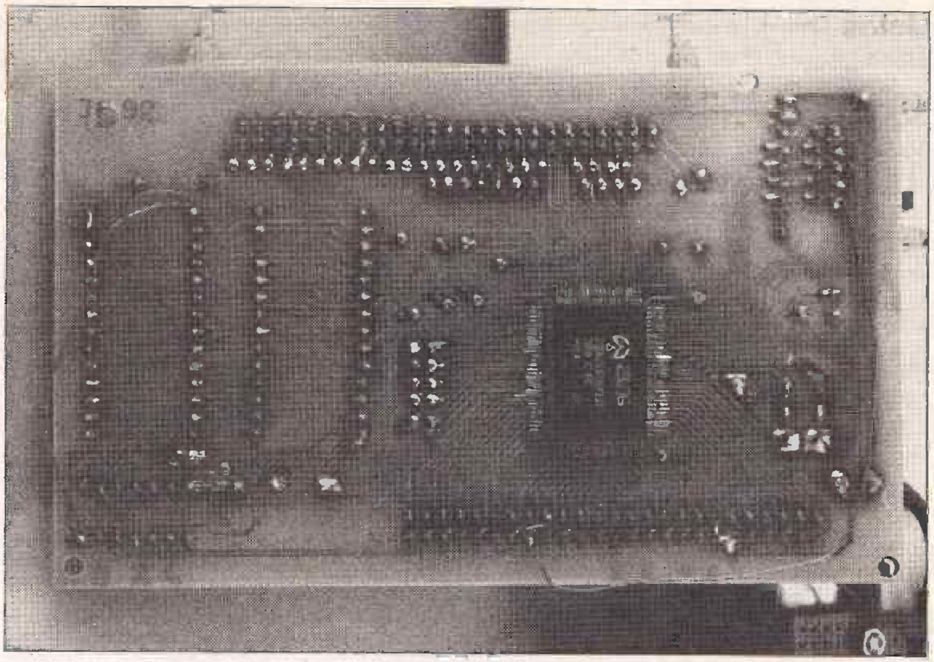
V1,2,3	ECC83 or 12AX7 dual triode valves
V4,5	EL84 pentode valves (matched pair)
D1-4	1N5408
D5	1N4001
ZD1	15V 1.3W Zener

Miscellaneous

T1	15W Valve output transformer, primary resistance 8k anode-to-anode, secondary 8 ohms
T2	Mains transformer, secondaries 250V 150mA and 6.3V 3A
SW1	Single way, single pole switch to choice (can be part of RV1, see text)
SW2	Two way single pole mains toggle switch
SW3	Single way dual pole mains toggle switch
SW4*	Single way dual pole switch (can be part of RV1, see text))
NE1,2	250V mains neons, colour to choice
LS1	Celestion G10S-50 PE or Vintage 30 (see text)
SK1-4	Standard jack sockets

Printed circuit boards; chassis (see text); case (see text); insulated mounting pillars (Maplin type FS36P with countersunk M3 screws BF36P); B9A valve sockets (5 off, see text); tag strips for heater and output transformer connections; mains cable restraint; chassis (in the prototype, two 15in lengths of 2in by 3in 1/8in thick aluminium U-channel); bolts, nuts and shake-proof washers; wood for cabinet; wood screws; wood glue; cabinet covering; loudspeaker cloth; knobs, wire, solder, etc.

PROJECT



In part 2 of this project Jason Sharpe describes how to add the monitor software to the board described last month.

Z-80 Single Board Computer

A basic machine code monitor program is available on ROM. It has facilities to download software from a computer via the serial port.

The monitor program allows the IPC to communicate with a terminal emulator via a RS232 port and can be used for developing programs. Alternatively, an EPROM emulator could be used for development. The commands available are described below, but should be familiar to those of you who have used debuggers such as SID.

?	Brings up a help message.
B	Boot. Restarts system by jumping to location 0.
D [<AAAA>[,<AAAA>]]	Dump memory contents in hex and ASCII, e.g. D D1000 D1000,2000
G [<AAAA>]	GOTO. Transfers control to specified address or 2000h if no address supplied.
I[<AAAA>]	Input file from serial port to 2000h or <AAAA>. File reception will terminate when 'TERMINATE' is read in.
L [<AAAA>[,<AAAA>]]	List. Prints disassembly of memory, e.g. L L2010 L3000,3200
T [<AAAA>[,<NNNN>]]	Trace instruction. <NNNN> is the number of instructions to trace.
S <AAAA>	Set value of memory locations. Enter '.' to exit.
X	Examine registers. Prints register states.
-[?]	If '-' is entered, control is passed to 2003h, which should contain a jump instruction. This enables users to add their own commands.

Pressing Esc terminates long traces, dumps, or listings. Ctrl H deletes characters. Note that spaces are not printed, all other characters are echoed back.

Using the I, Input File, Command

This is probably the most important of the monitor commands. Software can be developed on any assembler, cross assembler, or compiler capable of producing ROMable Z80 code. Many PD/Shareware libraries carry cross assemblers (see Ref. 1 at the end of this article). The assembler must produce plain output, i.e. not formatted in, for example, Intel hex format, etc. Assemblers for native Z80 machines such as CP/M machines are suitable. CP/M and Z80 emulators are also available for PCs to enable development to be carried out on the PC.

To load the binary file into RAM, type 'I' in the terminal emulator. A ready message should appear. The file can now be sent. When using the windows terminal program, select 'Send TEXT file' from the TRANSFERS menu. Be sure to remove the cross from the STRIP LF box, otherwise anything with the value 0Ah will be removed from the file, resulting in strange behaviour. Select the file to send. When 'TERMINATE' (in upper case) is received, control is returned to monitor. This can be achieved by typing TERMINATE after the file has been sent, or the preferred way is to add:

```
DM "TERMINATE"
```

(DM=Define Message, maybe different on your assembler), as the last line of your file.

Typing 'G' will start the program. Since I, followed by an address, can be used to load the program into an address other than 2000h (start of RAM), G followed by an address will jump to a location other than 2000h.

Programming Details

Due to the many peripherals in the IPC, it is not possible to give full programming details, it would fill half a dozen magazines! Full programming and architectural information can be found in the title referred to in Ref. 2. There are many texts containing examples of programming Z80 peripherals for those new to this area. The IPC contains standard Z80 peripheral chips and several custom devices. Routines in the monitor ROM can be called to perform various tasks, such as serial character I/O.

Ports

The I/O map of the IPC is shown below. The file shown in Listing 1, EQUATE.ASM contains all the definitions required to access the I/O devices.

Address	dev	Chan	Register
10h	CTC	Ch0	Control register
11h	CTC	Ch1	Control register
12h	CTC	Ch2	Control register
13h	CTC	Ch3	Control register
18h	SIO	ChA	Data register
19h	SIO	ChA	Control register
1Ah	SIO	ChB	Data register
1Bh	SIO	ChB	Control register
1Ch	PIO	PortA	Data register
1Ch	PIO	PortA	Command Register
F0h	WDT		Watch dog timer Master Register (WDTMR)
F1h	WDT		Watch dog timer Control Register (WDTCR)
F4h	IPR		Interrupt Priority Register
EEh			System Control Register Pointer (SCRP)
EFh			System Control Data Port (SCDP)

```
                *-------------Z8C15 EQUATE FILE-------------*
      ****************************PORT ADDRESSES***************************
CTC         EQU        010H              CTC BASE
CTCCH0      EQU        CTC               CHANNEL 0
CTCCH1      EQU        CTC+1             CHANNEL 1
CTCCH2      EQU        CTC+2             CHANNEL 2
CTCCH3      EQU        CTC+3             CHANNEL 3
SIO         EQU        018H              SIO BASE
SIOCAD      EQU        SIO               CH.A DATA
SIOCAC      EQU        SIO+1             CH.A CONTROL
SIOCBD      EQU        SIO+2             CH.B DATA
SIOCBC      EQU        SIO+3             CH.B CONTROL
PIO         EQU        01CH              PIO BASE
PIOPAD      EQU        PIO               PIO PORT A DATA
PIOPAC      EQU        PIO+1                        CONTROL
PIOPBD      EQU        PIO+2             PIO PORT B DATA
PIOPBC      EQU        PIO+3                        CONTROL
SCRP        EQU        0EEH              SYSTEM CONTROL REGISTER POINTER
SCDP        EQU        0EFH              SYSTEM CONTROL DATA PORT
WDTMR       EQU        0F0H              WATCH DOG TIMER MASTER REGISTER
WDTCR       EQU        0F1H              WDT CONTROL REG
INTPR       EQU        0F4H              INTERRUPT PRIORITY REGISTER

      **********************SYSTEM CONTROL POINTERS************************
WCR         EQU        00H               WAIT STATE CONTROL REGISTER
MWBR        EQU        01H               MEMORY WAIT STATE BOUNDAY REGISTER
CSBR        EQU        02H               CHIP SEL BOUNDRY REGISTER
MCR         EQU        03H               MISC CONTROL REGISTER
```

```
     *****************RELOCATED INTERRUPT JUMP BLOCK*********************
RAMBASE     EQU       2000H                 START OF USER RAM
USERCMD     EQU       RAMBASE+3H
INT010      EQU       USERCMD+3H
INT018      EQU       INT010+3H
INT020      EQU       INT018+3H
INT028      EQU       INT020+3H
INT030      EQU       INT028+3H
INT038      EQU       INT030+3H
NMI         EQU       INT038+3H

     ******************************MISC**********************************
EOT         EQU       "$"                   END OF TEXT MARKER
LF          EQU       0AH                   LINE FEED
FF          EQU       0CH                   FORM FEED
CR          EQU       0DH                   CARRIAGE RETURN
BELL        EQU       07H                   BELL CHARACTER
DEL         EQU       08H                   DELETE CHARACTER
ESC         EQU       01BH                  ESCAPE CHARACTER
```

Listing 1 Equate file

Listing 2, INIT, shows how the devices are initialised by the monitor. Listing 3, SIO_CODE, shows the BIOS routine to read and write characters from the SIO.

Listing 2 Initialisation Code

```
        **********SYSTEM INITIALISATION CODE EXECUTED BY MONITOR*********

        *                                                   J.M.Sharpe 1993*

INIT          LD          A,CSBR           CHIP SELECT REGISTER
              OUT         (SCRP),A         SCRP
              LD          A,31H            CS BOUNDRYS
              OUT         (SCDP),A         SET
              LD          A,MCR            MISC REGISTER
              OUT         (SCRP),A         SCRP
              LD          A,03H            ENABLE BOTH CS LINES
              OUT         (SCDP),A
              LD          SP,SS            SET UP STACK POINTER

              LD          A,07H            x16,RST,FALL EDGE
              OUT         (CTCCH3),A       CTC CONTROL WORD
              LD          A,04D            DIVIDE BY 4(4800x16 @5MHz)
              OUT         (CTCCH3),A       CTC TIME CONSTANT

              LD          A,05H            WRITE TO REG 5
              OUT         (SIOCAC),A       SIO CH.A CONTROL
              LD          A,0EEH           DTR,8,TX,CRC16,RTS
              OUT         (SIOCAC),A

              LD          A,04H            WRITE TO REG 4
              OUT         (SIOCAC),A       SIO CH.A CONTROL
              LD          A,044H           X16,1STOP,NO PARITY
              OUT         (SIOCAC),A


              LD          A,03H            WRITE TO REG 3
              OUT         (SIOCAC),A       SIO CH.A CONTROL
              LD          A,0E1H           8BIT,AUTO ENABLE,Rx ENABLE
              OUT         (SIOCAC),A
              LD          A,01H            WRITE TO REG 1
              OUT         (SIOCAC),A       SIO CH.A CONTROL
              LD          A,0
              OUT         (SIOCAC),A
```

```
        ************************SIO WRITE BYTE******************************
* IN:   A HOLDS DATA TO WRITE
* OUT:  A PRESERVED
SIOWB           PUSH            AF              SAVE A
SIOWB1          IN              A,(SIOCAC)      READ SIO STATUS 0
                AND             04H             CHECK TX BUFFER
                JR              Z,SIOWB1        LOOP TILL EMPTY READY

                POP             AF              GET CHARACTER TO TX
                OUT             (SIOCAD),A      SEND
                RET             DONE

        ************************SIO READ BYTE******************************
;* IN:          NOTHING
;* OUT: A HOLDS DATA READ.  WAITS FOR INPUT BEFORE RETURNING

SIORB           IN              A,(SIOCAC)      READ SIO STATUS 0
                AND             01H             CHECK RX BUFFER
                JR              Z,SIORB         LOOP TILL CHARACTER READY

                IN              A,(SIOCAD)      READ CHANNEL A DATA
                RET                             DONE
```

Listing 3 SIO Read and write byte code

BIOS COMMANDS

Various subroutines in the monitor ROM can be called by user software. This is achieved by loading C with the appropriate value and then performing a RST 8, e.g.:

```
LD              C,1
RST             8
...etc.
```

