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ELECTRONICS and Beyond

The race for the best flat screen technology is on. With so many new developments out there it is difficult to see which one will eventually become the de facto standard say for TV. Part of that race is determined by factors such as speed to market and retail price. This time though there may not be a 'standard' that wins through as it may be a case of 'the most appropriate technology for the job'. The characteristics demanded for mobile phone displays and head-up displays are different from that required for PC monitors and car dashboards which again might be different for TV displays and cinema screens. If it emerges that one particular type of display is extremely flexible and versatile on display size, resolution and current consumption then it could equally be incorporated in all of these consumer items. Our article by Reg Miles on flat screen technology highlights the current rapid developments going on.

Superconducting power cables are now being constructed for use in the electrical power industry. Despite the practical problems of keeping the cables at low (liquid nitrogen) temperatures throughout, the benefits of zero power loss in transmission lines continues to make the idea of using these cables, an attractive one. Superconductivity was first discovered in the early part of the 20th century, but the real excitement began in the 1980s when higher temperature superconductivity was observed in exotic ceramic compounds. Now superconducting cables are being made, the first real world three phase High Temperature Superconductor (HTS) trial is expected to begin this summer in Detroit, US. Martin Pipe reports on this interesting development in Technology Watch.

Paul Freeman-Sear

Britain's Best Magazine for the Electronics Enthusiast

NEWS REPORT

Home Network Technology for 2001

Numerous early wireless home networking products have appeared in the last year or so, however, none of these have fully met the needs of the home market.

The technology is typically expensive, difficult to configure and reception from room to room is often poor.

Towards the second half of this year, products that incorporate technology from ShareWave will be the first that can transmit multimedia wirelessly throughout the home at 100Mbps.

For further details, check: <www.sharewave.com>.

ibrite Announces Availability of Palmtop-Publishing Software

ibrite has announced the availability of powerViewer, a Windows PC-based tool that converts Microsoft PowerPoint 2000 presentations into a format that can be easily viewed on a Palm-OS handheld computer.

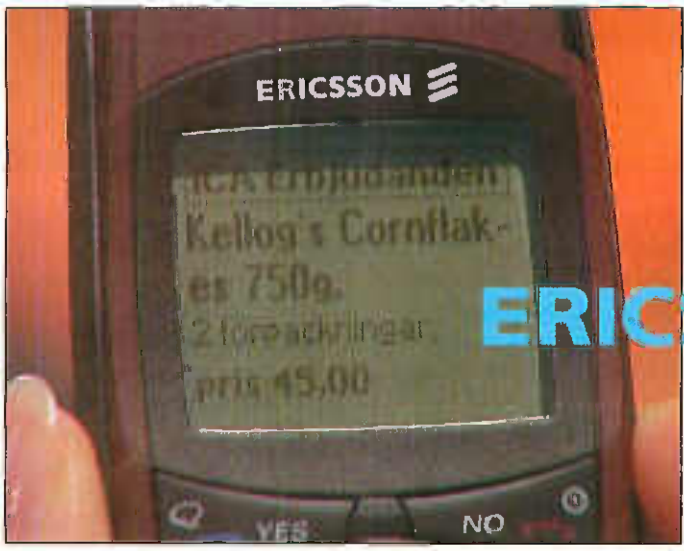
With powerViewer, presentations can be viewed in any location where using a conventional PC or laptop would be impossible or inconvenient. PowerPoint presentations can be easily transferred via hot-sync connection or handheld beaming of information.

For further details, check: <www.ibrite.com>.

Rio 800 Completes MP3 Family

The Rio 800 has joined the Rio 600 and Nike 60 and 120 to round off the Rio family of portable digital audio players. The Rio 800 offers up to two hours of music storage, a voice recorder, rechargeable battery, remote control and works with a selection of other Rio accessories such as an FM tuner and a car cassette adapter.

For further details, check: <www.riohome.com>.



Swedish Consumers Try Buying by Mobile

Ericsson and ICA Ahold, one of the Nordic region's leading retailing group, have conducted the world's first trials with Bluetooth wireless technology in retail stores.

The purpose of the trial has been to test payments and payment related services for customers and to test Bluetooth wireless technology for communication in retail store environment.

Using mobile phones equipped with WAP and Bluetooth technologies, customers have been able to pay for goods, check their account status and find out about current offerings.

For further details, check: <www.ericsson.se>.

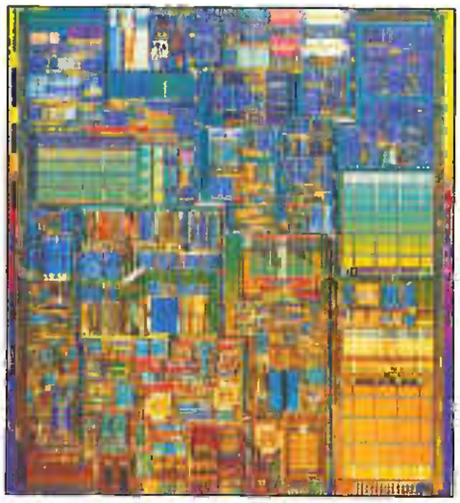
Intel Develops Smallest, Fastest CMOS Transistor

Intel researchers have achieved a significant breakthrough by building the world's smallest and fastest CMOS transistor.

This breakthrough will allow Intel within the next five to 10 years to build microprocessors containing more than 400 million transistors, running at 10GHz and operating at less than one volt.

The transistors feature a structure just 30 nanometres in size and three atomic layers thick. Smaller transistors are faster, and fast transistors are the key building block for fast microprocessors, the brains of computers and countless other smart devices.

These new transistors, which act like switches controlling the flow of electrons inside a microchip, could complete 400 million calculations in the blink an eye or finish two million calculations in the time it takes a speeding bullet to travel one inch.



Scientists expect such powerful microprocessors to allow applications popular in science-fiction stories – such as instantaneous, real-time voice translation – to become an everyday reality.

For further details, check: <www.intel.com/research/silicon>.

NEWS BYTES

IBM and Infineon to Advance Memory Technology

IBM and Infineon Technologies are to jointly develop a memory technology that could significantly increase battery life of portable computing devices and lead to instant-on computers.

The two companies have signed an agreement to collaborate in the development of Magnetic Random Access Memory (MRAM), which uses magnetic, rather than electronic, charges to store bits of data.

MRAM may significantly improve electronic products – from computers to mobile phones to game systems – by storing more information, accessing it faster and using less battery power than the electronic memory used today.

MRAM also retains information when power is turned off, meaning products like personal computers could start up instantly, without waiting for software to boot up.

For further details, check: <www.chips.ibm.com>.

Intel Wafers Made in Ireland

Intel has announced that its new wafer fabrication facility currently under construction in Leixlip, Ireland, will begin production in 2002 using state-of-the-art 300mm manufacturing technology.

The project, announced in June 2000, was originally planned as a 200mm wafer fabrication facility. The new Irish fab will be Intel's second production fab dedicated to 300mm technology and the first high-volume 300mm facility in Europe.

The 300mm wafer technology, based on silicon wafers that are 300mm – or 12 inches in diameter – will allow more than double the number of die per wafer and reduce costs by approximately 30%.

Originally scheduled for first production in the second half of 2001, the Irish fab is now scheduled to begin production of wafers in the second half of 2002 as a result of the change to 300mm technology. The facility will include 135,000 square feet of clean room manufacturing space.

For further details, check: <www.intel.com>.

NEWS BYTES

Speechify Converts Text-to-Speech

SpeechWorks has announced the general availability of its Speechify 1.0 Text-to-Speech (TTS) engine, which turns text-based content into a spoken audio format.

Speechify has already been successfully integrated into popular, consumer phone services such as AOL by Phone and Yahoo! by Phone, both of which allow subscribers to listen to incoming e-mail through any phone.

Speechify 1.0, a product of the partnership between SpeechWorks and AT&T, is the first to capitalise on 30 years of AT&T Labs research developing human sounding, synthesised speech with sophisticated language analysis capability.

For further details, check: <www.speechworks.com>.

SyncML Initiative Delivers Data Synchronisation Standard

SyncML, the initiative sponsored by Ericsson, IBM, Lotus, Matsushita, Motorola, Nokia, Palm, Psion and Starfish Software, has has released the SyncML 1.0 specification providing tomorrow's synchronisation technology for today's mobile solutions.

In less than one year, SyncML has successfully developed and published a powerful protocol for universal data synchronisation of both remote and local data. In addition to the specification, SyncML initiative also released a SyncML Reference Toolkit source code, enabling companies to rapidly bring SyncML-compliant products to the market.

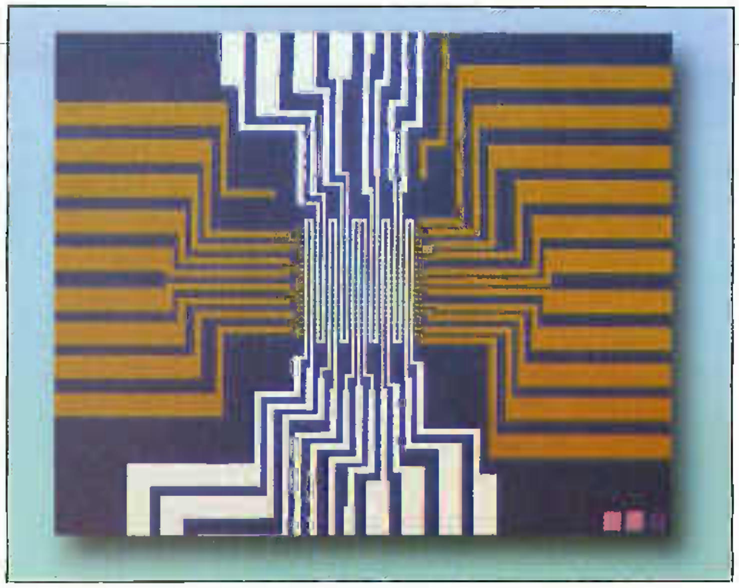
SyncML-enabled products and services will offer consumers mobile freedom by synchronising personal data and providing interoperability among all SyncML-compliant products and services.

Consumers and business professionals alike will be able to synchronise their personal data, such as contacts and calendars, in mobile terminals with various applications and services including corporate personal information managers, Internet calendars, Internet address books and more.

Synchronisation will be possible locally and remotely through various transports, such as infrared, Bluetooth, HTTP and WAP, regardless of platform or manufacturer.

For further details, check: <www.ericsson.se>.

IBM Unwraps World's Most Advanced Chip-Making Technology



IBM has announced production of powerful new microchips for servers, communications gear and pervasive computing products, using the most advanced chip-making technology ever developed.

The new technology, named CMOS 9S, unites IBM innovations in copper wiring, silicon-on-insulator (SOI) transistors and improved, low-k dielectric insulation to build chip circuits as small as 0.13microns, or nearly 800 times thinner than a human hair.

The smaller circuitry and improved materials can pack more processing power on a single chip, helping electronic products from computers to mobile phones support new, performance-hungry applications like speech recognition, fingerprint authentication and wireless video.

For further details, check: <www.ibm.com>.

Charging Controllers Target Consumer Products

Fairchild has introduced two battery-charging controller integrated circuits that provide constant-current and constant-voltage (2.5V to 16V) charging of Li-ion batteries used in handheld applications, such as mobile phones, personal digital assistants (PDAs) and consumer products.

For further details, check: <www.fairchildsemi.com>.

Wireless World Launched by Industry Leaders

The Wireless World Research Forum created by Alcatel, Ericsson, Nokia and Siemens aims to formulate visions on strategic future research directions in the wireless field, among industry and academia, and to generate, identify, and promote research areas and technical trends for mobile and wireless system technologies.

It is intended to closely co-operate with the UMTS Forum, ETSI, 3GPP, IETF, ITU, and other relevant bodies regarding commercial and standardisation issues derived from the research work.

The forum is open to all interested parties. Members are expected to contribute papers and ideas. In 2001, the forum will organise three working sessions and a workshop towards the end of the year.

The WWRF is a further development of work started during 2000 in the Wireless Strategic Initiative (WSI). The Wireless Strategic Initiative was started in May 2000 by Alcatel, Ericsson, Nokia and Siemens as a project under the Information Society Technologies programme of the EU.

For further details, check: <www.ist-wsi.org>.

Sony Display is Picture Perfect

Setting the latest design trend in flat panel displays with flexible horizontal or vertical viewing, Sony's newest 42in. model is available in brushed silver or charcoal grey.

The Sony display has a resolution of 1,024 by 1,024 providing clear images and superb detail, with a 160 degree viewing angle. The only problem is the price which is expected to be around £6,000 when the display reaches the UK later this year.

For further details, check: <www.sony.com>.

Boeing to Build Satellite for European Satellite Services Provider

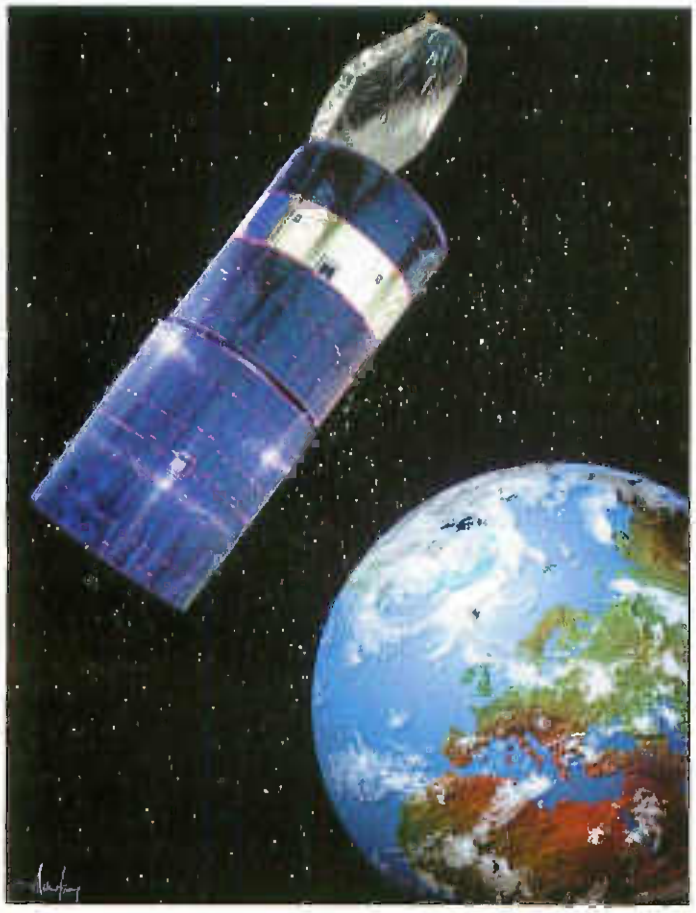
Societe Europeenne des Satellites (SES) of Luxembourg, the operator of Europe's leading ASTRA direct-to-home (DTH) Satellite System, has ordered its tenth satellite from Boeing Satellite Systems.

The satellite, ASTRA 3A, is a high-power Boeing 376HP model spacecraft and is scheduled for launch in 2002. The contract also includes launch services and ground station control software.

ASTRA 3A will augment SES's existing fleet of 13 to help meet growing demand for digital satellite services.

