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NEW PRACTICAL ELECTRONICS

SCIENCE AND TECHNOLOGY

Musical Technology

This month's special feature looks at the world of High Fidelity

New Products

Sir Clive's Zike
64-bit Alpha Microprocessor
Toshiba's Colour Laptop
Canon Reflex Camcorder
A One Handed Computer
The Weather Watch
Rap Goes Portable

Reviews

Technics Surround Sound
FM Stereo Sound TX
Canon Super Speakers

Plus

How It Works: The Loudspeaker
Infra-Red Headphone Extension
Ceramic Batteries
Barry Fox Has The CD-ROM Blues
Feel The Bass With Our Sub-Woofer Project

This month...

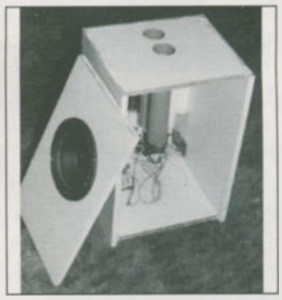
Sir Clive Sinclair is well known for his inventions. At PE we have seen them come and go, some have been successful like the ZX Spectrum and the black watch. Others were not so well received – the QL and the C5 to name but two. With the launch of the Zike Sir Clive is trying again to make a success of the transport marketplace. We take a look at the attempt on page 6.

The project this month is a unique design for a sub-woofer. This speaker system takes over where most others leave off and aims to produce sounds you can feel in a box that will not take over your home.

Kenn Garroch, Editor

Features

The Zike – page 6



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Next month...

TV and Satellite – the latest TVs, flat, wide screens and 100Hz technology, satellite receivers, dishes and how they work.

Out On 7 May

Cover illustration Kenn Garroch

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Wavelengths

If you have any comments, suggestions, subjects you think should be aired, write to PE

Time And Again

Last month (the April edition of PE) you devoted a whole page to Eamon Fitzpatrick's rant about decimal time. Was this an April fool or is this guy serious? The idea of changing the way the whole world tells the time just to satisfy the digital imagination of a few is ridiculous. With calculators being so common these days, there is no real need to worry about decimals, converting between various systems is simple.
A J Kahn
London N22

Mr Fitzpatrick's ideas for a decimal time system have my wholehearted support. How we got saddled with the crazy 60, 60, 24 system is beyond me. The big problem is that no-one has ever had the opportunity to change it – perhaps the French should have tried it when they revolted. Alas, it is probably too late now, the whole world ticks to the same clock.
L Hanson
Liverpool

Caught In The Act

I think I spotted the April fool in the your April edition. The 3DTV article may read well but it is a little impractical. First of all, the scanning system is a little awry. Of the three beams, each would have to scan a large number of times faster than the others to cover all of the positions in the 'tank'. For example, if a cube of dots 10x10x10 were to be created, as the first beam scans across the second would have to scan across it 10 times in the time it takes to make one scan. The third would then have to scan across the second ten times during its scan. The result is that the second beam must scan at a frequency ten times the first and the third 10 times the second or 100 times the first. For a large box of dots, this exponential scanning could create a few problems if not be impossible.

The second obvious error is in the gas that emits light when struck by three but not one or two beams. There is, as far as I am aware, no gas that would do this.

The most obvious giveaway to anyone who has read any children's science fiction (Tom Swift and his 3D telejector to be exact) is the caption on the first illustration.

Its a pity that such a 3D TV system probably won't work, if it did, someone would make a mint of money licensing it.
P Jones
Woodbridge
Suffolk

Your article about 3DTV in the April issue of PE was nice but it won't work. April fool I presume.
L Allen
Bebington
Wirral
Merseyside

OK we admit it, it was all pure fantasy.

Correction

I was attempting to build the video fader in the March issue of PE and after studying the article for a while, I noticed a few errors. Could you possibly print the corrections and let me know if there is anything else wrong?
T Larch
Nottingham

Sorry about the errors, here are the corrections:
C6 and C7 are both 10µF tantalum beads rated at 16V.
VR1 is a 1k linear potentiometer
VR2 is a 250Ω linear panel mounting potentiometer
C5 is shown with its polarity reversed on the schematic but is correct on the PCB layout.
Some readers wrote in to ask where they could get some of the components. The CD4052 and NE592 are both available from RS Components – also known as Electromail Tel. 0536 204555. Maplin do similar components called the 4052BE and LM592 as do Cricklewood Electronics with the NE592 and Verospeed the CD4052.
Another question that cropped up about this project was whether two faders could be used to join two video signals. Unfortunately, to be joined together, two video signals must be "genlocked". That is, all sync pulses and the phase of the sub-carrier must be identical.

Cyberspace... More Info

Back in January you ran a feature on Multimedia and virtual reality. While I enjoyed this article, I think there could have been more information. Can you tell me where I can find out more about virtual reality systems?
K Macnally
St Helens
Merseyside

There is magazine called Cyberedge which may give you the information you need. It has been running for about a year but is only available from the US (as far as I know). For more information, write to:
Cyberedge Journal
928 Greenhill Road, Mill Valley, CA 94941, USA. Fax 0101 415389 0251 – far more useful than a telephone number due to the time difference ■

Innovations

This month, Sir Clive's new electric bike a break-out box and Toshiba's new colour laptop.

Better Than C5?

Called the Zike, it's the latest thing in personal transportation from Sir Clive Sinclair – the well known inventor of the ZX series of computers and the infamous C5. Also known as the Zero emission bicycle, the Zike is a bike with an electric motor.

The idea of a powered bike is not new but, until now, most attempts have usually been either cumbersome or impractical – in the UK at least. New technologies in the form of high capacity, low weight batteries, a neodynium-iron-boron electric motor, an electronic controller and low weight frame make Zike a first in its class.

The power for the motor comes from a fairly standard 24V nickel cadmium (NiCd) battery system which, compared with the alternative lead-acid batteries available, is lighter and a lot more rugged. The electronic controller converts the voltage from the batteries to that required by the motor under any specific conditions. Charging can be either from the regenerative braking system or the external mains charger – this offers a recharge from empty to full in one hour and is said to cost about 1p.

Three modes of operation are possible selected from a switch on the handlebars. In the first, the Zike will run for about 30 minutes, depending the wind and terrain, with no effort on the part of the rider. The second mode expects a little pedal power from the rider to assist the motor and extends the range to about one and a half hours. The third mode is similar but requires even more pedal power to give two to three hours of motor power. In all cases, any braking will recharge the battery, extending the range and saving on the brake blocks.

The Zike takes advantage of government legislation passed in 1983 which allows a special class of electrically power-assisted bicycles to be used on the road. Riders must be over 14 years of age and the machine must not exceed 15mph – the Zike's top speed is said to be about 12mph.

The most obvious problem that could arise for riders of the Zike is when encountering bumps in the road. Anyone who has ridden around London on a normal bicycle, or even driven in a car, will have noticed the rather numerous pot-holes, some of them up to 6in deep. The small size of the Zike's wheels and the vertical positioning of the steering above the front wheel could cause a few tumbles – other towns in the UK may not have the same problems.

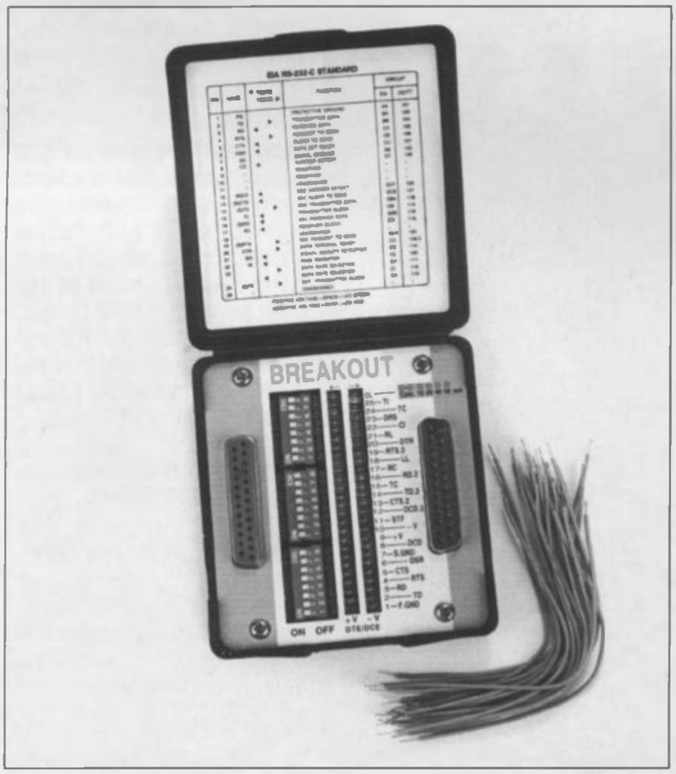
Able to cope with riders from 5ft to 6ft 6in and up to 17 stones, the Zike weighs a mere 11kg, is 115cm in length and 100cm high. It costs £499 (inc VAT) and has a large carrier basket available as an optional extra at £25 (inc VAT).

For more information contact Sinclair Research Ltd on 071 636 4488, or Vector Services Ltd on 0933 279300.

Break Out

The trouble with serial connections between computers is that they can be very hard to wire up. They will usually work with just three wires but may need up to 20 or so connections. To help get around the problem, Maplin has introduced a break-out box which allows all 25 connections on the link to be individually isolated and tested. The relevant signals can then be cross patched with jumper cables to make the right connections. In addition to all this, the 50 lines can all be visually monitored via LEDs. The only drawback is that it only supplied with one male and one female connector. A gender changer (male to female convertor) is all that it needed to make the unit a complete package for serial linkers.

Priced at £29.95, the break out box is available from Maplin Electronic Supplies Tel. 0702 554161.



Teaser

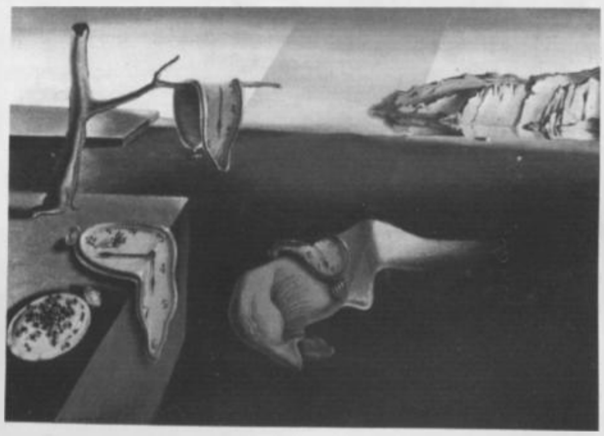
The set of pictures on the right were sent to PE over the course of a week, starting at the top and eventually getting to the bottom. Only the pictures were sent, no text, compliments slips or anything else. Obviously it was a teaser campaign for the new Toshiba laptop a 25MHz 486SX TFT colour LCD screened machine costing £5550 for the 80Mbyte hard disk version and £5750 for the 120Mbyte. Very nice but very expensive. ■

Blue Segment, Vassily Kandinsky, 1921

The purest ...

The Red Room, Henri Matisse, 1908

The purest and most thoughtful minds.



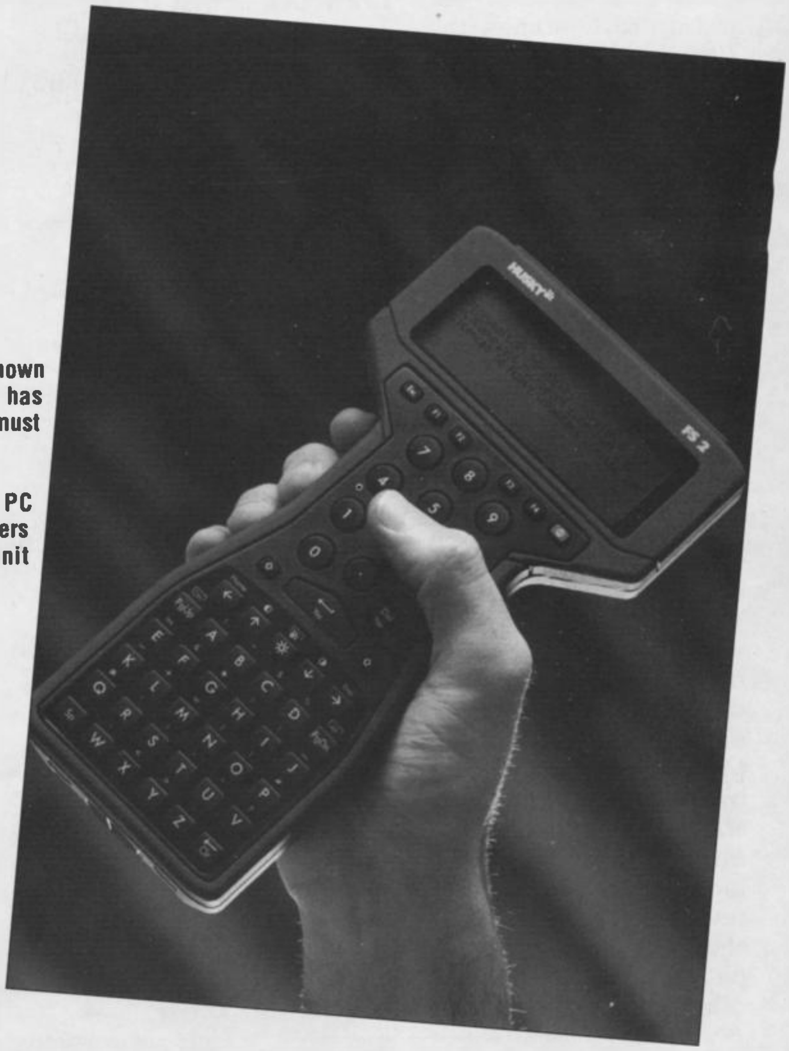
The Persistence of Memory, Salvador Dali, 1931

The purest and most thoughtful minds are those which love...

Starry Night, Vincent Van Gogh, Toshiba, 1992

The purest and most thoughtful minds are those which love colour the most. John Ruskin 1851

What's New



Computers have always needed two hands until now. Husky, known form making some of the toughest computers in the world, has introduced the FS/2 to be used in situations where one hand must be elsewhere.

Running MSDDS 3.3, the FS/2 is a fully functional IBM PC compatible with a 240x64 pixel resolution screen (40 characters by 8 lines). Built from lightweight magnesium alloy the unit weighs 750g and is fully shock, dust and shower proof.

Also from Husky is a more conventional laptop machine. Featuring CGA compatible graphics on an LCD display the machine is not very much different from most of the other portables in the market, apart from the fact that it will withstand much more in the way of shocks and general maltreatment.

For more information contact Husky on 0203 668181

The Ultimate Microprocessor

The new Alpha from Digital Equipment Corp has a specification that makes major mainframes look puny.

The launch of the Alpha microprocessor from the Digital Equipment Corp looks set to revolutionise the size and power of computers. Claimed to offer the power of a Cray-1 – one of the world's fastest super-computers – the single chip microprocessor can be built into systems ranging from palmtops to super mainframes.

The incredible power of the 21064 should give rise to computer systems able to understand speech as well as being able to answer back – all in a device the size of a wallet. In slightly larger machines, the high speed processing capabilities will allow graphics and computer animation currently only available in large, expensive mainframes. By using a number of alpha microprocessors in parallel, super computers approximately 100 times faster than the current best and eventually a thousand times faster will be possible. Cray, a major manufacturer of super-computers had already expressed an interest in the device and is looking at a Multiple Instructions, Multiple Data system with a speed of over 100GFLOPs (Giga FLOPs)

The 21064 chip uses a 64-bit RISC architecture able to address up to 1.8×10^{19} memory locations – 4 billion times the address space of current systems. It can execute up to 400 million instructions per second (MIPs) and 200 million floating point operations per second (MFLOPs) with an internal clock frequency of 200MHz. It has a built in floating point unit (FPU) which is fully IEEE 64-bit compatible as well as an 8kbyte cache and piplelined parallel instruction processing system.

The units will be manufactured in the US and Scotland to begin with but Digital is hoping that a number of other chip manufacturers will provide second sources. As with the alliance between IBM and Intel which worked so well in the IBM PC range of machines, Digital wants the chip to become an industry standard. To help with this, the architecture of the chip has been designed not to have a bias toward any particular operating system hopefully making it attractive to all manufacturers.

To ensure that the design does not go quickly out of date, Digital aims to increase the clock speed, allow it to execute more instructions in parallel and enable it to operate along side other processors to form a massively parallel processor (MPP). The design is claimed to have a 25 year lifetime and over this period its performance should improve by a factor of 1000. ■

Vendor	Digital	MIPS	Sun/TI	IBM	HP	Intel	Motorola
Device	21064	R4000	Viking	RIOS	PA-4	i860XP	88110
Max internal frequency	200MHz	100MHz	50MHz	50MHz	66MHz	50MHz	50MHz
No. Chips required	1	1	1	7-9	2	1	1
Peak MIPs	400	100	150	200	132	150	150
Peak MFLOPs	200	50	50	100*	132*	100*	100
Architecture	64-bit	64-bit	32-bit	32-bit	32-bit	32-bit	32-bit
Available	now	now				now	mid 92

* combined floating point multiplication and addition

Glossary

Cache – on-chip fast memory used to store repeatedly needed instructions – accessing data in the main memory is relatively slow in comparison

CISC – complex instruction set computer requires a number of clock cycles per complex instruction

FPU – floating point unit off-loads floating point calculations onto a separate piece of hardware which performs them much more quickly

IEEE – institute of electrical and electronic engineers (in the US)

MFLOP – a million floating point operations per second

MIMD – Multiple instructions multiple data, effectively a parallel processing computer

MIP – million instructions per second

MMP – massively parallel processing

Pipelining – a system which queues instructions by fetching more while the current ones are being executed

RISC – a reduced instruction set computer aims to execute one simple instruction per clock cycle

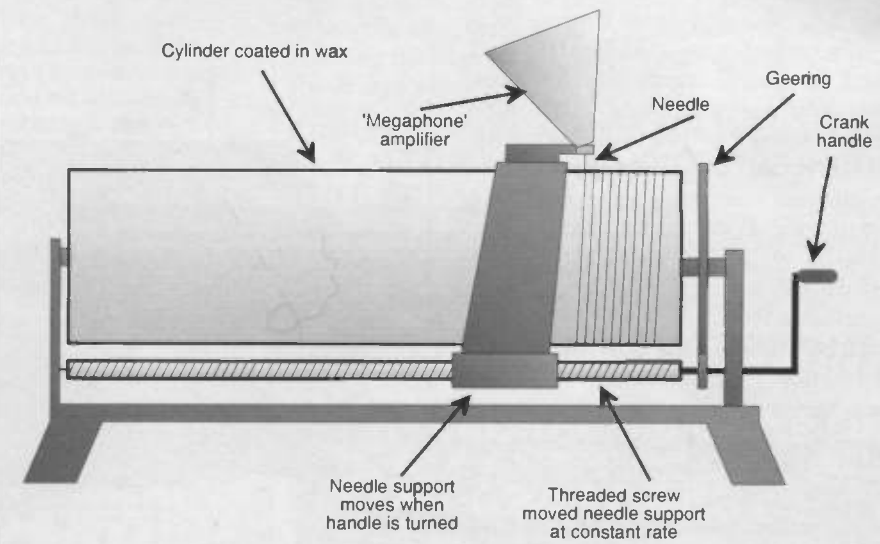
VMS – an operating system used in DEC minis and mainframes

Music Reproduction Goes Digital

Kenn Garroch surveys the HiFi scene and finds that LPs and 45s are no longer in the groove. Everything is going digital.