Sends the character in register A to the terminal emulator. RST was used as it is faster and more compact than a CALL. The following commands are available,

```
C=0
FUNC:   RESET,JP 0000
IN:     NOTHING
OUT:    N/A

C=1
FUNC:   Write Byte To Sio Channel A
IN:     A=Character
OUT:    All preserved

C=2
FUNC:   Wait For Byte From Sio Channel
        A (SIOA)
IN:     NONE
OUT:    A=Byte Read

C=3
FUNC:   Write String To Sio Channel A
IN :    HL Holds Start Of String,
        Terminated With A '$'
OUT:    A,B,HL CORRUPT

C=4
FUNC:   Read String, Max 256
        Characters, Buffer Must Be 258
        Chars Long
IN:     HL=Address Of Buffer To Place
        Text In
OUT:    A,HL CORRUPT, C=Number Of
        Characters In Buffer
        String Terminated With '$$'

C=5
FUNC:   Send Hex Character For A To
        SIOA
IN:     A Value To Print
OUT: A CORRUPT

C=6
FUNC:   Convert String Pointed To By DE
        To Uppercase
IN:     B=No. Of Characters, DE Holds
        Address Of List To Convert
OUT:    A,B,DE CORRUPT

C=7
FUNC:   Turn ASCII String Into Hex
        Number
IN:     DE Holds Start Of ASCII Number
        (Max 4 Byte Number)
OUT:    Carry Set If Error, Else HL
        Holds Valid Number
        And DE Points To End Of ASCII
        Number +1

C=8
FUNC:   Same As DUMP Command In
        Monitor.
IN:     DE=Start Address, HL=End
        Address, If HL=0 Does 16 Lines
OUT:    A,BC,DE,HL CORRUPT
```

INTerrupts and ReSTarts

Interrupts are disabled when a user program is invoked. So interrupt mode 1, NMI and the free RST instructions can be used. They are redirected from the ROM locations to the start of RAM. If Interrupts are to be enabled, programs should have the following at the start,

```
          PROGRAM HEADER FORMAT
ORG   2000     Start of user memory
JP    START    Jump to start of program
JP    USERCMD  If '-' entered in
               monitor, this routine is
               called, use for adding
               new monitor commands,
               set to 'jp 0' if not
               used
JP    RSTH010  RST 10 Redirected here *
JP    RSTH018  RST 18 Redirected here *
JP    0000     Reserved for system use
JP    RSTH028  RST 28 Redirected here *
JP    RSTH030  RST 30 Redirected here *
JP    RSTH038  RST 38 Redirected here *
JP    NMI      NMI redirected here, set
               to 'JP 0' if unused
 * SET TO 'RET' OR 'JP 0' IF NOT USED
```

Listing 4, SECOND, demonstrates how interrupts can be used. In interrupt mode 1, a jump is performed to 0038h when an interrupt occurs. The instruction at this location performs a jump to the jump block so the user can service the interrupt. In this case the interrupt comes from the CTC. The program outputs location INTCLK2, which acts as a seconds counter. If more than one interrupt source is active it will be necessary to determine which device caused the interrupt.

More Speed

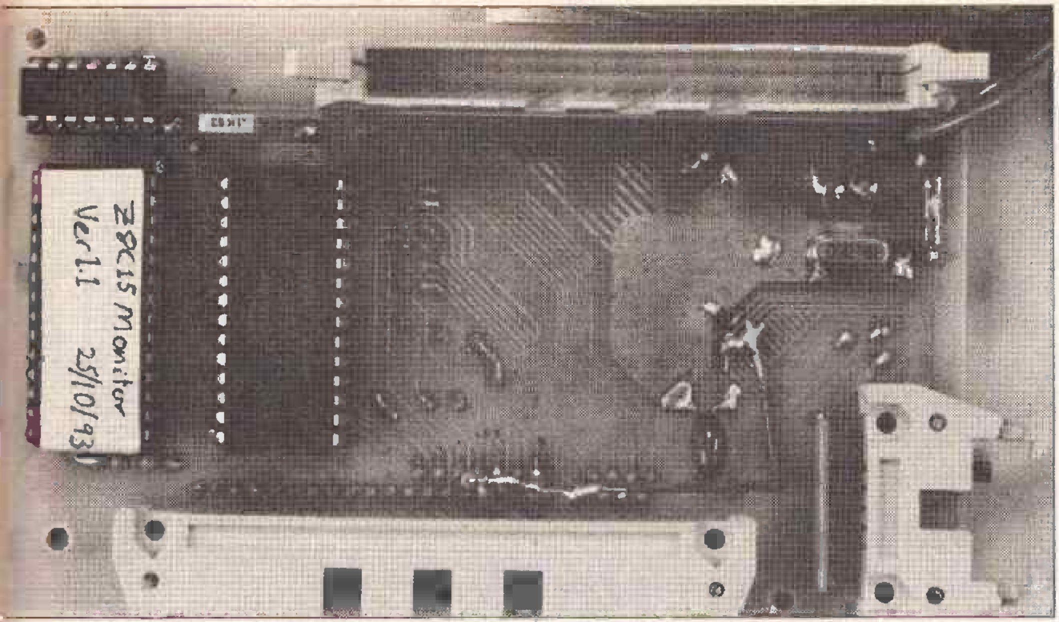
The system starts up with the CGC running in divide by two mode, i.e. the clock input is 5MHz. If required, the clock input can be switched to divide by one mode by writing to the system control registers. This has the effect of doubling the clock speed to all peripherals, including the CTC which provides the serial data clock. Thus, the baud rate is doubled. Also, remember that increasing the clock speed increases the system power consumption.

Listing 5, CLKDBLE demonstrates how the system control and data ports are accessed, this example sets the clock divide by one flag, increasing the system clock speed to 10Mhz. Run the program by typing

`T2000,A`

in the monitor. On exit, change the host computer's baud rate to 9600 baud and press enter several times.

```
           ***DEMONSTRATION OF USING INTERRUPT MODE 1 AND CTC INTERRUPTS***
           ***LOCATION INTCLK2 IS INCREMENTED EVERY SECOND    J.M.SHARPE***
           ORG 2000H
                         *-----------JUMP BLOCK-----------
JPBLK      JP            START            Jump to start of program
           JP            0
           JP            0                 RST 10 Redirected here
           JP            0                 RST 18 Redirected here
           JP            0                 Reserved for system use
           JP            0                 RST 28 Redirected here
           JP            0                 RST 30 Redirected here
           JP            INTHAND           RST 38 Redirected here (USED BY IM 1)
           JP            0                 NMI redirected here
                         *-----------MAIN PROGRAM-----------
START                                     PROGRAM CTC CHANNEL 0
           LD            A,085H           INTERRUPTS ENABLED,x16,CONTINUOUS
           OUT           (CTCCH0),A       CTC CONTROL WORD
           LD            A,0FAH           DIVIDE BY 250, GIVING 1250Hz
           OUT           (CTCCH0),A       CTC TIME CONSTANT
           LD            HL,04E2H         1250 DECIMAL
           LD            (INTCLK1),HL     CLOCK COUNTER1
           XOR           A                A=0
           LD            (INTCLK2),A      SECONDS COUNTER
           IM            1                IM1 JUMPS TO 38H ON AN INTERRUPT
           EI                             ENABLE INTERUPTS
LOOP       LD            A,(INTCLK2)      GET SECONDS COUNTER
           LD            C,5
           RST           8                PRINT IT IN HEX
           LD            A,CR  LD         C,1
           RST           8                RETURN TO START OF LINE
           JP            LOOP             REPEAT FOREVER
                         *-----------INTERUPT HANDLER-----------
INTHAND    PUSH          AF               SAVE AF
           PUSH          BC
           LD            BC,(INTCLK1)
           DEC           BC
           XOR           A                A=0
           CP            B
```



Watch Dog Timer

A watch dog timer (WDT) is a mechanism designed to allow crashed systems to recover. The program accesses the WDT periodically to reset the count. If a program has crashed and does not do this, the WDT will time out, causing the /WDTOUT pin to go low. Connecting this pin to /RESET, will restart the system in the event of a crash. The WDT register also controls the power saving modes. The system clock to various devices can be stopped to minimise the power consumption in battery operated systems.

Note that the /RESET pin functions as an OUTPUT during power up, and so only open collector logic should be connected to it if an external Reset is required. Due to the design, a push button switch from /RESET to GND will normally reset the CPU correctly.

At this speed, older EPROMs may be too slow. If this is the case, the on chip wait state generator can be programmed to slow memory access. If a program works when run in RAM at 10MHz, but fails in ROM, access time could be the problem.

```
         JR       NZ,INTEXIT
         CP       C
         JR       NZ,INTEXIT       IF BC>0 EXIT

         LD       A,(INTCLK2)      GET SECONDS COUNTER
         INC      A
         LD       (INTCLK2),A      INC AND STORE
         LD       BC,04E2H         1250H
INTEXIT  LD       (INTCLK1),BC     SAVE COUNTER1
         POP      BC
         POP      AF               RESTORE REGISTERS
         EI                        ENABLE INTS
         RETI

INTCLK1  DS       02H              DIVIDE BY 1250 LOCATION
INTCLK2  DS       01H              SECONDS COUNTER
         DM "TERMINATE"
END
```

Listing 4 Seconds counter using interrupts

Listing 5 Seconds counter using interrupts

```
             ***********Routine Increase clock speed to 10Mhz**********
* To run type T2000,A
* then change the terminal emulator baud rate to 9600 baud
              ORG 2000H
              MCR     EQU     03H         MISC CONTROL REG
              SCRP    EQU     0EEH        SYS CONTROL REG PNTR
              SCDP    EQU     0EFH        SYS CONTROL DATA PORT
Start         LD  A,MCR
              OUT (SCRP),A    Point to Misc register
              IN  A,(SCDP)    Get current state
              OR  10H         Set clock divide by one flag
              OUT (SCDP),A    Clock now 10Mhz
              NOP
              NOP
              NOP
              NOP
              DM  "TERMINATE"
END
```

```
         *******************************************************************
         * PIO TEST PROGRAM                                J.M.SHARPE 1993 *
         *******************************************************************
           ORG 2000H

INIT       LD             A,0FFH
           OUT            (PIOPAC),A         PUT PORT A IN CONTROL MODE
           OUT            (PIOPAC),A         SET ALL BITS AS INPUTS
           LD             A,0FFH
           OUT            (PIOPBC),A         PUT PORT B IN CONTROL MODE
           LD             A,00               ALL BITS OUTPUTS
           OUT            (PIOPBC),A         SET DIRECTIONS

LOOP       IN             A,(PIOPAD)         READ PORT A
           OUT            (PIOPBD),A         OUTPUT TO PORT B
           LD             C,5
           RST            8                  PRINT HEX VALUE
           LD             A,020H
           LD             C,1
           RST            8                  PRINT A SPACE
           JR             LOOP

           DM             "TERMINATE"
END
```

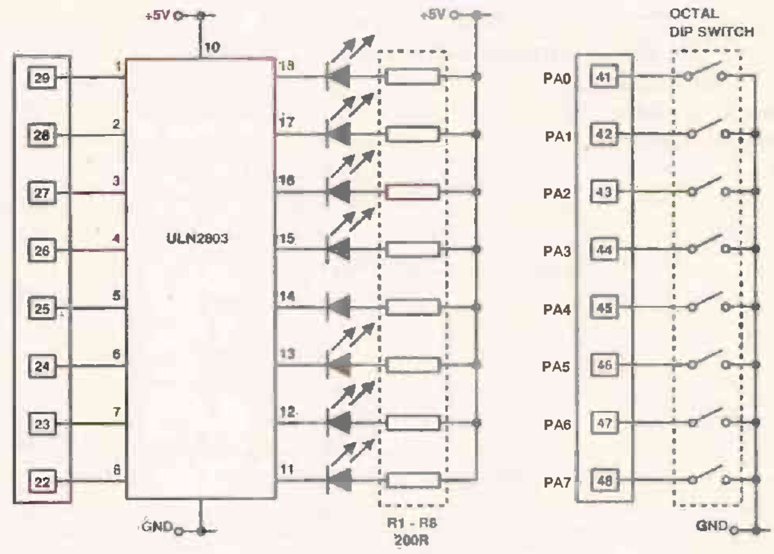


Figure 1 PIO test circuit

PIO

External devices can be attached to the three connectors. The PIO is probably the most useful of these. A circuit such as the one in Figure 1 and listing 6, can be used to test the port. The state of the LEDs should correspond to the state of the switches.

Component Sources

The Z84C1510 is available from RS, order code 264-490, £16.15 plus VAT.

The solder paste used in the prototype was code 22-65185A, £6.24 plus VAT from Verospeed. The low profile 10Mhz crystal was also purchased from Verospeed.

References

Ref. 1: Scientific Shareware - Winscombe House, Beacon Rd, Crowborough, East Sussex TN6 1UL. Tel. 0892 663298

Ref. 2: Z80 Family Data Book, Zilog, 1991. Available from Maplin Electronics, code: RQ54J £6.95

Note: The monitor software is public domain and may be copied freely. It may not be sold, although a nominal copying fee may be charged, plus the cost of ROM if distributed in said form.

A programmed 2764 containing the complete monitor programme for this project is available from **ETI Reader Services, Price £12.99 inc. Order No. ROET/42.** A printed listing is also available **Price £2.00.**

Cheques payable to ASP and sent to: **ETI Reader Services, Argus House, Boundary Way, Hemel Hempstead, Herts HP2 7ST**

PARTS LIST

Capacitors

C1-2	33pf ceramic
C3-5	0.15F Surface mount ceramic
C6	105F Tant
C7	0.15F Poly

Resistors

R1-8	4K7 SIL
R9-13	4K7

Semiconductors

IC1	Z84C1510
IC2	6264
IC3	2764
IC4	74HC32

Xtall 10MHz low profile

2 x 50 way DIL IDC headers plg

10 way DIL ICD header plg

Electronics equipment review

In this month's review section we take a look at three relatively low cost commercial EPROM programmers, which can be used in conjunction with a PC to program a range of EPROMs and Microcontrollers.