The payload consisting of 24 Ku-band transponders, 20 active, will provide high-power DTH services to the German-speaking markets of Germany, Austria and Switzerland from SES's new orbital position of 23.5 degrees East longitude.

For further details, check: <www.boeing.com/space>.



NEWS BYTES

Dallas Demos Wearable Java Computer

Dallas Semiconductor has announced a new wearable, Java technology-based computer with ample storage for safekeeping all the credentials of an individual.

The DS1957B Java-powered iButton serves as both a physical key for touch and go access to buildings and a computer key for secure network log-on as well as trusted e-signatures for the Internet.

Inside the 16mm steel-encased iButton is a Java computer with a 64 kbyte ROM and 134 kbyte RAM that can store over 30 certificates with 1024-bit keys using ISO X.509v3, the most widely recognised public-key certificate format.

In addition, the DS1957B can store hundreds of user names and passwords, a colour identification photo, and the application programs of many different service providers.

All personal credentials are both cryptographically and physically secure on the steel-armoured chip, wear-tested for 10 years of durability to insure extreme up-time-paramount because of the critical role this hardware token plays in establishing a person's digital identity.

For further details, check: <www.ibutton.com>.

Motorola Licenses ARM Architectural to Expand DigitalDNA Portfolio

ARM and Motorola have signed a licensing agreement expanding Motorola's DigitalDNA embedded processor portfolio from its to include the ARM microprocessor families and implementations.

Under the agreement, the ARM product line will join Motorola's PowerPC, M-CORE and ColdFire families of 32-bit embedded processors.

ARM cores are noted for their excellent combination of high performance, small die size, low power consumption, tight code density, and multiple supply sources. Instruction set compatibility between processor families promotes design reuse and reduces software development time.

For further details, check: <www.motorola.com>.

NEWS BYTES

Personal Palm Protection

DataGator from JAWZ is the first product of its kind to automatically encrypt all data on Palm O/S handheld devices.

JAWZ DataGator provides an application-independent method for maintaining encrypted data on Palm O/S handheld devices. It works seamlessly in the background to secure the data of all record-based applications and is compatible with Palm O/S 3.0 or greater.

Until JAWZ launched DataGator, most existing security applications for the Palm restricted access to the device by requiring a password when the device was turned on. This front door was easily bypassed and the sensitive data on the Palm became available to the hacker or thief.

For further details, check: <www.jawzinc.com>.

Speech Recognition Software Works Without Training

Sensory has introduced the Sensory Fluent Speech engine, which it reckons is capable of accurately recognising up to 50,000 words without the need for training by the speaker.

Sensory's new Fluent Speech technology is expected to provide low-cost, large-vocabulary speech recognition capabilities to such everyday applications as portable MP3 players, Internet access devices, mobile phones, cars, personal digital assistants (PDAs) and a variety of medical and electronic instrumentation.

For further details, check: <www.sensoryinc.com>

Intel and Power X to Develop Internet Switches

Intel and Power X Networks have agreed to work together on development of technology to easily connect Intel's fastest network processor with Power X's intelligent switch fabric, a significant step toward streamlining development of next-generation Internet networking equipment.

For further details, check: <www.intel.com>.

Cell Computing Introduces Plug-N-Run Modules

Cell Computing has added three Intel Pentium processor-based modules to its flagship Plug-N-Run line of embedded PC products.

The Plug-N-Run family now includes a total of nine plug-compatible modules that provide complete PC functionality in an ultra-compact 3in. by 5in. footprint.

All of Cell's modules use Intel's low power mobile processors; two of the new modules incorporate Intel's 166MHz and 266MHz Pentium processors with mmX technology while the third is based on a 400MHz Celeron processor.

For further details, check: <www.cellcomputing.com>.

World's First Fabric Keyboard Makes Debut

The Elektex keyboard, developed by the UK company ElectroTextiles, can be folded, scrunched and washed, without losing functionality.

The keyboard enhances the flexibility and functionality of handheld devices, greatly improving rapid input of text and simplifying device operation. The latest prototype wraps around a palmtop to form a protective case, and includes an integral stand for easier screen viewing.

The keyboard is the first of many applications of Elektex technology currently being developed. The company is also developing a gel-bodied mobile phone sleeved with fabric, that has already attracted the interest of major mobile telecoms manufacturers.

For further details, check: <www.electrotextiles.com>.

UK Funds Study of Mobile Phone Safety

The government is to invest £6 million in a research program designed to investigate potential health hazards of mobile phones.

It is also set to mount a public information campaign advising mobile phone owners that they should keep their calls short to minimise their exposure to radio waves, and that they should discourage mobile phone use by children.

Presenting its action as essentially a precautionary step, the government acknowledged that there is no irrefutable medical evidence that mobile phones pose health risks.

For further details, check: <www.dti.gov.uk>

ELECTRONIC DESIGN *Comes of Age*

How do engineers go about designing a 10 million transistor integrated circuit or chip? Here we report on the birth and development of the electronic design automation (EDA) industry.

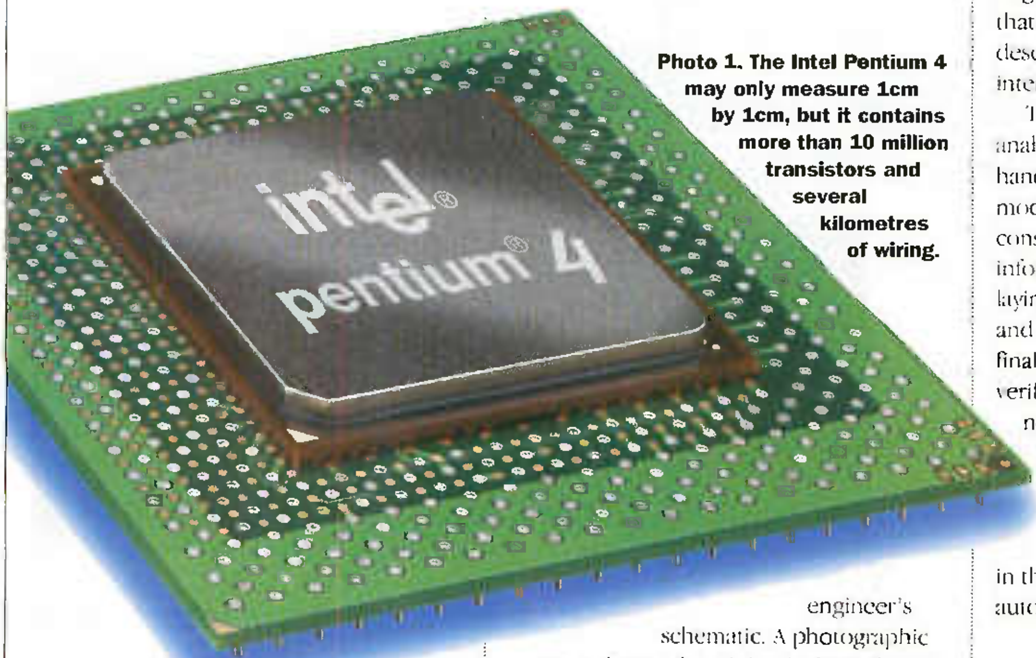


Photo 1. The Intel Pentium 4 may only measure 1cm by 1cm, but it contains more than 10 million transistors and several kilometres of wiring.

Integrated circuits (ICs) are the most complex structures designed by mankind. IC technology continues to follow Moore's law, which states that the number of transistors that can fit on a chip doubles every 18 months.

The size of the smallest features on a state-of-the-art IC is comparable to the length that your fingernails grow in one minute. Modern ICs such as the Intel Pentium 4 shown in Photo 1 may measure only a centimetre on a side, but can easily incorporate 2 kilometres of wiring joining tens of millions of transistors. The task of designing these ICs design is, of course, hugely complicated and requires highly specialised skills.

In the early 1960s, when the first ICs hit the market and consisted of a mere handful of transistors, the design process was entirely manual. An electrical engineer would create a circuit schematic on paper and hand it to a professional drafter.

Here, the drafter would create a representation of the design on drafting film, laying out the various components of the chip according to the electrical engineer's schematic. A photographic process then reduced the drafter's design to a size that allowed the chip to be manufactured on a silicon wafer as shown in Photo 2.

As the number of transistors on a chip increased exponentially, it was not long before the manual method of design became inadequate. Fortunately, the arrival of microprocessor technology, itself a result of the explosion in IC design, created the opportunity to automate the electronic design process.

Thus the electronic design automation, or EDA, industry was born and the term design tool shifted away from its implication of a pencil and paper and toward its current meaning of an advanced, automated software system.

Design process

The typical present-day design process begins with some type of imprecise paper specification. Engineers use a hardware design language (HDL) such as VHDL or Verilog to produce a computer model of the design.

The Cadence Verilog-XL simulator shown in Photo 3 for the desktop provides a powerful environment for designing and verifying the functional building blocks of complex application-specific integrated circuits (ASICs) and systems on a chip. It is designed to meet the capacity requirements of block-based design, while providing the same quality, reliability, and functionality of the industry standard Verilog-XL simulator.

They then verify that the design does what they want by simulating how the model responds to a variety of test stimuli. Engineers then use a synthesis program that automatically reduces the HDL description down to a network of interconnected logic gates, or netlist.

This stage in the design process is analogous to when the electrical engineer hands a paper design to the drafter. The modern drafting process, or layout design, consists of unraveling the tangle of information contained in the netlist and laying out the corresponding transistors and the connections between them. The final stage before manufacture, physical verification, checks the design against the netlist and ensures that it contains no short circuits.

Managing design complexity

We are currently at another watershed in the evolution of electronic design automation. The tiny feature size of current

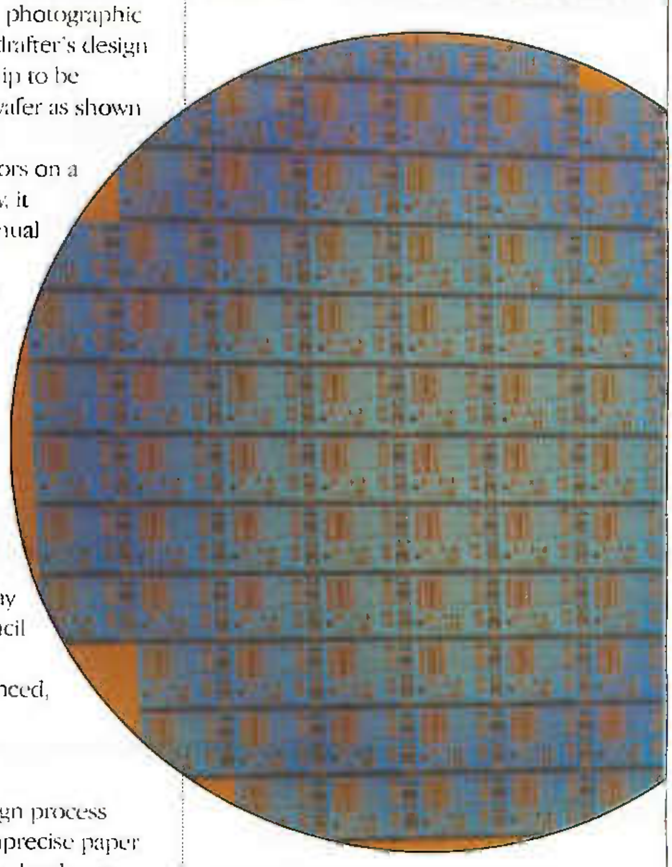


Photo 2. Silicon wafer etched with numerous integrated circuits.

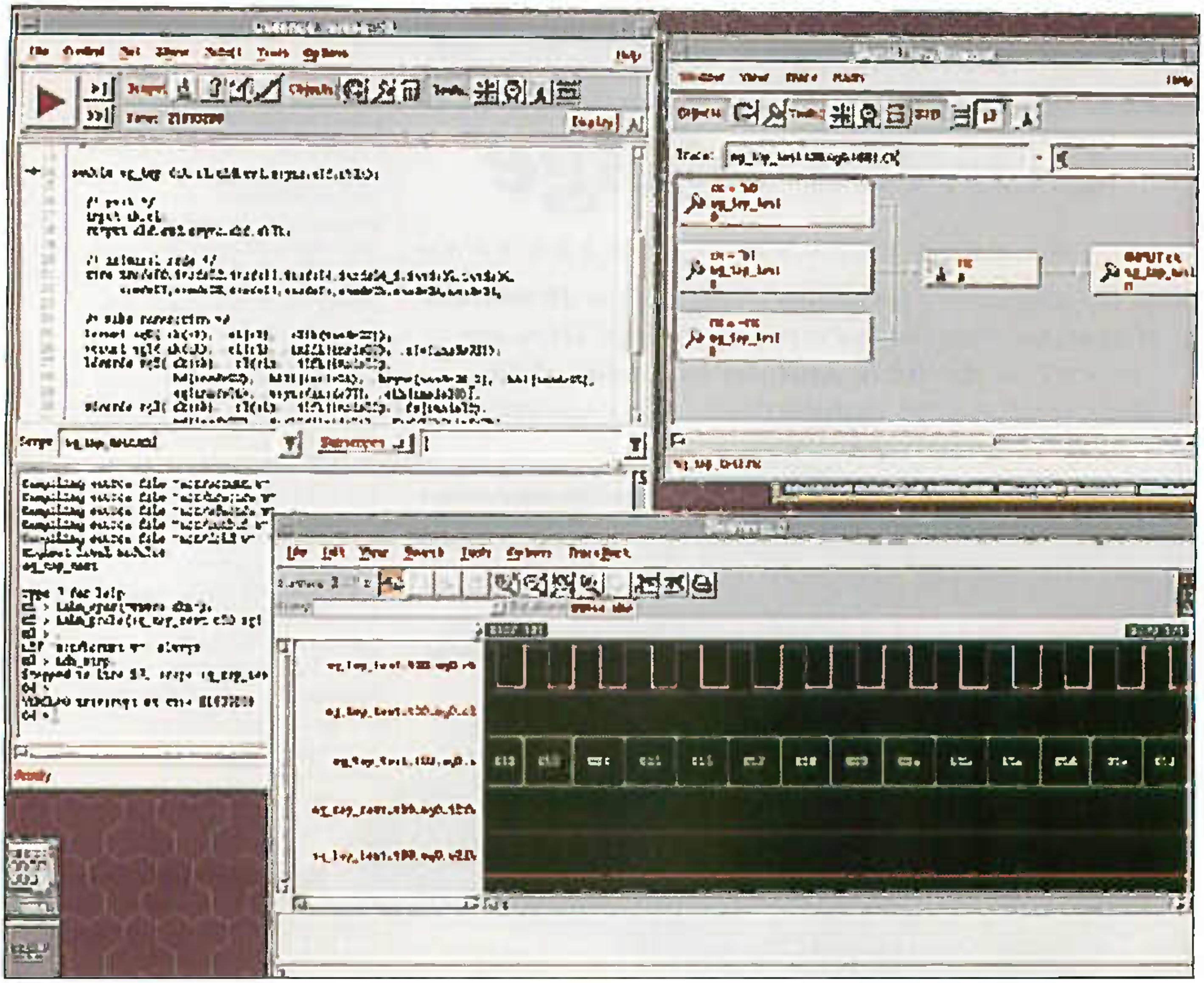


Photo 3. Cadence Verilog-XL simulator

generations of IC technology forces designers to process much more detail than ever before. On the other hand the complexity of the chips and the number of transistors that they contain forces designers to discard as much detail as they can get away with.