Music has become an integral part of modern society. Few people have access to no music at all and radios, record, CD and cassette players are ubiquitous household items.

A multi-million pound international industry caters to the tremendous buying power of the 'thirty somethings' reproducing the hits from their youth in more readily accessible and easier to use formats than ever before.



Early recording systems were relatively simple if rather low fidelity.

Golden Oldies

The technology for recording sound has been around for a long long time. There are recordings of Queen Victoria and even Chopin in existence and the recitation of Mary Had A Little Lamb by Thomas Edison is legendary.

The first sound recording machines used cylinders of wax onto which a spiral groove could be cut. As the cylinder turned, a diaphragm picked up sounds and transferred them to the cutting needle. This movement was recorded in the wax and could be played back by reversing the process and allowing the wax to move the needle and hence the diaphragm. Although the sound may not have been very good, it served as a model for recording techniques that have been used ever since.

The development of the gramophone with its rotating disc, needle and horn gave rise to the early music industry with commercial production of large quantities of 78s – the number referred to the speed which which the disc rotated, 78 revs per minute.

Improvements in materials and the development of the valve amplifier saw the introduction of the 45 and 33 – the single and long play (LP) formats. The use of a microgroove in a piece of vinyl plastic gave rise to improved quality and eventually to high fidelity or HiFi and stereo.

Using Both Ears

Until the introduction of stereo sound, all record players, tape recorders and radios used one speaker and produced fairly low quality sound – just like listening to a concert through a small hole in the wall of the theatre. The idea of stereo is based on the fact that most human beings have two ears and perceive sound across a stage in front of them. In practice, human hearing is a good deal more flexible than this and is able to discern height as well as whether sounds come from behind. Consequently, conventional two speaker stereo is something of a trade off. It gives a horizontal sound stage image similar to that heard in a concert hall. However, it can't easily reproduce reflections from the rear, ceilings and floor – mainly because most listening rooms are much smaller than the original hall and therefore have very different acoustics.

Stereo is a good deal better than mono and has become the standard method of reproducing sound and music. Quadraphonic and surround sound systems are available but the need for at least four speakers and extra musical information has kept them in the background – apart from in the world of cinema where it is worthwhile installing all the extra speakers in a theatre to get the desired effect.

In The Groove

Until recently, there were only two practical ways to record and reproduce sound: with a vibrating needle in a groove or on magnetic tape. Records, be they single (45) or LP (33), and cassettes were the only ways to buy music recordings. The invention of cheap lasers and super miniaturisation lead to the development of the laser disc and then the compact disc (CD). Mass production of CDs and CD players along with the dramatic increase in quality has given a boost to a floundering music industry and lead to the demise of the now obsolete vinyl records. Although many shops still stock LPs and singles, a number of music publishers have stopped producing them and gone over entirely to CDs. It will only be a few years before the old style LP becomes a specialist item used only by HiFi buffs who can hear and prefer the difference.

On The Wire

Compact cassette tapes are still going strong but they will soon be headed for the museum if Philips' new Digital Compact Cassette (DCC) system takes off. Until the invention of the Sony Walkman and its miniature brethren, cassettes had not been competing well with LPs. Their quality was not as good and they had the drawback of having their tracks recorded sequentially. It is impossible to skip from one to another very quickly. However, they found wide use in in car entertainment (ICE) systems since the bouncing of a car would not affect them and the general background noise covered up any lack of quality.

DCCs are the same size as ordinary compact cassettes but are digital and offer much better quality. The clincher as far as Philips is concerned should be the ability of DCC systems to play the older compact cassettes as well.

Sony's Magneto optical disc.

A DCC Player

Philips Bitstream

Anyone with a large collection of cassettes need not worry about being able to play them on the new system and will be able to replace worn cassettes with their digital counterparts when necessary.

Doing Things Digitally

What makes digital recording better than the older analogue (so

Reel to reel tape systems are now for specialists only.

The shape of tape to come.
At the top DAT, below it DCC.

called because it stores air pressure waves as either waves of plastic or variously rotated magnetic areas) is that once a sound has been coded up as a series of numbers it can be stored and manipulated without any loss of quality. The numbers need never change so they always represent the original exactly.

Converting sounds into digital form is simply a matter of sampling them. A sound is a continuously varying air pressure wave and is converted to its electrical analogue by a microphone. Taking repeated measurements of its amplitude and converting them to numbers results in a digital representation of the signal. Two main things are important in this process, the number of levels that can be measured and the speed at which the measurements take place. The usual format for digitising sound is to use 16-bit numbers to give 2^{16} or 65536 levels. The speed of measurement or sample rate must be at least twice the highest frequency being recorded and is usually around 44kHz (human hearing generally ranges from 20Hz to 20kHz). Once in numerical or digital form, the information is stored either on a CD with a laser which cuts tiny pits in the surface, or on a magnetic tape as in DAT (Digital Audio Tape).

To convert the numbers back to sound, a digital to analogue convertor is used. This transforms each number into a voltage resulting in a stream of voltages that represent the original samples. These can then be put through the usual amplification system and loudspeakers resulting in the original sound.

There are both advantages and disadvantages to this process. One big plus is that the dynamic range is very good – the loud sounds remain earsplitting and the quiet ones soft. A disadvantage is that frequencies over about 20kHz are removed at the original sampling stage. It has been found recently that although human ears cannot actually hear sounds above 20kHz, they do sense them and their presence affects the overall feeling of the music – frequencies up to 90kHz have this effect. This may be one reason why some purists say that they prefer old style LPs to CDs. A recent CD system from

Pioneer tries to replace the lost frequencies by interpolating them from the existing sound although it requires a very good set of loudspeakers and amplification to hear the difference.

Technologies In Sight

Apart from the appearance of DCCs later this year, Sony has developed a magnetic disk technology which provides a CD like format but with the ability to re-record. A problem with CDs is that they cannot be recorded in the home. Only DAT systems could provide the high quality digital recording capabilities on a home based unit and DAT has not been available in the UK for very long – it is also quite expensive. The Sony system uses small 2.5in disks which can hold 70 minutes or so of music. Recording is by means of a hot laser which loosens the magnetic material in the disks and allows an overall field to be set. After cooling the new information can be read with a cooler laser which detects the different magnetic areas. In other respects it is like CD with the ability to skip from track to track at random and reproduce high quality digital sound.

Other new technologies are enhancements on what is already available. Bitstream is a new method of reproducing the digital information from a CD. Instead of using a 16-bit DAC, single bits are used and the results averaged to get the sound signal. This offers quite an improvement over older methods and looks set to take over in the second generation of CD players.

From the top, a personal stereo using compact cassettes, a multi-CD disc player and a personal stereo using DCC

Technologies Out Of Sight

After the market has become used to DCC, Sony Magneto Optical Disks and CDs have become rather old-fashioned, something will come along to take over. What this might be no-one really knows yet but a few guesses can be made by looking at the way in which the computer industry is moving. Ten years ago, personal computers had memories of around 64k. Now 1M is commonplace and many machines come with 4 to 8M as standard. This is an increase of between 16 and 64 times. Current CD technology supports around 600M per disk so it would appear that cramming 70 minutes of music onto a memory chip will take more than a few years advance in electronics. However, DCC systems reckon to increase the storage capacity of ordinary magnetic tape by a factor of four. This compression means that 70 minutes of audio should fit into 150M of memory, only an increase of about 40 times the current technology. It seems that an album on a chip should be with us in the next ten years making players the size of credit cards or smaller. Perhaps a personal stereo will consist of two ear-pieces connected by a small radio transmitter, only one of which actually has the album chip on it. ■

Technology Update

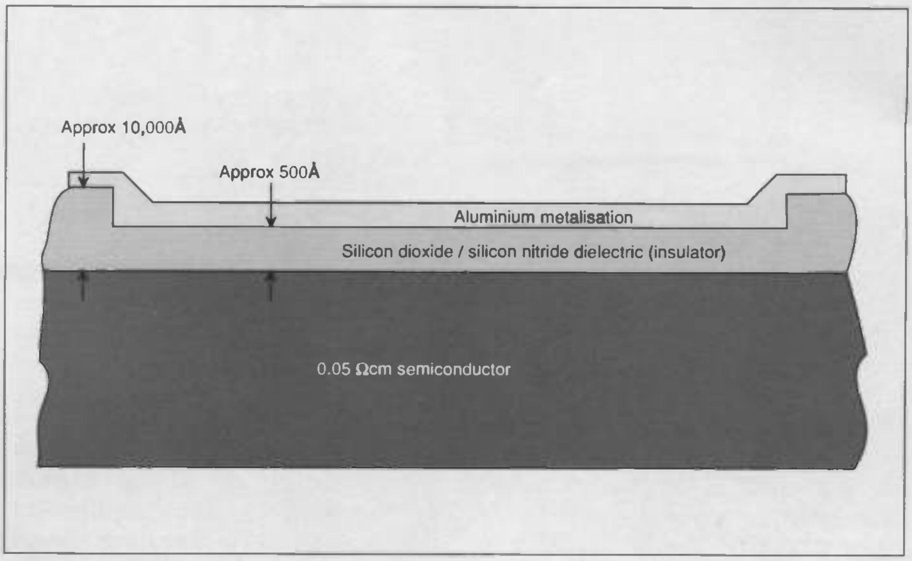
Ian Poole takes a quick tour around some of the latest inventions and techniques in the world of electronics and semiconductor engineering.

The pressure for ever decreasing sizes of integrated circuit (IC) has given dynamic RAM designers significant problems. One of the major ones arises because these RAMs store their information in individual cells as a charge in capacitors. For these to be reliable each capacitor must have a certain minimum capacitance. To a large extent this is dependent upon the physical size of the capacitor.

One solution to this problem was to design capacitors using a trench or V in the structure. This gave a larger area for the capacitor whilst taking no more space in the horizontal plane. Although this method was reasonably successful and used in some 4M bit DRAMs, it only gave a limited increase in capacitance.

To help fully overcome the problem researchers at Siemens AG in Munich have been able to produce very thin and pure layers of titanium oxide. This is ideal for use as a dielectric material for capacitors in ICs because it has a very high dielectric constant – about 20 times that of silicon dioxide/silicon nitride which is normally used for the purpose. This means that the size of the capacitors can be reduced by almost the same ratio.

Not only does the titanium dioxide give an improvement in size but it has also been found not to suffer from the same loss of charge which has plagued designers for some time. Most silicon dioxide/silicon nitride capacitors loose their charge by currents due to quantum mechanical tunnelling. As this does not occur with titanium dioxide new ICs using it are expected to be more reliable.



Although there are many advantages to using titanium dioxide the processes which are needed to handle it have to meet stringent requirements. Even so the processes are now well advanced and it is hoped that Siemens will be able to launch a 256 M bit DRAM using the new capacitors

Ceramic Batteries

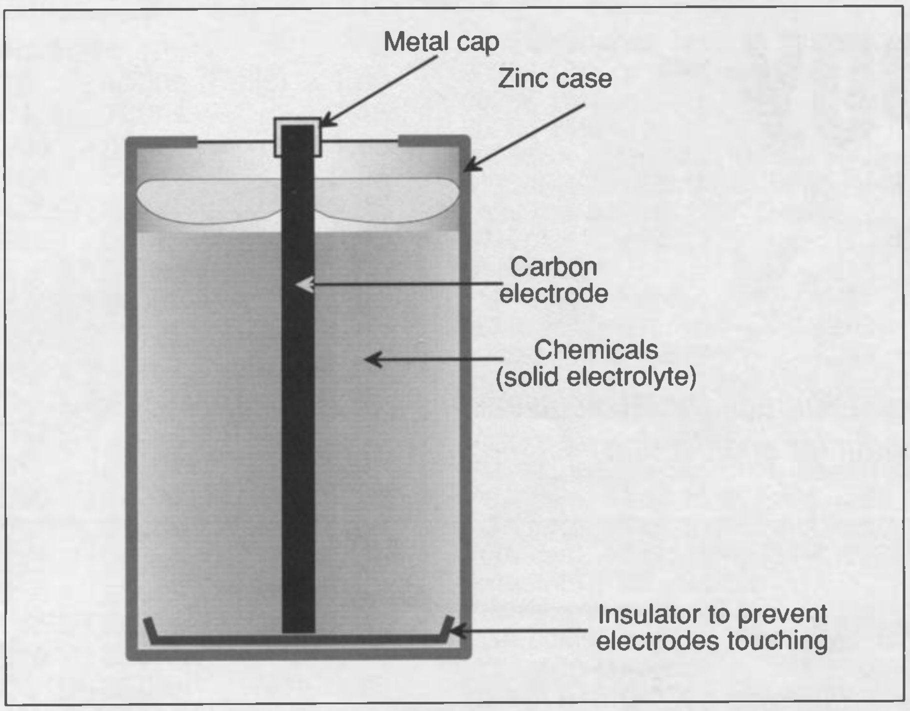
Batteries are being used increasingly as sources of power. This is partly due to the fact that there is more portable electronic equipment available than there was a few years ago. In view of this increase in battery usage any improvements which can be made could pay very large dividends on the investment spent in any development.

The existing technologies which are used have many drawbacks. Primary or non-rechargeable cells are expensive and cannot be recharged despite the fact that they remain basically intact. In addition to this their disposal gives rise to environmental problems, a factor which is becoming increasingly important.

Rechargeable cells offer a sensible alternative and of those available, NiCds currently hold a virtual monopoly, but they are not ideal. In the first instance they only give 1.2 volts in comparison with the 1.5 volts of a standard cell and they are also very expensive. In addition to this they have a finite number of charge / discharge cycles because the mechanical stresses setup in the cathode by normal use eventually leads to failure.

A lot of work is currently being undertaken to overcome these problems. One investigation has discovered that a form of ceramic called a ternary oxide could be the key to a whole new generation of batteries.

Ternary ceramics can produce a wide variety of voltages by



selecting the make up of the ceramic. This means that a voltage of 1.5 volts can be used. In addition to this the number of charge /discharge cycles is almost unlimited because there are no internal stresses set up in the cell during normal use.

Results so far have been very encouraging. A laboratory made cell using the anode from a commercially made NiCd, an electrolyte of sodium hydroxide and a ternary oxide cathode has shown no noticeable reduction in efficiency after several thousand charge / discharge cycles and the cell voltage has remained stable at 1.45 volts.

Investigations of the cell using X rays have proved that none of the stresses of NiCds were exhibited by this cell. Another advantage of ternary oxide cells is that they have a much greater energy storage capability than ordinary NiCds. This will means that the cells will need charging less frequently.

Although the experimental cells have used liquid electrolytes there is no reason why a solid one could not be used. This could be done by firing three layers of ceramic together to give a completely solid state cell.

Once the technique has been perfected it should give a much more reliable cell and at a much reduced cost. It will also not have the same environmental problems after the cell has exceeded its useful life and needs disposing. The only bad news is that there is still a considerable amount of development to be completed and these cells are unlikely to be available for at least five years.

New Photoresist

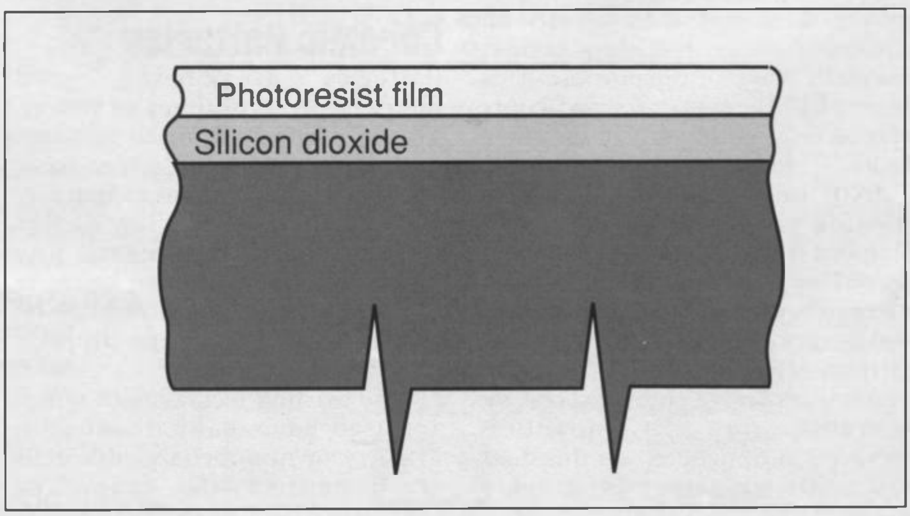
The ongoing quest for higher performance electronic equipment has meant that IC operating speeds and frequencies have had to rise. To achieve this IC dimensions have had to be reduced. However, many of the processes which were perfectly adequate some years ago are reaching their limits unless new ways of increasing their performance can be found.

One of the main processes in IC manufacture is called photolithography. Although there are other processes which can be used instead they are much more costly. Unfortunately for many of the new breeds of ICs which are currently being produced the limit of resolution for photolithography is being reached. Generally it can produce structures with dimensions down to about 1 µm. If anything less than this is required then X-ray lithography is used.

The limitations behind photolithography arise from basic physics. To get sufficient resolution of the image onto the IC very short wavelengths have to be used. This means that a wider aperture is required in the optics and in turn this results in a very small depth of focus. As the light has to act on a sufficient thickness of photoresist to resist the chemical attack a limit is reached.

To overcome this problem researchers at Siemens have produced a new technique which has enabled them to achieve resolutions of better than 0.3 µm. The process involves using a two layer resist. The top layer is very thin and is sensitive to light. Once this has been exposed the resist pattern is transferred to the lower and thicker layer of resist by a chemical process called dry etching. This bottom layer forms two functions. The first is to give a sufficiently flat surface and ideal exposure conditions for the top layer. Secondly it is thick enough to act as a mask in the chemical etching process.

This process is currently used on an experimental basis. However when it is at a sufficiently advanced stage in development it could be a key process in the production of future Gigabit memory ICs which are just over the horizon. ■



Review... Canon S-50 Speakers

Domestic loudspeakers have not changed a great deal in design over the years until now. James Smith examines a completely new concept in sound and finds he likes it.

Possibly the most unusual loudspeakers ever produced, in appearance at least, the Canon S-50s are an attempt to usher in a new era of sound.

Unlike normal loudspeakers, which are housed in large square cabinets – usually made of wood but sometimes of concrete or plastic – the most striking thing about the S-50s are their round domes mounted on cone shaped pedestals. This is not an attempt at modern art or even post modern art, it is all functional. The sound is produced from normal speakers mounted facing down inside the domes. It is then reflected into the room by the cones to give a wide spread of sound known as 'wide image stereo'.