EPROMs are finding increasing usage in a great many electronics projects, not just for storing computer programs but also as specialist logic devices, a specific input pattern generating a specific output pattern. In ETI, we have over the years done a number of EPROM programmer projects, many of which have been very successful. However, even though ETI readers have a penchant for building things themselves, it is occasionally a good idea to look at some of the commercial products, as very often they can be surprisingly good buys.

In this short review, we are examining three EPROM programmers from different manufacturers. All are designed to be connected to a PC, from which object code produced by an assembler can be downloaded.

SP-1000

The Saje SP-1000 is a full featured stand alone EPROM programmer and EPROM emulator with the extended power of a PC via a remote control link. As a stand alone device it has a 16 character supertwist backlit display providing high clarity in all lighting and viewing conditions. The programmer also has a small keyboard with which the user can easily operate the unit's many functions, including programming/emulating data. There is a 32pin ZIF socket to hold the chip to be programmed.

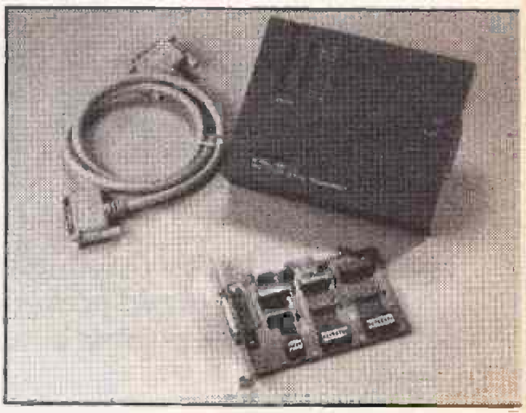
The unit is mains powered and is linked to the PC via its RS232 serial communications port. Standard download formats include binary, ASCII, Intel Hex and Extended Intel Hex. PC interface software is provided and handles all the main control functions, as well as handling communications between the PC and the programmer.

The SP-1000 will emulate a range of different EPROMS including 2716, 2732, 2764, 27128, 27256, 27512, 27010, 27020 and 27040, plus all compatibles. It will program the same range of devices.

The unit is supplied complete with all cables and software, all that is required is a mains plug! Full documentation is also provided.

Cost - £299 + VAT **Available from:** Saje Electronics Ltd, 117 Lovell Road, Cambridge, CB4 2QW. Tel. 0223 425440 Fax. 0223 424711.

HEP-101



The HEP-101 is the simplest and cheapest of a family of EPROM programmers, the HEP-800 series. It is a simple, but nonetheless powerful, device which relies heavily on the PC based control software to perform many of the programming functions. The hardware comes in two parts, the SAC-101A high speed interface card, a PC half card which plugs directly into the PC's expansion bus, and a programmer unit with quick release socket, the two being linked by a cable.

The HEP 101 can be used to program a wide range of different devices. These include byte wide NMOS/CMOS EPROMs ranging from 2716 to 27512 and 8Mbit. It will also program EEPROMs including 2816, 2816A, 2864A, 28256A, 28F512, etc. Page mode EPROMS, such as the 27513 or 27011 can also be programmed. Programming is quick, it taking about 20 seconds to program a 27256. The HEP-101 will accept object code as Intel 80/86 HEX, or Motorola S1/S2/S3 HEX, as well as binary and ASCII.

The unit comes complete with interface card, programmer, cable and control software. It can be used with any XT/AT or 100% compatible PC with MS-DOS 2.0 or later, floppy disk drive and 640K RAM (note max. system clock speed is 25MHz zero memory wait state).

Cost - £149 **Available from:** Citadel Products Ltd, 50 High Street, Edgware, Middx. HA8 7EP Tel. 081 951 1848 Fax. 081 951 5857.

Dataman S4

The S4 is a battery powered PROM programmer that has been specifically designed for use by microsystem designers. It contains 128K, 256K, or 512K of RAM, which retains data and configuration even when the unit is switched off. The RAM can be downloaded with data and manipulated either remotely from a computer via a RS232 interface, or directly from the S4's keypad.

The S4 provides plug in emulation for PROMs via a 24/28/32 pin emulator lead. The development method is that a new program can be tried out by emulation. Then when it works a PROM can be programmed and plugged into the system. The S4 can program EPROMs of the 27 series, such as the 2716 or 278000, also FLASH EPROMS and most EEPROMs, including 28, 52, 55 and 98 series. Other devices can be programmed, such as single-chip microprocessors, but some require a plug in adaptor.

The S4 comes complete with a comprehensive manual, a mains charger, a WRITE lead 2mm plug to Minihook, EMULead ribbon cable with 32 pin DIL plug, Library ROM, Disk with terminal driver program and utilities. The whole system, with the exception of the batteries, is covered by a three year parts and labour guarantee.

Cost - £495 **Available from:** Dataman Programmers Ltd, Station Road, Maiden Newton, Dorset, DT2 0AE. Tel. 0300 320719 Fax 0300 321012

Power supplies for electronic equipment

John Linsley Hood takes a new look at building improved power supplies for low signal level electronics circuitry

I have heard comments from constructors, from time to time, to the effect that when they had substituted a more permanent, mains-operated power supply for the batteries which they had used during initial testing and operation of some piece of low power audio gear, such as a pre-amplifier module, they were left with the feeling that it had sounded rather better when it had been powered by batteries.

This observation has never really surprised me, since batteries, provided that they are new, are very nearly an ideal source of power for electronic hardware - their output voltage is intrinsically hum-free (provided, of course, that one isn't doing something daft, like taping them onto the side of one's mains transformer), it is easy to arrange their connections so that they don't introduce hum-generating 'earth loops' and they have both a nearly constant output voltage and a very low noise level.

When they are new, their output noise level is certainly better than most stabilised power supply systems, though I would not have expected this to make a noticeable difference. However, I also know that the human ear can detect very small defects in audio systems, which is why I am more reluctant than the average engineer to dismiss claims made by the bat-eared brigade that effects which are measurable, but very, very small, are nevertheless audible. This consideration provided me with the incentive to take a somewhat closer look at the relative characteristics of batteries vs. other kinds of power supply.

Battery Types (Primary)

1. The LeclanchÈ.

A large range of cells has been devised over the years, of which a few have become widely used because of specific advantages, such as high energy capacity or low cost, and these can be broadly subdivided into 'primary' (use until flat, then throw away), and 'secondary' (use until it is convenient to remove and re-charge).

Of the 'primary' cells, the most common is the venerable 'LeclanchÈ', or zinc-carbon design, which consists of a cylindrical cup-shaped negative electrode, called the 'anode', pressed out of thin zinc sheet, inside which there is a cloth bag containing a carbon rod, surrounded by a mixture of graphite and manganese dioxide to form the positive (cathode) terminal of the cell, as I have shown in Figure 1. The cell is activated during manufacture by saturating the carbon powder mix with a solution of ammonium chloride in water and the top of the cell is then sealed over with pitch, to prevent this 'electrolyte' from leaking out.

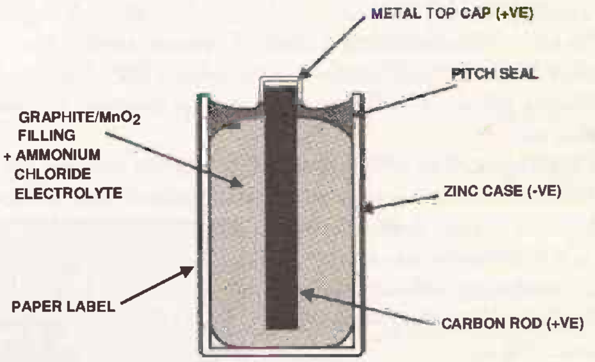


Figure 1. The traditional 'Leclanche' flash lamp

When current is drawn from the cell, atomic oxygen is released on the inner surface of the zinc cup, which it attacks and converts the metal into various zinc salts, while hydrogen is released at the cathode. The gas evolved here would impede the current flow through the cell and cause its output voltage to fall, on load, a process which is called 'polarisation', so manganese dioxide powder is mixed with the carbon powder filling to combine with, and get rid of, this unwanted hydrogen. For this reason it is called the 'depolariser'.

The working life of the cell is limited by the progressive corrosion of the zinc outer cup - which continues slowly, due to impurities in the zinc, even when no current is being drawn from the cell - by the using up of the electrolyte and by the exhaustion of the depolariser. The cell manufacturers usually allow a little surplus zinc on the anode cup, to try to lessen the risk of the cell case perforating and allowing the highly corrosive goo to leak out into ones 'Walkman' or pocket calculator.

2. The Zinc Chloride Cell

About twenty years ago it was noticed that if the ammonium chloride solution used as the electrolyte in the standard LeclanchÈ cell was replaced by a zinc chloride solution (which was at least as cheap), the cell had better electrical characteristics. This observation, which had been known to the chemists for about a hundred years, was hailed by the battery manufacturers as a huge technical breakthrough, especially since it enabled them to charge more money for their batteries.

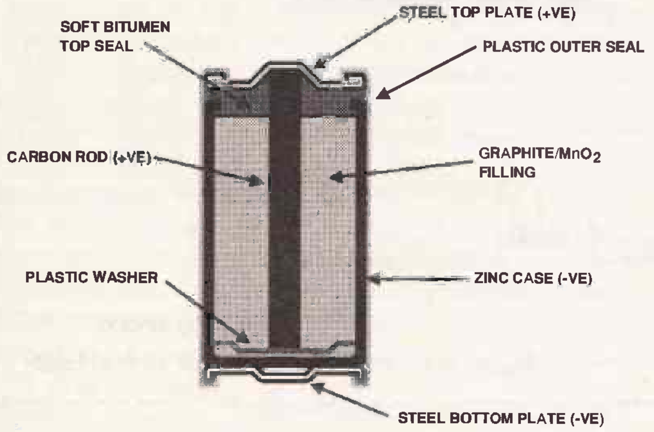


Figure 2. Modern zinc chloride cell, with tight fitting outer plastics sleeve

The way 'zinc chloride' cells work is virtually identical to that of the original LeclanchÈ, though such cells, the most common type on any supermarket shelf, are usually fitted with tin plated steel top and bottom caps and an outer plastics sleeve, as shown in Figure 2, to help prevent leakage of the corrosive electrolyte from the cell.

3. The Alkaline-Manganese Cell

This type of cell really is better than the zinc chloride or ammonium chloride based versions and it has the same 1.5-1.55V output voltage as its predecessors, though with a capacity about seven times as great. The main difference is in the electrolyte used, which is a concentrated solution of caustic potash (potassium hydroxide). This would be quite nasty if it escaped, which demands that the cell is made completely leak-proof, both when new and when fully discharged, which is a good thing for the forgetful user.

Although caustic potash solution is a much better conductor of electricity, it reacts much less vigorously with zinc than, say, a zinc chloride solution, so for the same output current it is necessary to increase the effective surface area of the zinc anode. This is done by forming the anode from finely divided powdered zinc, made into a paste with the electrolyte. The cathode is still a mixture of graphite and manganese dioxide, but pressed into a series of hollow cylinders, which are fitted inside the steel outer case as shown in Figure 3.

4. Button Cells

Electronic wrist watches, automatic cameras, hearing aids and contemporary designs of pocket calculator, have created a demand for very small, relatively low output batteries, often of just single-cell type, mostly based on zinc in combination with silver or mercuric oxides, with output voltages in the range 1.3-1.55V. Like the alkaline manganese cell types, these all use a potassium hydroxide electrolyte and are both fully sealed and leak-proof during their entire life.

The most common of these cell types, the 'mercury' cell, is so widely used that, in the more popular forms, such as those employed in miniature hearing aids, individual cells can cost as little as 30p each. The 'zinc-air' cell is very similar in design, except that instead of using mercuric oxide as the source of oxygen to power the electro-chemical system, a small hole is made in the base of the cell to allow oxygen from the air to reach a water impermeable catalytic carbon layer in the base of the cell.

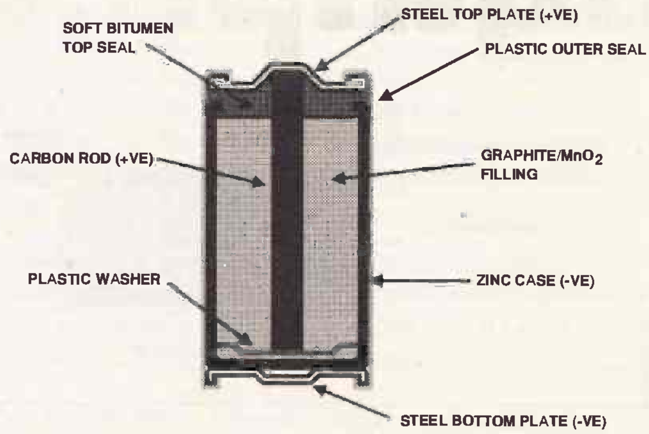


Figure 3. 'Alkaline manganese' high energy cell

Since this occupies less space than the mercuric oxide layer, there is more room inside the cell for the zinc/mercury amalgam anode and the cell has a somewhat greater electrical capacity. It is commonly supposed that a 'zinc-air' cell will last twice as long as the standard mercury cell, which is used to justify the fact that it will also, usually, cost twice as much. However, the Duracell catalogue quotes the RM312 mercury button cell as having a 57mA hour capacity, as compared with 70mA hour capacity for the physically equivalent DA312H zinc-air type - which is only 23% greater.