This situation seems less paradoxical if we look at the design at two levels. The system level is analogous with the electrical engineer's paper design. The design is very abstract at this level - the engineer knows what the design is required to do but has not yet decided how it will do it. On the other hand, the implementation level is similar to the drafter's view of the design. The design is very detailed at this level and the esoteric effects due to the microscopic feature sizes are well understood.

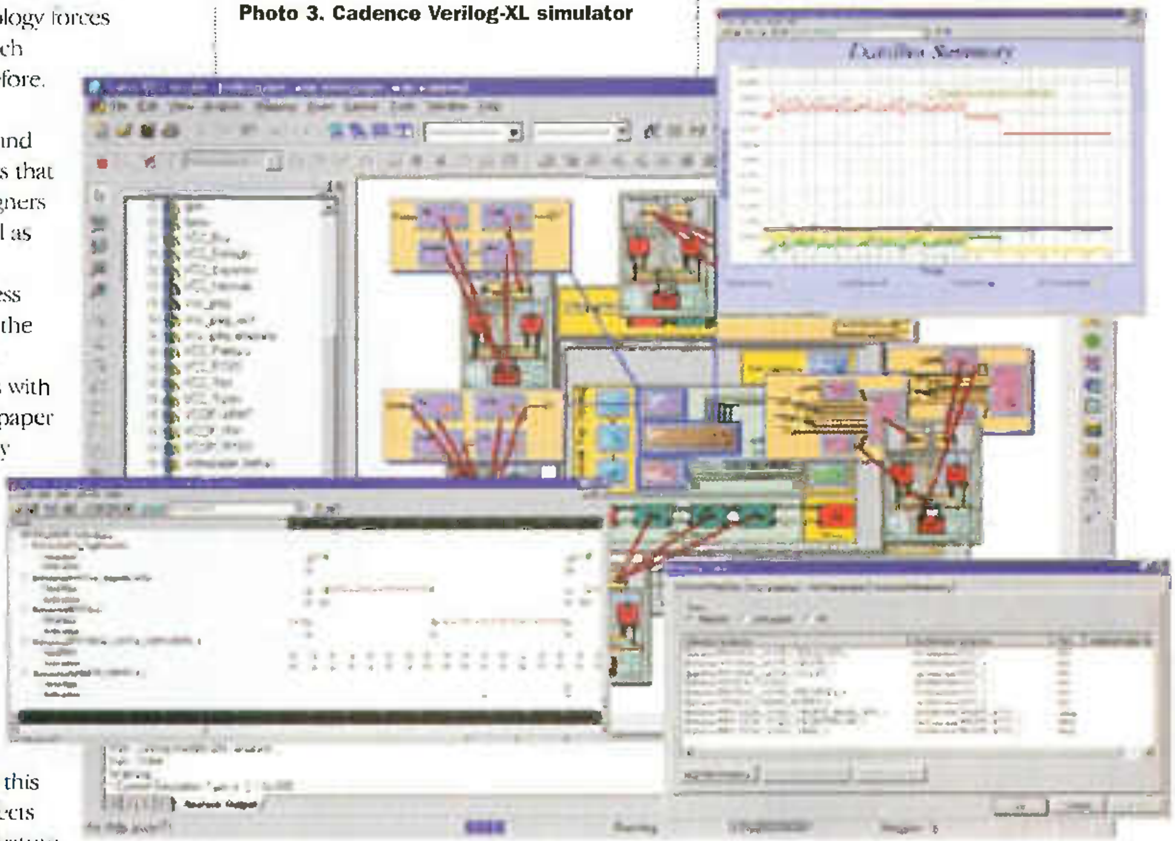
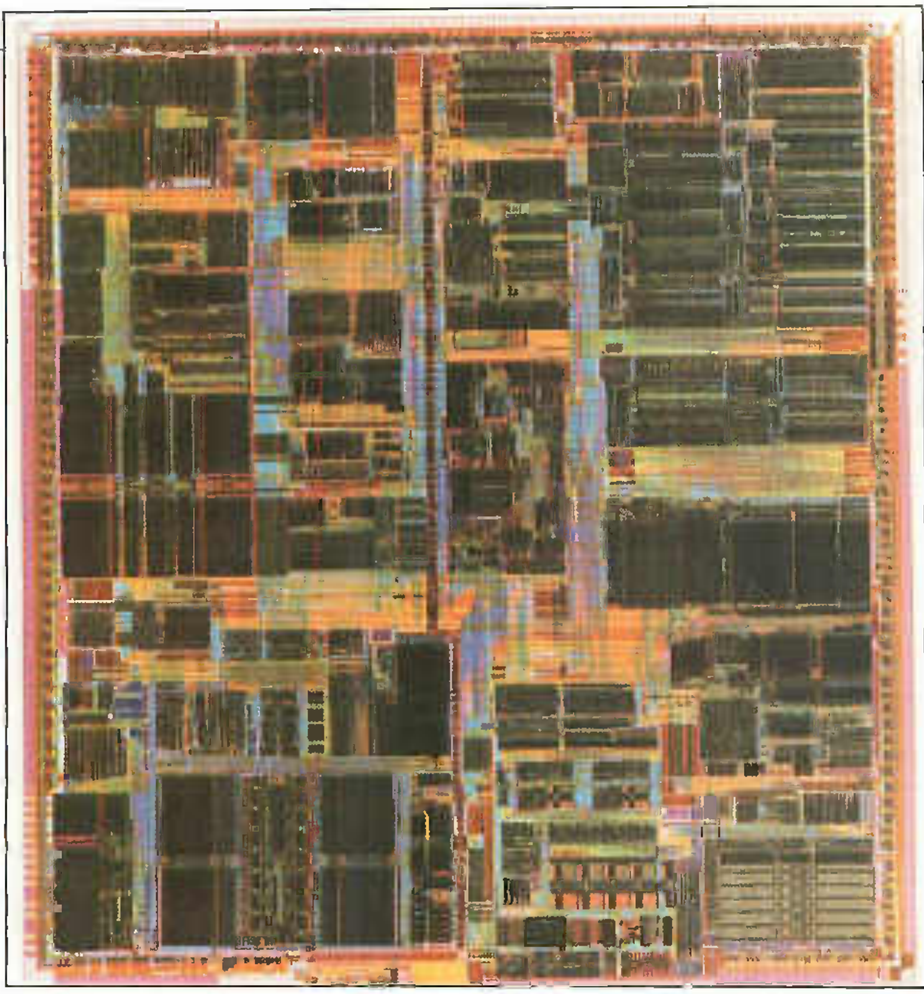


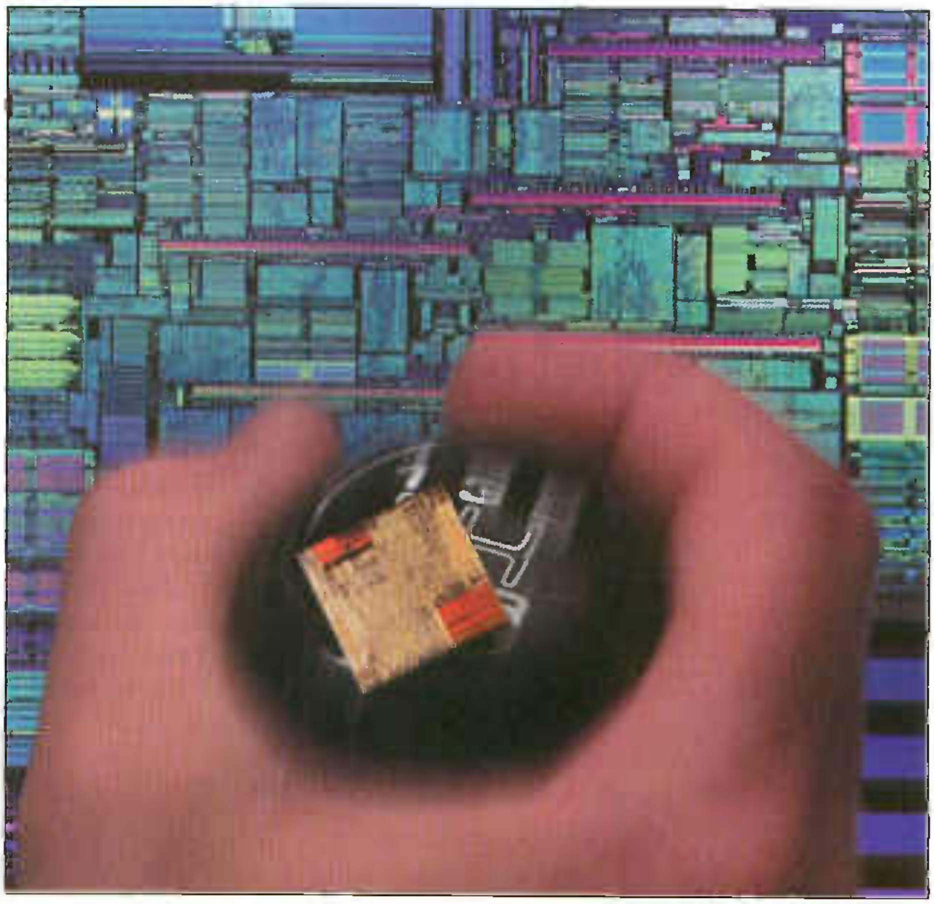
Photo 4. Cadence Virtual Component Co-design (VCC) system



The Cadence Virtual Component Co-design (VCC) system shown in Photo 4 solves the challenges of hardware/software co-design by separating behavior from architecture. For example, the first mobile phones were briefcase-sized designs with hundreds of components. These unwieldy and expensive units were quickly refined down to a handheld unit containing just a couple of chips, and now many of the functions are implemented as software. In all of these different forms, the behavior of the phone is unchanged - it allows you to make phone calls while on the move. The only real difference is how the architecture of the phone changed as features were implemented either in hardware or in software.

The VCC tool allows a designer to describe the behavior of a system and to simulate it to ensure that it is correct. The tool then guides the designer to the implementation that best suits the needs of the product by evaluating a number of alternative architectures. The VCC tool then automatically assembles HDL code for input into logic simulators and synthesis

Photo 5 and 6. Chip plots of 10-million plus transistor integrated circuits.



The solution to this dilemma is to provide an automated process for taking a design from the abstract system level to the detailed implementation level.

Shift to system-level design

Design specifications are not fixed entities – they shift continuously during the design process, so designers are always trying to hit a moving target. This necessitates a design approach that allows changes to the design right upto, and even after, the product is released to the market. For this reason, design teams implement as many of the product's features in software as IC performance permits. This change to a reliance on software is reflected in the composition of design teams, where software engineers now typically outnumber hardware designers.

So modern electronic systems are becoming little more than platforms for running the software that enables most of the features of the product. The problem is that the software cannot be written without prior knowledge of the hardware platform, and the hardware design needs enough software to test it. Engineers require design tools that allow them to develop hardware and software together as a complete system.

Another challenge arises from the tight deadlines that engineers face in order to bring new products to market. It is too time-consuming to design every new system from scratch, so engineers must build large portions of the design from pre-existing blocks of hardware known as intellectual property, or IP. Designers must therefore be able to predict how blocks of IP will perform when connected together in the system.

systems, providing an automated path into physical implementation tools. The tool simultaneously generates the software for the system, targeted at specific microprocessor cores and real-time operating systems.

Right first time

The shift to system-level design was initiated in part by the need to raise the level of abstraction at which engineers create their designs. But in order to solve the problem of modern electronic design, design tools must simultaneously manage the huge level of detail at the implementation level.

Just as the delay through long, undersea cables hinders transatlantic telephone conversations, the signal delay through connections across an IC creates a similar problem for designers. Although the distances involved are much smaller, the signals are much faster. Designers need to have an accurate model of this delay early on in the design process if their design is to work at the gigahertz speed that is characteristic of modern products. Without an accurate model of delay, design times are stretched out as designers loop through endless iterations, trying in vain to reach the nirvana known as timing closure.

The previous generation of synthesis tools incorporated statistical wireload delay models, but this gives a poor estimation of interconnect delay in current-day ICs. Furthermore, synthesis tools and physical implementation (place-and-route) tools typically use different models of interconnect delay, which means that the synthesis tool's delay model is a poor predictor of how the design will actually perform, leading to further iterations through the design loop.

The Cadence Synthesis, Place and Route (SP&R) system solves this problem by using the same, physically accurate models of interconnect delay within the synthesis tool and the place and route tool. The two tools therefore agree on the timing of the design, meaning that designers can reach precise timing closure in one step.

Hierarchical design

The key to controlling the complexity of modern chip designs is to use a hierarchical approach. The job of designing a 10 million transistor IC such as those shown in Photos 5 and 6 is impossible if tackled head-on, but a divide-and-conquer strategy makes the problem solvable. Divide the design into two parts, and suddenly each part is half as complex as the whole. Divide the design several more times, and the resulting blocks become manageable and, equally importantly, reusable. In practice, the boundaries between these hierarchical blocks are dictated by the structure of the design rather than by some arbitrary practice that makes life easier for the designer.

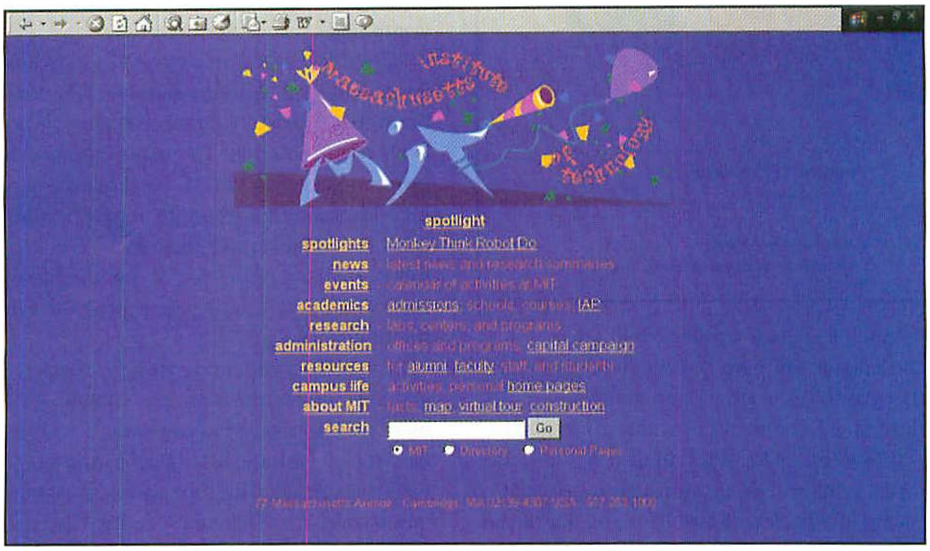
But this process of hierarchical design introduces its own problems. The hierarchical blocks that comprise the design are assembled using a place and route tool and connected by global interconnect; this is wiring that pervades throughout the IC and therefore has a huge effect on the design's performance. Design blocks that function perfectly in isolation will break down if the characteristics of the global interconnect are ignored during chip assembly. It is therefore necessary to switch the order in which the design is done so that global interconnect is created first.