The S-50 speakers can be used with any HiFi sound system and have been especially designed for use with the latest HiFi television sets and Nicam digital stereo. Special shielding has been incorporated into the design to allow them to be placed relatively close to the TV set without affecting the electron beams inside the tube – anyone who has accidentally, or otherwise, placed a magnet close to a TV will have noticed the disastrous effect on the image.

Wide Image

The concept of wide image stereo stems from the idea that a normal pair of stereo loudspeakers have a definite hot spot where they give a perfect stereo image. All of the instruments, singers, band and so on, appear in their correct places and the sound from one speaker does not drown that from the other. Sitting with your head in this position results in the best listening.

Unfortunately, it is not practical for a number of people to sit with their head in the same location so those on the outside edges of the 'hot spot' will not get the best stereo effect. The Canon S-50s produce a much wider 'hot' area allowing a number of people to get, more or less, the same stereo effect. The area is also not just a straight line a certain distance from the speakers, it is an oval or circle so no special listening positions are necessary. So much for the theory, what about the practice.

After quite a lot of listening and and demonstrating to amazed friends, the general opinion of the S-50s was a definite thumbs up. The only real problem with the speakers is that they tend to have their best effect at one position vertically. Sitting with them at head height produces much better effects than if they are much higher or lower. It is probably worth spending the extra money on the stands as this brings the units up to the correct height.

Aesthetically the S-50s go with fairly modern decor – with other styles such as victorian or farmhouse, they look rather out of place. Quite apart from anything else, the speakers provide a very good talking point being variously described as ornaments, wig stands and even vases (though they are the wrong way up)

Specifications

Product: Canon S-50 Wide Imaging Stereo Speakers

Anechoic frequency response: 70Hz to 18kHz ±3db

Nominal impedance: 8Ω

Power handling: 50W but can be used with any amplifier with an output from 15W to 100W per channel.

Price: £349.99 (inc VAT) £399.99 with stands

Availability:
Canon Audio Tel. 0483 740005 ■

Review...

Technics Surround Sound

Ian Burley connects up a Technics SA-GX505 and likes the video inputs, Dolby surround sound but thinks it is a little heavy on the gimmicks.

Is your stereo image keeping up with the Joneses or is it just a bit two dimensional? Surround sound was born in the cinema and now, along with the video age, it's a big growth market for customers in America who hanker after their own private movie theatre at home. Surround sound decoders have been available in the UK for a little while now and most of the big HiFi brand names offer the hardware.

This month we look at the Technics SA-GX505 receiver. A bit of a monster this unit provides a digital tuner, a 100 watts per channel amplifier sections, a fancy 'parametric' tone equalising system and bar-chart display, video input for video edits, a versatile infra-red remote control unit capable of controlling tape and CD decks, a motorised volume control knob and an optional remote control link with audio and video tape decks for synchronised operation. The knobs and buttons on this beast will either terrify you or keep you happy for months.

In many ways the SA-GX505 is typical of the latest generation of high-tech tuner-amplifiers, mainly from Japanese stables, but it's the Dolby Pro Logic decoder which makes this receiver stand out. Pro Logic is used in most cinema film sound tracks these days and has been for some time. It is also compatible with earlier Dolby Surround systems. The latter requires a minimum of four speakers, two behind and two in front of the viewer in order to construct the three dimensional sound stage. Pro Logic adds a central speaker at the front which is usually designed for focusing key sounds like dialogue. In addition there is a 'phantom' or wide mode

for ordinary stereo sound tracks plus Dolby 3 which is designed to reduce a stereo 'hot-spot ' in the sound stage.

How does it perform? Unfortunately the review machine arrived late and we only had a limited time to play with it. We had mixed results. Some Dolby Surround movies we played through the SA-GX505 were disappointing compared with others. Hunt for Red October was an example of the former while Steven Spielberg's Always, which has lots of noisy planes zooming around the sound stage, was amazing. Both sound spectacular in a good cinema. Playing back ordinary stereo tracks from music CDs produced some interesting effects with phantom mode on. Some pop music videos were certainly enhanced by the surround sound trickery.

The conclusion one comes to is that a surround system needs careful choice of speakers and lots of trial and error experimentation when setting up. You really can't just bung the speakers anywhere you like, hence the US trend for family home to incorporate a special room for home theatre.

Personally, I'm sold on it. My ten year old HiFi system is well overdue for replacement and I could do with the video input facilities. Surround coded tracks are beginning to appear on CDs as well as videos and laser discs. It's something we will be taking for granted in future years. I'm not sure I'd necessarily go for the Technics. It's big, the controls are very confusing and the remote control didn't always do what you expected it to. I can report, however, that the tuner section was very strong - grabbing stations in stereo which my old system easily gave up on and overall the sound was very clean. I'll need to look at the competition before finally making up my mind.

Technics SA-GX505 Stereo Receiver with Dolby Pro Logic Surround Sound Decoder.
Price: £349.95 ■

Review...
Stereo Sound Sender

Julianne Christian plugs her personal stereo into a gadget that turns it into a private radio station giving perfect stereo at home and on the move.

The idea of a stereo sender is actually quite simple and although, at first sight it might appear to have limited uses, in practice it is a very handy gadget indeed.

The basic concept of the device is to take a standard high quality stereo sound signal, say from a CD, cassette or Nicam Stereo decoder, and convert it into a standard format FM stereo radio signal. This can then be picked up by any FM radio and replayed. The transmission power is very small and the signal can only be picked up within a small area – much like having an FM radio station just for your house.

Virtually any HiFi output can be connected to the device via its two phono sockets. The input circuitry is flexible enough to take signals from a variety of impedences and voltages, even the headphone output of a personal stereo. It is completely portable and powered by a single PP3 battery so it can be used in a wide range of situations.

On The Move

The most obvious use for the stereo sender is to connect up a personal stereo, say a Sony Walkman, to a standard HiFi via the tuner. Another use it to be able to connect portable sound systems to a car stereo. This has the great advantage that portable CDs and cassette players can be used in a car with no loss of portability removing the need for expensive removable In Car Entertainment (ICE) systems and leaving only a cheap stereo radio receiver for any prospective thieves.

Possibly the most flexible use of the sender is to connect it to an unused output of a standard stereo system. This allows any music playing on it to be heard on any radio throughout the house – no messy wiring needed. One CD, tape or turntable serves every radio receiver in the building.

Other uses include remote TV, and general HiFi listening via radio headphones and connecting computer game sound cards to the HiFi. Since the system basically serves as a very sophisticated connection cable, it will find a multitude of uses – just like any other piece of connecting cable.

Not So Legal

The most obvious problem with the sender is that it is not strictly legal to operate an unlicensed radio transmitter on the necessary frequencies. The device puts out a signal that can be picked up at the top end of the FM dial where there are few stations and consequently very little to interfere with. If, by any chance, a neighbour is using the same frequency then a small adjustable screw on the device allows the channel to be changed to remove any interference. Apart from this, the quality is as good as that from any FM station with perfect stereo and a good dynamic range. It is easy to install and use and its portability and the international FM stereo format allow it to be used anywhere in the world – licences permitting of course.

Specifications

Product:
Lazerline Stereo Sound Sender
Price: £64.95
Availability
Lazerline, Unit 2, Castle Commerce, Leighton Buzzard, Beds, LU7 7RG, Tel. 0525 377916 ■

A Look At The Latest Gadgets And Gizmos

Ian's bag of goodies this month includes a weather station on a watch, portable rap machines and a selection of camcorders.

This month in addition to the usual news from the consumer electronics arena, I continue my look at what was new from this year's Winter Consumer Electronics Show (CES) earlier this year in Las Vegas.

Wide Screen TV In Gear

CES shows have often been used by companies to showcase high definition TV (HDTV) prototypes in recent years, but all the HDTV hype appears to be obscuring what will probably be the next stage in domestic audio/ visual development – namely wide-screen TV. Last month we brought news that RCA/Thomson showed a 16:9 aspect ratio wide-screen TV at CES. Also in the pipeline from RCA is a VHS (full-size cassette) camcorder which can be switched between 16:9 wide and ordinary 4:3 recording modes. Video 8 and Compact VHS versions are also under development. Laserdisc, which commands generous popularity in the US compared to the UK, already counts nearly 500 wide-screen or 'letterbox' titles and to accommodate this growing library we can expect switchable letterbox mode laserdisc players in the second half of this year. Video publishers are even bringing out special edition letterbox versions of earlier movie releases. For example the whole Star Trek the Movie series up to Star Trek V is now available in a wide-screen box-set. With wide-screen epics like Dances with Wolves, for example, which don't translate to conventional video format acceptably, public demand for wide-screen TV, which is relatively inexpensive compared with HDTV, could kick-start the market before HDTV broadcasts start in earnest, probably 2-3 years from now. There will also be no wasted investment as standard resolution widescreen TV sets will probably be designed to accept HDTV upgrade modules.

Canon reflex lens CL 250mm f/4 mounted on Canon L1 Hi-Band 8mm Camcorder.

Canon at CES

With the US firm Honeywell successfully forcing Minolta into submission over a patent dispute regarding autofocus technology used by most of the Japanese still and video camera manufacturers, brave faces were the order of the day at CES.

Canon's video division had a number of interesting models on show at CES. Attracting the most attention was an ultra-telephoto mirror lens for the top of the range L1 Hi8 camcorder (called the A1 here in the UK). This camera uses a special interchangeable lens mount system – you can even attach Canon still–camera lenses. The extremely compact 250mm lens is equivalent to a 3000mm telephoto in terms of your traditional 35mm SLR camera. And this is a video camera system aimed at the keen amateur!

A bit more down to earth is the new hi-band version of the Canon UC20 palmcorder, the UCS1. This effectively steals the limelight from Sony's TR705 Hi8 camcorder, which was the first Hi8 palmcorder. Canon claims the UCS1 takes over as the smallest and lightest hi-band camcorder on the market. The distinctive Canon UC range of camcorders incorporates a design

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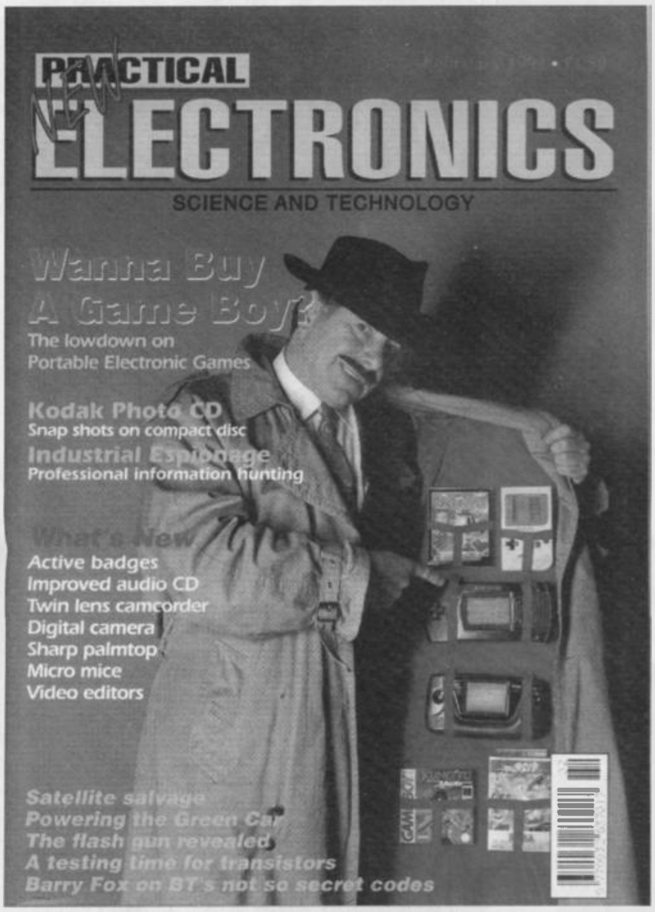

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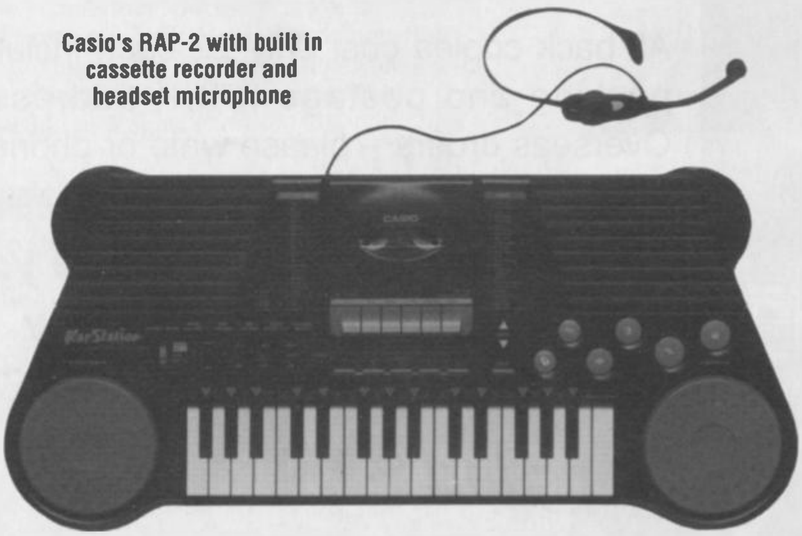
Casio's RAP-10 portable rap machine.

Casio's RAP-2 with built in cassette recorder and headset microphone



whereby the obligatory infra-red remote control clips onto the camera's case and folds neatly out of the way. Internally, Canon claims it has taken camcorder chip integration to new limits with as many as 13 chips used previously now incorporated in just four chips for the UC series. The new UCS1 makes my nine month old Canon A10 palmcorder look distinctly obsolete!

Do The Casio Rap

Casio showed an electronic Rap machine at CES. If you've read this far and haven't the foggiest, rap is one of the current pop music crazes where performers sort of talk rather than sing in time to a rhythmic musical beat. The Casio Rap provides the rhythm and beat and combines the performer's amplified voice to boot via a built in microphone. Two versions are offered: the portable $70 (£40) RAP-10, which is small enough to wear on a belt and the RAP-2 ($220 or £125). The latter has a built in cassette recorder and head-set mike. A three-note polyphonic synth is built in. Both models offer electronic record 'scratching' and selectable rap drum patterns. It would seem ghetto-blasting has finally reached the 90s.

Other Casio bits include the KL-2000, a pocket sized electronic label printer complete with LCD display and QWERTY keyboard. Besides typing in the wording for your label and using the built-in selectable fonts, there is a PC link option enabling you design custom graphics on your IBM compatible or Apple Mac and then squirt them across to the KL-2000. Costing $300 (£170), the KL-2000 could well be in gadgets catalogues by the end of the year.

From the company which brought us the watch which could monitor your pulse and blood pressure (PE – last year), Casio launched its 'personal weather station' watch at CES. The ALT-6100-IV, which is priced $150 (£86) is a chunky LCD wrist watch with built in altimeter, barometer and thermometer. The altimeter can measure up to 19,680 feet while a tiny bar graph can show either the change in altitude or barometric pressure over the last few hours. The thermometer ranges between -4 and 122 degrees Fahrenheit. A Celsius scale is optional. Rumour has it the watch also tells the time.

Another innovative Casio time-piece is the IA-1000L-9A. It's a databank watch, useful for storing things like Casio model numbers. However, you wouldn't think it was anything other than a conventional analogue watch at first glance. To get at the databank bits you need to flip the analogue time-face disguise to reveal a keypad and an LCD display. Included are basic calculator functions, a password protected 'tele-memo' database and diary/scheduling functions. I fully expect Casio to be the first company to produce a Thunderbirds-style TV/communicator wrist watch...

Sharp At CES

Those wall-mounted LCD TVs from Sharp were at CES once again not as prototype technology demonstrations, but this time as pukka products which domestic

The Casio "Flip top" DataBank watch.

The Casio weather station watch.

Digital Diary with computer link

Business organiser

A handful of casios

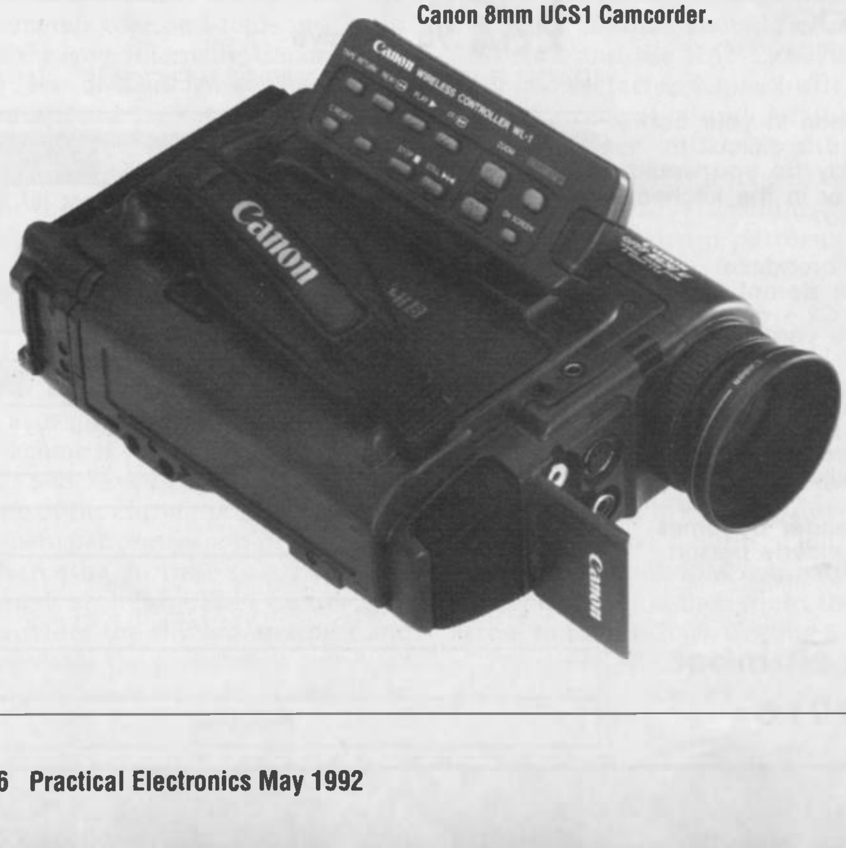
Label printer

Graphic display calculator

Japanese customers can now buy. Eight styles of 'frame' can be selected to match your 8.6" active matrix LCD screen. The range will be marked as the Liquid Crystal Museum series. Unfortunately pricing wasn't available at press-time. The controversially styled wall TVs have generated much heated discussion in PE's usually tranquil letters pages in recent months.

Also on the Sharp stand at CES: a new colour LCD video projector offering 650,000 pixel 400 line horizontal resolution in a compact and relatively lightweight package, a re-launch of Sharp's diminutive camcorder which takes full-size VHS tape, the SlimCam, and a newly developed 5.6" colour LCD panel which uses comb filtering to enhance picture quality.

Canon 8mm UCS1 Camcorder.



Franklin At CES

Finally from CES, Franklin, which produced the first ever pocket-sized electronic bible, unveiled an enhanced version of its Language Master electronic pocket dictionary and thesaurus, the 6000-SE. This one speaks, not only to people with normal hearing but to the deaf as well. The device contains a 110,000 word spelling dictionary, 300,000 definitions and 500,000 thesaurus synonyms. If you can't take advantage of the headphone socket, you can see the pronunciation of words on the 6000-SE's LCD screen instead. The audible output can be speeded up or slowed down to suit your needs. The 6000-SE is priced $495 (£283). Currently it has an American accent, but if there is demand over here the 6000-SE could end up speaking the Queen's English.