The extra convenience of not having to replace zinc-air cells quite as frequently as the mercuric oxide equivalents is offset by the fact that, once the sealing tab has been removed from the base of the zinc-air cell, to allow ingress of air and to start the cell working, the cell begins, slowly, to discharge. This favours applications where the cell will normally be replaced in weeks or months, at the latest, rather than those where it is in intermittent use and a long shelf- life would be an advantage.

The construction of both of these cells is very similar and I have illustrated them in Figures 4a and 4b. The silver oxide cell, which I have shown in Figure 4c, has a somewhat higher output voltage of 1.55V, as compared with 1.35V for the mercuric oxide or zinc-air equivalents and it also has a very flat output voltage vs. discharge curve. However, it is more expensive and has, other things being equal, a capacity which is only about 75% that of the mercuric oxide type.

The final important cell of this kind is the Lithium-manganese dioxide type, which is notable for its high (3V) output voltage, its good storage capacity - though this is not a lot larger than the

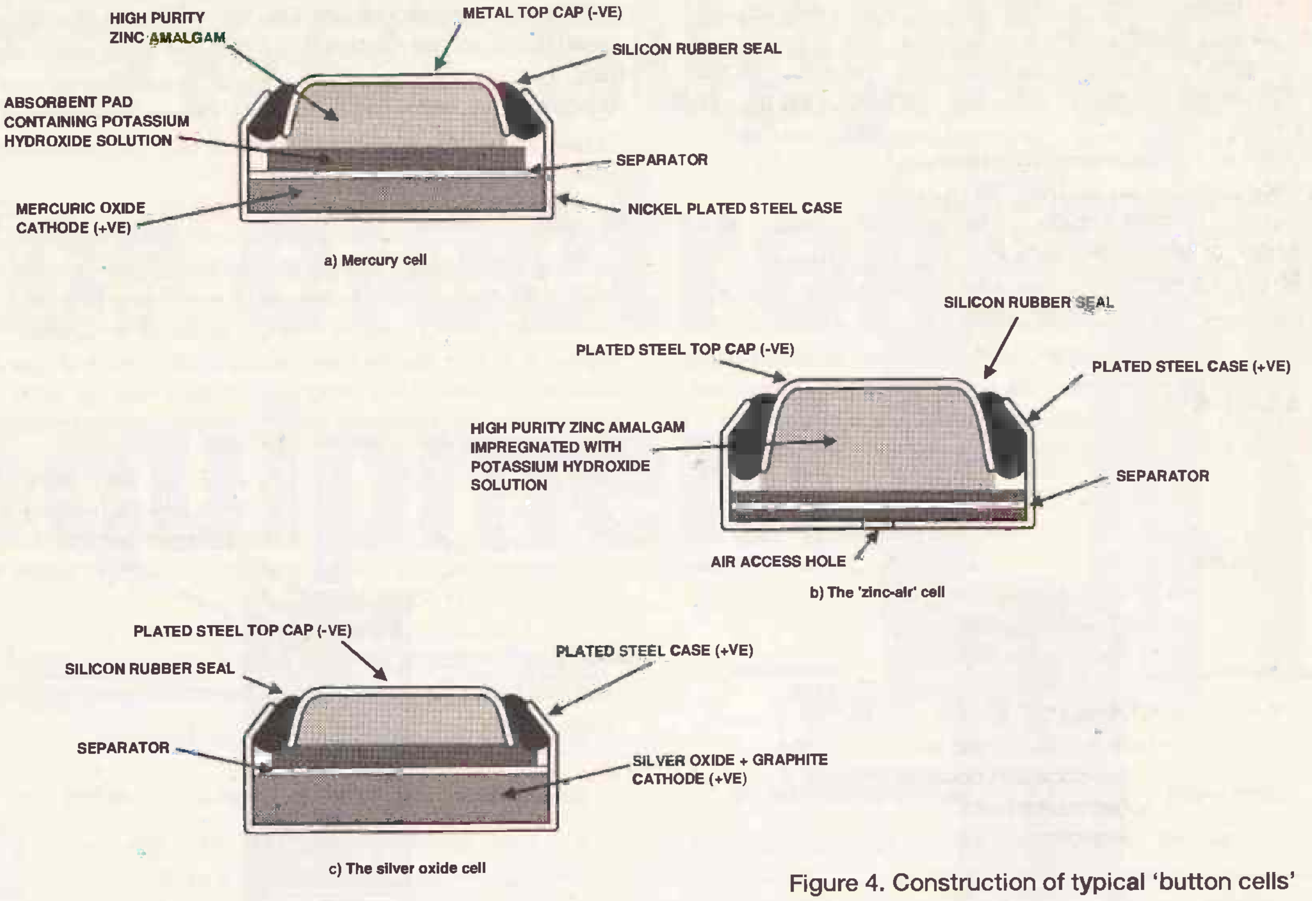


Figure 4. Construction of typical 'button cells'

mercuric oxide type - and its exceedingly long shelf life, a quality which has led to its widespread use in computer memory back-up applications. Because lithium metal reacts violently with water, exotic electrolytes which are not water based must be used and these are, in general, not very good conductors of electricity, which makes lithium cells suitable only for low current applications.

Rechargeable (Secondary) Batteries

For all practical purposes, these are now either lead-acid, the system used in car batteries, or nickel-cadmium 'NiCad', which are used in mobile 'phones and the like.

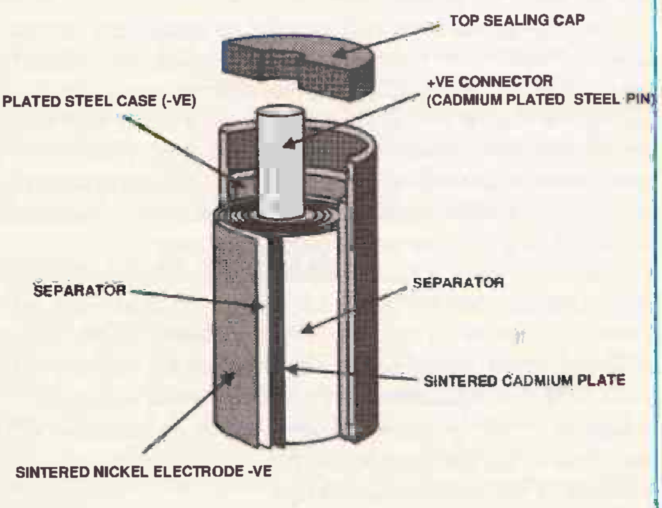


Figure 5. Typical construction of cylindrical Ni-Cad cell

1. NiCad

As in the alkaline manganese cell, the electrolyte is a potassium hydroxide solution, which gives the cell a very low internal resistance and allows high discharge currents. However, in order to get large storage capacity, it is necessary to provide a large effective surface area for the plates. This is done by depositing the metallic nickel (negative) and cadmium (positive) electrodes in the form of a sintered powder, within a micro-porous matrix formed on the surface of a pair of nickel or cadmium plated plates.

In the case of the cylindrical type cells, these plates are made of thin foils, which are wound up into a kind of 'swiss-roll' structure shown in Figure 5. This is similar to an aluminium foil electrolytic capacitor and the surface of the cadmium metal is oxidised to form the positive, cadmium oxide, electrode when the cell is given its initial charge.

During charging, both hydrogen and oxygen are released, but only in very small quantities up to the point where the cell is fully charged and these gases recombine chemically, in the cell, to form water. Provided that the charging rate of the cell is not too high, no 'free' gas is evolved at all and the fully charged state is indicated by an increase in temperature of the cell as all the input power is absorbed in breaking down the electrolyte into gases, which then recombine.

This increase in cell temperature at the end of a charge is a much more reliable indication that the cell is fully charged than the measurement of cell voltage and is used as a control mechanism in some of the charger systems provided, for example for use with battery powered hand tools.

The normal cause of deterioration in NiCad cells is that frequent gentle charging and discharging of the cells tends to produce a smooth surface to the plates. Because these have a relatively low surface area, it lessens the storage capacity of the battery. To avoid this problem periodic complete discharge and fast recharge cycles are recommended.

Catastrophic failure of the cell, so that it has neither output voltage nor storage capacity, is usually caused by the growth of thin metallic tree-like structures called 'dendrites', which penetrate the porous 'separator' layer between the plates and produce internal short circuits. The recommended cure for such a dud cell is to 'treat it rough', by forcing current through it at a 'one hour' or faster charging rate, i.e. a 1A charging current for a 1Ah cell. If a voltmeter is connected across the cell in question, success in fusing the dendrite will be indicated by the cell voltage suddenly 'taking off'.

2. Lead-Acid

I have included these for completeness, because they are, like the zinc-carbon LeclanchÈ flash-lamp battery, within the range of nearly everyone's experience, though seldom used in electronics applications. They consist of a pair of lead plates, one of which is pocketed with cavities filled with lead dioxide, to make the positive electrode, while the other is left simply as plain lead. The electrolyte is dilute sulphuric acid, at approximately 20% concentration and the output voltage is in the range 2-2.25V.

Recharging 'Primary' Cells.

Most cells can be recharged, to some extent, even those which are intended to be used once and discarded when flat and, from time to time, schemes are proposed in patents or in electronics magazines, for gadgets which will do this. Taking, as an example, the zinc chloride cell, the requirement is that the cell should not be allowed to become too fully discharged - obviously, if the outer zinc case becomes corroded away, the cell is an unwelcome neighbour anyway - and it should be recharged in such a way that the zinc is replaced as a smooth, continuous layer. This usually means using a pulsating uni-directional charging current, having a fairly high repetition rate for the current pulses.

Also, since the recharging process is likely to cause the loss of water from the cell, by electrolysis, the charging process should not be allowed to continue beyond the extent which is necessary, nor should the charging rate be so high that the gases formed cannot recombine, or leak away.

Power Supply Characteristics

The desirable characteristics of a power supply are that its output voltage should be constant, that its internal resistance should be as low as possible and that the noise voltage superimposed on the output shall be negligibly small. Because most cells have press fit contacts and the possibility of multiple internal current paths, the noise they suffer from is mostly 'excess' or '1/f' noise - a kind of noise which is basically only noticeable below, say, 100Hz. It will, for physical reasons, worsen as the cell discharges.

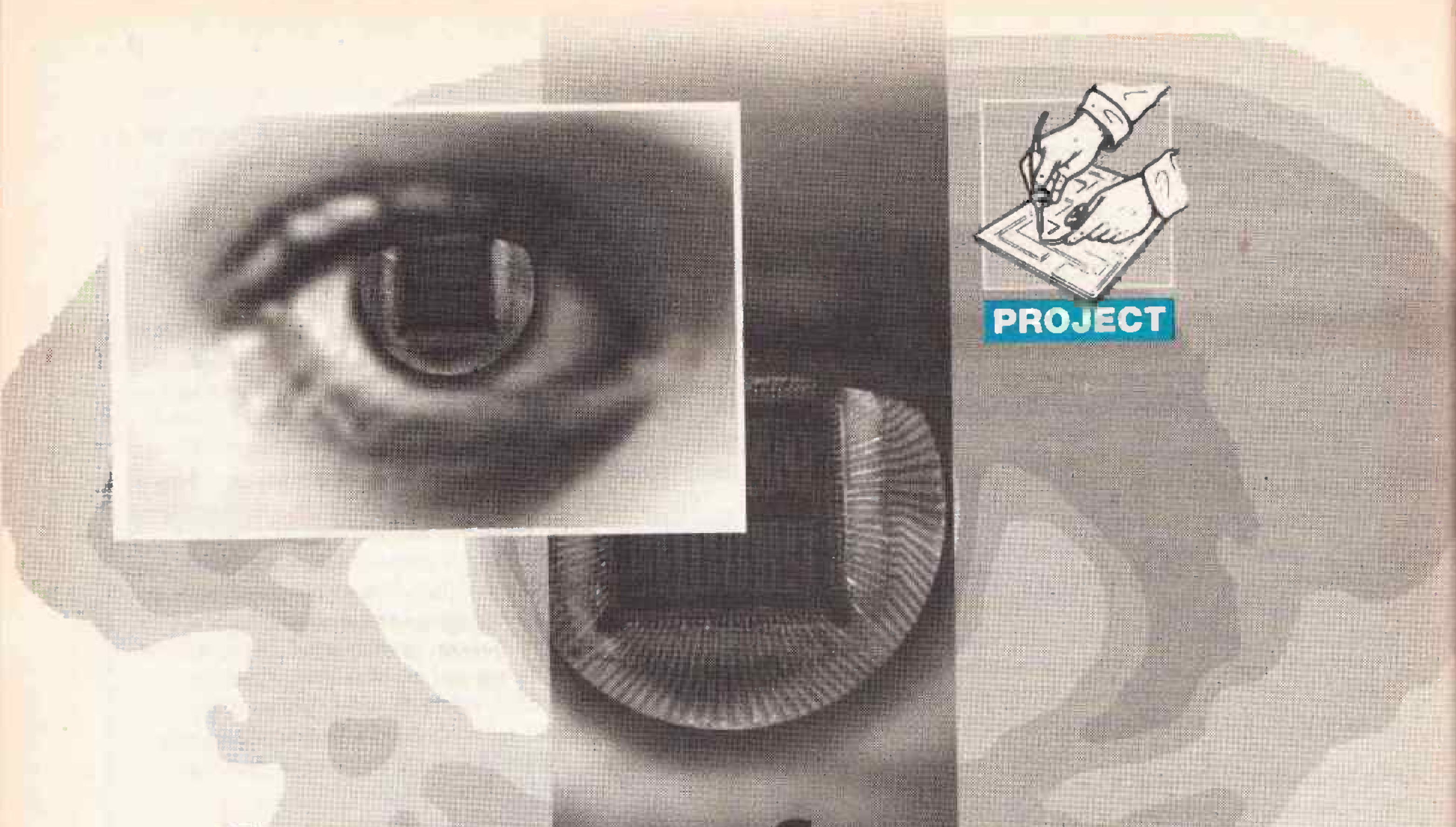
Cell and Power Supply Characteristics

I have listed the relative characteristics of typical supply systems in the table below, where all cells are of HP7 or 'AA' size.