Cadence has collaborated with designers to create a new hierarchical synthesis and chip assembly technology. At the core of the technology is the ability to predict global interconnect timing by performing hierarchical synthesis as well as hierarchical place and route. The technology is based on a large portfolio of existing, mature design tools, hence minimising the impact to our customers' design processes.

The new hierarchical technology automates the best practices of today's most advanced design groups. It allows designers to share data much earlier in the design process, hence improving timing predictability and leading to earlier timing closure.

MONKEYING *Around*

Monkeys in the US have remotely operated a robotic arm 600 miles away in MIT's Touch Laboratory – using their brain signals. Stephen Waddington reports.



Here's a topic to keep you occupied down the pub one evening. How do you get a monkey to control a robot over six hundred miles away?

Well for a start let's get one thing clear – it could only happen in the US. In the UK, scientists would have the monkey control something far more practical such as a coffee machine or kettle.

The feat is based on a neural-recording system reported in Nature in November. In that system, tiny electrodes implanted in the animals' brains detected their brain signals as they controlled a robot arm to reach for a piece of food.

According to the scientists from Duke University Medical Centre, MIT and the State University of New York, the new system could form the basis for a brain-machine interface that would allow paralysed patients to control the movement of prosthetic limbs.

The Internet experiment 'was a historic moment, the start of something totally new,' Mandayam Srinivasan, director of MIT's Touch Lab, said in the Wall Street Journal at the end of last year.

The work also supports new thinking about how the brain encodes information, by spreading it across large populations of neurons and by rapidly adapting to new circumstances.

In the Nature paper, the scientists described how they tested their system on two owl monkeys, implanting arrays of as many as 96 electrodes, each less than the diameter of a human hair, into the monkeys' brain.

The technique they used allows large numbers of single neurons to be recorded separately, then combines their information using a computer coding algorithm. The scientists implanted the electrodes in multiple regions of the brain's cortex, including the motor cortex from which movement is controlled. They then recorded the output of these electrodes as the animals learned reaching tasks, including reaching for small pieces of food.

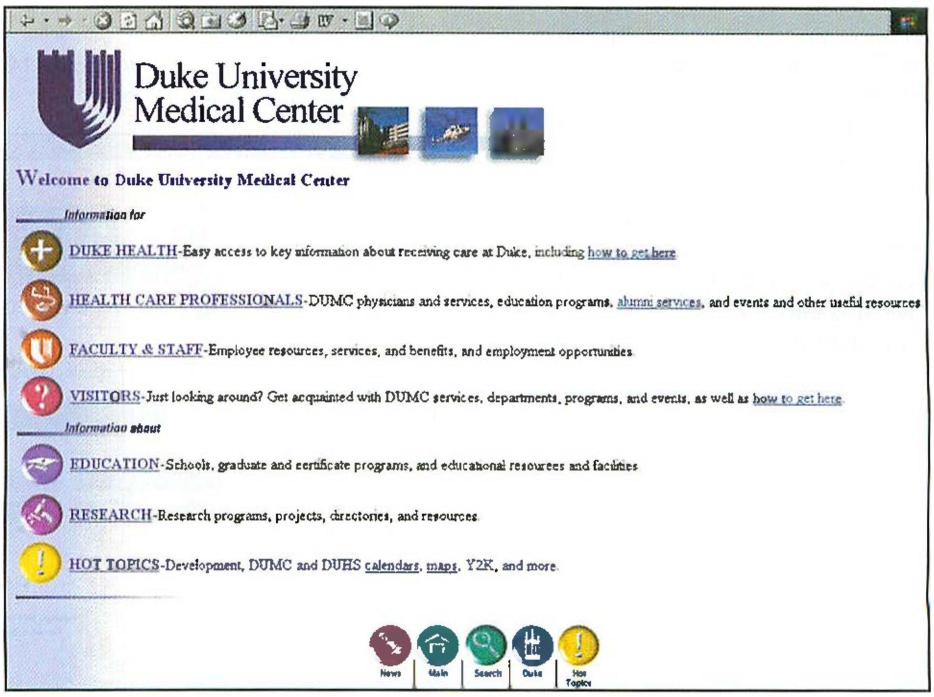
Analysing Brain Signals

To determine whether it was possible to predict the trajectory of monkeys' hands from the signals, the scientists fed the mass of neural signal data generated during many repetitions of these tasks into a computer, which analysed the brain signals. In this analysis, the scientists used simple mathematical methods and artificial neural networks to predict hand trajectories in real time as the monkeys learned to make different types of hand movements.

"We found two amazing things," said Miguel Nicolelis, associate professor of neurobiology at Duke. "One is that the brain signals denoting hand trajectory show up simultaneously in all the cortical areas we measured. This finding has important implications for the theory of brain coding, which holds that information about trajectory is distributed really over large territories in each of these areas even though the information is slightly different in each area.

"The second remarkable finding is that the functional unit in such processing does not seem to be a single neuron," Professor Nicolelis said.

"Even the best single-neuron predictor in our samples still could not perform as well as an analysis of a population of neurons.



So this provides further support to the idea that the brain very likely relies on huge populations of neurons distributed across many areas in a dynamic way to encode behaviour."

Over the Net

Once the scientists demonstrated that the computer analysis could reliably predict hand trajectory from brain signal patterns, they used the brain signals from the monkeys as processed by the computer to allow the animals to control a robot arm moving in three dimensions. They even tested whether the signals could be transmitted over a standard Internet connection, controlling a similar arm in MIT's Laboratory for Human and Machine Haptics, informally known as the Touch Lab.

"When we initially conceived the idea of using monkey brain signals to control a distant robot across the Internet, we were not sure how variable delays in signal transmission would affect the outcome," said Dr. Srinivasan. "Even with a standard TCP/IP connection, it worked out beautifully. It was an amazing sight to see the robot in our lab move, knowing that it was being driven by signals from a monkey brain at Duke. It was as if the monkey had a 600-mile-long virtual arm."

The researchers will soon begin experiments in which movement of the robot arm generates tactile feedback signals in the form of pressure on the animal's skin. Also, they are providing visual feedback by allowing the animal to watch the movement of the arm.

Such feedback studies could also potentially improve the ability of paralysed people to use such a brain-machine interface to control prosthetic appendages, said Professor Nicolelis. In fact, he said, the brain could prove extraordinarily adept at using feedback to adapt to such an artificial appendage.

Augmenting the Body

"If such incorporation of artificial devices works, it would quite likely be possible to augment our bodies in virtual space in ways that we never thought possible," said Dr. Srinivasan, a principal research scientist in mechanical engineering and the Research Laboratory of Electronics.

"In fact, the robot that was controlled by the monkey brain signals is a haptic interface – a device that is part of a multi-sensory virtual-reality system in our lab. It enables us to touch, feel and manipulate virtual objects created solely through computer programs, just as computer monitors enable us to see synthesised visual images and speakers enable us to hear synthesised sounds.

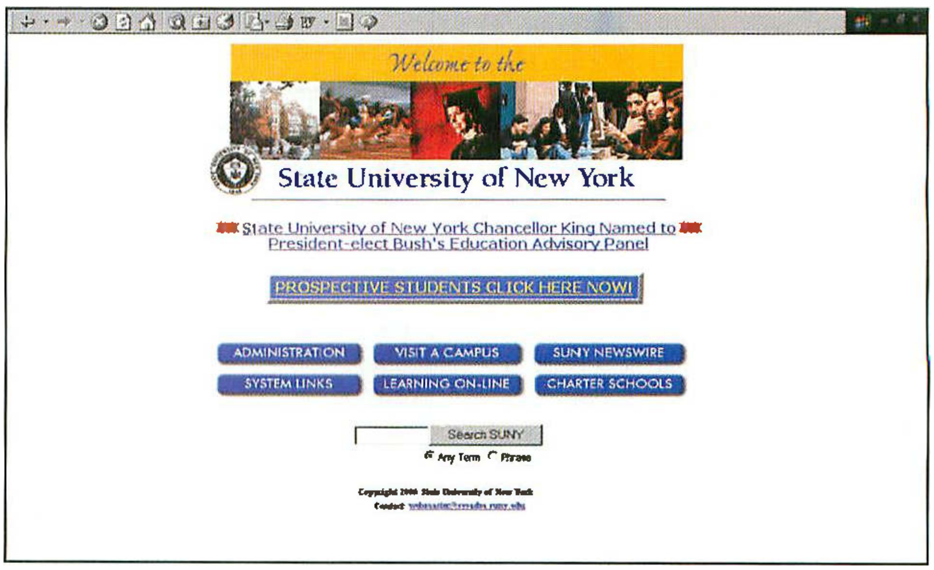
"In our experiment at using brain signal patterns to control the robot arm over the Internet, if we extended the capabilities of the arm by engineering different types of feedback to the monkey – such as visual images, auditory stimuli and forces associated with feeling textures and manipulating objects – such closed-loop control might result in the remote arm being incorporated into the body's representation in the brain," Dr. Srinivasan continued.

"Once you establish a closed loop that is very consistent, you're basically telling the brain that the external device is part of the body representation. The major question in our minds now is: what is the limit of such incorporation? For example, if we program the virtual objects such that they do not follow the laws of physics of our so-called real world, how will they be represented in the brain?" he said.

Besides experimenting with feedback systems, the scientists are planning to increase the number of implanted electrodes, with the aim of achieving 1,000-electrode arrays. They are also developing a 'neurochip' that will greatly reduce the size of the circuitry required for sampling and analysis of brain signals.

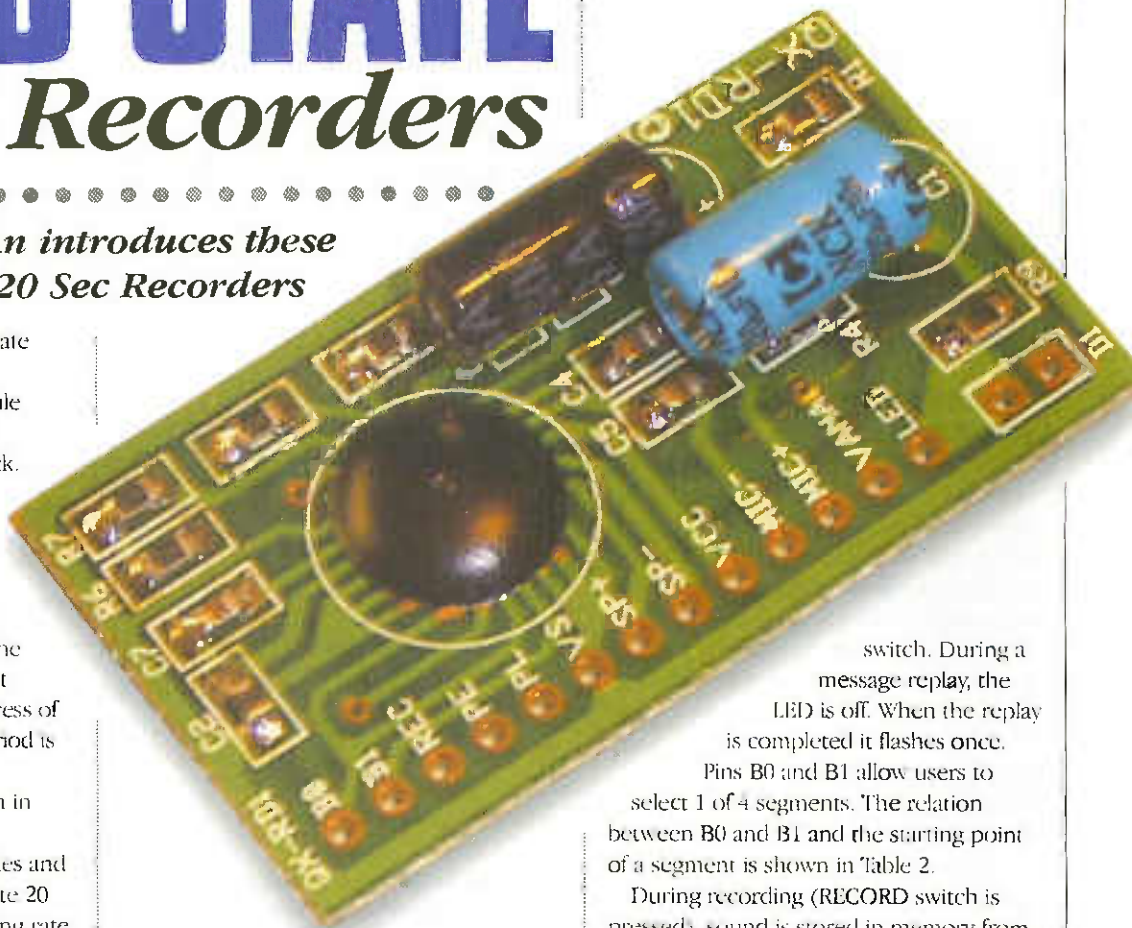
Web Links

Duke University Medical Centre
<www.mc.duke.edu>
MIT
<www.mit.edu>
Nature
<www.nature.com>
State University New York
<www.suny.edu>



SOLID STATE
Sound Recorders

Dr Pei An introduces these novel 20 Sec Recorders



This article introduces a solid state sound recorder and playback module, QX-RD-20. The module allows 4 separate sound tracks to be recorded individually and played back. Each segment has 5 seconds recording length. It can also record just one 20-second sound track.

Sound is stored on its on-board non-volatile memory and is retained after the power supply is removed. The recorded sound can be played back at anytime. The recording cycle is in excess of 100,000 times. The data retention period is over 100 years.

Measuring 45mm x 25mm x 15mm in size, the device only requires a microphone, two pushbutton switches and an 8 Ohm speaker to form a complete 20 seconds sound recorder. The sampling rate is 6.4 kHz. The bandwidth of sound recording is 2.6kHz that is adequate for speech recording. It requires a power supply from 4.5 V to 6.5 V DC. In record and play modes, current consumption is typically 25mA. In idle mode, the current drops to 0.05mA. This makes the device favorable for battery-operated applications.

Pin-out of the Module

The device is shown in Figure 1. There are 13 soldering pads on the module. The pin pitch is 0.1 inch. Their functions are summarised in Table 1.

How to use the module

The basic connection of the module is shown in Figure 2. It consists of an LED, 3 pushbutton switches (named as RECORD, PLAYE and PLAYL), one speaker (8-16 Ohm), one 2-way switch, an electret microphone and a power supply (4.5-6V DC). It is very easy to operate. Let us first set B0 and B1 to logic 0. This causes the module to record/play only one segment. B0 and B1 can be set to other values to select other segments.

To record sound, press and hold the RECORD switch. The LED illuminates. Sound is recorded via the microphone or through the VANA input (Line-in input). When the RECORD switch is released or when the total recording time is over 20 seconds, recording is terminated. Inside the chip, an end-of-message marker (EOM) is placed at the end of the sound track in the memory.

To playback the sound, press PLAYE switch once. The complete sound track (from the start of the track to the end-of-message marker) is played through the speaker. To stop replaying, press PLAYL switch. During a message replay, the LED is off. When the replay is completed it flashes once.