Computers Out Of Step

A new development in microprocessor architecture could save processor chip technology from an evolutionary dead end and as well as breed a new generation of ultra-low power-consumption processors. What's more, the increasingly rare phenomenon of a British-lead microchip engineering development could develop the first commercially viable example of such chips.

Modern microprocessor architectures are clock driven. Each clock tick steps the processor

Sharp high resolution projector.

through its instruction processing cycle and RISC (reduced instructions set computer) processors can complete one or even 'cycles' in a single clock tick, sometimes up to 200 million times a second. The theory goes that there is a physical limit to the potential development of single-chip clock-driven architectures as chips get bigger and faster. All the transistors, perhaps several million, on the chip have to be switched in unison – this is a synchronous mode of operation. One day a chip will be made where that just isn't physically reliable any more.

UK researchers are therefore looking into asynchronous processor architectures. Put crudely, this means that parts of the chip will only communicate with other parts as and when necessary and there is no overall external clock driving it all along. In other words the processor cycle drives itself along and only the parts of the silicon relevant to the task dictated by the program it is running will be 'active'. This will save power – a goal of one-tenth power consumption has been set. This could enable a battery powered super-computer to be a reality. The technology shouldn't compromise performance as parts of the chip can be optimised. The first example of a general purpose asynchronous microprocessor could be an adapted version of the ARM RISC processor originally designed by Acorn Computers in Cambridge and it's predicted it will run marginally faster than an equivalent synchronous chip. Chief computer engineer at Manchester University, Professor Steve Furber, leads the Eureka-funded project and he co-designed the original synchronous ARM architecture.

One by-product of asynchronous technology is that chip performance will be directly related to silicon quality rather than a set external clock speed. It's quite conceivable that asynchronous chips from different silicon production batches could differ in performance by several tens of percent, though in many applications this won't be noticeable by the average user. An asynchronous ARM chip would be able to run existing synchronous ARM coded programs but a question mark hangs over time-critical routines.

As the demand for very low power-consumption chips accelerates in line with the development of compact portable battery-powered devices, asynchronous chips could be a key resource in the not too distant future. Meanwhile, it so happens that the very first valve-powered digital computers were also asynchronous. History does have this habit of repeating itself!

Thought For The Month

To end this months scribblings I'll leave you with this snippet of news to ponder on. IBM has developed a an experimental switching chip which can handle data transmission at the rate of 5 billion bits per second over 16 channels simultaneously. That's 80 billion bytes per second, or ten gigabytes per second (10x1024x1024x1024 bytes or 10,2400 megabytes). IBM suggests that this system could empty the contents of 16 60Mb PC hard discs in less than a tenth of a second – the only problem being that the drives can't work that fast! or think of it another way, the chip could transfer 18,000 average-sized novels in a second. It's technology like this which should make pipedreams like global high definition videophone systems connected into vast multimedia databases a reality, one day. ■

Franklin's Language Master

How It Works... The Loudspeaker

There is more than one way of making a noise. Alan Jones explains how it is done by the average HiFi system.

In many ways, a loudspeaker is like an electric motor. It uses the interaction between a coil of wire carrying a current and a magnet. Following Fleming's left hand rule where the thumb, first and second fingers are extended at right angles to each other. The thumb points in the direction of wire motion for the first finger representing the lines of magnetic force and the second finger the direction of current flow – this is the opposite of the electron flow. A current flowing through the coil of the loudspeaker creates a magnetic field which interacts with the field of the magnet. This forces the coil to move in and out of the magnetic field depending on the amount and direction of current flow.

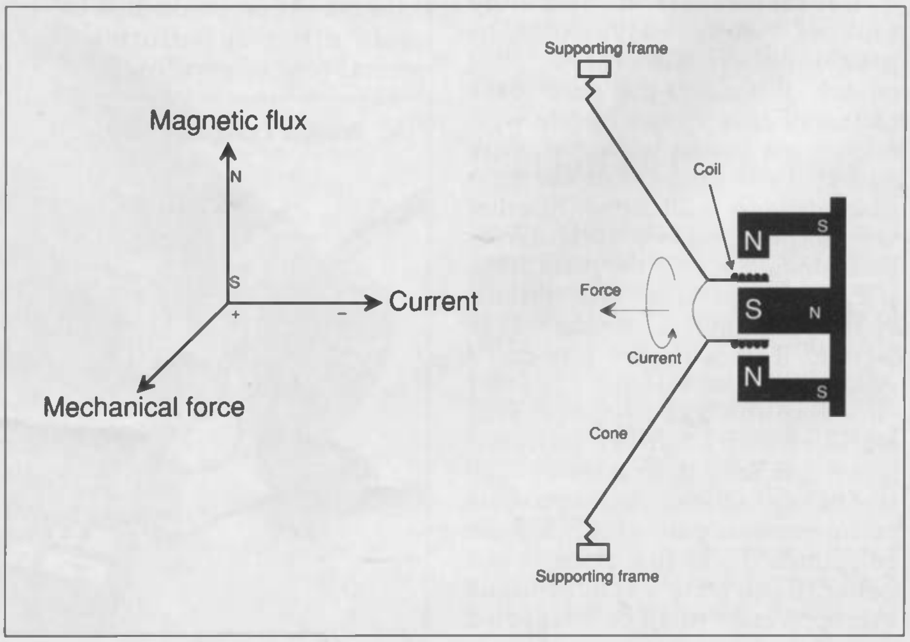
The output from an amplifier is connected to the coil of the loudspeaker to generate the required current. This coil is wound around a card or plastic cylinder and glued in place. Any movement of the coil results in a movement of the cylinder which is attached to a cone. In early days, this was simply card supported at its edges by corrugations that allowed it to move in and out without hinderance. Modern speakers use all sorts of different materials such as special polymer plastics to give a better frequency response.

Although the moving coil loudspeaker is probably the most common type, there are other ways of converting electrical signals into sounds. One method used extensively for high frequency work is the piezo sounder.

When an electric voltage is applied across certain types of crystal or ceramic it causes a change in size. By placing the piezo material onto a metal plate and applying a voltage across it, the plate flexes. Changing the voltage at high speed causes the plate to flex at the same rate which creates a sound. When used in a tweeter or high frequency speaker, the frequency response usually ranges from 4kHz to 20kHz. This combines with the mid-range response of a magnetic coil loudspeaker to increase the overall frequency range of a loudspeaker system.

Another way of producing sound from an electrical signal is with a ribbon or film. This is a large flat area of material placed between two plates which can be charged electrostatically. Changing the charge moves the film and produces sound. The disadvantage of this type of system is that it requires special high voltage drivers and transformers. However, it avoids many of the resonances inherent in traditional cone speaker designs and provides a higher quality signal.

One way to get around problems that crop up with limitations in particular speaker designs is to use combinations of different methods. A large cone speaker (woofer) could be used to get the low frequencies but, due to its mass, not be very good at producing mid and high frequency sounds. A smaller cone may be used in the mid range area and a piezo system (tweeter) for the high frequencies. To stop all signals being sent to all three speakers, a crossover circuit is used. This consists of a low pass filter for the woofer, a band-pass for the mid range and a high pass for the tweeter. The correct settings of the cut-off frequencies of the crossover can result in a good overall linear response from 70Hz to 20kHz. ■



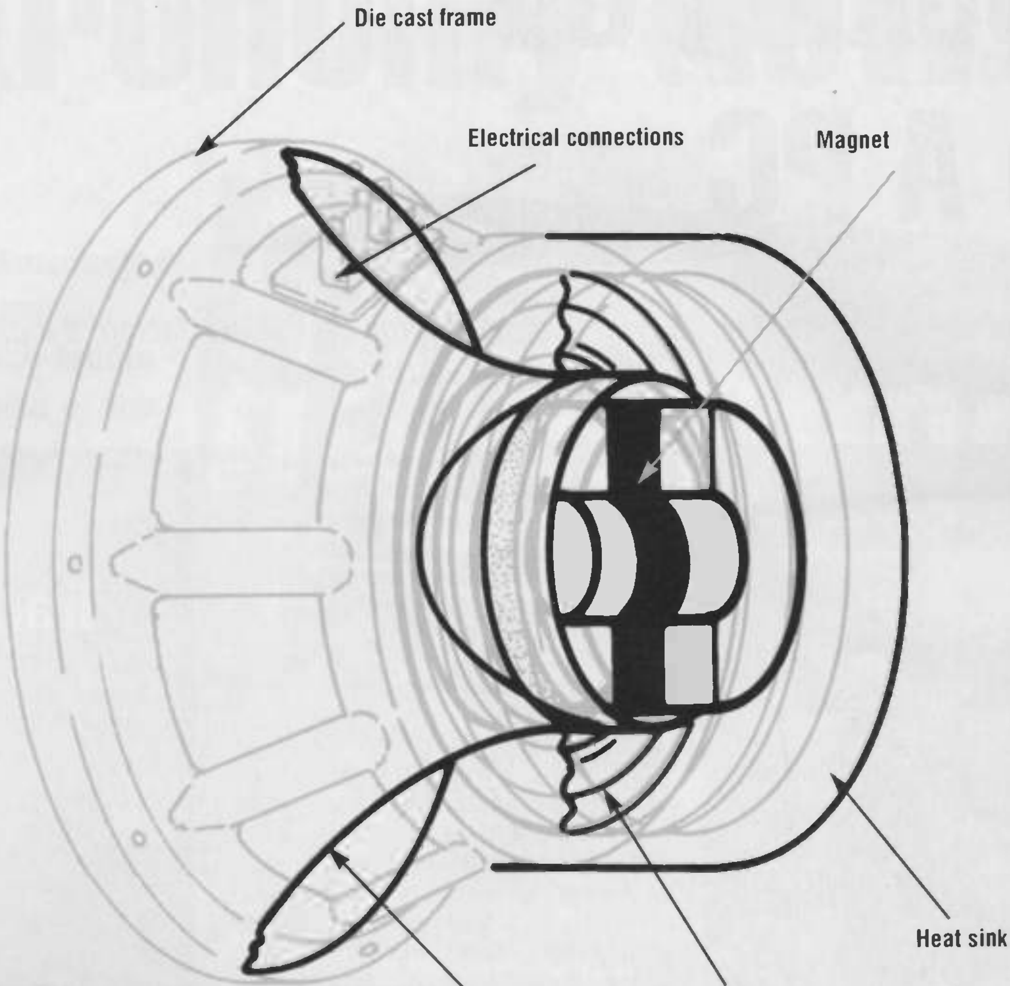
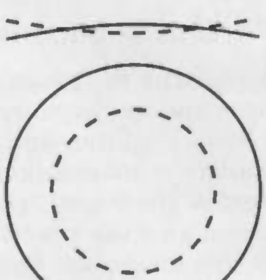
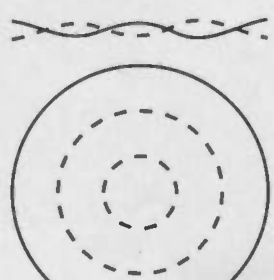
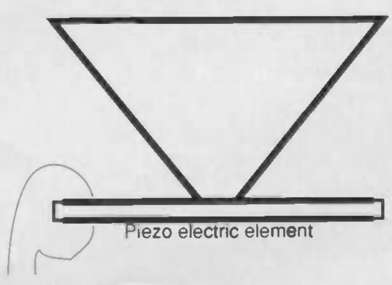


Illustration: Derek Gooding



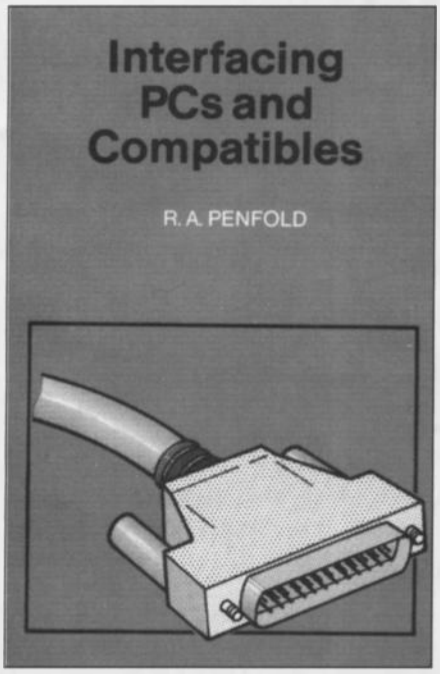




The piezo electric crystal sounder makes use of the fact that certain crystals deform when an electric voltage is applied to them.

Hooking Up To A PC

Three book reviews starting off with a short volume on PC interfacing, a look at a new electronics reference book and the complete work on sensors.



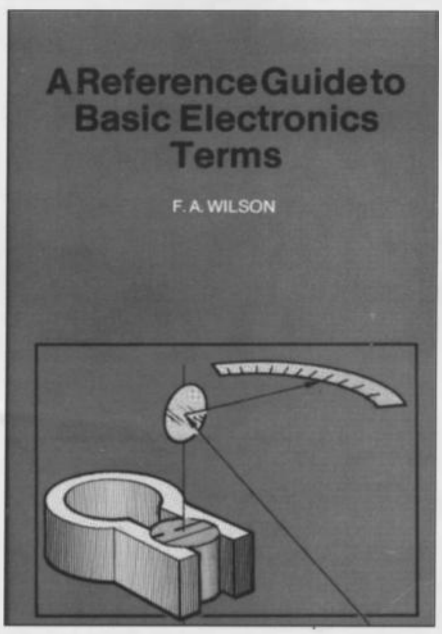
This book takes the reader from knowing very little about PC interfacing up to the point of putting theory into practice is possible. It starts off with a quick look at the various PC interfacing systems around and makes the comment "this is not something we will pursue further here" about most of them. What this comes down to is that the book covers the ISA (Industry Standard Architecture) slot and not much else.

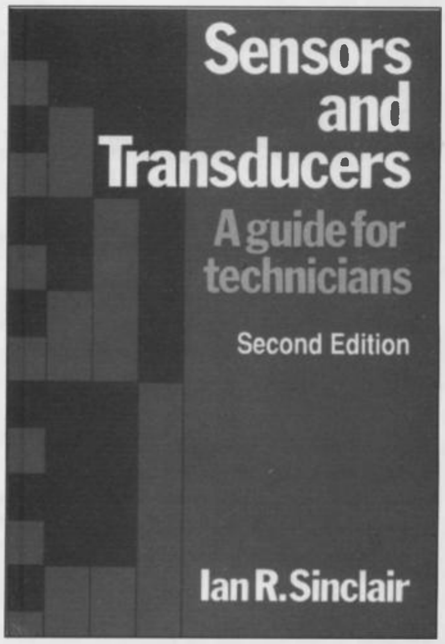
Unusually for a Babani book from R A Penfold, there are no actual projects. All of the information is purely factual, nothing is really put into practice. Having said this, there is information about getting at the I/O card from GWBASIC and slot numbers, memory positions and so on. For the relatively experienced constructor this book could prove quite useful. Anyone who hasn't built something of this type before would probably be better off with a PE project.

Book: Interfacing PCs and Compatibles
By R A Penfold
Published by Bernard Babani
Price £3.95
ISBN 0-85934-217-4

From absolute temperature to Zener diode, the reference guide to electronics terms is an alphabetical list of all you ever wanted to know about electronics. It covers most of its topics in some detail with quite a selection of diagrams and maths where necessary. The explanations are both lucid and logical and there is a mass of information.

Because of the way it is written, the guide can be used either as a straight reference book or as something to browse through – some of the topics are fascinatingly put, I found myself quite engrossed by the explanation of deBroglie waves.





Overall, this is a book well worth looking at if you need a reference guide to electronics.

Book: Reference Guide To Basic Electronic Terms
By F A Wilson
Published by Bernard Babani
Price £5.95
ISBN 0-85934-231-X

Covering a wide range of devices and environments, this book explains how to convert a variety of information to electrical signals. The theory is kept to a minimum and the practical explanation to a maximum. This is a fascinating book for people who like to know how things work.

Book: Sensors and Transducers
By Ian R Sinclair
Published by Newnes
Price £19.95
ISBN 0-7506-0415-8 ■

On The Making Of Semiconductors

The second of Mike Sanders' articles looks at how silicon wafers are oxidised, etched and implanted with impurities before they can be made into chips.

Silicon is a popular material for semiconductors for many reasons. One is that it can be easily oxidised to provide a protective barrier. This oxide layer can also be used in a photolithography process to make patterns and shapes to form electronic components.

The oxidation source is either oxygen or water vapour at temperatures between 900C and 1300C. The reactions are:

$$Si+O_2 = SiO_2$$
$$Si+2H_2O = SiO_2+2H_2$$

The furnace is usually a stack of three or four heating systems each with its own control where the temperature is kept within ±0.5C of the required temperature.

Before oxidation the surfaces are cleaned thoroughly and not touched by human hand. Contamination by sodium can cause surface leakage and failure of the device – human hands are a source of sodium.

The wafers are dried and loaded onto the quartz holder called a boat before the oxidising process takes place. Sometimes, in order to decrease cost, a nitrogen-oxygen mixture is used as it is more readily available than pure oxygen.

There are two processes which use water vapour. One uses a hydrogen and oxygen mixture to create water. This is a pyrogenic (hot) process, commonly a torch system of burnt hydrogen. Its drawbacks are that it requires extreme precautions against explosion and the combustion of the oxygen-hydrogen mixture at the entrance to the reactor causes a non-uniform temperature over the chamber.

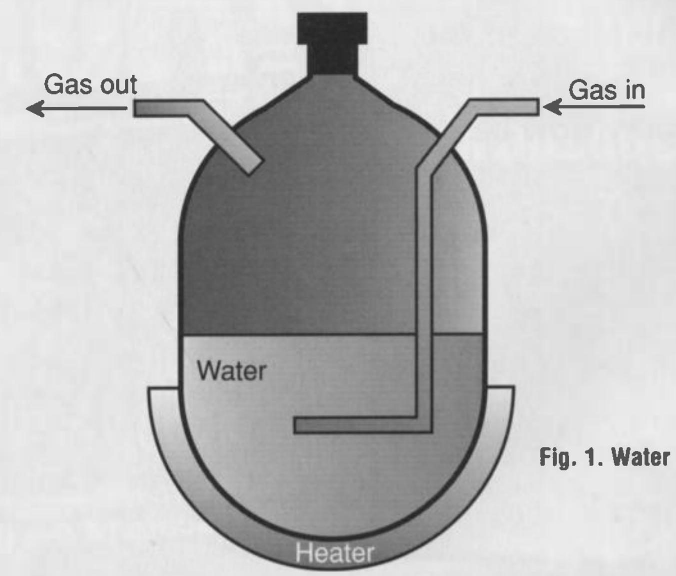


Fig. 1. Water bubbler.

Another method uses a chamber called a bubbler (Fig. 1). Water in this is maintained at a constant temperature below its boiling point of 100C – since a constant pressure is required and the pressure varies greatly over the temperature range – Fig. 2.