Cells	Output voltage (new)	Output voltage (partially used)	Internal resistance (new)	Internal resistance (partially used)	Noise voltage*
LeclanchÈ	1.55V	1.45V	1.5ohm	7ohm	<1µV
Zinc chloride	1.55V	1.45V	1.2ohm	3.5ohm	*
Alkaline Manganese	1.57V	1.39V	0.76ohm	1.15ohm	*
NiCad	1.33V	1.25V	0.03ohm	0.05ohm	*
Regulator ICs (at 1KHz or lower)		Output voltage	Output resistance		Noise voltage
7805	5V	0.007ohm	40µV		
78L05	5V	0.09ohm	40µV		
7812	12V	0.008ohm	75µV		
78L12	12V	0.18ohm	80µV		
7815	15V	0.18ohm	90µV		
78L15	15V	0.21ohm	90µV		
7905	-5V	0.01ohm	125µV		
79L05	-5V	0.15ohm	40µV		
7912	-12V	0.01ohm	300µV		
79L12	-12V	0.5ohm	96µV		
7915	-15V	0.01ohm	375µV		
79L15	-15V	0.625ohm	120µV		

*Note. The noise level of all of the cells tested, measured over a 20Hz-20KHz bandwidth, was less than 1µV on a 10mA load current. My standard (op. amp. stabilised) variable voltage bench power supply has a typical output noise + ripple figure of 300µV, and tests made on the various 78xx type IC regulators confirm the makers quoted 'typical' noise levels, listed above.

Next month, in the second part of this article, John Linsley Hood will describe an add-on circuit which will improve the noise characteristics of a conventional IC series voltage regulator so that it is comparable in performance to a battery, as a source of power for low-level audio circuitry.



An eye for a robot

Simple optical sensors can help a robot find out about the world around it. In Part 1 of this series, Nick Hampshire looks at some of the basics

A true robot is a self contained autonomous system. It has sensors to provide information about the world in which it lives, it has a knowledge base which allows it to interpret the input from these sensors, and it has actuators which allow it to respond to the sensor input in a manner determined by its knowledge base. If it does not have all three of these components, then it is doubtful that we can regard the system as a true robot.

Simple mobile robots rely almost exclusively on touch sensors to stop them bumping into any object they encounters, in much the same way that a mouse running along a burrow uses its whiskers to stop it bumping into the walls. But trying to navigate around even a simple environment with just touch sensors is very much a hit and miss affair, as anyone who has played blind man's buff will testify. A far better way of sensing the objects around one is to use some form of visual input in addition to the touch sensors.

Visual input can take many forms. It could be a sophisticated image analysis system with a TV camera and high speed computer for doing the analysis or, at the other extreme, it could be a simple light sensor that can be used to steer the robot towards or away from a light source, or even follow a white line painted on the floor.

In this short series, we shall be looking at a few simple and practical forms of visual input and pattern recognition for robots. We will not be considering the sort of sophisticated visual input that allows an industrial robot to accurately identify a part lying in any orientation in a bin of mixed parts and then assemble it with other parts it has picked out, but we will be looking at visual systems that allow a small mobile robot to build a visual map of the world around it to aid in its navigation. We will also be looking at simple image input and a system which can, with a reasonable degree of accuracy, recognise simple patterns. With a bit of expansion it should also be able to recognise your face from those of your friends.

Simple optical input

The simplest form of optical input device is a single phototransistor, onto which light is focused using a lens. Phototransistors are sold as infra-red light detectors but they are also efficient detectors of light in the visible part of the spectrum (infra-red sensitivity means that your robot can see things you can not!). The output from a phototransistor is a current that is roughly proportional to the intensity of the light falling on it. We need to change this variable current into a variable voltage if we are to either measure the light intensity or simply feed it into a threshold detector, which tells the computer that it is light when intensity is above a certain level and dark when that level.

A simple signal conditioner that will turn the variable current output of the phototransistor into a variable voltage is shown in Figure 1. The first thing to note

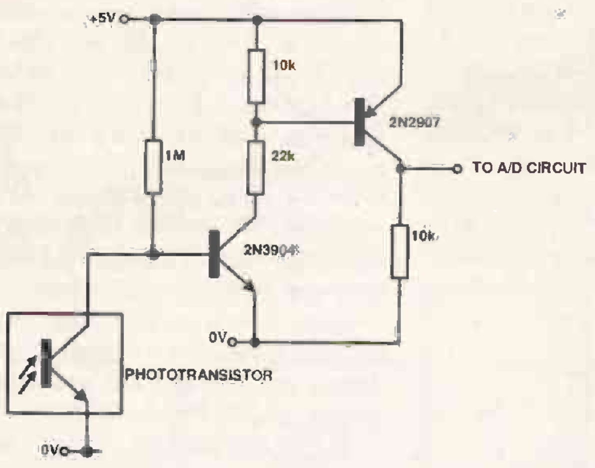


Figure 1. Optical sensor circuit

about this circuit is that its sensitivity can be altered by changing the value of the 1Mohm resistor. It can have any value between about 5Kohms and 3Mohms, the higher the value the greater the sensitivity to light. With the optical set-up that I used, a value between 500K and 1M gave the best sensitivity in a room with a mixture of artificial and natural light.

In order for it to work properly as a sensor, light needs to be focused onto the phototransistor with either a lens or a small parabolic mirror. Because I happened to have a small lens available which had a focal distance of about 1in, I decided to use that as the basis of a small camera type system. For the camera body I used an old plastic container in which 35mm film was packaged. This was about the right size and, most importantly, was designed to be light-proof.

A small hole was cut in the bottom, with a diameter slightly less than that of the lens I was using and the lens was glued to the container so as to cover the aperture. Great care should be taken when doing this, to ensure that no glue is spilt onto the central part of the lens, as cleaning it off can be quite difficult. The focal plane of the lens was then determined by using a piece of tracing paper covering the end of a small cardboard tube, which could be slid in and out of the plastic container with the lens mounted in the bottom.

With the lens pointing at a well lit object about 10ft away, the tracing paper screen was slid in or out until it displayed a sharp image of that object. The position of the screen from the lens was then measured to determine the actual focal distance. The phototransistor was mounted by simply making two holes through the push on lid with a needle and pushing the two leads of the phototransistor through it. The phototransistor leads should be pushed far enough through the cap so that the actual phototransistor chip lies on the previously measured focal plane.

The output from the circuit in Figure 1 will be an analogue signal between 0 and +5V, where 0V will correspond to high light intensity, and 5V to total darkness. This output could be connected to an input port of a computer using a 7404 buffer inverter as a simple threshold detector (the gate output will only switch from logic low to logic high when the input voltage exceeds a certain level, and vice versa). A more sophisticated threshold detector can be constructed using an op amp and a preset reference voltage, although, in most applications the NAND gate approach works quite well and the threshold light intensity can be changed by altering the sensitivity.

Expanding the visual input

Since the output from the phototransistor and its signal conditioning circuit is a variable voltage, we can extract a lot more information from it by measuring that voltage and thus determining the light intensity at the position where the camera is pointing. We can measure the voltage by using an analogue to digital converter circuit and outputting the digital value to the controlling computer.

The degree of precision in measuring the voltage need not be that great, dividing light intensity into 64 levels (often referred to as grey scale levels) is more than enough for most forms of image analysis. This means using an analogue to digital converter with six bit digitisation and sufficient speed and ease of connection to a computer to allow it at a later date to digitise multiplexed input from a small array of photodetectors. The choice was the Harris CA3306 A/D converter chip as the basis of the circuit shown in Figure 2.

This circuit is designed to measure

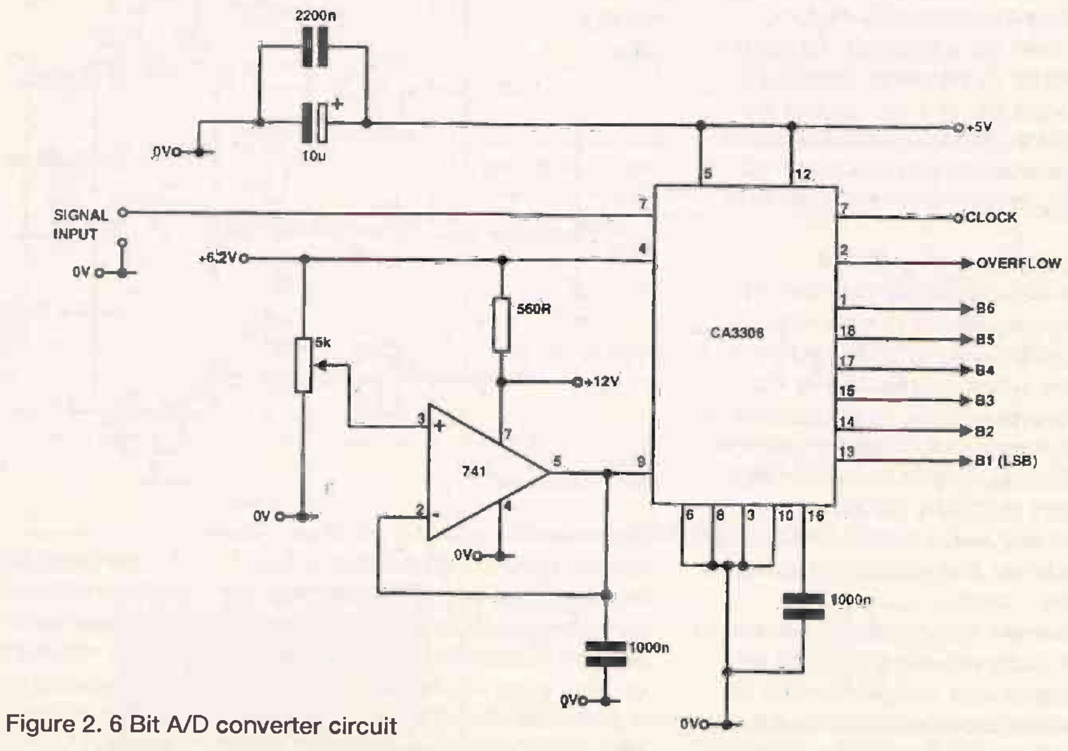


Figure 2. 6 Bit A/D converter circuit

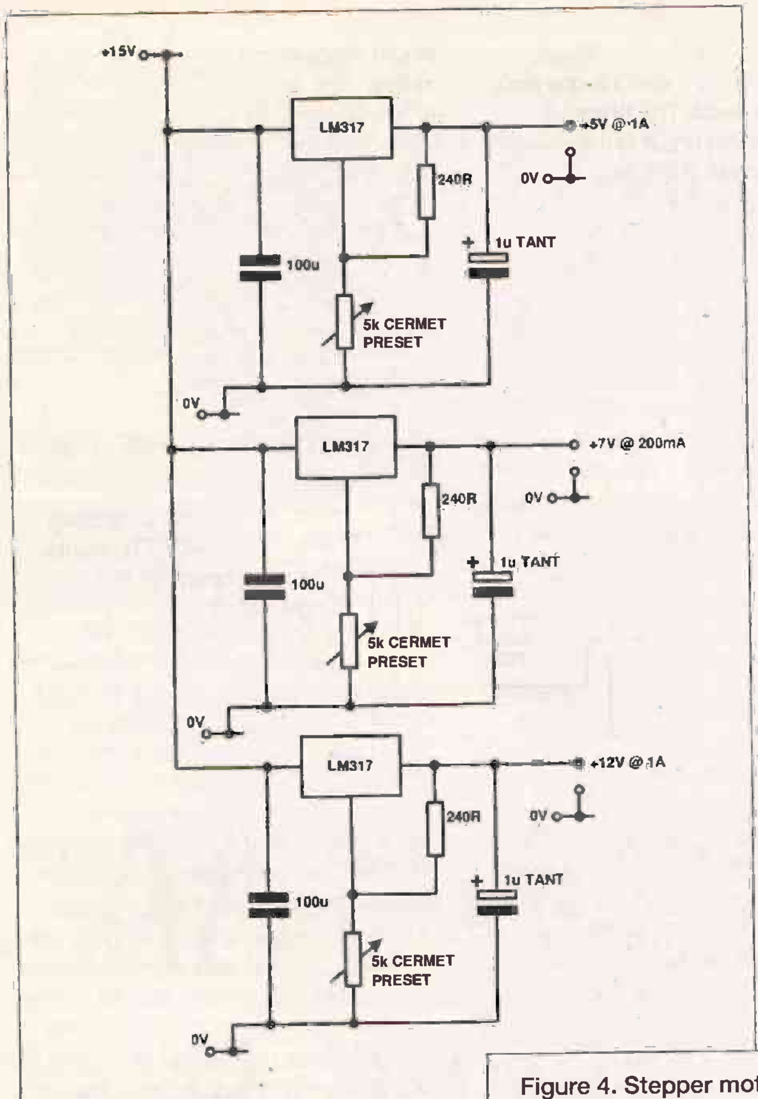


Figure 3. Power supply circuit

Scanning the world

So far in this design for a simple robot vision system, we have an optical sensor that can measure the light intensity in a particular direction with a resolution of 64 grey scale levels. If this were mounted on top of a mobile robot it could tell the robot's computer something about the 'whiteness' or 'darkness' of the world in front of us. Similarly if it was mounted looking at the floor it would tell the computer if the white line painted on the floor which the robot is following is still there. If not, then the robot could retrace its steps and hunt for the white line.