Pins B0 and B1 allow users to select 1 of 4 segments. The relation between B0 and B1 and the starting point of a segment is shown in Table 2.

During recording (RECORD switch is pressed), sound is stored in memory from the start point of a segment specified by B0 and B1. When the RECORD switch is released, an end-of-message marker (EOM) is placed in memory. The module allows in total 4 markers to be stored in memory. The marker plays an important role during replaying. After the PLAYE switch is toggled, sound stored in memory is played back from the start point to the next EOM marker.

If the RECORD switch is held for more

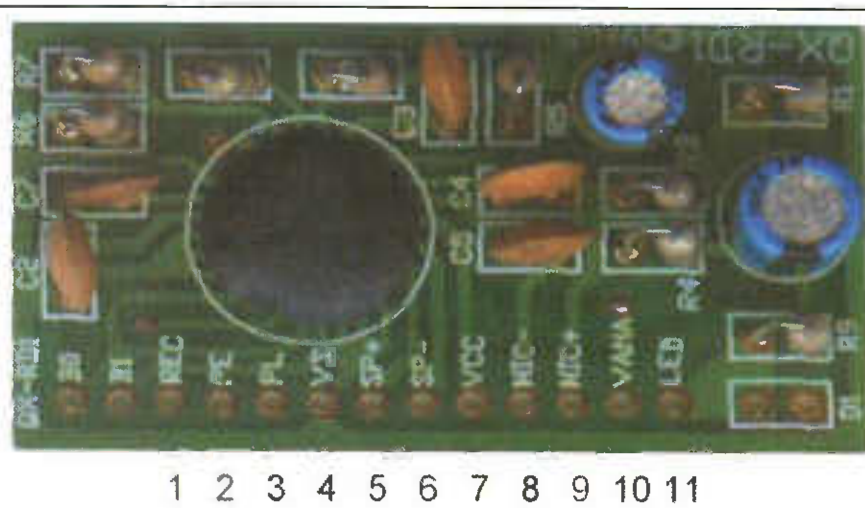


Figure 1. QX series sound recording module. Overall size 45mm×24mm×5mm. Pin connector pitch: 0.1 inch. The above module is 20 second 4 segment version. You can use B0 and B1 to select the start of a segment.

than 5 seconds, the end-of-message marker will be placed in the next segment. When you replay the sound, the sound track covers two segments (time length will be longer than 5 seconds). As a result, you loose one segment. Hence in order to have 4 separated messages, the end-of message marker should appear in every segment. This means that the maximum recording time for each segment should be less than 5 seconds.

Application circuits: Basic circuit

Figure 2 gives the circuit diagram for basic operation. The circuit can be used for a simple message memo.

Circuit for continuous play of a sound track

It is often required that a sound track is played again and again. A circuit shown in Figure 3 can be used for such a purpose. In that circuit, the LED pin is connected to a 555 mono-stable and the output from the mono-stable is connected to the PLAYE pin. The LED pin is normally at logic high (LED is off). After a complete message is played, the pin generates a short low-going pulse. The LED flashes and the signal triggers the mono-stable. The output of the mono-stable goes high for a pre-set period of time then becomes low. At the high-to-low transition on the PLAYE pin, the sound track is played again. The delay period is determined by R and C values.

To record message, just press RECORD

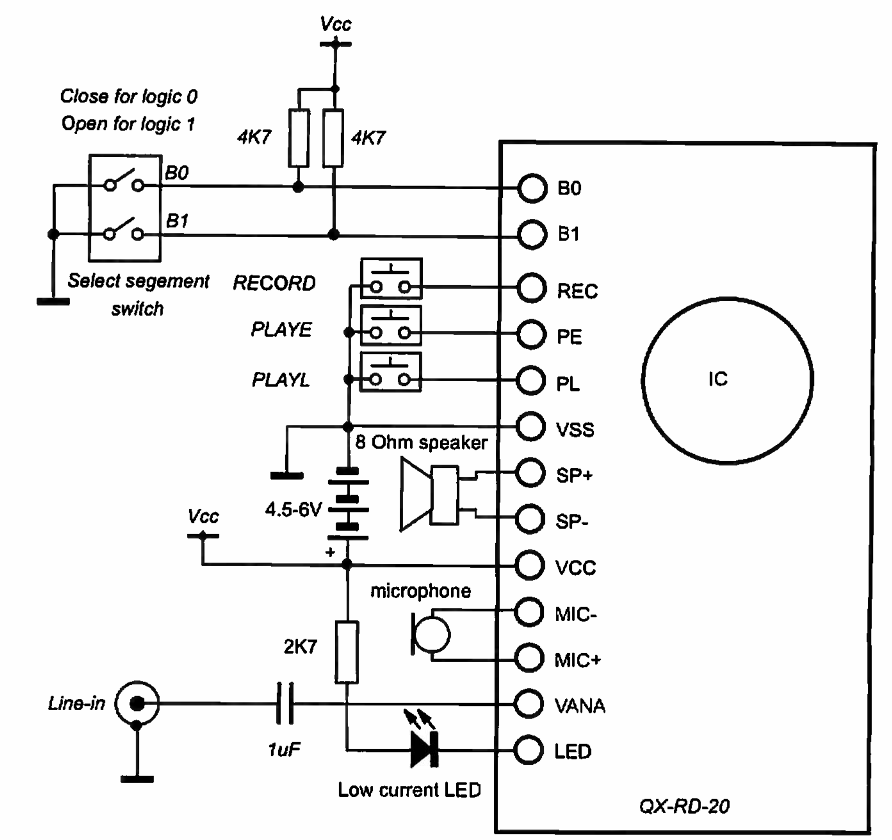


Figure 2. The basic circuit contains Three push-button switches (RECORD, PLAYE, PLAYL), one speaker, one microphone one SW and one LED. Power supply is 4.5V to 6V DC.

Pin	Functions
1	RECORD, Record (active at high-to-low transition)
2	PLAYE, Play (active at high-to-low transition)
3	PLAYL, Stop (active at high-to-low transition)
4	Ground
5	Connected to 16 Ohm Speaker. 12.5mW RMS output. Tests show that an 8 Ohm speaker is also acceptable
6	Connected to 16 Ohm Speaker. 12.5mW RMS output. Tests show that an 8 Ohm speaker is also acceptable
7	VCC (4.5 to 6.5 V DC) Active mode > 25mA, Idle mode: < 0.05mA
8	Electret Microphone -
9	Electret Microphone +
10	VANA: Audio line input (<50mVp-p). signal connected between VANA and Ground. A 0.1uF capacitor should be between VANA and input signal to filter out DC components. VANA recording has better sound quality than microphone recording.
11	Open collector output for an LED indicator. The LED illuminates during sound recording. It flashes once after a complete sound track is played.
B0 and B1	Selection pin for segments (each segment has 5 seconds length) B0=0 B1=0 1st segment B0=1 B1=0 2nd segment B0=0 B1=1 3rd segment B0=1 B1=1 4th segment

Table 1.

switch. In this circuit B0 and B1 are pulled to ground. So the message length can be up to 20 seconds.

Circuit for recording and playing 4 sound tracks

Figure 4 shows a circuit that allows one of four sound tracks to play by pressing one of four switches. The circuit is based on a standard CMOS logic IC, CD4532 keyboard encoder. It converts 8 parallel data (D0 to D7) into a binary data on Q0, Q1 and Q2 pins. D0 through to D7 are pulled down to ground via pull-down resistors (RL). While no switch is pressed, Q0, Q1 and Q2 output zero. Qgs pin is also at low. If a segment-select switch is pressed, the corresponding line (D0 to D3) becomes high. Q0 and Q1 output a binary data, which supply the address bits for B0 and B1. While the switch is pressed, Qgs pin also goes high. When the switch is released, Qgs pin goes low. At the transition from logic high to low, the module replays the sound stored in that particular segment.

In order to play 4 sound tracks, 4 separate sound tracks must be stored in each segment. This is done by holding the segment-select switch and pressing

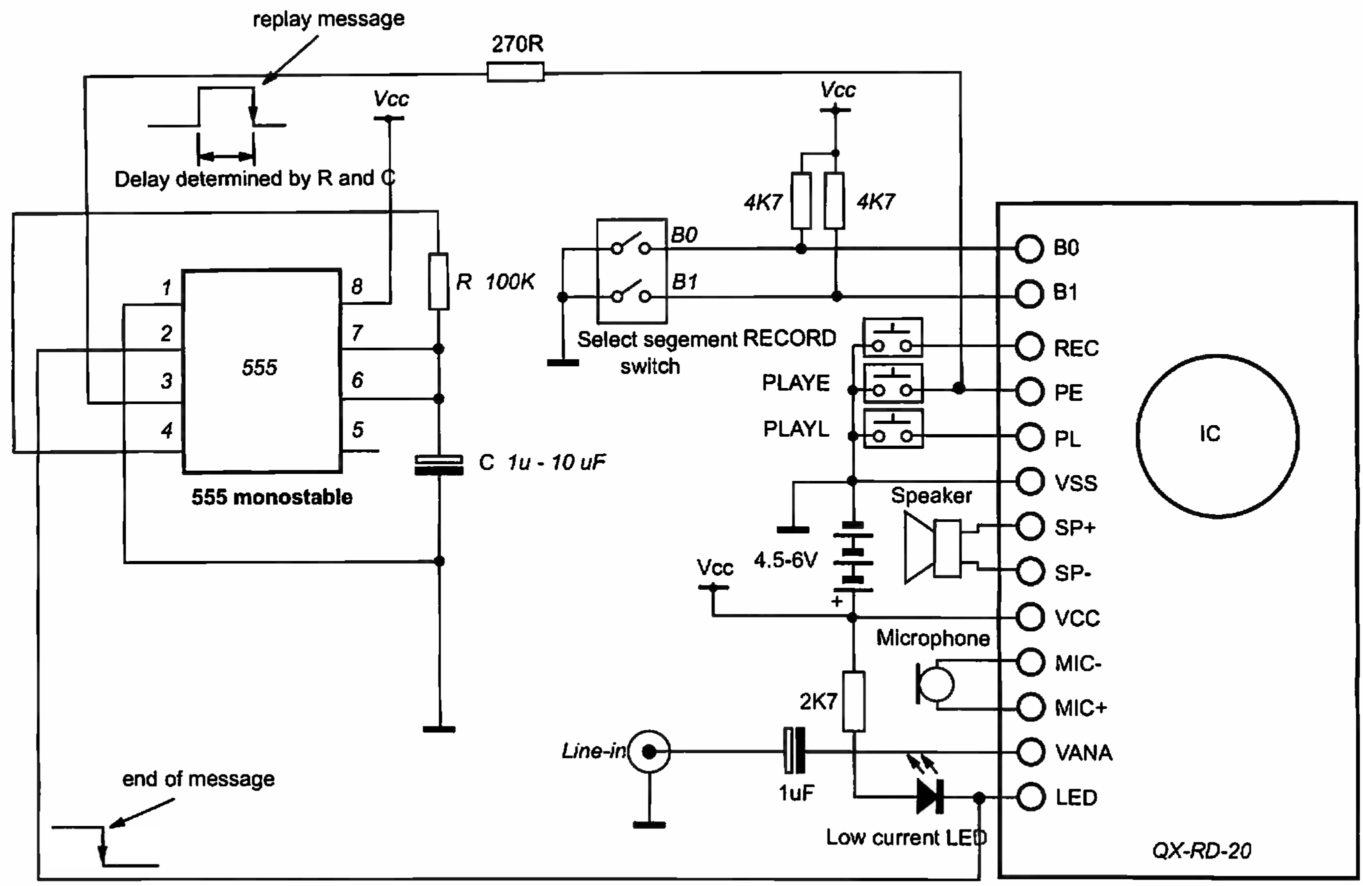


Figure 3. A 555 mono-stable circuit is used here to enable the module to play a sound track continuously.

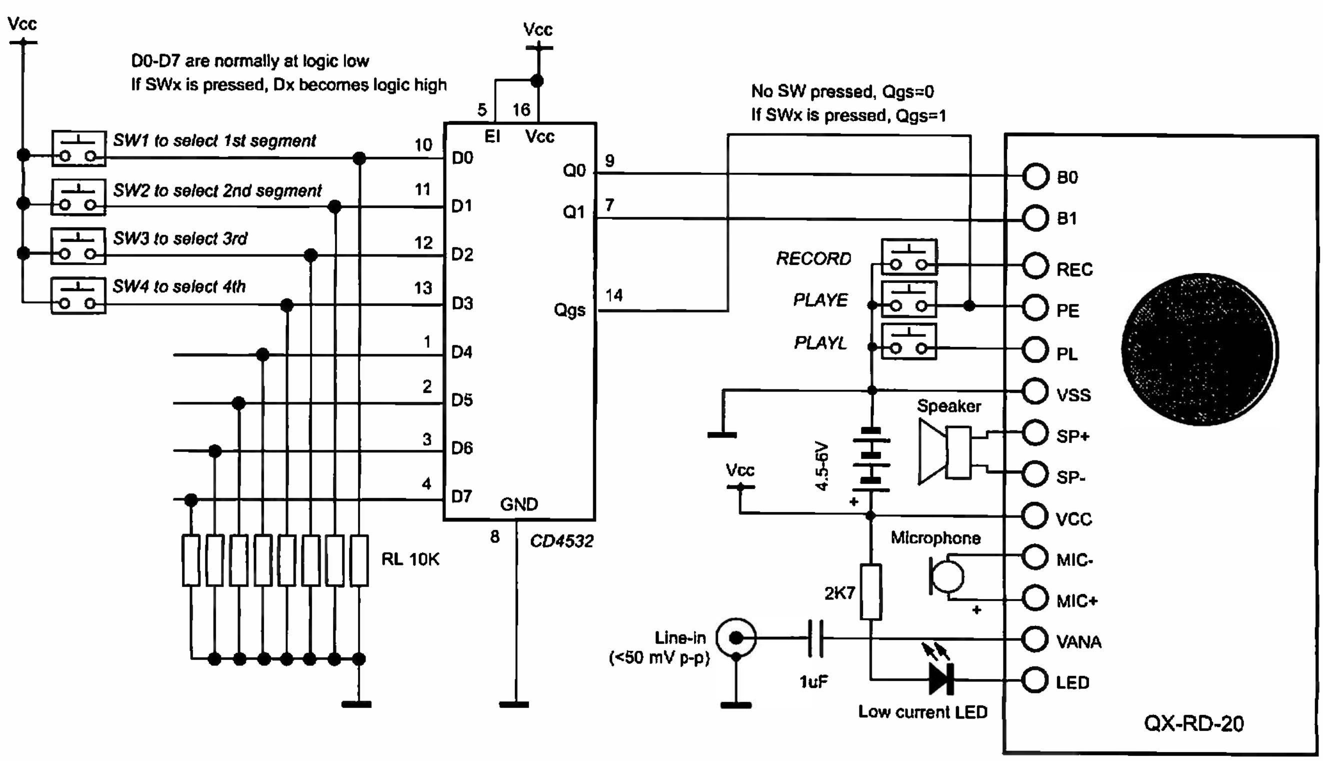


Figure 4. Application circuit to play 4 messages. CD4532 is a CMOS keyboard encoder IC.