Oxygen or nitrogen is used as a carrier gas and bubbled through the water to pick up water vapour. The exit is close to the oxidation furnace so that the vapour doesn't cool. One of the disadvantages of the bubbler is that when refilling the container with water there is the risk of contamination. The jar must be filled with warm water since cold water would reduce the vapour pressure.

The amount of contamination can be decreased if hydrochloric acid is also fed into the vapour. The chlorine combines with the impurities and prevents them from moving. For the same time and temperature, the oxide layer grown with water vapour is thicker than that produced by the burnt oxygen method. Fig. 3 shows the rate of growth of the oxide layer for both methods over 10 minutes at different temperatures. The table is for (III) silicon, the thicknesses for (I00) silicon being in general slightly less.

To grow thick layers of oxide at atmospheric pressures requires high temperatures and long periods. Devices requiring shallow junctions cannot be subjected to high temperatures for long periods and therefore a high-pressure oxidation process is used instead.

If a thin layer of oxide up to 500Å thick is required, electrolytic oxidation is employed as shown in Fig. 4. The wafer is connected to the anode and a voltage is applied between it and the cathode. The thickness of the oxide will depend

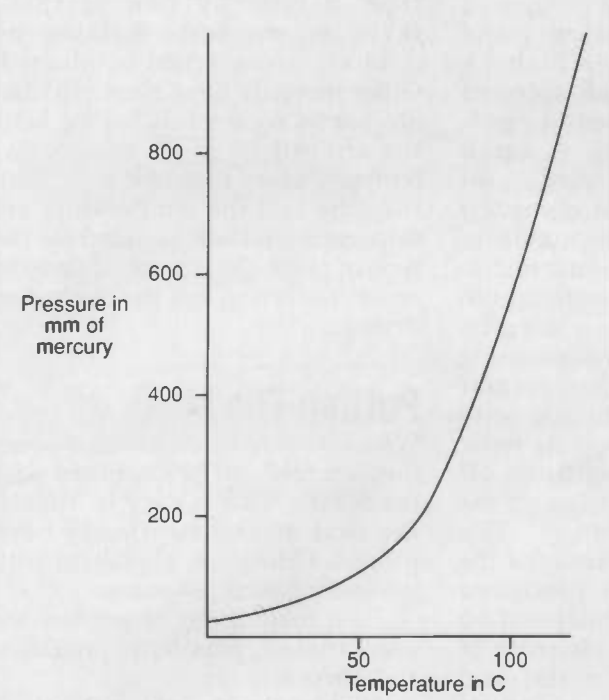


Fig. 2. Temperature vs pressure of water vapour.

on the voltage applied and although, electrically, the oxide layer is not very sound, the process does not interfere with the doping profiles of the layers underneath.

Creating A Mask

A simple definition of photolithography is printing with light. Several templates or masks are used in the process with oxidation or introduction of impurities after each masking step. This allows the necessary circuits to be built up.

The image of the mask is transferred to the wafer by the use of photoresist, a light sensitive material held in suspension in a solvent. This is sensitive to the blue light from a mercury arc lamp but immune to the red and yellow lights used in dark rooms.

Photoresist comes in two types, positive and negative. In the first, the light increases the solubility of the resist in the solution whereas in the negative resist, the light causes polymerisation or hardening.

Both types can be used as etch resistant masks but whereas the negative photoresist could be used more often in the early days of photolithography, positive photoresist is gaining importance as line widths and spacings become smaller than 5μm.

A resist is a complex organic material made up from of carbon, hydrogen, oxygen and nitrogen molecules. Its performance is assessed on the grounds of:

- The resolution or size of the lines to be produced
- Sensitivity to various light sources
- Adhesion to the wafer surface
- Resistance to etching

Before looking at the detailed process it may be as well to look at the basic principles of photolithography. There are two main steps, transfer of the image from the mask to the photoresist and then from the photoresist to the silicon dioxide.

Fig 5a shows a substrate of silicon covered with a layer of silicon dioxide and then photoresist. The mask is lowered and light is shone over it to transfer the image to the photoresist – Fig 5b. The second property of the photoresist, the resistance to etching can now be used and the silicon etched wherever it is not protected by photoresist – Fig 5c. When the etching is complete, the remaining photoresist is removed from the surface – Fig 5d.

This viscosity of photoresist depends on the amount of solvent and is measured in centipoise. Most photoresist material is as sluggish as syrup and in the 14-60 centipoise range.

Before any masks are manufactured, the circuit is built and tested. It may also be simulated on a computer to check for variations in temperature, humidity, voltage variation and so on. When the engineer is happy with the performance, the drawing office sets about converting the circuit into a three dimensional drawing and turning this into a series of masks (photolithographic plates) to represent the layers of the circuit.

Each layer of the circuit is photographed and transferred to a glass plate called a master. From this a submaster is produced. This is then used to provide a number of working plates. A photosensitive glass plate which has an image transferred to it has clear and dark patches – Fig. 6.

A glass plate covered with photosensitive emulsion is liable to be scratched and other materials are sometimes used such as iron oxide or chromium oxide. The iron has the advantage that yellow light may be used to align the mask without affecting the exposure.

Revealing The Details

After the substrate of silicon has been prepared by oxidation, diffusion or metalisation, its top surface is cleaned and blown with nitrogen to dry it. The resist is then put on and dried.

Photoresist may be applied by brushing or spraying but the best method is by spinning. The wafer is

Oxide thickness in μm

	800C	900C	1000C	1100C	1200C
In dry oxygen	0.008	0.01	0.02	0.05	0.08
In pyrogenic steam	0.01	0.04	0.15	0.2	0.35

Fig. 3. Growth rate of oxide layer over 10 minutes for (III) silicon.

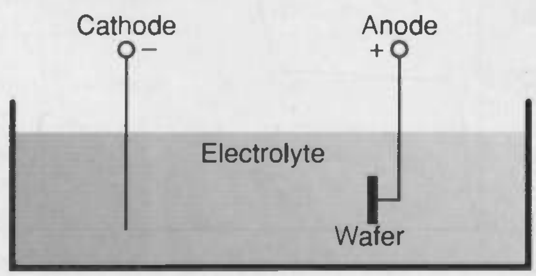


Fig. 4. Electrolytic oxidation.

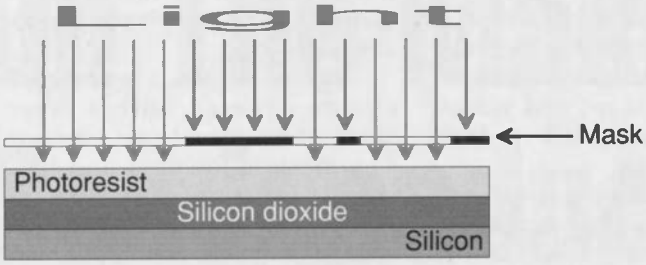


Fig. 5a. Exposure of photoresist to mask.

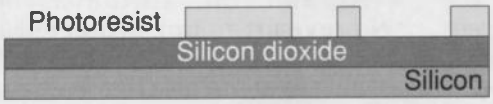


Fig. 5b. Development of photoresist.

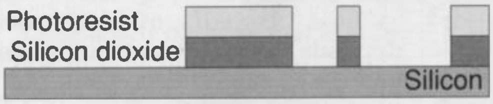


Fig. 5c. Silicon dioxide etched.

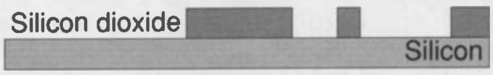


Fig. 5d. Photoresist removed.

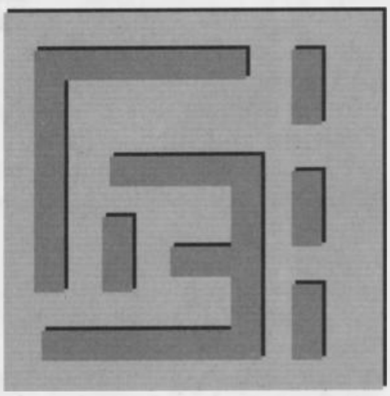


Fig. 6. Photosensitive glass plate.

held by a vacuum wand in a chuck which spins as shown in Fig. 7. A small quantity of resist is applied to the middle of the wafer and as the wafer spins, the resist spreads coating the wafer uniformly with the excess resist being flung off the edge off the wafer. The thickness of the film produced will depend on the viscosity of the resist and the spinning speed.

The spins lasts for about 30 seconds and goes up to about 5000 revs per second – it is quite an art form to get this absolutely right. Fig. 8 shows the five identifiable parts to the process. First, the resist is applied and the wafer spun up to 2000 revs/sec. It is held at this speed for about eight seconds and then accelerated to 5000 rev/sec where the speed is maintained for about 18 seconds. It is then decelerated rapidly, the wafer removed and the next one started.

The resist is dried moderately (soft baked) by one of three favoured methods, heating by conduction, convection or infra-red. Other methods have been tried but are not as successful. Baking lasts for around 10 to 20 minutes at temperatures of around 80C. Both the time and the temperature are important and will depend on the type of resist, the type of surface the resist is covering and the method of drying.

Putting The Mask On

When the wafers have cooled down they are ready to be imprinted with the masks. This is easy to align if the first mask has already been printed. Otherwise, alignment with the wafer flats is necessary.

Four main types of printers are used: contact, proximity, projection and direct step on.

With contact printing, the mask is placed in contact with the wafer as shown in Fig. 9. This means that the mask wears out and the print quality deteriorates. It is a cheap method and is used where the print detail is not fine and slight deterioration can be tolerated.

Proximity printing (Fig. 10) does not allow contact between the mask and the wafer and so the mask lasts a bit longer. Apart from that, it has the same drawbacks as the contact printer and is used to produce only low density chips or discrete components.

The idea of the proximity printer can be extended to provide a projection printer (Fig. 11).

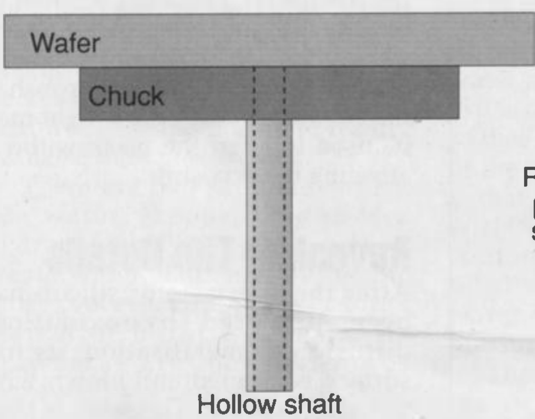
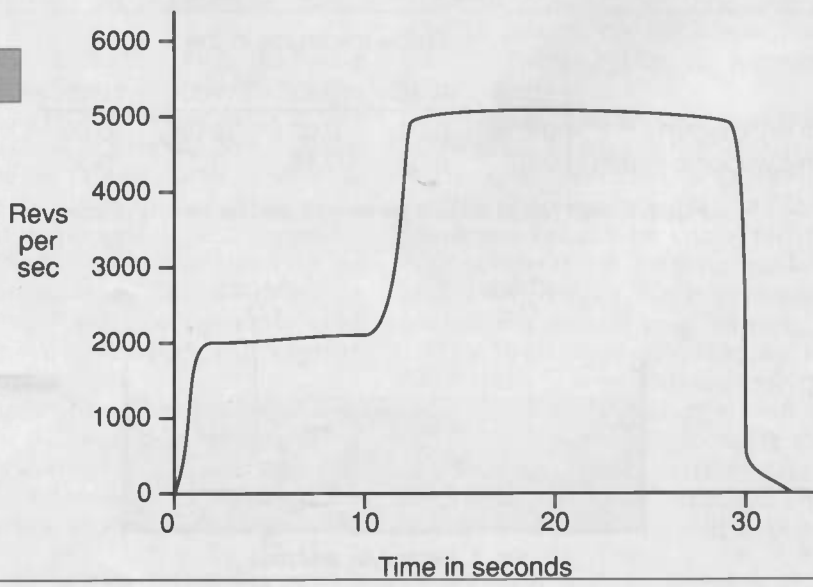


Fig. 7. Wafer clamped to spinner.

Fig. 8. Spin cycle for photoresist application.



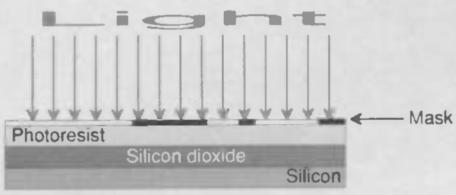


Fig. 9. Contact printing.

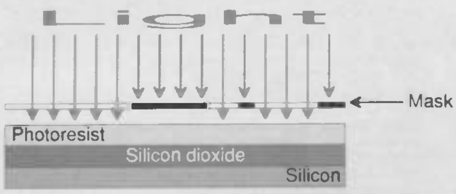


Fig. 10. Proximity printing.

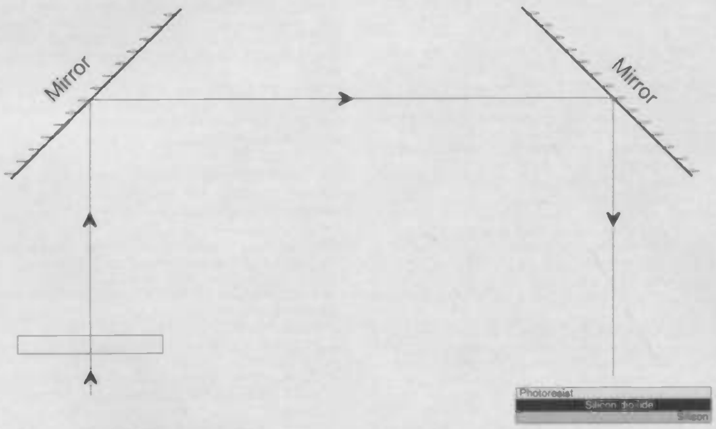


Fig. 11. Projection printer.

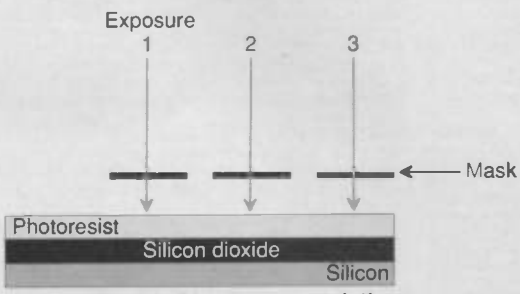


Fig. 12. Direct step-on printing.

However, the projection optics is unable to expose the whole wafer at once so instead an arc shape has to be scanned.

With direct step- on printing, the mask is a magnification of the final pattern, Typical magnifications are five times and ten times though it can be done without any magnification at all, the main feature being the step-on process shown in Fig. 12. Only part of the wafer is exposed each time and the circuit is built up in steps in the horizontal plane according to a grid marked out on the mask.

Xenon flash and the mercury arc lamps give out enough energy to affect most negative photoresists. These would normally react with oxygen so the process is blanketed in nitrogen. Fig. 13 compares the printing processes showing that the direct step-on can print the smallest pattern but also handles the smallest number of wafers per hour.

After printing, the resist is developed by etching the exposed areas, if positive resist has been used, or on the unexposed areas, if the negative resist has been used. The developer can be applied by spraying or dipping. Spraying atomises the developer in the same process as that used in aerosol cans and is less wasteful than dipping.

Once it has finished its work, the developer is rinsed off and if the process has been successful, the edges of the mask will be sharp rather than ragged or blurred. If the develop and rinse processes have been automated then the two cycles overlap slightly so that the developer does not dry out.

Checking It Out

After processing, the wafer is examined either visually or automatically for accuracy of image transfer. Poor specimens are rejected and good ones hard baked to dry any remaining solvent. The temperatures used range from 110C to 130C for 10 to 20 minutes – similar to soft baking but at a slightly higher temperature.

Etching It In

Liquid etching was widely used in the early days of photolithography but these days the need for narrower tracks has seen dry etchants take over. An etchant must be selective in removing only the exposed area and not attacking the photoresist. This selectivity is expressed as a ratio of the etching of the exposed area to the unexposed area and 10:1 is the minimum acceptable.

Of the two mains types available, the isotropic etchant removes material equally in all directions – Fig. 14, whereas an etchant that is anisotropic etches downwards more rapidly than sideways leaving vertical side walls – Fig 15.

Fig. 16 shows some liquid etchants, the materials they are capable of etching, the required temperature and the rate of etching. After the etching, the wafer is rinsed in de-ionised water to stop any further action.

One of the drawbacks of wet etching is the formation of bubbles. Also, dry etching is more suited to anisotropic etching in addition to achieving smaller line widths. Three main types of dry etching are used: plasma, physical and reactive.

In the plasma system, a wafer coated with resist is placed in a chamber. This is then evacuated and the reactive gas allowed in. The type of gas depends on the material being etched – for aluminium it would be a chlorine compounds and for silicon, silicon nitride and silicon dioxide, a fluorine compound. An electromagnetic field is applied to

Printing method	Mask to pattern ratio	Minimum pattern produced (μm)	Wafers per hour
Contact	1	5	60
Proximity	1	4	60
Projection	1	2.5	40
Direct step on	1 to 10	1.25	20

Fig. 13. Comparison of printing precesses.

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HAND GENERATORS as fitted in the above field telephones, this hand generator is a permanent magnet type and has an AC output of approximately 50V depending on how quickly you wind it. If you want a higher voltage then simply connect the output to a transformer. We have lit a 60W bulb quite successfully. The hand generator, complete with handle, £4. Order ref 4P51.

DRY BATTERIES CAN BE RECHARGED, but not with a normal d.c. charger, it must be a periodic current reversal type. We can supply the kit, with data. £9. Order ref 9P10.

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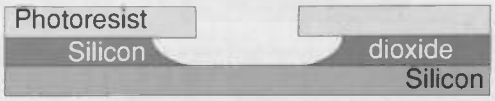


Fig.14. Isotropic etchant

Fig.15. Anisotropic etchant

electromagnetic field is applied to activate the gas and etch away the unprotected parts of the wafer.

Physical etching uses only the physical energy of the gas particles and is also called ion milling. Reactive etching combines chemical etching with physical etching.

Moving On

When the etching process is complete, the resist must be removed completely and, once again, either wet or dry methods can be used. Whatever the method, the aim is to remove the resist completely without damaging the wafer.

Wet processes use solvents like acetone, or sulphuric acid and ammonium sulphate or hydrogen peroxide and sulphuric acid.

Dry techniques use oxygen so that the resist turns into carbon dioxide, nitrogen and water vapour. Once complete, a final inspection is made under a microscope.

Not So Pure

Impurities are introduced into wafers to give them different properties and two main methods are used, diffusion and ion implantation. The first is a process whereby liquids and gases move slowly from an area of high concentration to an area of low concentration. An example is a spoonful of dye colouring a glass of water. The rate of diffusion is called the diffusion coefficient and depends on the temperature of the fluids; since hotter particles have more energy, they move faster.

There are two main stages to diffusion, predeposition and drive-in. In the first case a small amount of impurity is introduced into the wafer after which it is "driven in".