But we may want our robot to have more than this, we may want it to be able to build up some simple visual image of the world around it to help it navigate its way around this environment and recognise certain key features. To do this, we ideally need more than a single light sensor, we need a means of detecting the spatial relationship between variations in light intensity, preferably an array of photosensors.

However, all we have for the time being is a single photosensor, but even that can be used to provide spatial information by sweeping it around a field of vision. In this way, the robot's computer can be provided with information about the rela-

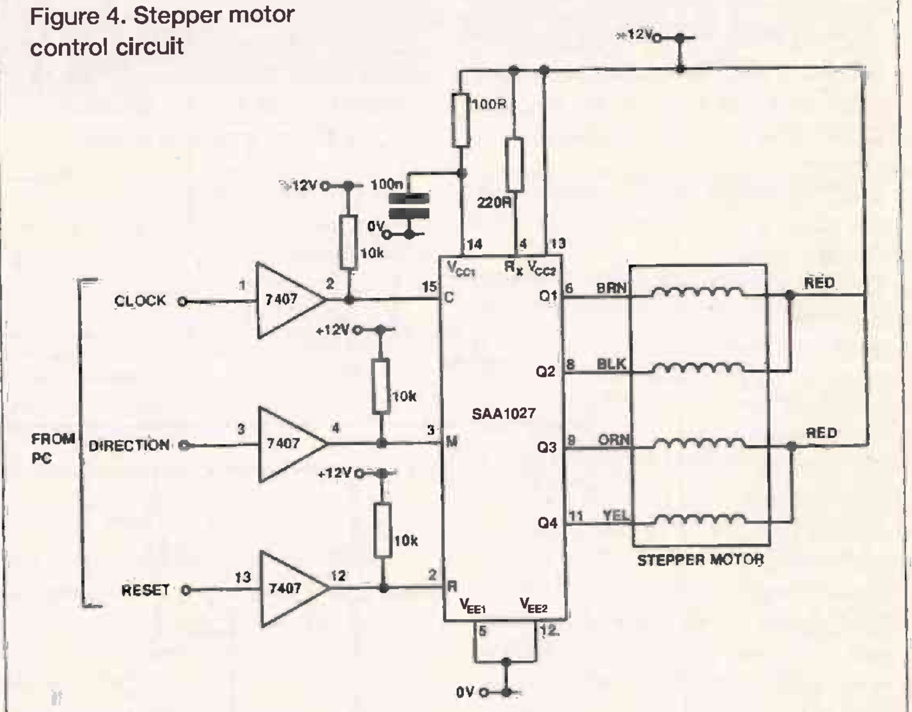


Figure 4. Stepper motor control circuit

voltages between 0V and +5V and can, if necessary, digitise up to 10 million samples per second. The output lines are all TTL compatible, so can be connected directly to a processor I/O port. Digitisation of the voltage on the input is initiated by the processor toggling the clock input line. The 741 op amp and associated circuitry provide a reference voltage which can be adjusted for calibration using the 5K potentiometer.

A question of power

The analogue to digital converter circuit needs three different positive voltages, +5V, +6.2V, and +12V. With digital circuitry, power supplies tend to be restricted to just +5V, so some additional power supplies will probably be needed. The robot system, for which this vision system is eventually intended, has its own battery power supply with an output of just under 15V, high enough to supply the main motors.

The vision system therefore has its own set of voltage regulators to provide the necessary supply voltages from this 15V battery power supply. The circuit is shown in Figure 3 and consists of three identical variable output voltage regulator circuits based upon the LM317 regulator chip, the output from each of which can be set using the appropriate 5K preset potentiometer. In this way we can get stabilised outputs at the three required voltages with the minimum additional circuitry.

tive positions of light and dark areas, not just directly in front of it but to each side of it and even behind it. Information from which it can build up a crude visual map of the world in which it lives.

Thus, if the mobile robot was designed to find its way around a maze constructed from white painted walls, it would be able to discover passageways to the left or right of it because these would exhibit a lower reflected light intensity than the walls. Such a system is a lot more clever than blindly bumping around using touch sensors.

This visual scanner can be constructed by mounting the optical sensor onto the shaft of a stepper motor. The processor can take a sequence of light intensity readings which are of locations one step, or 7.5 degrees, apart. This therefore brings us to the last circuit in this simple robot image sensor, the stepper motor controller, shown in Figure 4.

The motor used was a small 12V model with a 7.5 degree step angle. A small stepper motor of this sort is best controlled using one of the integrated circuit stepper motor controller chips, in this case the Philips SAA1027. The chip makes a stepper motor very easy to control, the motor will turn clockwise when pin 3 is low and anti-clockwise when it is high. The motor will turn one step for every low to high transition on pin 15, the reset line on pin 2 will normally be kept high, when it is taken low it will reset the chip and take pins 6 and 9 low, and 8 and 11 high. The reset is not normally used.

One thing to note from the circuit diagram is that the SAA1027 does not operate with normal +5V TTL inputs. Instead it operates at +12V (logic high is >7.5V, and logic low is <+4.5V). Hence the 7407 buffers and pull-up resistors in the circuit - these allow the chip to be driven by TTL logic, including a processor output port.

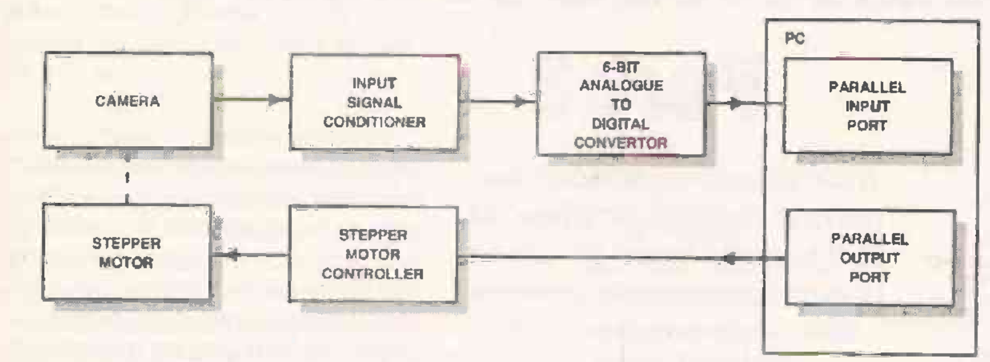


Figure 5. Block diagram for simple robotic eye

Next month...

Next month we will look at assembling the circuits, connecting them to a computer and writing some software to both control them and input some visual data. We will also look at how the circuit can be expanded to handle multiple photosensors, the start of a true image input system!

Microprocessor Fundamentals

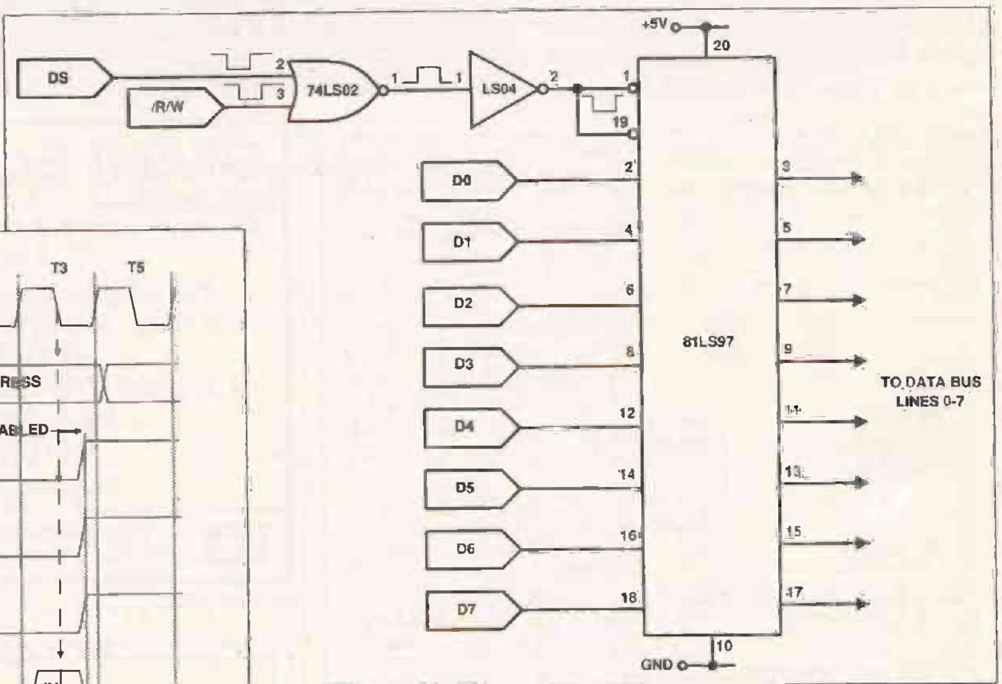
Part 3

Alex Stuart continues his series, looking at some of the various ways in which a microprocessor system can communicate with external devices

There is little point in having a computer system which does not communicate with the outside world. This communication could be via switches, keyboards, flashing lights, TV monitors, modems... The list of devices and circuitry which can be connected to a computer to either provide data for the computer or receive data from it, is virtually endless.

Although the range of I/O devices is enormous, there are a number of basic fundamentals in the way that all such devices are connected to a computer system. This month, we will be looking at some of these basics and examining the various ways in which data is transferred between the computer and external circuitry.

Figure 1. Tri-state buffer input on memory mapped system.



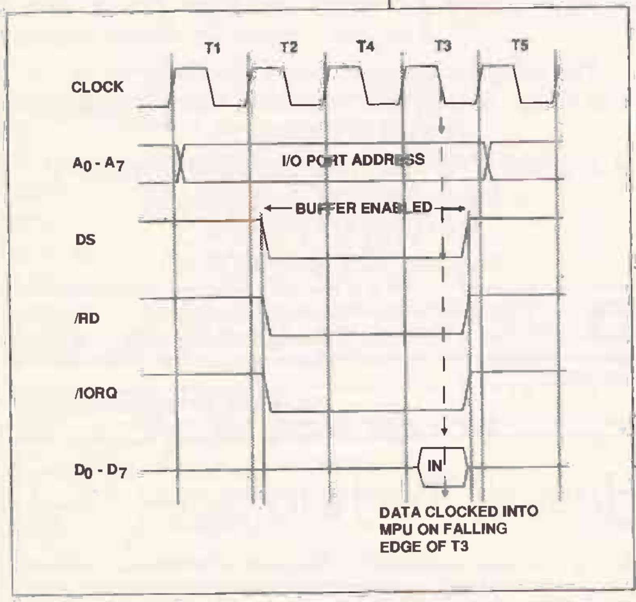


Figure 3. Waveforms for buffer input to I/O mapped system

The Question of I/O Addressing.

In the last issue, we looked at memory mapping and address decoding. We saw that there are two types of microprocessor, those where input and output devices are mapped as part of memory and those which have a separate I/O addressing area. Amongst the eight bit processors, the 6502 and 6800 families fall into the first category, whilst the Z-80 and 8080 families fall into the second category.

Whether any attached I/O devices communicate via memory locations or locations in a special I/O area, they are all accessed by the processor outputting a specific address on the address bus and then either reading data from, or writing data to, the location pointed to by that address. This means that all I/O circuitry must have an address decoding component and a means of allowing the external circuitry to communicate via the data bus when, and only when, the correct address has been detected by the decoding circuit.

The Most Basic Form of I/O Circuit

If the processor uses straight forward memory mapped I/O, then the output from the address decoding circuitry can be used to enable an eight bit tri-state buffer, or a latch, which is connected between the external circuitry and the processor system's data bus. But it also needs circuitry to define whether the lines connected to the buffer or latch are input lines or output lines. In other

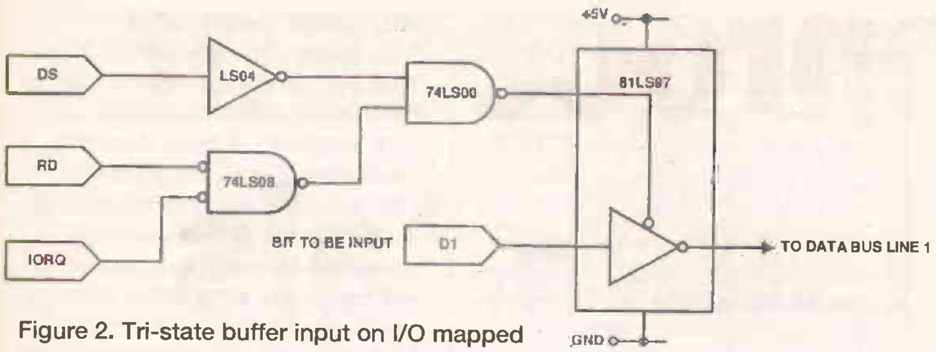


Figure 2. Tri-state buffer input on I/O mapped system (only one of eight lines shown).

such an input circuit, we are faced with a problem. When is the data on the input lines valid data and when is it spurious data? For example, if the inputs are derived from switches we can have a problem with switch bounce, which means that data input when the switch position is being changed could be invalid. Alternatively, the system could be receiving a regular sequence of input pulses from some other piece of circuitry. Once again, the question is when is the input valid?