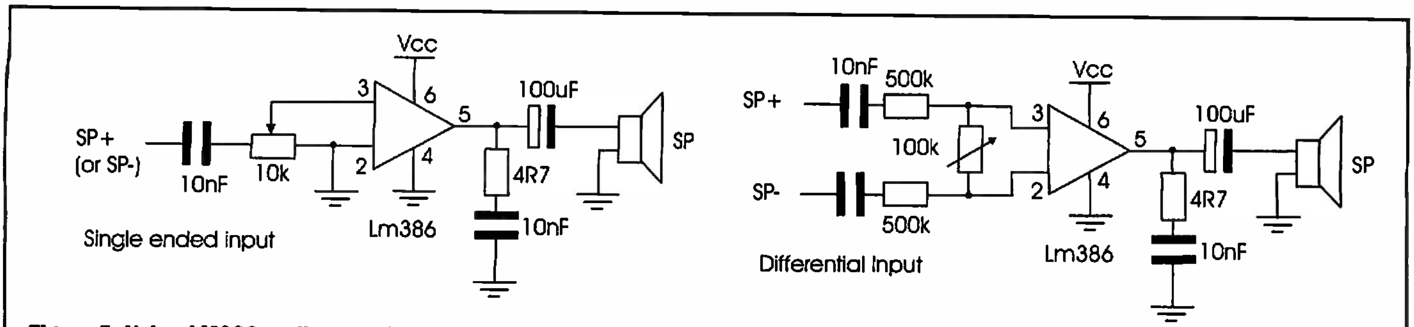


Figure 5. Using LM386 audio amplifier to boost audio output power. Two connection methods can be used: single-ended input and differential input.

Segments	B1 setting	B0 setting	Start point in memory
To select Segment 0	0	0	0 second (start of memory)
To select Segment 1	0	1	5 second (1/4 of memory)
To select Segment 2	1	0	10 second (2/4 of memory)
To select Segment 3	1	1	15 second (3/4 of memory)
NOTES: connected to VCC = Logic 1 connected to VSS = Logic 0			

Table 2.

the RECORD switch at the same time. The record time for each segment must be less than 5 seconds.

Audio amplifiers

An 8 to 16 Ohm speaker can be connected to the module directly without using any amplifiers. To boost audio output, LM386 or other types of audio amplifier can be used. Circuits using an LM386 IC are shown in Figure 5. Figure 6 shows a circuit diagram using hybrid audio amplifiers (details of these amplifiers can be found at **<www.intec-group.co.uk>**).

Tips to obtain better sound quality

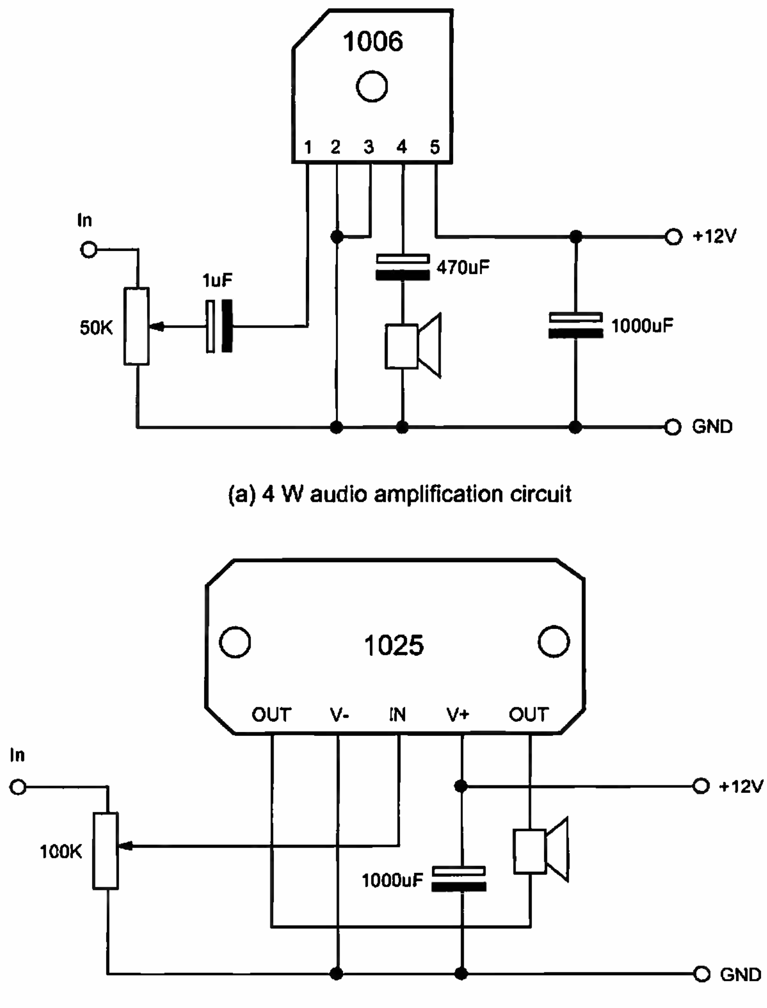
Use a good quality 8 Ohm speaker with a cavity such as speakers for computer sound systems. Do not use a bare speaker.

For better sound quality, speak to the microphone with a distance and speak clearly. Also keep the background noises as low as possible.

For best sound quality, use the Vana pin (Audio Line In). The audio signal is injected into the module between Vana and Ground. The voltage range is 100mV peak to peak.

Other modules

There are two more sound recording modules with slightly different specifications. These are the QXLM-10 and QXLM-20. They are single section sound recorders. The former has a recording length of 10 seconds and the latter has 20seconds. For both modules, the recorded sound can be replayed once or continuous under the control one pin. This feature is useful for some applications.



(b) 10 W audio amplification circuit

Figure 6. Two circuits (4W and 10W version) using hybrid audio amplifiers. In both circuits, the speaker is between 4 to 8 Ohm.

Technical Support

QX-RD-20 and QXLM-20 are both priced at £7.50 each (including VAT). Postage and packing is £3.50. QXLM-10 is £5.80. The Evaluation board (excluding sound modules itself) is £18.00. Please direct your enquiry to the author.

Telephone/fax: 44(0)1614779583.
E-mail address: **<pan@intec-group.co.uk>**

Improved MOBILE ANTENNA

A remarkable way to greatly reduce mobile phone radiation and save on battery power.
A report by Reg Miles

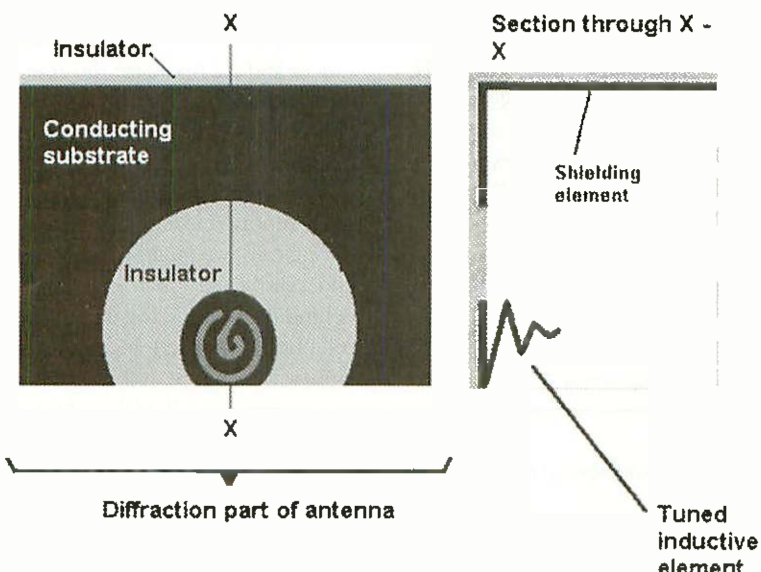


Figure 1. Basic antenna structure

The safety or otherwise of mobile phones continues to make news headlines - mainly because the media like to scaremonger. However, behind the published sensationalism of cooked brains there is a growing concern that mobiles could inflict some form of damage on their users, particularly children, as a result of the RF signals passing through the head.

Whatever the reality of the situation is, and there is a 'somewhat' reassuring study to end this piece, things could well change for the better if the Warwick Ultrasafe mobile telephone antenna were to be adopted by all mobile phone manufacturers. This has been developed by Professor Roger Green at Warwick University, and it is claimed to cut the energy passing through a user's head by 97 percent. But, more than that, the redirection of energy will also double the battery life or, alternatively, allow the size of the battery to be halved.

The invention came about because Professor Green noticed that antennas for mobiles tend to be based on well-established simple structures, usually quarter wave dipoles. Because of their need to be compact, there is no room for greater sophistication using conventional techniques. There are ways of achieving compact antennas using the dielectric technique, which give a reduction in size by radiating energy within a dielectric environment prior to sending out the signal, and some mobile phones have adopted this approach. But although these techniques do allow a reduction in antenna size a radiation field is still produced, part of which passes through the users' head. They require the use of a low loss dielectric material, along with directors and reflectors, and diffraction techniques.

The design of the Warwick Ultrasafe antenna is based on a combination of three elements, a diffraction antenna, an impedance-correcting helical antenna, and a contoured electric field structure that directs radiation away from the user. It reduces it to anything between 1/10 and 1/30 by comparison with standard in-head radiation levels (Figure 1 shows the combination of elements). Although a diffraction antenna can be short, it can also be rather wide. Another problem with it is that its electrical impedance can have the correct real component, but can have a significant capacitive reactive impedance component as well.

In operation the diffraction antenna creates a rising electromagnetic field perpendicular to the plane of the antenna, which is similar to that produced by a quarter wave dipole of height perpendicular to the plane (see Figure 2) thus reducing the height necessary for the same effect. The centre of the diffraction antenna (the 'driven element') contains the inductive antenna (which will usually be a helical structure except at the higher frequencies). This has two advantages: the capacitive nature of the diffraction antenna is partially or wholly compensated for by the inductance at the design frequency, and the electromagnetic field peak intensities are raised above the plane of the antenna - making the antenna electrically higher. The design is such that the added inductance is less than half the height of a shielding element. The shielding element is actually a perpendicular ground plane, which acts to contain the majority of the electromagnetic field from the top of the inductive antenna. When this is helical it is tapered so that the electric field is accentuated from the top of it; when it is too short to be helical, the top of the inductive pillar is tapered. In order to reduce the overall size of the structure, the whole antenna is encased in a low loss dielectric material.

The result of this combination of elements is to produce a compact and directional antenna in which radiation is reduced in the direction of the shielding and roughly doubled by comparison with a standard antenna away from it. A graph

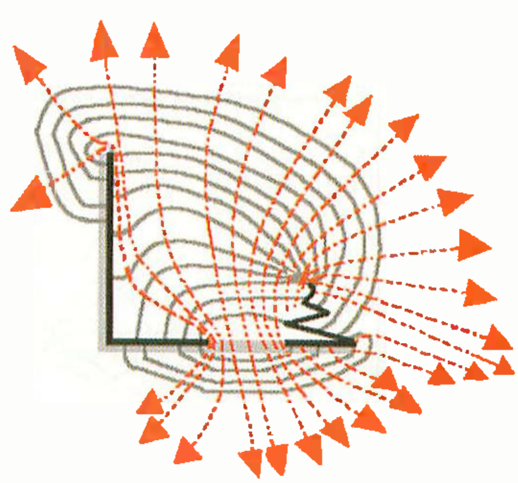


Figure 2. Diffraction antenna effect, concentrating electric field (grey). Also, propagation direction shown (dotted). Dielectric omitted for clarity.

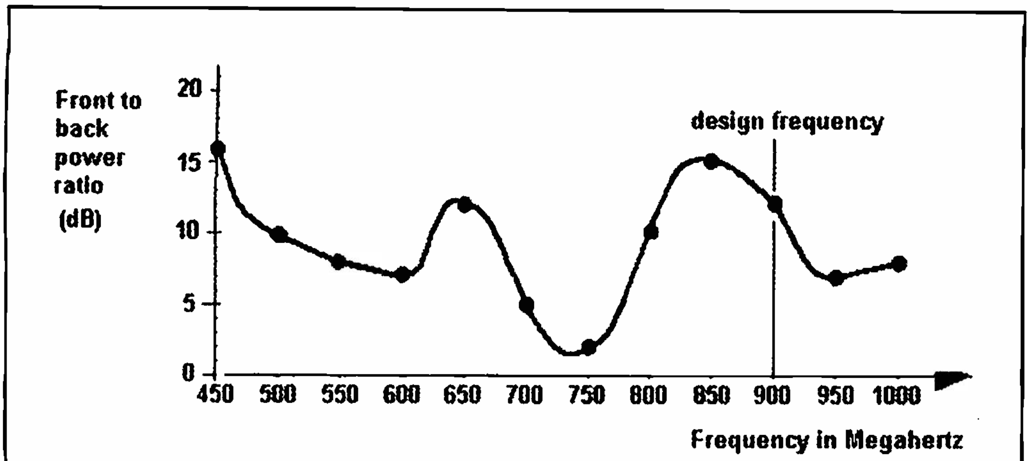


Figure 3.

showing typical front-to-back ratio, of forward to reverse power, as a function of frequency, is shown in Figure 3. This shows the front-to-back ratio of transmitted power in dB. For example, at a frequency of 850MHz, the ratio is 15dB, which corresponds to 31 times. In other words, the transmitted power into a user's head is only 1/30th of the usual amount, while the transmitted power in the required direction is up to twice the amount given out by a standard antenna. So a net advantage (in terms of radiation in the head) of up to 60 times can be achieved if the transmitter power is halved. Figure 4 provides a graphical representation of the differences.

Although its application for mobile phones is accentuated for obvious reasons, the antenna has been designed for general use in the UHF band, and the principle can be extended to a wide range of frequencies. The prototype has been used to detect TV signals in the frequency band 400MHz to 900MHz. While an antenna half the size indicated can operate successfully at the mobile phone frequencies of 1800MHz or higher.

Professor Green is now seeking interest from Mobile telephone companies to develop commercial models of this technology.

For more information contact:

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Email: <**puapjd@admin.warwick.ac.uk**>

And that 'somewhat' reassuring piece: A case-control study of 891 people who regularly used a mobile phone showed no statistical association between the amount of usage and the likelihood of developing brain cancer, according to researchers from the American Health Foundation and Memorial Sloan-Kettering Cancer Center and four United States medical centres.

"The recent phenomenon of widespread use of cellular phones had been a suspected risk factor for the development of brain cancer and needed to be clarified by a study," explained Joshua Muscat, MPH, of the Division of Epidemiology of the American Health Foundation and the study's first author. "The data showed no correlation between the use of cell phones and the development of brain cancer. In addition, there was no association between the amount of cell phone usage and brain cancer."

In a retrospective, case control study, 469 men and women diagnosed with primary brain cancer and 422 people without brain cancer were interviewed between 1994 and 1998 using a structured questionnaire. They were asked which type of phone (manufacturer) they used, the usage per month in minutes and hours, the year of first use, and the number of years of usage. In addition, an estimated monthly phone bill was ascertained. The patients, aged 18 to 80, were scrupulously matched to the control group by age, sex, race, years of education, and occupation.