During predeposition, a concentrate of the dopant is placed near the wafer surface and the wafer is heated. The concentrate is absorbed into the wafer until the solid solubility is reached – this is the maximum concentration of dopant possible at a given temperature and is achieved only if there is an excess of dopant at the surface of the wafer.

A typical solid solubility for boron in a silicon wafer is 2×10^{20} atoms per cubic centimetre and for phosphorous in silicon, as high as 9×10^{20} atoms per cubic centimetre at 1000C.

Another important factor in predeposition is the time taken and the thickness of the oxide mask where doping is not required. Fig 17 compares the thickness of silicon dioxide mask required to guard against boron compared to phosphorous. For instance, if the time required is 10 mins then at 1000C an oxide layer of just over 0.02μm is required for guarding against boron whereas a layer greater than 0.1μm is necessary to guard against phosphorous. This follows since phosphorous penetrates much more readily than boron.

Predeposition is carried out in a reactor similar to that used for oxidation. The wafers are cleaned and placed in a boat and then loaded into the reactor. The dopant may be used in solid, liquid or gaseous form. The powder is heated either at one end of the reactor or in a separate reactor – Fig 18. A carrier gas such as nitrogen may be used but a nitrogen-oxygen mixture is often used since oxides of the dopant produce better

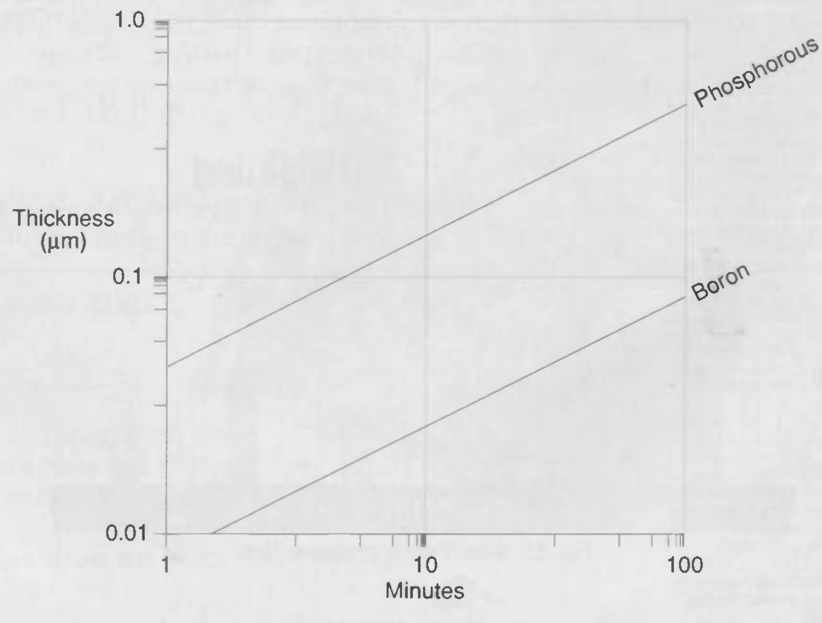


Fig. 17. Silicon dioxide thickness to guard against boron and phosphorous deposition.

Material to be etched	Etchant (ratio)	Temperature in C	Rate of etch in Å/min
Aliminium	Phosphoric acid, acetic acid, nitric acid, water (50:10:2:3)	20-40	2000-6000
Polycrystalline silicon	Potassium hydroxide or HF, HNO_3, H_2O (1:50:20)	20-30	3500-5000
Silicon nitride	Phosphoric acid	160-175	50-75
Silicon dioxide	NH_4F, acetic acid, water (3:3:2)	20-30	1800-2200

Fig. 16. Wet etchants.

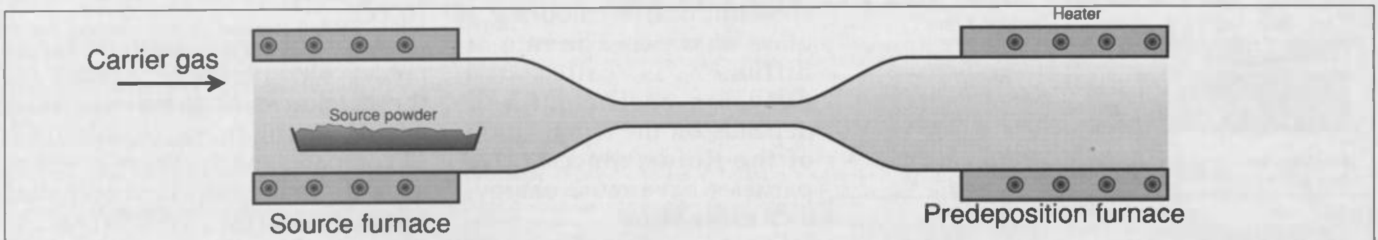


Fig. 18. Predeposition using a powder in a separate furnace.

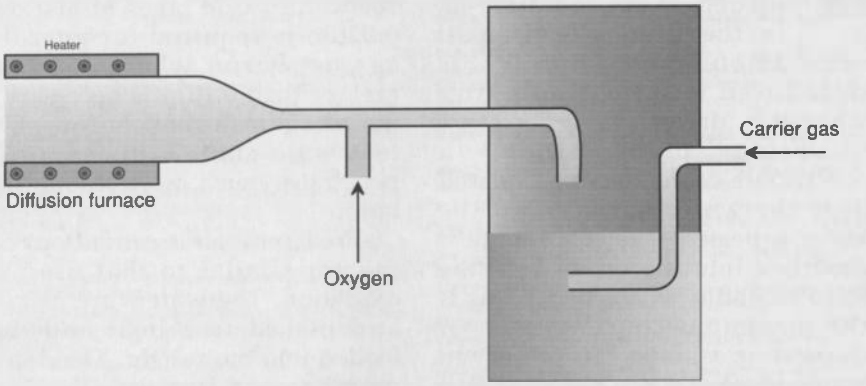


Fig. 19. Liquid predeposition.

predeposition.

Similarly, when a liquid dopant is used, nitrogen is bubbled through it but oxygen is also introduced – Fig 19. It may appear that using a gas dopant would be the simplest of the three choices but some gas dopants could decompose during storage. Also, some of them are toxic and therefore a gas leak could be lethal.

Another method of predeposition employs the layout shown in Fig. 20 where a wafer made of the dopant is used as a source wafer. The recipient wafer is placed a fixed distance away and every source wafer has two recipient wafers facing it.

The next step in diffusion is drive-in to disperse the dopants within the wafer to obtain the required junction depth and diffusion profile. These are controlled by time and temperature.

Ion Blasting

The basic principles of ion implantation are to select ions of the required impurity and impart sufficient energy to them to fire them into the wafer. In order to generate ions of the required type, a gas of the dopant is heated with an electric filament and the ions are separated by bending their paths with a magnetic field – the same method as in a mass spectrometer.

The change in the path depends on the charge and mass of the ions. After separation, the ions are accelerated to strike the target. Two parameters are important here, the energy of the ions and the number of them hitting the target.

The energy is controlled by the electric field and the number of ions by an ion counter. Since both the quantity of the dopant as well as the depth of implantation can be controlled ion implantation is valuable experimental tool as well as a commercial production process. It is used for such things as defining the threshold voltage of field effect transistors, manufacturing more exact resistors and so on.

A big advantage of ion implantation is that it is a low temperature process and so, low temperature photo resists can be used. One of the disadvantages is that ion bombardment can damage the crystal lattice. Fortunately, any damage can be repaired by heat annealing since the wafer can be completely re crystallised above 600C. ■

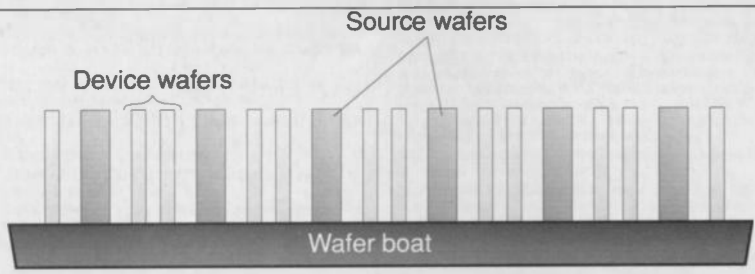


Fig. 20. Doped wafer predeposition.

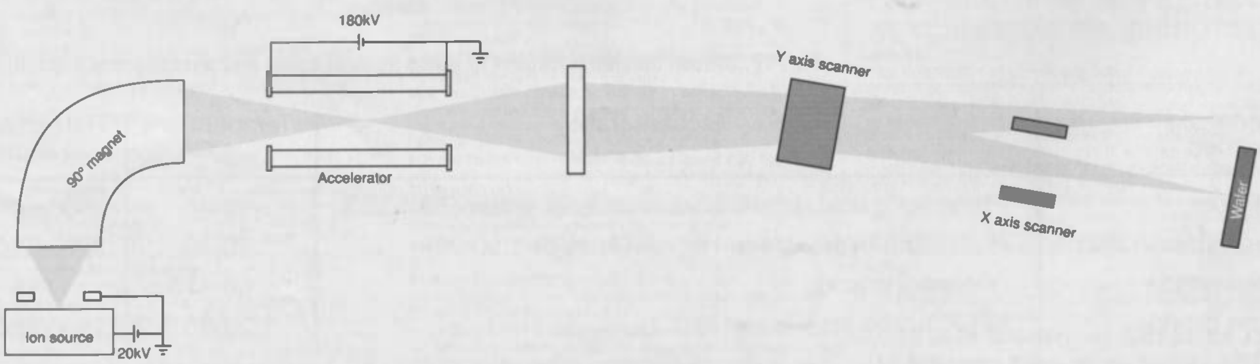
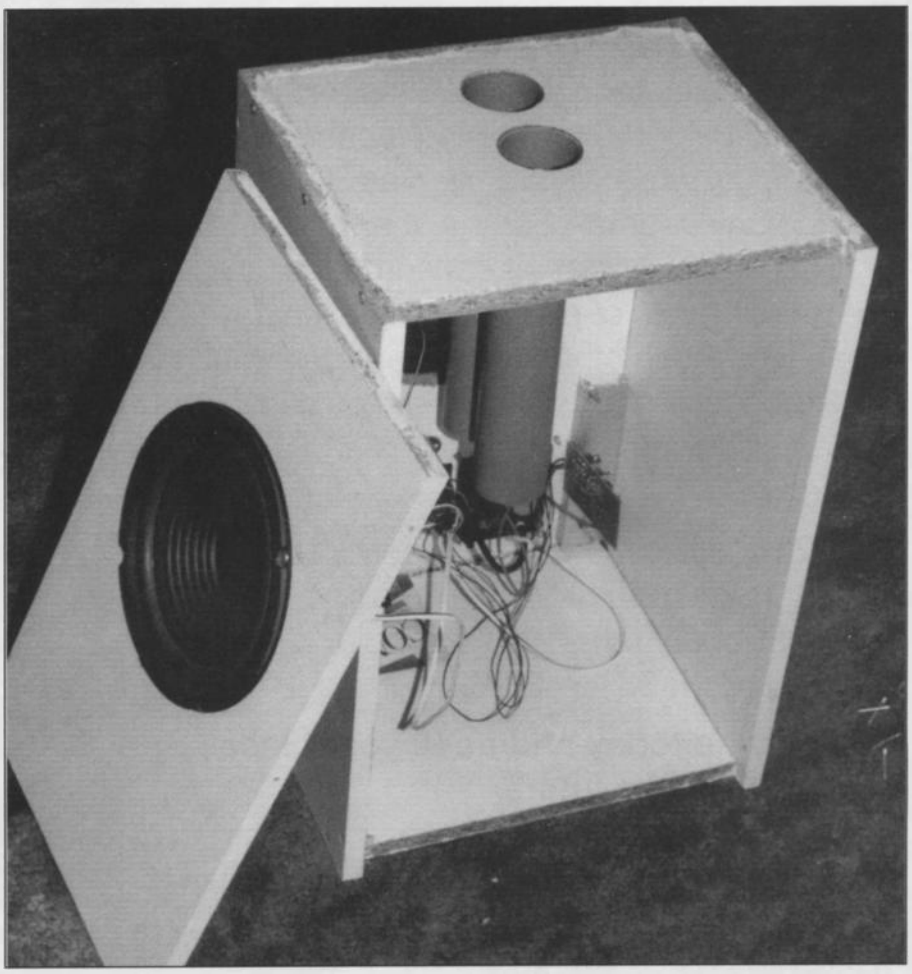


Fig. 21. Ion implanter.

Getting To The Bottom Of Things

Jeff Macauley's latest invention is a sub-woofer that will blow your socks off. Unlike other designs, however, this one fits neatly into a standard speaker case.



Undoubtedly the quality of sound reproduction equipment has improved greatly over the last couple of decades – except in one respect, decent bass response. One of the main reasons for this must be domestic. Using standard design techniques, the cabinet size required to reproduce real deep bass just cannot be accommodated in the average sitting room.

This size problem is probably why most subwoofer designs that have been published either are transmission lines disguised as window seats or simply don't go down far enough. I have probably been spoiled in this respect. I built my first subwoofer in 1978 and have used one ever since. Once the bass response of a system is extended to 30Hz or so, a whole new world of music opens up which is a simply out of reach of 90% of the systems you can buy. The cost however, used to be a 4 cubic foot enclosure dominating the listening room.

What is really required is a small unit which will extend the response of existing speakers down to low frequencies. If you feel your bass is lacking or simply want to feel the music as well as hear it, this project is definitely for you.

Before getting down to the nuts and bolts of the circuit it's probably as well to get some background information into the problems associated with bass reproduction. If the average speaker unit (driver) acted as a massless piston all that would be required to secure good bass would be to mount it into a sealed cabinet. Unfortunately, because the speaker cone has mass and the surround compliance, the mechanical equivalent to electrical capacitance or the inverse of stiffness (the ability to flex), there is a bass resonance with all drivers.

It's bass resonance that ultimately determines the response of the driver and to damp it out properly, the system, driver and box has to be carefully calculated to operate properly. You might ask why the driver needs to be mounted in an enclosure anyway. The reason is that the radiation from the front of the cone is 180° out of phase with that emanating from the back. The result is an acoustic short circuit because the bass from the rear cancels out that produced at the front. This is a natural consequence of the long wavelengths of bass signals, the result being that the speaker is not large enough to cause an obstruction at low frequencies.

Until relatively recently, the design of speaker enclosures was a bit of a hit and miss affair. This has now changed due to the pioneering work of Theile and Small. Given the driver's basic parameters, resonant

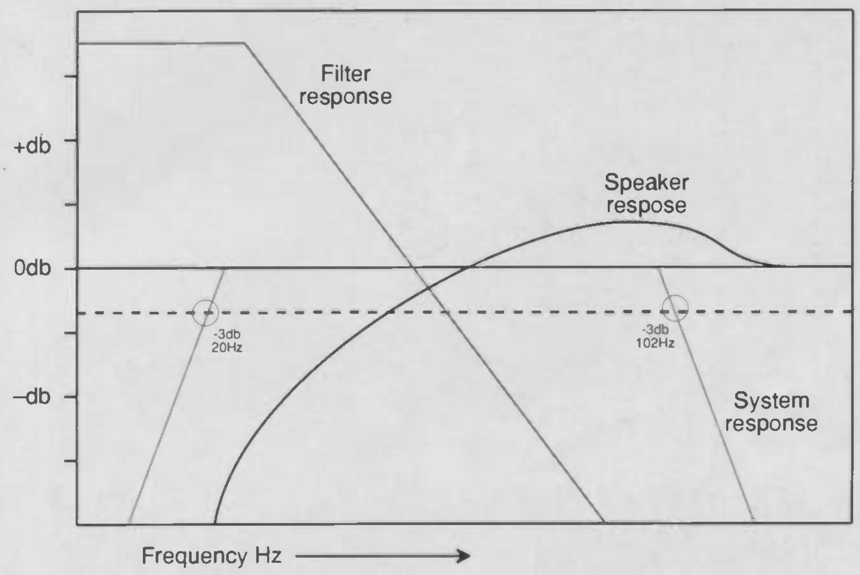


Fig. 1. The frequency response of the sub-woofer.

frequency fs, the Q of this resonance, Qts, and the equivalent air volume to the compliance of the surround, Vas, the response of a speaker in the bass region can be accurately calculated. The basis of this is the similarity of the bass response of a speaker to that of high pass electrical filters. The behaviour of which has been well understood for decades.

When a driver is fitted into a small airtight case, the resonant frequency rises because of the extra stiffness of the enclosed air. Below the resonant frequency, the response looks like that of a second order high pass filter with an ultimate 12db/octave roll-off. Therein lies the rub for domestic audio systems. Most speakers comply with the above description and suffer from compromised bass as a result.

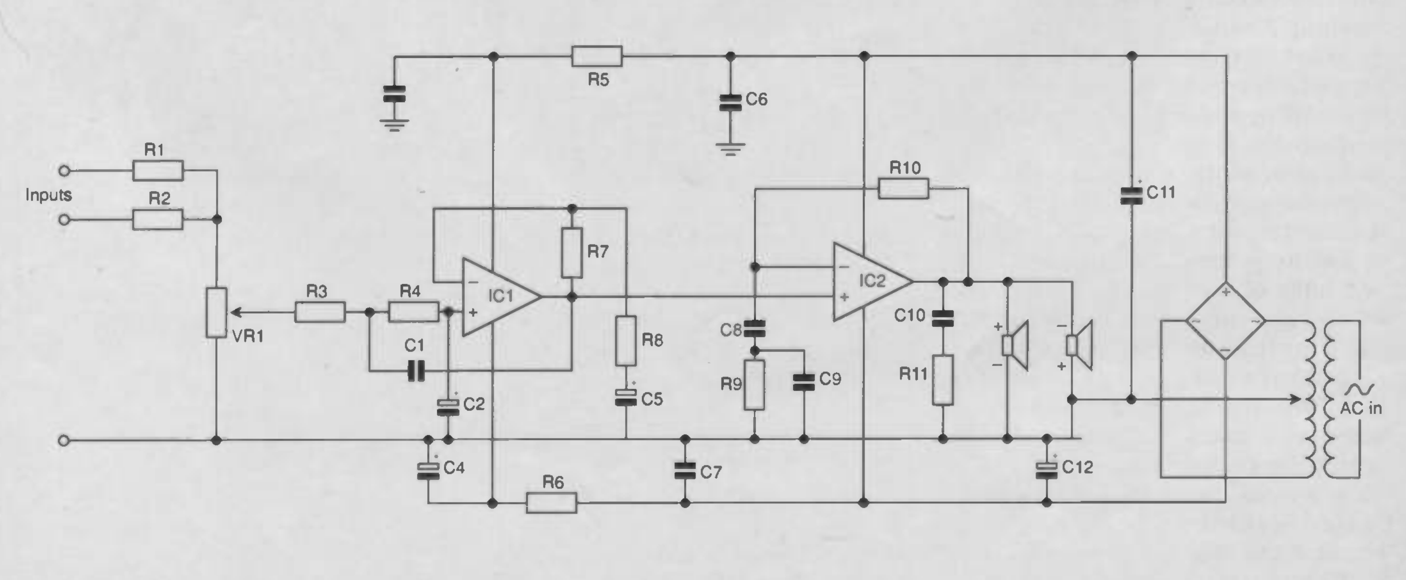
Less common is the bass reflex enclosure. Here a vent or duct is inserted into the case and acts as a Helmholtz resonator. That is, the stiffness of the air in the enclosure resonates with the mass of the air in the vent to produce a mechanical tuned circuit. The result is that over a small range of frequencies, the bass radiated from the rear of the cone is phase inverted and radiates from the port. This is an efficient system which, when properly designed, can extend the bass response of the driver. However, it suffers from some disadvantages. The enclosure size, vent length and diameter as well as the speaker parameters already mentioned must be considered in the design.