With the problem of switch bounce, the solution is to test the input lines several times in order to ensure that the status on each line has settled to a steady state. However, when faced with inputting a sequence of pulses, the problem is much harder and it is not something which can be done by pure software techniques. Indeed, the only practical solution is to use one of the input lines as a strobe line, in other words a line which will only go high

words, something to define the direction of data flow. This is achieved by using the processor's R/W line - note the use of an inverter to make the port function as an input in the example circuit shown in Figure 1.

If the processor has separate I/O mapping, such as when using the Z-80, then some slightly different circuitry is required. Such an I/O circuit will not rely on the R/W line to provide information on data direction but will instead rely on the RD and IORQ lines to provide the same information. Note that the IORQ line is used by the processor to signal that the address being decoded lies within the I/O addressing area, rather than the memory addressing area. An example of such a circuit in a Z-80 system is shown in Figure 2. and its waveform diagram in Figure 3.

When writing the software to use

Figure 4. Latched 7475 output circuit.

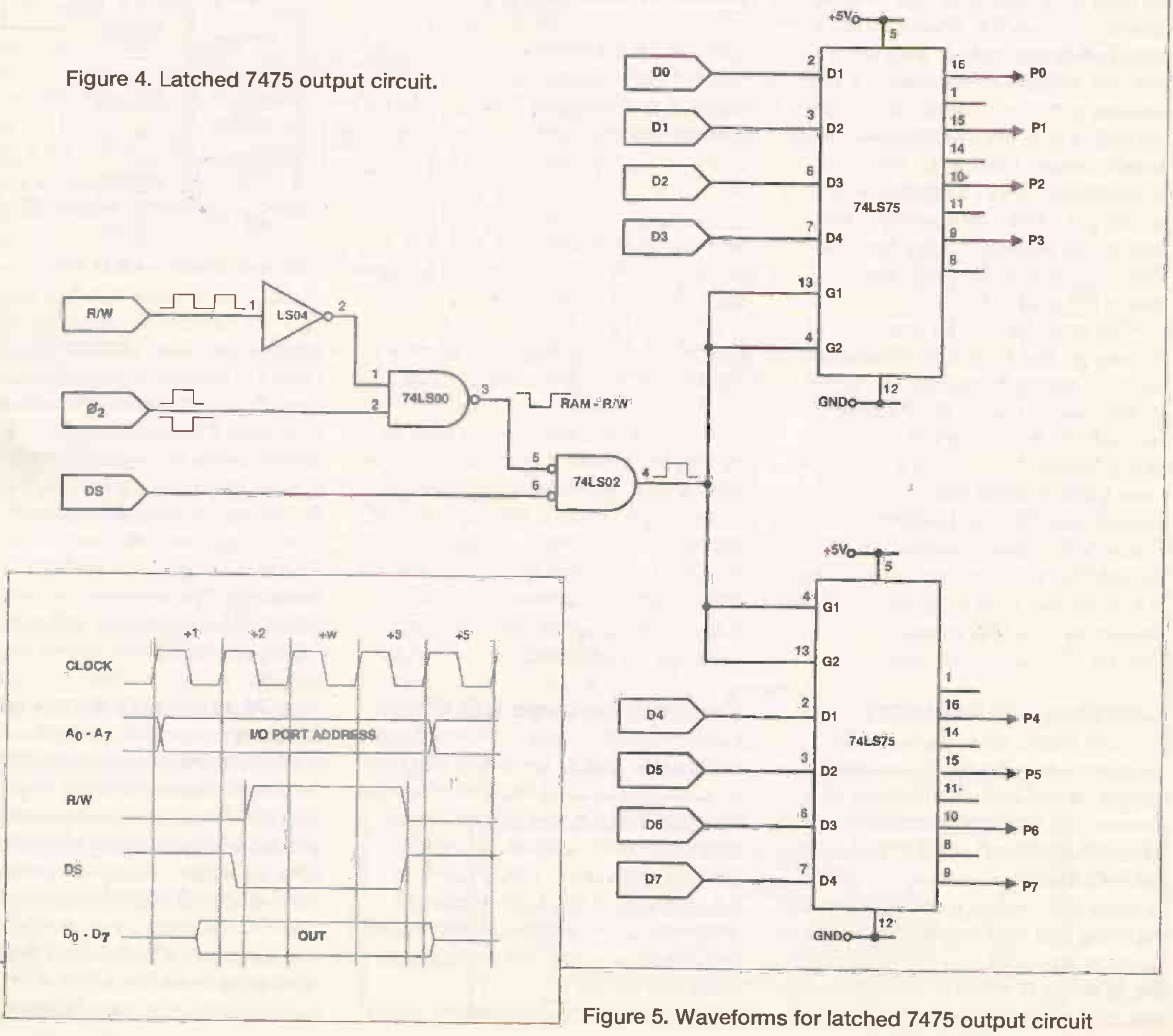


Figure 5. Waveforms for latched 7475 output circuit

when there is valid data on the other seven input lines.

With such a strobe line, the software simply has to test the status of the strobe line in order to determine whether there is valid data on the other input lines. Alternatively, the processor's interrupt request line could be used to signal the arrival of valid data. By pulling the IRQ line low, the processor will be forced to execute a routine which will input data from the port. The choice of technique depends on whether data is being input continuously from the port or whether it appears at irregular intervals. Thus, switch status would require no strobing, input of an analogue waveform would need a strobe pulse derived from the A to D converter. On the other hand, input of data from another computer or a terminal would require a combination of an interrupt to signal the start of transmission and a strobe to clock in successive bytes of data.

Of course, this type of circuit can also be used as an output, all that is necessary is to reverse the direction of the tri-state buffers and remove the inverter from the R/W line. Once again, the major problem is that any circuitry attached to the output lines will not know when there is valid data on those lines. The solution is to dedicate one of the output lines as a strobe line, which can be used to indicate to any external circuitry that data on the output lines is valid only when the strobe line goes high.

This kind of simple buffered I/O circuitry is ideal for simple I/O functions, such as reading the status of a number of switches. These could be placed between the input lines and earth, with pull up resistors to +5 to ensure that the input line is at either logic 0 or logic 1. As one can see from the waveform diagram in Figure. 3, it is not, however, suitable for applications which require more than a brief transitory output pulse. For applications such as LED indicators a latching I/O circuit is required.

Latching I/O Circuitry

For data output applications data is present on the data bus for too short a period, what is needed is a circuit which catches the data during a memory write, or output, cycle and holds it. We can do this with the aid of a simple TTL latch, such as a 7475 4-bit bi-stable. It should be noted that this is a unidirectional port, primarily an output port. This means that the R/W line, or WR and IORQ lines, are not performing a data direction determining operation, but are instead providing a latch enable function. A simple circuit for such a latched output on a memory mapped system is shown in Figure 4.

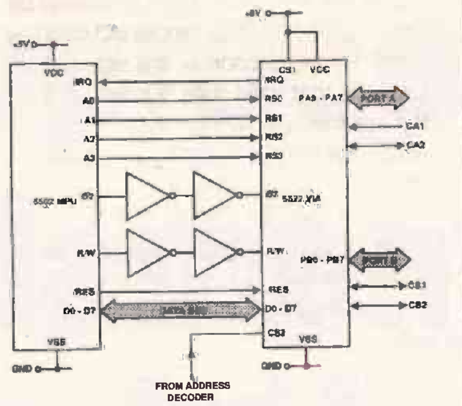


Figure 6. Connection of a 6522 to a 6502 processor

In order to perform the data latching operation we simply feed the R/W line and the address decoder output into an AND gate and thereby generate a positive going pulse which will clock the data on the data bus into the latches. The data is then latched on the falling edge of the pulse. The waveform diagram for the above circuit is shown in Figure 5.

The output from the 7475 latch can then be used to directly drive an LED, or when fed through a transistor or a driver circuit (such as the ULN2803A octal Darlington driver chip), it can be used to switch a relay or control a small motor.

The software used to output data on a latched port is extremely simple. All that is required is for the processor to write the required byte of data to the memory or I/O address where the port is located. If multiple bytes of data are to be output then it might be necessary to use an output strobe coupled with a delay loop within the output routine.

General Purpose I/O Chips

Both of the above types of latched and buffered I/O circuits are simple and easy to understand, but as we have seen they are not particularly versatile and suffer from drawbacks, such as the need to use one of the lines to strobe data on the others. One way to overcome this, and at the same time reduce the overall chip count, is to use one of the general purpose I/O chips.

Virtually every microprocessor manufacturer produces one or more of these general purpose I/O chips, often referred to generically as PIAs (Peripheral Interface Adapters), or PIO (Parallel Input/Output) devices. Fundamentally, all these chips are very similar in their design. They all offer the user either two or three eight line user ports. They allow data direction in individual ports, or even on individual lines, to be set by software rather than hardware. They offer latched input and output, plus one or more control lines to generate interrupts or strobe data in or out. They also allow the programmer to test the status of the chip.

As one can see, this offers the user greater flexibility and many more functions than are available on any of the circuits outlined at the beginning of this article. They are all designed for ease of implementation within a microcomputer system and the only additional circuitry they require is some form of address decoding. With a memory mapped I/O processor this could simply be a 74138, using the top three address lines to divide the address space into 8K blocks, which could be used for RAM, ROM and PIAs (see last months ETI for information on address decoding). The connections between a processor and a PIA, in this case a 6502 and a 6522, are shown in Figure 6.

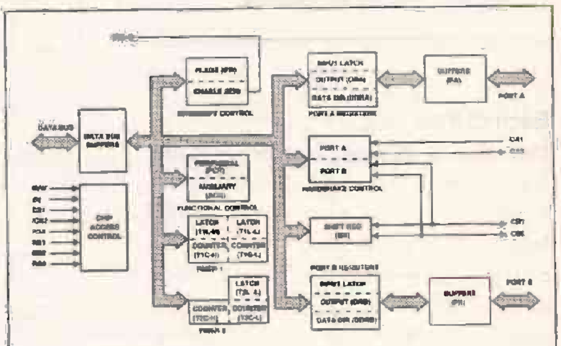


Figure 7. Block diagram of 6522 VIA

As far as connections to the outside world are concerned a PIA will neither source nor sink a very high current. In fact, it will really only drive a single TTL load. This means that if, for example, you want to switch LEDs off and on, then some form of driver circuitry will be required (the ULN2803A octal Darlington driver IC is a good choice for this purpose). Similarly, input or output voltages greater than 5V will have to be converted in some way and for higher voltages, it is a good idea to use an opto isolator to protect the processor circuitry from accidental high voltage inputs. Indeed, it is good practice to buffer or isolate all I/O lines for the same reason.

If we look at the block diagram, Figure 7, of a typical PIA chip, in this case the widely used 6522 VIA chip, we can see that it is a complex collection of registers, latches, timers, counters and buffers. But if we look a bit more carefully, then we can see that it is possible to put each of the blocks into one of the following categories:

- Data input/output registers.
- Data direction registers.
- Counter/timers.
- Shift register.
- Control registers.
- Interrupt registers.

Each of these registers, latches, counters, etc., is assigned a memory location, the 6522 uses sixteen memory locations, a far cry from the single location used in the simple I/O ports examined at the beginning of this piece. As can be seen from Figure 6, these sixteen registers form a continuous block of memory or I/O address space and are accessed by the processor using the address decoding circuitry and the bottom four address lines. The function of each of the 6522s addressable locations is shown in Table 1.

The actual I/O section of this chip consists of two 8-bit bi-directional ports. Each of these ports has an associated input register, an output register and a data direction register. The data direction register determines which lines in the port are acting as inputs and which lines are acting as outputs. As far as the computer is concerned the input register and output register are not separate - all there is, is an output register. If the data direction register has defined lines as inputs, then the current state of the input lines is reflected in the 'output register' which the processor can then read. If the lines are defined as outputs, then the processor can set these lines high or low by writing to the appropriate bits in the output register.

On the 6522, data can be input or output under what is referred to as 'handshake' control. This is in essence the same function as that performed by the strobe line in our simple I/O circuitry. It tells the processor, or the external circuitry, that valid data is present on the appropriate I/O port - the way in which the handshaking function is determined by the peripheral control register. The data contained in this register is set by the programmer and determines whether the data on the I/O port is clocked in, or out, on a rising or falling pulse on the handshake line. It also, in conjunction with the interrupt flag and enable registers, determines whether a handshake line on an input will generate a system interrupt and thereby initialise a special interrupt routine to service that input.

The timers in the chip allow the programmer to generate precision delays and, in conjunction with the shift register, allow the serial input and output of data. Here, eight bits of data are loaded into the shift register and then output one bit at a time on the CB2 line, with pulses being clocked by either the timer or the system clock.

The 6522 is a very versatile and flexible chip which can operate in a wide variety of ways all under software control. It is typical of most parallel I/O controllers. Of course, it is now about fifteen years since devices like the 6522 first appeared on the market and many of these chips have now been integrated into the processor chip to produce the so called microcontroller chip. With a small amount of RAM and ROM plus two or three I/O ports, microcontroller chips have integrated an entire basic processor system onto a single chip, ideal for many applications, but not always as flexible as designs based on a number of chips. We can therefore expect to see chips like the 6522 around for many years to come.