The usage reported for cancer patients and the control group was not statistically significant. The median monthly use was 2.5 hours for cases with cancer and 2.2 hours for the control. The mean duration of use was 2.8 years for brain cancer patients and 2.7 years for the controls.

"Because 85 percent of people in the study reported extending the antenna during calls, we might have expected to find a disproportionate cluster of tumors behind the eye and the ear on the side the cell phone was used since radiation emission is highest at the antenna," said Mark Malkin, MD, a neuro-oncologist at Memorial Sloan-Kettering Cancer Center and study co-author. "In fact we found no link between cell phone usage and temporal lobe tumors, nor was there any association between handedness and tumor location."

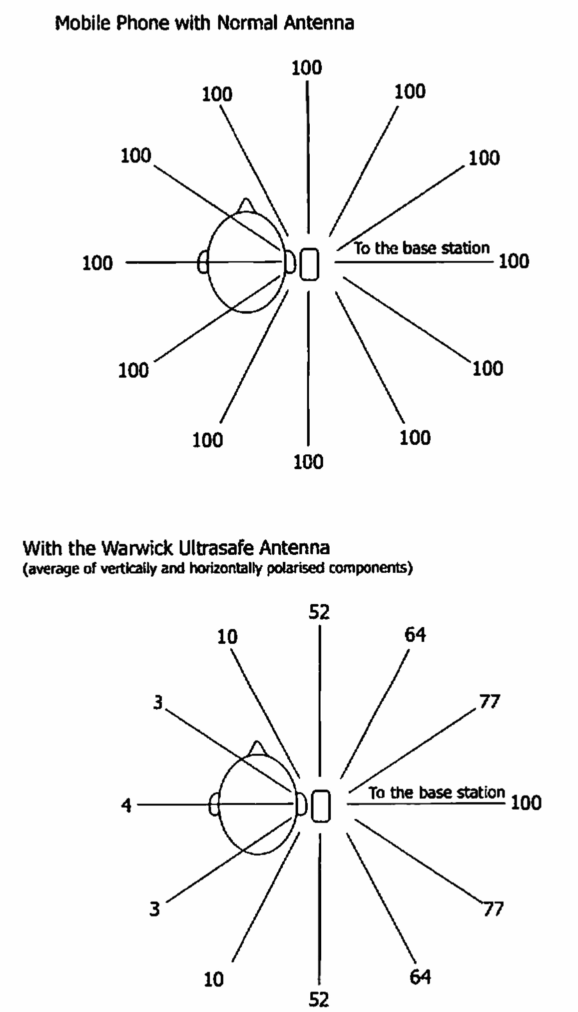


Figure 4.

Based on all available data including studies by other groups, the researchers believe that extended use of mobile phones does not appear to cause brain cancer. However, further research is indicated as this study covers people who have mostly used analogue mobile phones for a relatively short period of time (two to three years). As people continue to use mobile phones for extended durations, the long-term health effects, if any, need to be monitored.

For more information contact:

Memorial Sloan-Kettering Cancer Center **Joanne Nicholas** 212-639-3573
American Health Foundation **Monica Bynoe** 212-551-254

RESEARCH NEWS

Nanocrystal Quantum Dot Lasers

Scientists at the US Department of Energy's Los Alamos National Laboratory led by Dr Victor Klimov and the Massachusetts Institute of Technology led by Professor Moungi Bawendi have observed stimulated emission from nanoscale semiconductor particles called nanocrystal Quantum Dots (QDs). CdSe QDs offer efficient emission of laser light, opening the fabrication door for novel optical and optoelectronic hybrid devices, such as tuneable lasers, optical amplifiers, and light emitting diodes, from large scale assemblies of otherwise invisibly small particles.

"Our results provide a proof-of-principle and should motivate the development of nanocrystal quantum-dot-based lasers and amplifiers," said Los Alamos' Victor Klimov, who has led the research efforts in this field.

Quantum dots are so small that quantum mechanical effects come into their own at this scale, controlling their behaviour strongly. Quantum mechanics apply in the microscopic realm but are seldom seen in the macroscopic world around us. QD lasers work like other semiconductor lasers, such as those found in audio Compact Disc players. The goal of the QD laser is to manipulate the dot material into a high-energy state and then properly convert it to a low energy state. The result is the net energy release of many in step photons.

But first let us take a brief diversion into the history and the current state of laser developments worldwide. The demonstration of the first pulsed ruby laser by Maiman in 1960 with significant hype at the time, adding to the drama created in that notorious scene in Goldfinger with 007 Sean Connery!, was a milestone in the technological development of modern applied physics. Without the laser spectroscopic techniques such as stimulated Raman, Rayleigh and Brillouin scattering would not be possible. Equally many telecommunications applications, to say nothing of non-linear optics and high power lasers necessary for the next generation of confined nuclear fusion experiments and the revamped 'Star Wars' program would not exist. The advent of the Laser (Light Amplification by the Stimulated Emission of Radiation) is well suited to these tasks because of the high intensities and high degree of collimation (focusing) achievable. To understand how this is possible let us look a little more closely at the operation of a simple laser.

Laser Operation

Laser operation is markedly different to normal emission phenomena. In a conventional source, such as a neon tube, energy is pumped into the neon atoms which are consequently 'raised' into excited atomic states. Each atom may then drop back spontaneously and randomly to the ground state. All atoms radiate independently and the photons are emitted having no phase relationship with each other, so that the light produced is therefore incoherent.

In 1917 Albert Einstein predicted that an excited atom can revert to a lower state by photon emission through a second quite distinct mechanism which triggers the excited atom into emission by the presence of electromagnetic radiation of a precise frequency.

This process is known as stimulated emission and is the cornerstone of laser operation. In spontaneous and stimulated emission the photon is emitted with an energy difference hf_{if} between the initial excited energy state ei and a final lower energy state ef, i.e.:

$$e_i - e_f = hf_{if}$$

The emitted (stimulated) photon has the same polarisation and phase, and propagates in the same direction as the stimulating photon.

However, since most atoms are usually in the ground state, absorption is much more likely to occur than the process of stimulated emission. To achieve sufficient gain and observe lasing action it is necessary to achieve population inversion where very many of the atoms are in the excited level, leaving the ground state virtually unfilled. An incident photon of the correct frequency is then able to generate a cascade of stimulated photons.

In the Ruby laser, composed of a synthetic aluminium oxide crystal doped with chromium oxide, the Cr^{3+} ions are excited and then decay spontaneously into a metastable state lasting several milliseconds Figure 1. If the pump beam is of sufficient high intensity, population inversion may occur and the first few spontaneously emitted photons stimulate a chain reaction from the upper metastable level. One quantum of light triggers the rapid, in-phase emission of others, taking energy from the metastable atoms into the coherent light wave. Such a laser is known as a 3-level system with broad absorption bands, making initial excitation simple, with a long-lived metastable state and a ground state.

The wave grows as it passes many times up and down the active medium of the laser cavity which acts as a Fabry-Perot etalon, where light is reflected many times with one end partially silvered. Light that is not coaxial with the ruby rod passes out of the sides and is lost; this accounts for the remarkable degree of collimation of the emerging beam with a linewidth typically ~0.1nm due to the narrow energy transition between levels.

Significant advances have been made in the last few years with the demonstration of the first single-mode Continuous Wave fibre laser where a GaAlAs pump diode produced lasing at 1.088nm (in the Near Infra-Red) in a Neodymium-doped glass fibre. Since then technological development has been rapid with many doping materials exhibiting lasing in fibres: Th^{3+}, Ho^{3+}, Er^{3+}, Sm^{3+},Pr^{3+},& Yr^{3+}, etc.

The advantage of fibre lasers is that they are easily fabricated and are convenient for conveying large amounts of information over long distances and into otherwise inaccessible areas for applications as in vivo monitoring of body glucose, gas sensing and radiation monitoring at remote sites and many other novel applications. Clearly such lasing optical fibre will be an integral part of technological developments in the three optical telecommunications 'windows' at 850nm, (local area networks), and at 1300nm, and 1550nm for long distance communications (wide-area-networks).

Recent work at Southampton University has developed the planar waveguide laser which has a narrow channel defined by conventional microelectronics fabrication techniques in Neodymium-doped BK7 glass. In a planar

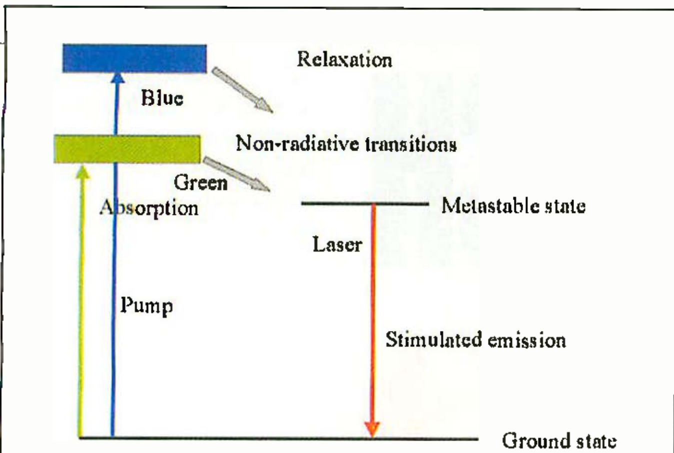


Figure 1. Ruby laser transitions.

geometry there is strong confinement of the electromagnetic fields needed for lasing to occur. Lasing action takes place above a minimum threshold when gain is greater than material absorption. Thresholds are now of the order of a few mW of pump power and herald a whole new area of technological development where planarity is the crucial design requirement. In terms of integrated optics and multi-sensor arrays, all designed on one chip of either glass or silicon, the potential of an in-built laser is a very attractive feature.

Classes of Laser

Lasers fall into several distinct categories and they are usually separated by the type of lasing material used. The most common types are given below:

Solid State Lasers

The well known Ruby laser is one of a class of solid state lasers, whose output wavelengths may range anywhere between 400 and 2500nm.

Gas Lasers

Gas is the active medium and may operate from the Far Infra-Red (FIR) right up to the Ultra-Violet. Helium-Neon, Argon, Carbon Dioxide (CO_2) and molecular Nitrogen are used. Some gas lasers and mixtures are very powerful such as the CO_2 laser that operates at 10.6mm.

Semiconductor Diode Lasers

The first semiconductor laser (Gallium Arsenide) dates from 1962. Semiconductor lasers, made from layered materials, operate between the Ultra-Violet and the Infra-Red. Particular advantages are: small size, precise fabrication and mass production. This has led to a wide variety of applications such as laser heads in CD audio and ROM players, checkout tills and light pens.

Liquid Lasers

The first of these were organo-metallic compounds; non-organic liquids are now often used, such as the fluorescent dye rhodamine. These lasers are especially useful as they can be tuned over a wide wavelength range (typically offering about 100nm tuning).

Optical Fibre and Planar Lasers

Significant advances have been made since the first demonstration of a single-mode optical fibre laser in 1985.

Quantum Dots -just a matter of the right Chemical Fabrication!

As previously stated the goal of the Quantum Dot laser is to manipulate the dot material into a high-energy state and then properly convert it to a low energy state resulting in the net release of many in-step photons. However the challenge is that there are competing mechanisms by which energy may be released, such as vibrational or electron kinetic energy. In QDs electrons are confined within a very small volume that forces them to strongly interact with

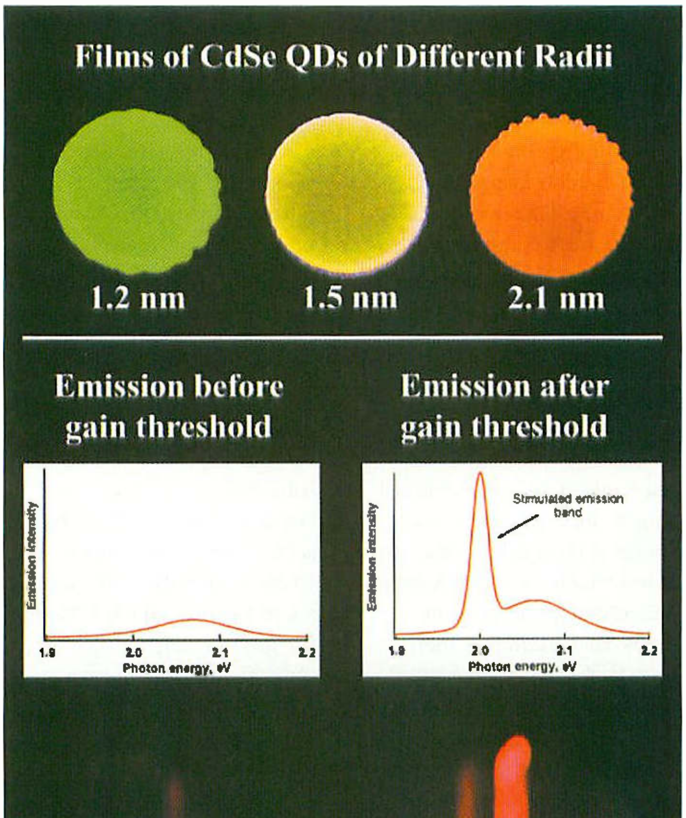


Figure 2. Colour stimulated output as a function of dot radii.
Courtesy Dr Klimov.

each other. These strong interactions can lead to deactivation of the dot through the non-radiative Auger process preventing it from emitting a photon.

The Los Alamos-led researchers examined QDs formed from several types of crystalline material. They showed that the QDs can exhibit sufficiently large optical gain for stimulated emission to overcome the non-radiative Auger process. Stimulated emission, or lasing was only possible however when the dots were densely packed in the sample.

Quantum dots offer this performance over a range of temperatures, making them suitable for a variety of applications, and can be tuned to emit at different wavelengths or colours (Figure 2). The emission wavelength of a quantum dot is a function of its size, so by making dots of different sizes scientist can create light of different colours.

The QD material Klimov and his colleagues worked with is easily manipulated through well-established chemical synthesis methods rather than more traditional epitaxial (layer by layer) semiconductor materials. Chemical synthesis should make fabricating densely packed quantum dot arrays a straightforward material processing technique.

Achieving their results also had to overcome the dramatic disaster of this summer's globally reported Cerro Grande fire, which hit the group very hard. Several researchers on the team lost vital data and equipment in the fire and much of Klimov's optics equipment was damaged. Klimov joined Los Alamos back in 1995 and received his master's and doctoral degrees from Moscow State University and was recently awarded the 2000 Los Alamos National Laboratory Fellows Prize for his work on nanocrystal quantum dots.

Semiconductor lasers have now embedded themselves into almost every imaginable human activity. Both optically and electrically pumped lasers are now widely used in fields ranging from telecommunications, information storage and processing to medical diagnostics. The use of semiconductor quantum well structures as optical gain media has resulted in important advances in laser technology. The electronic spectrum of

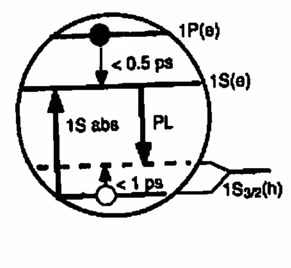


Figure 3a. Absorbing and emitting transitions in CdSe QDs along with intra-band relaxation processes. Courtesy Dr Klimov.