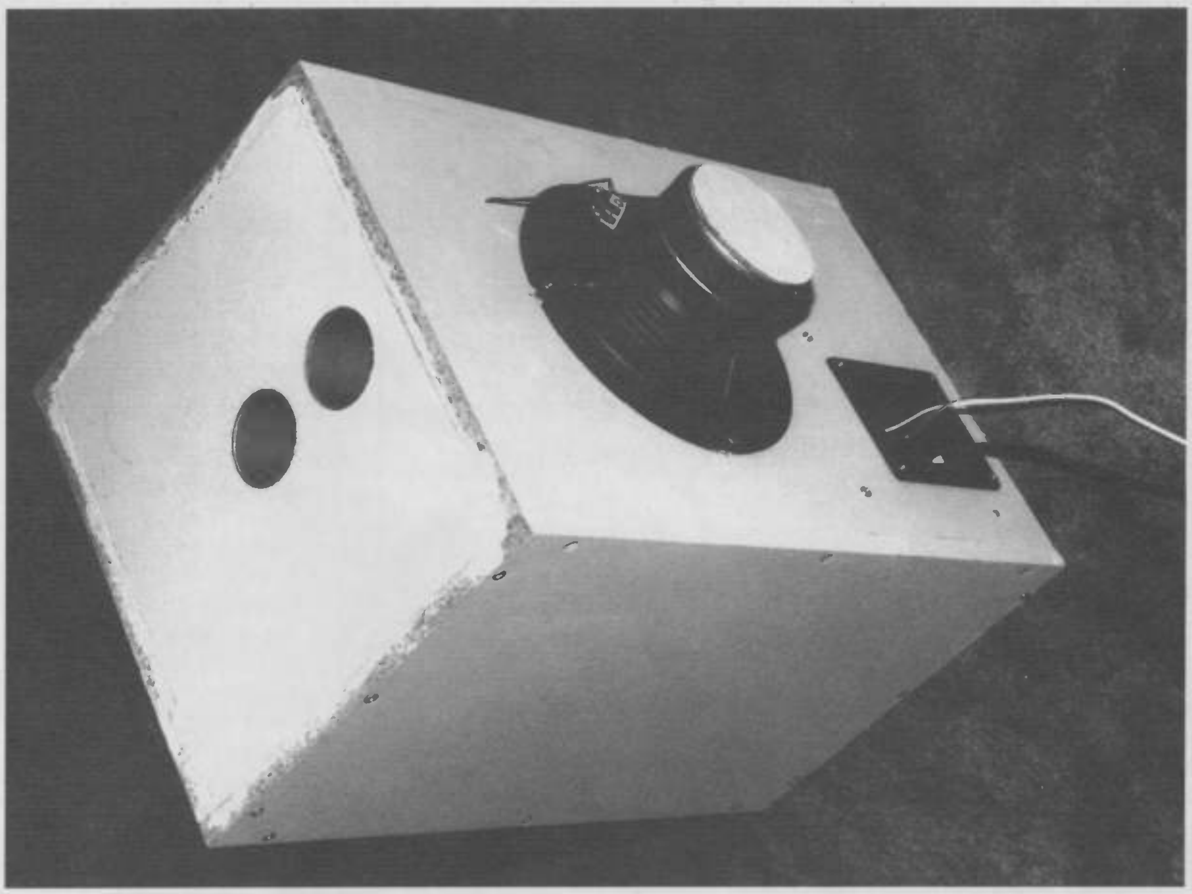
In addition, the reflex enclosure operates as a fourth order filter below resonance which compromises transient response. The result is that for any given driver, there is one and only one optimum sized enclosure. Usually prohibitively large. Another solution is to use a sealed enclosure together with a low pass filter. Again, if properly designed, the filter and enclosure combined operate as a bandpass filter in the bass region. The main difficulty with this is that below resonance the driver's motion is dominated by the cone surround resulting in large amounts of second harmonic distortion.

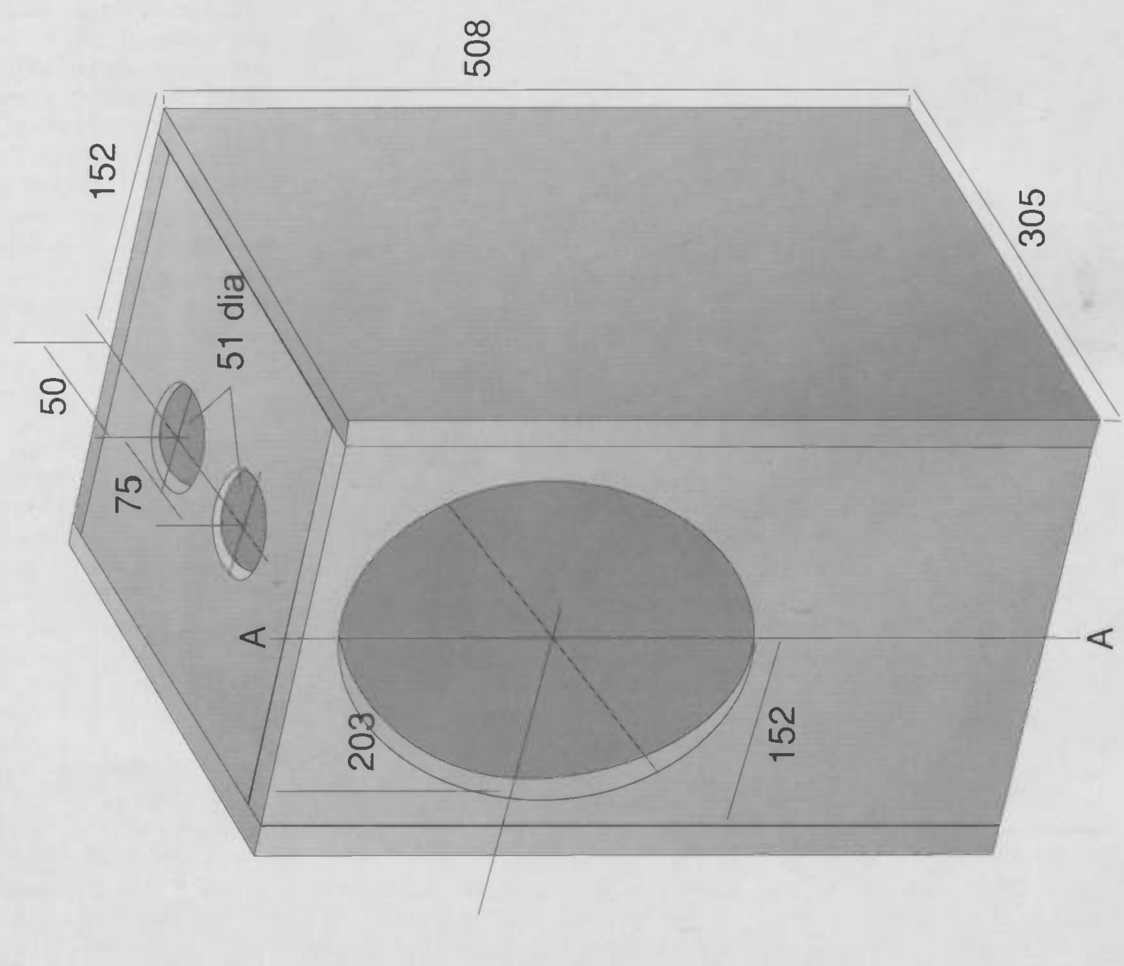
In practice, this is less of a problem than it appears. The ear can just detect 40% total harmonic distortion (thd) at 40Hz in the presence of program material. In this necessarily brief tour de force of speaker design, two other types of enclosure need mentioning. First, the active, filter assisted reflex enclosure. Here an auxiliary filter is added to a bass reflex enclosure to extend the bass response and reduce the required cabinet size. This works very well but, again, there is only one viable solution if optimum results are to be obtained.

Lastly there's the now venerable transmission line speaker. These are

Fig. 2. The circuit diagram.



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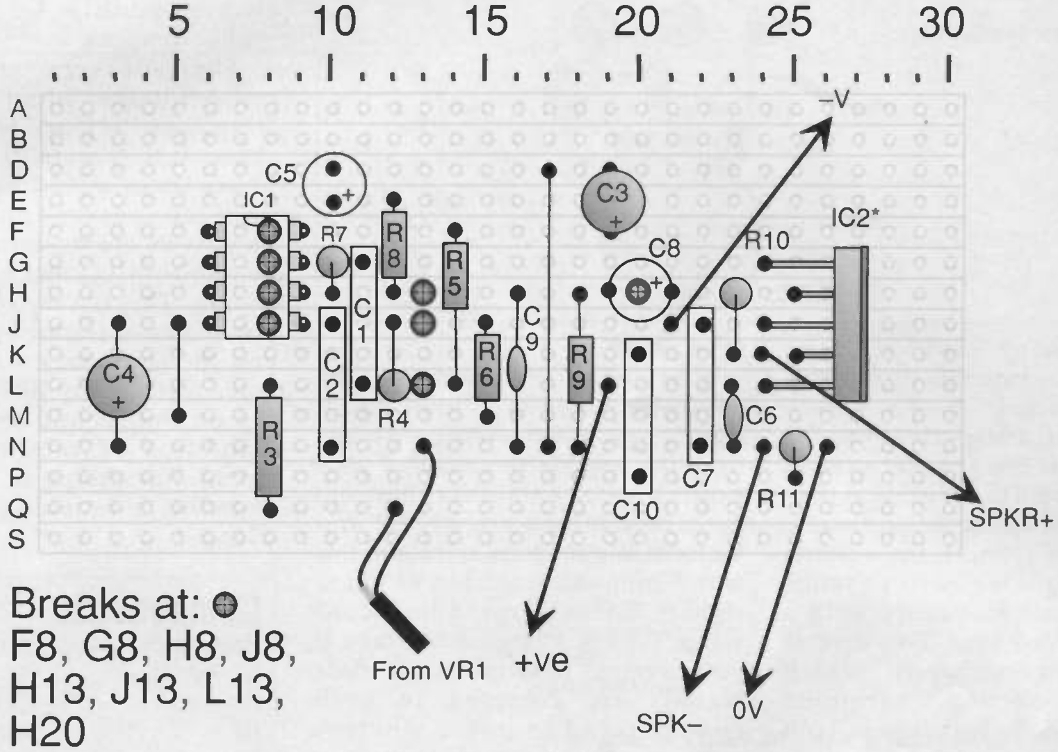


The stripboard layout.

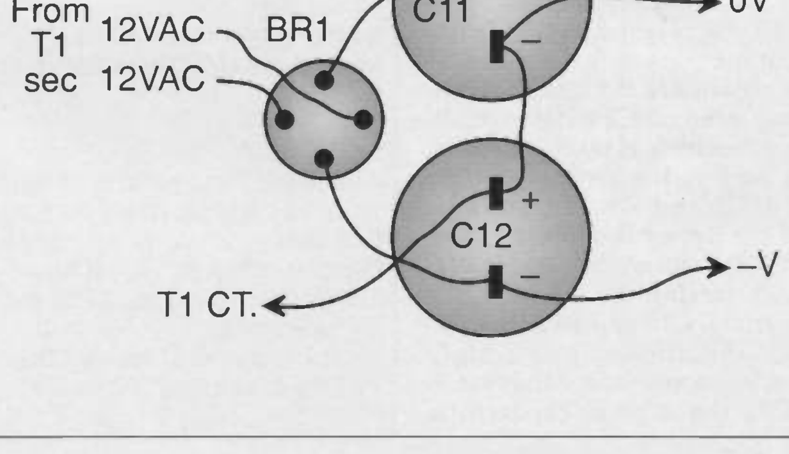
extremely good at reproducing deep bass but are large and unwieldy. Essentially, the bass from the rear of the driver is fed into a stuffed pipe. The stuffing both damps the speaker's natural resonance and slows the sound wave down making the pipe appear to be longer than it actually is. However, most designs have pipes at least seven feet long, folded to make them more manageable. The system acts as a highly damped organ pipe.

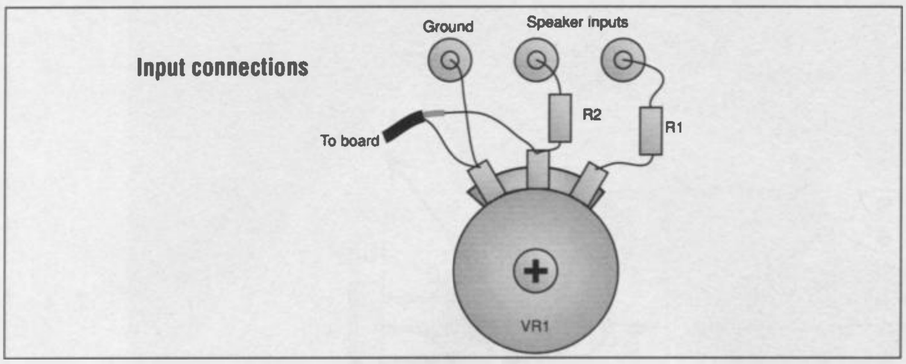
Where does this leave us? At first sight more or less where we started except that there is another method which I discovered more or less by accident. If you design a reflex enclosure with a cabinet much smaller that the optimum predicted by theory, a surprising thing happens. The phase relationship between the vent radiation and the speaker's direct output is altered so that the vent operates over a wide range of frequencies. The system response becomes that of a second order filter, that is, a closed box.

The small cabinet reflex has the advantage of superior transient response compared with a standard reflex design due to the slower rate of roll-off. The problem remains though that the response is falling but it's a simpler matter to design a suitable equalisation to render the system response flat. Here I've use a low-pass filter which produces a bandpass filter response in conjunction with the speaker system's high-pass effect.

This is illustrated in the graphs in Fig. 1 which show that the vent is still augmenting the drivers output down to around 10Hz before the characteristic rapid roll-off expected from a reflex system occurs. Full range systems have also been

Power supply connections.





produced using Linkwitz type filters and the system is subject to a patent application.

In our particular situation, the bandwidth of the speaker system extends from 20Hz to 102Hz at the -3db points. The case, or enclosure, is a domestic 1.4cu.ft, the volume being based on the need to reflex down to a low frequency with a reasonable sized vent. Two drivers are used in push-pull which eliminates second harmonic distortion and the two drivers, both 8in in diameter, operate as a single unit with a 12in diameter. Because both are connected electrically in parallel, the sensitivity is high at around 94db/W.

Circuit

The full circuit diagram is shown in Fig. 2. Before discussing this in detail a word is in order about the devices chosen. The audio amplifier is a TDA2030 chip. This is capable of delivering 21W into the speakers at full tilt and is enough to drive the speakers to their safe excursion limit – contrary to popular belief, the power required to take the speaker to maximum excursion gets smaller as the frequency is decreased and this has to be taken into account in the design. In its operating range, total harmonic distortion (thd) is less than 0.1%, the signal to noise ratio (SNR) is good and generally the device does a competent job. What more could you sensibly ask? The transient response of a moscode amp would be wasted where the frequency range is so restricted.

The required equalisation demands a low-pass filter with a second order roll-off and a Q of 0.6. A TL072 dual op-amp has been utilised in this design. Only one half has been used but the pin out of the device makes for much simpler layout than if a single op-amp were to be used.

Looking at the schematic, the device operates as follows. Input signals for the sub-woofer are taken from the speaker terminals of your existing stereo amplifier. These are passively mixed via R1, R2 and VR1. Mixing the bass signals in this way eliminates large out of phase signals that are caused by record warp. This is a large advantage if your system is vinyl based. Bass signals are common to both channels and in phase whereas these unwanted signals appear in antiphase at the cartridge terminals.

Of course, if your system is CD based this will not be a problem. Some HiFi pundits suggest that phase information is important at low frequencies. However, unless your ears are a couple of metres apart, it's unlikely that you will hear any. On the other hand, if the thought of missing something bothers you, why not make two subwoofers, one for each channel? Anyway, I digress. The signal from the slider VR1, the gain control, is fed into the low pass filter.

This is formed by IC1 and its associated circuitry. R3, R4, C1 and C2 determine the operating frequency whilst the ratio of R7 to R8 sets the filter's Q. R5, R6, C3 and C4 form decoupling circuits ensuring stability. Because a dual power supply is used, the bias voltage and input signal for IC2, the TDA2030, is taken directly from IC1's output.

The signals are fed into the non-inverting input of IC2 whilst overall negative feedback is taken from the output back to the inverting input via R10, C8 and R9. The voltage gain of the device is defined as the ratio of R10 to R9 whilst C8 acts as a DC block forcing the device's DC gain to unity. C10 and R11 provide a load for the amp at high frequencies to maintain stability. C6 and C7, the 100nF capacitors mounted close to the chip, also ensure stability. C9 performs a similar function.