Table 1.

Address	Function	
0000	Output data register Port B	
0001	Output data register Port A (controls handshaking)	
0002	Data direction register Port B, 0 = input	
0003	Data direction register Port A, 1 = output	
Timer	R/W=0	R/W=1
0004 T1	Write to T1 latch low	Read T1 counter low Reset T1 interrupt flag
0005 T1	Write to T1 latch high Write to T1 counter high Latch low -> counter low Reset T1 interrupt flag	Read T1 counter high
0006 T1	Write to T1 latch low	Read T1 latch low
0007 T1	Write to T1 latch high Reset T1 interrupt flag	Read T1 latch high
0008 T2	Write to T2 latch low	Read T2 counter low Reset T2 interrupt flag
0009 T2	Write to T2 counter high Latch low -> counter low Reset T2 interrupt flag	Read T2 counter high
000A	Shift register	
000B	Auxiliary control register	
000C	Peripheral control register	
000D	Interrupt flag register	
000E	Interrupt enable register	
000F	Output data register A (no effect on handshaking)	

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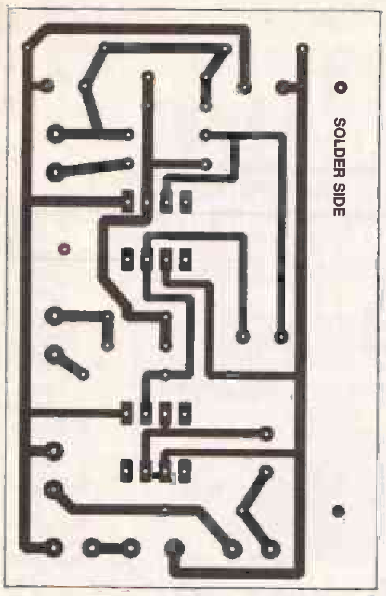

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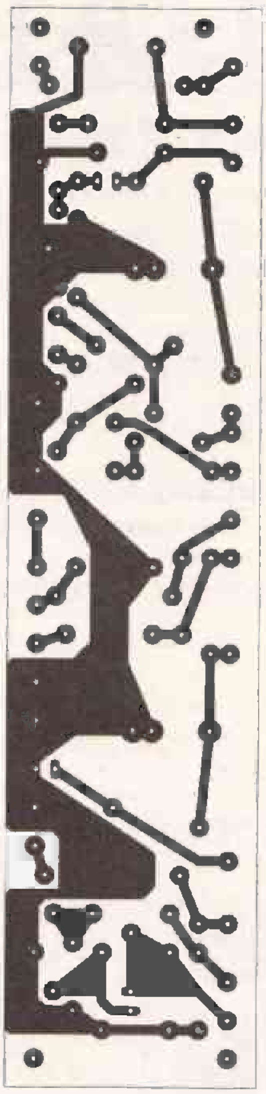

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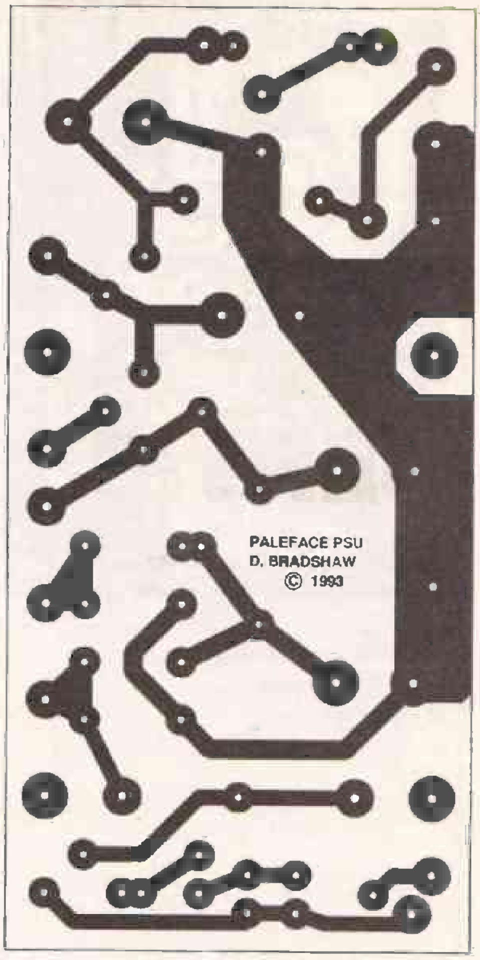

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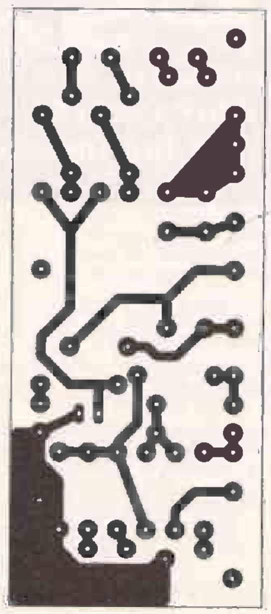

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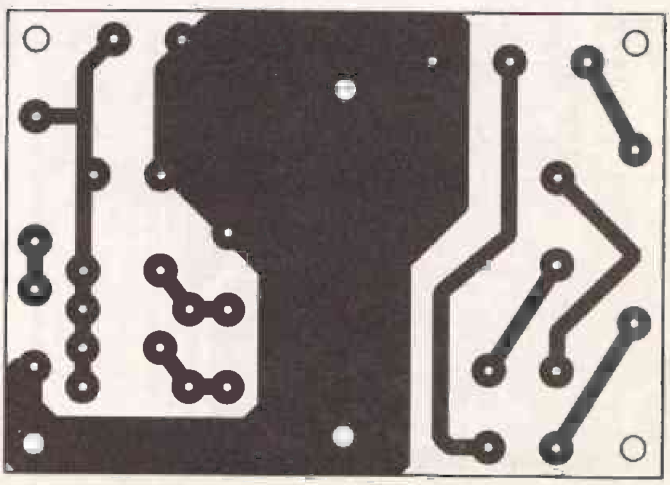

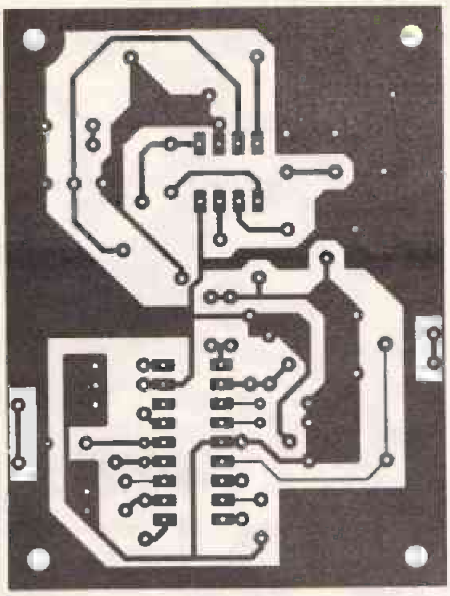

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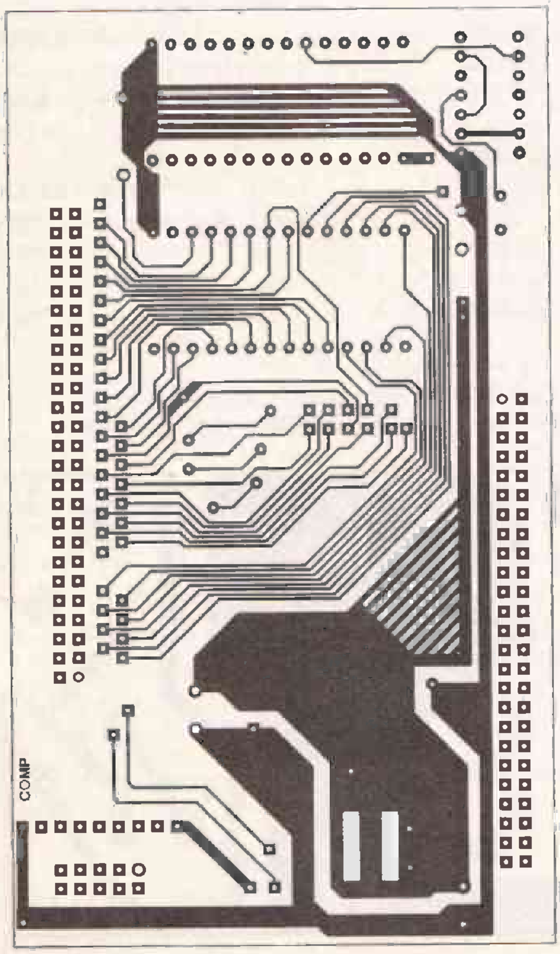

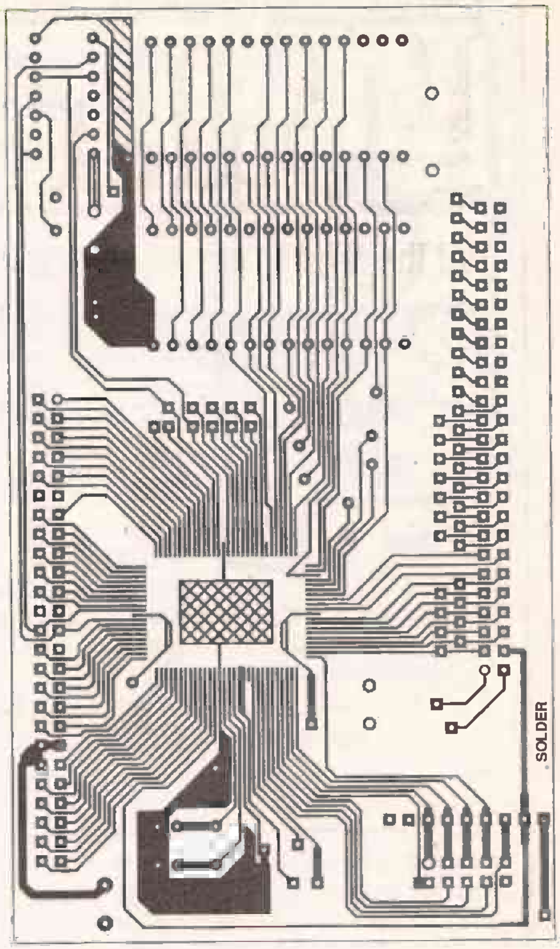

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Messing about with electronics is all about creativity and the hell of a kick one gets when something one has designed actually works, when it actually does what it was designed to do. Creating something is a great ego boost and the boost is even greater if you are one of the first people to do it.

It is the thrill of using one's brain and one's knowledge and skill to overcome problems which makes a hobby like electronics so addictive, but also rather daunting to the newcomer. In the early stages of learning about a technology as complex as electronics, any little problem can seem overwhelming and it is all too easy to walk away.

This is one of the major reasons why we are seeing a gradual decline in the number of people who would count electronics as one of their major hobbies. There is little doubt that learning about electronics is hard work, and particularly hard if you are trying to learn by yourself or you have a teacher who knows little more about it than his students.

If teaching a subject like electronics is to succeed, then the thrill of creating something which works, of overcoming problems, has to outweigh the frustration of trying to master a difficult subject. The practical element has to complement the theoretical element. Otherwise it is like trying to train artists without letting them ever pick up a brush - many will give up in frustration and those who do not will produce some pretty awful work when they actually do get hold of a brush.

Unfortunately, this is what is happening in schools all over the country. The technology curriculum, which includes electronics, is more often than not handed over to the school's former woodworking and crafts department. There are plenty of stories, many of them which I suspect are true, that tell of woodwork and craft teachers being given crash one week courses in teaching electronics.

A teacher may be able to teach English or History by being just a few lessons ahead of his pupils, but teaching electronics requires a good practical and theoretical knowledge of the subject to start with. Without it, the teacher will all too often find himself unable to answer even the simplest question and I have the utmost sympathy for teachers who are placed in this type of situation.

But perhaps there are ways around this problem. Perhaps computer based interactive tutorial systems are a solution, particularly when coupled with practical experiments. This is, however, an expensive solution, as each student will need his/her own computer system, software and experimental hardware. It will take a very serious commitment to electronics education on the part of educational authorities for such an investment to happen.

Unfortunately, there are few signs of this kind of commitment, though many high technology companies might be prepared to help. This brings us back to the knowledgeable hobbyist. Who better to instil some of his enthusiasm for the subject into those who are just starting? Above all it is this sense of enthusiasm, of the kick one gets in solving problems and creating something that works, which needs to be communicated to students.

So I end with a plea to readers to give the youngsters of today a hand. Think about giving talks at local schools, or invitations to your local electronics club. It is this sort of action which can help, it will help the individuals, it will help the country and it will help swell the ranks of electronics hobbyists, something that will be good for all of us!

Nick Hampshire.

If you organise an electronics club, why not let us know and we will publish your contact name, phone number and meeting dates in future issues of ETI.

Next month...

FORTH is one of the most powerful of computer languages for real time control systems and, next month, Jim Spence looks at building a FORTH computer. Dave Bradshaw builds an audio attenuator to accompany his Paleface Minor valve amplifier while, for campers and those who spend a lot of time in their cars, Terry Balbyrnie shows how to construct a low voltage power supply that allows you to run your Walkman from a car battery. We also take a look with Keith Garwell at virtual instrumentation and how to turn your PC into a chart recorder.

There will be the continuation of the series on robot vision, as well as John Linsley Hood's improved power supply and, of course, another useful piece of test equipment designed by Robert Penfold.

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