The speakers are directly coupled to the output of the amp. Note that they are wired out of phase. If they were to be wired in phase there would be no output from the speaker system because the drivers are mounted to operate in push-pull. Lastly, the power supply. This is very conventional. The mains is stepped down by T1 and the secondary voltage is full wave rectified by BR1. The centre tap on the secondary is used to provide a 0V reference for the circuit. Smoothing of the raw DC from BR1 is provided by C10 and C11. ■

Components

Resistors 1% Metal Film

R1, R2, R5, R6	1k
R3, R4	56k
R7	3k3
R8	10k
R9	2k7
R10	100k
R11	1Ω
VR1	1k log pot

Capacitors

C1, C2, C7, C10 polyester	100nF
C3, C4, C5, C8	100µF 25V elect
C6	100nF ceramic
C9	1nF ceramic
C11, C12	4700µF 16V elect

Semiconductors

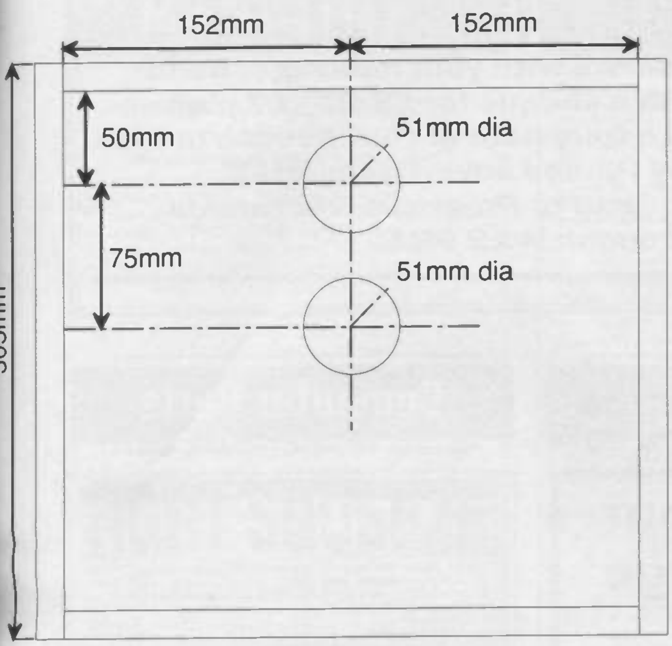
IC1	TL072
IC2	TDA2030
BR1 bridge rectifier	200PIV, 1.5A

Miscellaneous

T1 240VAC primary, 0-12, 0-12VAC secondary at 2A
Stripboard 15 strips by 30 holes
Recess plate
4mm or similar input sockets
Matched pair of 200mm Woofers, see text

Cutting list

4 lengths of 20in by 12in by 15mm veneered chipboard (sides, front and back panels)
2 lengths of 12in by 10.75in by 15mm veneered chipboard (top and bottom panels)
Vents 2 lengths of 51mm diameter PVC drainpipe tubing 290mm long



Design: Sub-woofer
Scale: 1:4
19th March 1992
Author: Jeff Macauley
Drawn by: K Garroch

A full designer approved kit for this project (minus wood panels) is available from:
Hobtek
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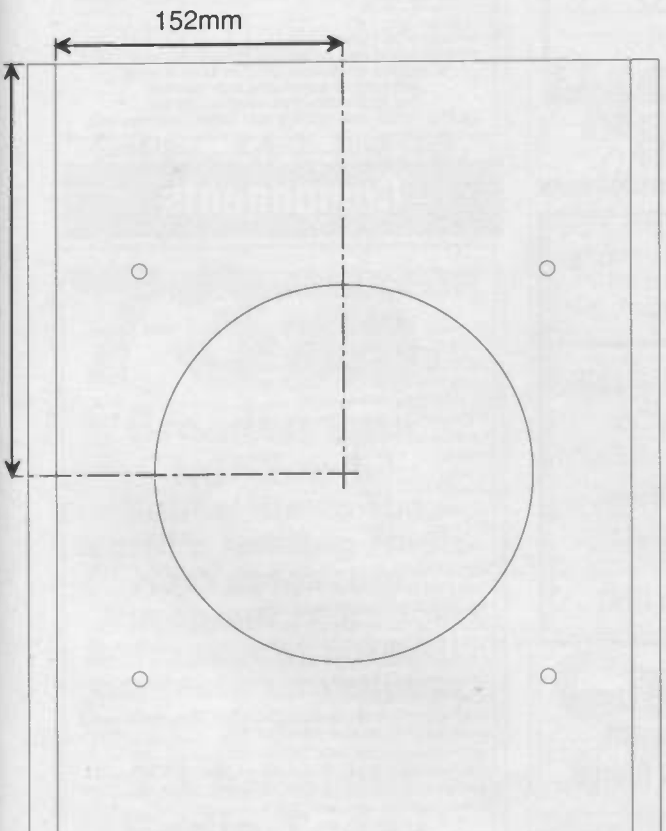
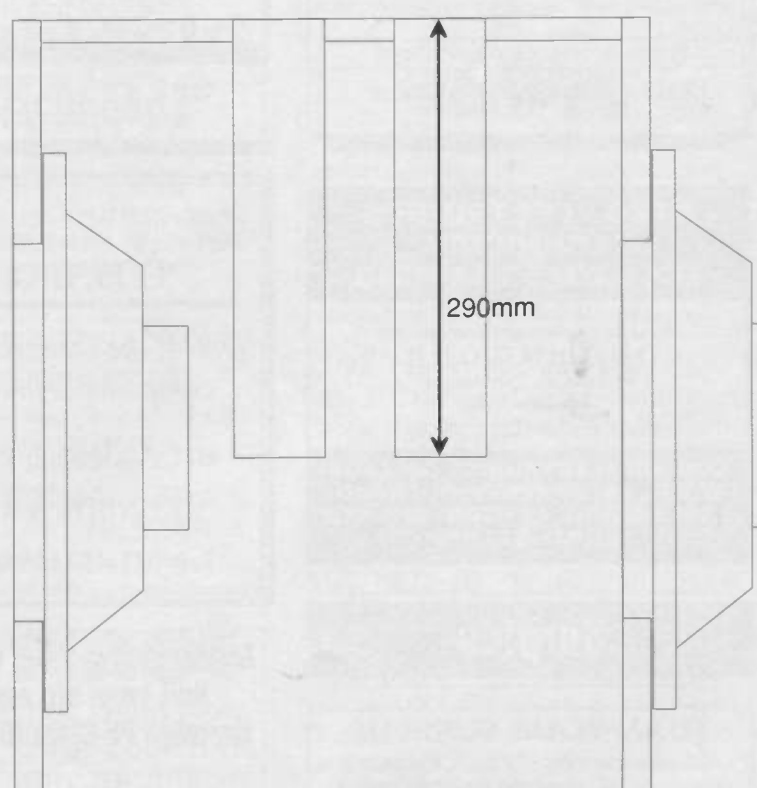
The kit price is £89.99 inclusive. Matched pairs of speakers can be obtained from the same source for £59.99 inclusive.





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Advertising Index

Techniques

Need an infra-red headphone link? Andrew Armstrong describes how it's done.

This month's query comes from reader David Williams in Monmouth who says: "I have seen the advertisements for infra-red cordless headphones. Is it difficult to build this kind of thing? Have you any suggestions how I should start?"

Infra-red cordless headphones normally work with a frequency-modulated squarewave infra-red signal. Most of those advertised seem to be monophonic and they use a single frequency, normally in the range 50 to 100kHz.

If stereo signals are to be transmitted, two modulating frequencies would be used, rather than one, but a single receiver diode would still be adequate.

Starting at the beginning, the circuit shown in Fig. 1 generates a frequency-modulated squarewave which is used to switch three infra-red leds in order to generate an adequate amount of power for a reasonable range.

The audio input signal, assumed to be at approximately line level, is AC-coupled to a volume control and then fed to an op-amp giving a voltage gain of approximately four. The output signal from the op-amp is fed via a (possibly superfluous) protection resistor to the frequency control input of the VCO (Voltage Controlled Oscillator) section of a 4046 phase-locked loop chip. This is set to a centre-frequency of approximately 70kHz.

The squarewave output is used to drive a small power FET which switches the current to the infra-red emitters. Three are shown in this circuit, but more may be used if more output signal is required. Almost any small power FET will do the job: VN46, VN66, most HEXFETs will all be suitable. If only two or three LEDs are required in the circuit, then a VN10 may be powerful enough.

This circuit should present few problems. The only point requiring special attention is that the earthing and decoupling must be commensurate with the sharp pulse currents drawn by the output stage. The decoupling capacitor should be near to the 4046 and it may be found necessary to add a small resistor, say 10Ω, in series with the power connection to the 4046, and then to add extra decoupling across its supply pins. Ground-plane construction would be ideal for this circuit.

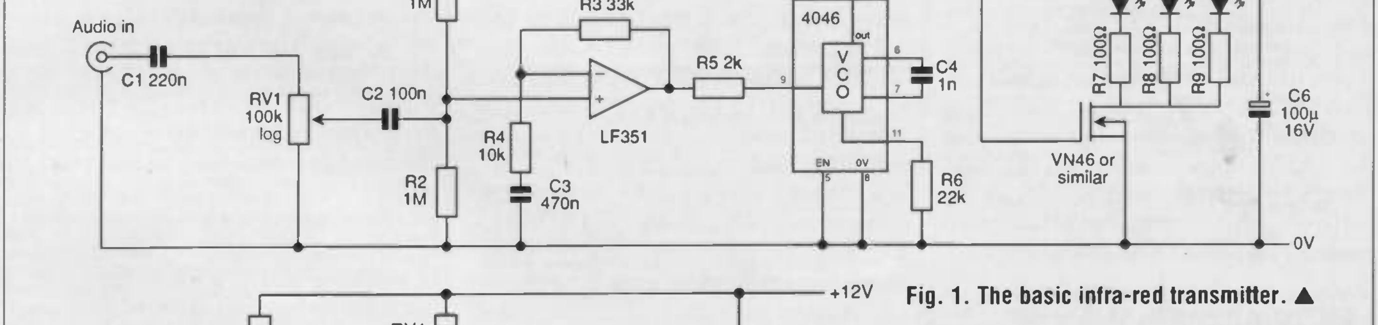
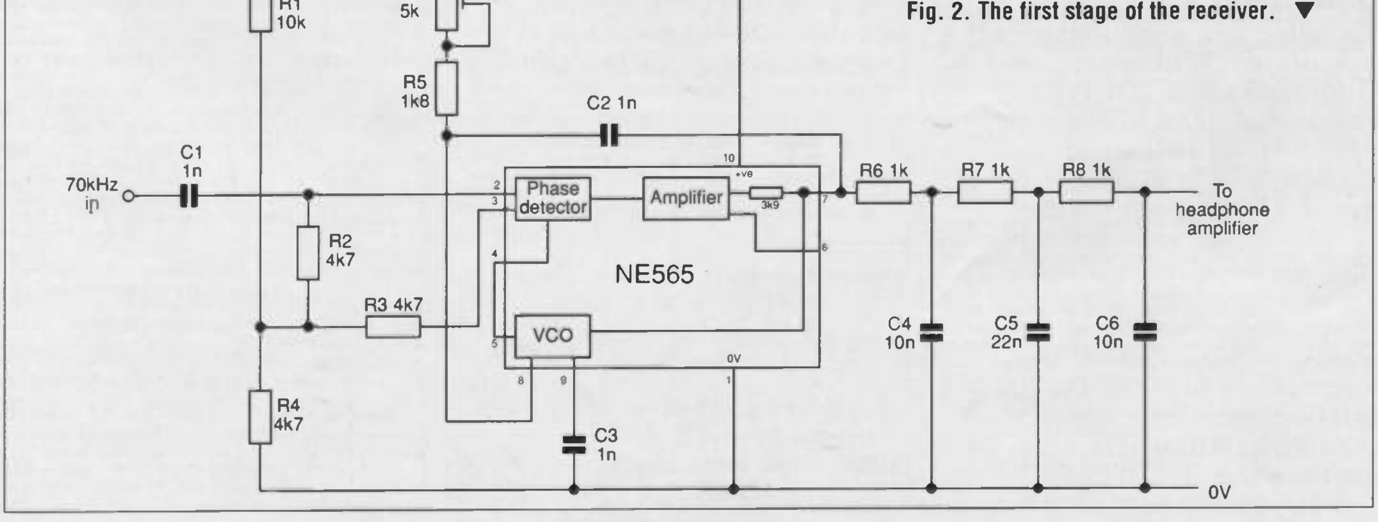


Fig. 1. The basic infra-red transmitter. ▲

Fig. 2. The first stage of the receiver. ▼



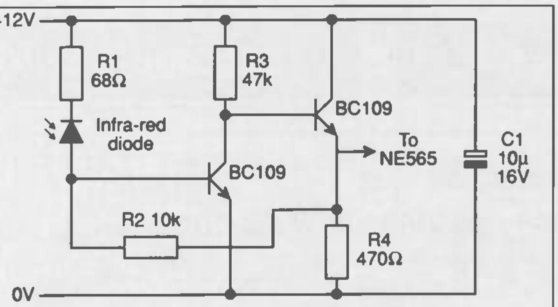


Fig. 3. Current to voltage convertor.

Demodulation

To demodulate the FM signal, another phase-locked loop is used. A 4046 could have been used for this job, but the NE565 is specifically intended for the task and is more linear. The demodulator circuit is shown in Fig 2.

The input signal is fed to the phase detector via a low-value capacitor to filter out any low-frequency noise that may be present. The phase detector inputs are biased by R1, R2, R3 and R4. Note that the signal inputs of the phase detector are differential, but only one half is used in this design.

The VCO is fed straight to the other half of the phase detector. The control signal for the VCO is connected internal to the chip. The frequency is set by RV1, R5 and C3. The demodulated audio output is filtered to remove unwanted high frequencies and is then fed to a headphone amplifier. Any conventional low-power amplifier design can be used as the headphone amplifier. For example, the LM386 power amp IC is ideal for the purpose, and readers can follow the application note normally provided with the chip.

Receiving

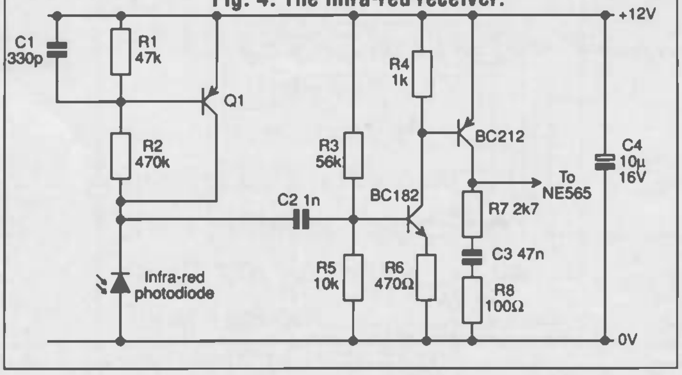
Reception and amplification of the modulated 70kHz infra-red is slightly more tricky, because the signal from the photo-diode will be of a low amplitude, and because most low-cost op-amps will not give usable gain at that frequency. For this reason, discrete transistor designs are required. Figs. 3 and 4 show two possible alternatives to serve as a starting point for experimentation. It is emphasised that these circuits, in common with all Techniques designs, have not been prototyped, and may require some experimentation to make them work as intended. This is more true of analogue circuits than of digital ones.

The circuit of Fig. 3 is effectively a current-to-voltage converter, working on the current in the photo-diode. The bias point of the circuit is stabilised by the feedback resistor which also sets the gain, in this case 10 V/mA. It may be found by experiment that extra gain is required to achieve the desired range, in which case the amplification part of the circuit of Fig.4 might be suitable. If this is to be used as a second amplifier stage, the signal should be fed in via the 1nF capacitor C2.

The circuit of Fig. 4 converts the output of the infra-red photodiode to a voltage directly and then amplifies the voltage. The diode is biased to approximately half the supply voltage by Q1. The collector voltage is set by the base-emitter voltage, and the ratio of R1 and R2. In order to allow the voltage to vary at the signal frequency, the base is decoupled via C1, so that the gain of the circuit starts to fall off at around 10kHz.

The signal from the photodiode is amplified by a fairly conventional two-transistor amplifier, whose voltage gain is set by the feedback network comprising R7, R6, R8 and C3. The DC gain is approximately 6, while the AC gain is increased by R8 and C3 to approximately 30 at the signal frequency. The resistor values are calculated to bias the output to approximately half the supply voltage, but the value of R3 may need to be altered by experiment if the correct output voltage is not at first achieved. In any event, a 12 V supply is shown for this circuit, and if another voltage is considered more convenient, then values must definitely be recalculated.

Fig. 4. The infra-red receiver.



Setting Up

If an oscilloscope is available, the first thing to check is that the circuit of Fig. 1 is providing a squarewave somewhere in the range 50 to 100kHz, whose frequency is varied by the input signal. Failing this, an AC voltmeter coupled via a capacitor can indicate the presence of a signal, even if the voltmeter is not efficient at 70kHz.

Assuming that the frequency modulated signal is being generated correctly, the next step is to test the demodulator by joining the 0V lines of the transmitter and the demodulator together, and coupling the output signal from the VCO to the NE565 via a 10 to 1 resistive attenuator. Measure the voltage on pin 7 of the NE565 while adjusting RV1, and set RV1 so that the voltage is in the middle of its range of variation. Then, apply a signal to the audio input of the transmitter, and check that the demodulated audio is present on the output of the demodulator.

When the transmitter and demodulator are working, the photodiode and receiver preamplifier should be connected to the receiver, and tests carried out to optimise the preamplifier performance to achieve a reasonable range. Even if the circuit is working badly, a very short range should be attainable, and component values can be adjusted to improve this.

If a stereo headphone unit is required, two transmitters and two demodulators are required, but the preamplifier and detector diode can be common. Widely differing and non-harmonically related frequencies should be chosen to avoid cross-channel interference.

The sound quality from this design should be very good, though it will probably fall short of strict hifi quality. ■

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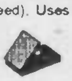

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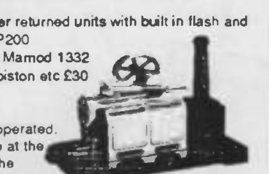

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Continued from page 54

program told me this was far too much, and a waste of memory. The software still froze and crashed.

By contrast the Guardian on CD-ROM is a dream to use. But it took the makers, Chadwyck-Healey of Cambridge, a long time to get there. The first discs the company released, a patent database, were a nightmare to use, with the sales team clearly trained to sell paper and hopelessly out of their depth on ROM publishing.

The publishers of the Indie disc, Bowker-Sauer, and people on the Indie now acknowledge that I am by no means the only user to throw up my hands in horror and give up trying to use their ROM. But no attempt seems to have been made to warn potential customers. Is it any wonder that CD-ROM remains a great missed opportunity?

CD-ROM cannot become the consumer product which the Frost and Sullivan report predicts until the industry grasps the consumer principle of "buy and play" or "plug and go". Any CD-ROM disc then plays on any drive, without the need to make any adjustments or modifications to the controlling PC.

So far there is only one company with a "plug and go" policy on CD-ROM, and that is Nimbus. Often working for third party publishers, Nimbus produces most of the CD-ROMs available in this country. Wherever possible, the ROM disc contains all the search software needed to use the information stored on the disc. No installation is needed.

The long term answer may well be a standalone ROM system, like Sony's Data Discman. This has the search software permanently stored inside, on ROM chips. The discs or Electronic Books carry no software, so there is no installation and no setting up to be done. DD is a true buy-and-play system.

But publishers are not anxious to invest in mastering electronic software for a format which sold like hot cakes in Japan during its first six months and much less well in the USA. Data Discman works well but the small monochrome LCD screen is very hard to use. The publishers were thus reassured by Sony's pledge to make Electronic Books compatible with the CD-I consumer interactive CD system which Philips has now launched in the USA and will launch in Europe this summer.

But Sony has not yet honoured this pledge. When Data Discman is launched in the UK this April, the Electronic Books launched with it will not be compatible with the CD-I players in the pipeline from Philips. ■

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GT 316	386SX 16MHz DESKTOP CASE	2 Mb	8 Mb	●	5 (4×16-bit 1×8-bit)	21 MHz	387SX-16	PARADISE	256K RAM	16 Colours	16 Colours	N/A	£599 +VAT=£703.83	£699 +VAT=£821.33	£799 +VAT=£938.83	£999 +VAT=£1173.83	£1299 +VAT=£1526.33
GS 318	386SX 20MHz DESKTOP CASE	2 Mb	8 Mb	●	5 (4×16-bit 1×8-bit)	25 MHz	387SX-20	PARADISE	512K RAM	256 Colours	256 Colours	16 Colours	£699 +VAT=£821.33	£799 +VAT=£938.83	£899 +VAT=£1056.33	£1099 +VAT=£1291.33	£1399 +VAT=£1643.83
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