Quantum Dots consists of well-separated atomic-like states with an energy spacing that increases as the dot size is reduced. In very small QDs the spacing of the electronic states is greater than the available thermal energy (strong confinement) inhibiting thermal depopulation of the lowest electronic states. This results in a temperature-insensitive lasing threshold at excitation levels of only 1 electron-hole pair per dot on average. Additional QDs in the strong confinement regime have an emission wavelength that is a pronounced function of size, allowing potential continuous spectral tunability over a wide energy range simply by changing dot size which is a real edge over existing laser systems. The prospect of realising QD lasers for which output colour can be controlled by simple manipulation of QD size and semiconductor composition has been a key driving force in nanocrystal QD research for over a decade which has now finally reached fruition.

Previously large lateral dimensions and difficulties in size control limited spectral tunability. As a result emission wavelengths in epitaxial dots were usually controlled by a material's composition rather than fine-tuned with the QD size.

The alternative approach tried here by Klimov was to fabricate them using chemical synthesis. Chemical methods can provide routine preparation of semiconductor nanoparticles with radii from 1 to 6nm and size dispersions as low as 5%. In this size range,

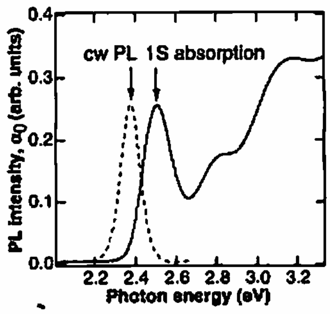


Figure 3b. Absorption and CW PL spectra of CdSe QDs with Radii of 1.2nm at300K. Absorption (solid line) PL emission (dashed line). Courtesy Dr Klimov.

electronic inter-level spacings can exceed hundreds of meV, and size controlled spectral tunability over an energy range as wide as 1eV may result. Nanocrystal QDs can be chemically manipulated like large molecules and can be incorporated into a host polymer or glass matrix and into different photonic structures, such as photonic crystals featured in recent Research News. Nanocrystal QDs can also be assembled into close-packed ordered and disordered arrays. The combination of tuneable electronic energies and chemical flexibility make nanocrystal QDs ideal for building blocks in the assembly of optical devices structures, such as optical amplifiers and lasers.

Although optical gain in nanocrystal QDs of CdSe and CdS grown in glass matrices have been reported previously, narrowband stimulated emission was only demonstrated for large dots with a radius of 7nm. The difficulty in achieving stimulated emission in glass samples is due to large non-radiative losses. Large size distributions 20-25% further hindered the achievement of gain big enough to compete with optical losses.

Direct chemical synthesis can produce colloidal QDs with narrow size distributions but even with quantum efficiencies as high as 50% and a decade of attempts it has not been possible up to now to observe laser stimulated emission from colloidal QDs.

The absorption of colloidal QDs in the 1s electron state results in a photoluminescent (PL) output (Figure 3a). The Continuous-Wave (CW) emission is red-shifted (to the left) with respect to the lowest 1S absorption Figure 3b. This shift is thought to be due to a splitting of the lowest hole state as a result of crystal field and electron-hole exchange interactions. Hole relaxation from the absorbing to the emitting state is required

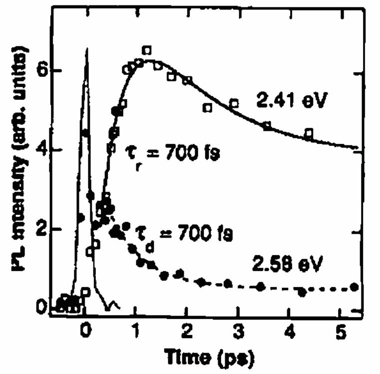


Figure 4 PL dynamics detected. Absorption (circles), and the emitting (squares) transition. Courtesy Dr Klimov.

for population build-up of the emitting transition and hence for the build-up of the optical gain.

The photoluminescent dynamics for QDs with radii of 1.2nm, was recorded at the positions of the 1S absorption (circles), and the PL emitting maximum (squares) shows a rapid 700fs decay of the 1S emission complementary to the emission at the centre of the PL band, Figure 4. This indicates a fast transition from the absorbing to the emitting state sufficiently fast to compete with non-radiative Auger relaxation which otherwise prevents optical gain in QDs.

Light amplification of the QD sample was observed by probing with broadband pulses of white light. In the past accidental overlap of pump induced absorption with the photoluminescence band may explain the numerous unsuccessful attempts to detect stimulated emission in nanocrystal solutions.

Gain is observed in solid state samples prepared from both QDs passivated with trioctylphosphine oxide or TOPO and QDs overcoated with a shell of ZnS (ZnS-capped). Figure 5 shows an example of normalised non-linear absorption gain spectra for two TOPO-capped samples with QD radii of 1.3 and 2.1nm and a ZnS capped sample with R=1.7nm.

The existence of optical gain however does not guarantee in itself the development of stimulated emission. Stimulated emission can only be observed if its build-up time is faster than the gain relaxation. Films made of 1.3nm QDs with random close packing and high packing densities are such that stimulated emission conditions are readily satisfied. Gain spectra would appear to be temperature independent, from liquid nitrogen to room temperatures.

Figure 6 shows an example of stimulate emission spectra for close-packed films of ZnS capped QDs with radii 1.35nm recorded at progressively

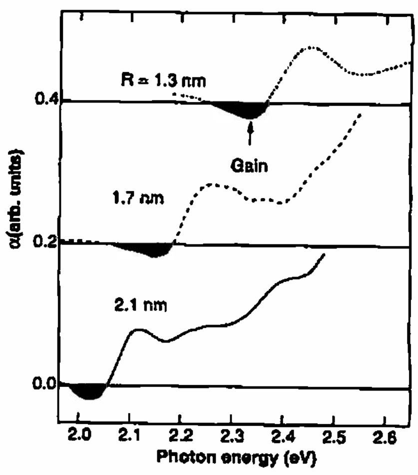


Figure 5 Non-linear gain spectra of 3QD film samples with radii of 1.3,1.7, and 2.1nm recorded at 1.5ps after excitation at 300K. Courtesy Dr Klimov.

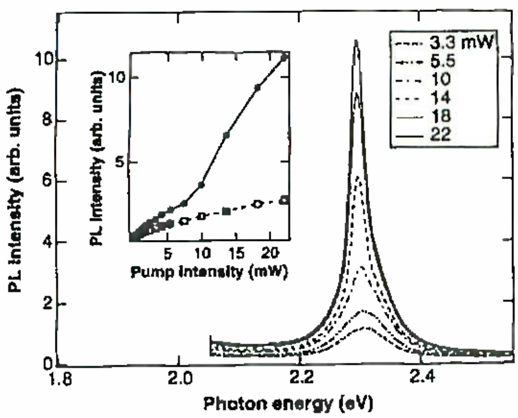


Figure 6. Stimulated emission as a function of pump intensity for ZnS films with radii of 1.35nm. Super-linear intensity of stimulated emission (circles) showing a clear threshold compared to the sub-linear dependence of PL intensity outside the sharp stimulated peak (squares). Courtesy Dr Klimov.

higher and higher pump levels. The films are optically pumped perpendicular to the sample plane and the stimulated emission is detected at the edge of the films that act as optical waveguides (Figure 7). The development of a sharp stimulated emission peak observed in samples at wavelengths characteristic for the dot size, highlighting the size controlled spectral tunability of the stimulated emission. The pump intensity dependence of this peak in Figure 6 shows a threshold behaviour that is a clear signature of optical amplification. Differences in the optical quality of deposited films in their lateral directions are such that not all films demonstrate stimulated emission.

Klimov has now demonstrated room and low temperature optical gain in nanocrystal QDs. Narrowband stimulated emission that is spectrally tuneable with dot size having clear threshold behaviour for films from room to liquid nitrogen temperature sets the scene for designer lasing on a nano-scale in strongly confined nanocrystal QDs. This should motivate the development of nanocrystal QDs-based lasers and amplifiers over a broad spectral range for dozens of nano-scale based future technologies well into the mid-half of the 21st Century.

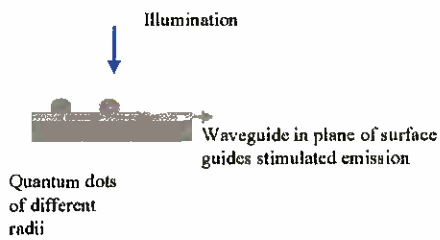
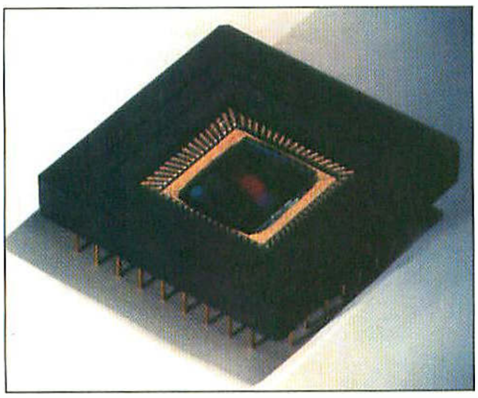


Figure 7. Dots illuminated at right angles to guiding of lasing output from dots.

Los Alamos quantum dot research was funded by the Laboratory Directed Research and Development Program.

For further information on Dr Klimov's work contact: Dr V Klimov, Chemistry Division, C-6, MS-J585, Los Alamos National Laboratory, Los Alamos, NM 87545, USA.
E-Mail: <klimov@lanl.gov>



Newsflash

Edging towards the 10M pixel full frame image sensor limit!

After recent discussion of the general move towards a 10 Million pixel imaging sensor (and then inevitably beyond), Eastman Kodak of Rochester New York, in America have just announced their latest Blue Plus™ Image sensor with 4.3 Million pixels for large image areas such as medical applications in radiography and mammograms. The Kodak Digital Science KAF-4300E image sensor is a high performance 2084 by 2084 pixel resolution Charge Coupled Device (CCD). The imager features large 24 micron square pixels, bigger than their 'usual' 6.8 microns pixel area dimensions to give a total imager size of 50mm (Horizontal) by 50mm (Vertical). It has improved quantum efficiency across the visible spectrum.

Kodak has also released a full frame-imaging sensor with improved sensitivity across the entire visible region of the electromagnetic spectrum (illustrated elegantly in fthe photo). The features of the KAF-1401 image sensor include 1320 by 1034 resolution (nearly 1.4 Million pixels), using their 'standard' 6.8 micron square pixels. It has a single on-chip amplifier and an ultra-low dark current (6pA/cm² at 250C). The image sensor has quantum efficiencies of 30% at 400nm, 50% at 550nm and 60% at 650nm compared with only 2% at 400nm, 35% at 550nm and 40% at 650nm for the previous top of the range KAF-1400 image sensor. The Kodak Blue Plus image sensor family continues to provide increasingly improved sensitivity which makes it especially well-suited for current and future demands within scientific, industrial and medical imaging applications.

According to Dona Flamme, General Manager of Image Sensor Solutions and Vice President of Digital and Applied Imaging at Eastman. "Making the Blue Plus colour sensors available throughout the industry will help drive market acceptance for digital cameras. Today's imaging systems demand extremely high performance yet competitively priced full-frame, solid-state image sensors. We've made a great reputation for these Blue Plus sensors because they perform so well under so many conditions."

A key component to digital cameras, optical sensors receive and react to the light coming through the camera lens. Kodak's Blue Plus Colour CCD image sensors are full-frame devices that offer enhanced photo-responsivity and a very low dark signal. The high dynamic range of these sensors provides exception performance in digital camera applications where superior image quality is required. As a result digital cameras deliver really good pictures even in difficult lighting conditions.

The sensor incorporates the company's Indium Tin Oxide (ITO) technology, along with integral colour filter arrays, provides enhanced photo-responsivity. The key issues Kodak have tried to address in this sensor range are:

- High dynamic range -with a very high charge capacity and linear response, low dark signal and 12-bit performance.
- High resolution -from between 2 to 6 million pixels in a variety of optical formats (they are getting there!).
- Colour fidelity -good red/green "blue colour fidelity.
- Anti-blooming protection.
- & Pixel sizes at: 6.8, 9, & 13 microns square with a high charge-transfer efficiency for high frame rate operation.

For further details on this evolving work contact:

<www.kodak.com/go/CCD>
or phone: US 716-722-4385
Laurie Fumia,
Eastman Kodak Company,
Image Sensor Solution,
Rochester,
NY-14650-2010 USA
<Email:laurie.fumia@kodak.com>

Diary Dates

Every possible effort has been made to ensure that information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments, please contact event organisations to confirm details.

February 2001

7 to 8 Feb. Softworld HR & Payroll ExCel. London. Tel: (0208) 541 5040.

7 to 8 Feb. Legal IT Business Design Centre, London. Tel: (01491) 575 522.

13 to 14 Feb. Technology for Marketing Olympia, London. Tel: (020) 8987 7905.

20 to 22 Feb. Smartcard ExCel, London. Tel: (01895) 454 545.

21 to 22 Feb. Computer Trade Show, NEC, Birmingham. Tel: (0208) 541 5040.

23 to 24 Feb. Digital Mapping Show, Barbican Centre, London. Tel: (01883) 652 661.

March 2001

7 to 8 March. Softworld Accounting & Finance Olympia, London. Tel: (0208) 541 5040.

13 to 15 March. Telecommercexpo ExCel. London. Tel: (020) 8910 7910.

22 to 23 March. Linux Expo 2001 Olympia. London. Tel: (01256) 384 000.

28 to 29 March. Softworld Supply Chain NEC Birmingham. Tel: (0208) 541 5040.

April 2001

3 to 5 April. Electronic Design Solutions, NEC, Birmingham. Tel: (020) 8910 7910.

3 to 5 April. NEPCON - Electronics Exhibition, NEC, Birmingham. Tel: (020) 8910 7910.

9 to 11 April. Convergence, Olympia, London. Tel: (01244) 881 777.

24 to 26 April. Webcom ExCel, London. Tel: (01732) 377 646.

May 2001

16 to 17 May. The Embedded Systems Show, ExCel, London. Tel: (0207) 681 1000.

16 to 17 May. European Cable Communications, ExCel, London. Tel: (020) 8910 7910.

21 to 23 May. Mediacast Communications & IT, ExCel, London. Tel: (020) 8910 7910.

21 to 23 May. Cable & Satellite Mediacast, ExCel, London. Tel: (020) 8910 7910.

22 to 24 May. Mobilexpo, NEC, Birmingham. Tel: (020) 8910 7910.

June 2001

26 to 28 June. Networks Telecom, NEC, Birmingham. Tel: (020) 8987 7905.

Please send details of events for inclusion in 'Diary Dates' by e-mail to: swaddington@cix.compulink.co.uk.

What's On?

CAT Opens Environmental Information Centre

The Centre for Alternative Technology marks its 25th anniversary with the official opening of the Autonomous Environmental Information Centre.

With a quarter of a century of knowledge and experience of living and working with ecologically sustainable technologies, CAT has chosen to use experimental low impact building materials within the new information centre in mid-Wales.

Designed by the UK's leading green architects Pat Borer and David Lea, the information centre is a test bed for ecological building techniques. Providing a model for commercial buildings, AtEIC is constructed using a range of innovative low impact materials, exploring modern versions of some very traditional technologies.

With buildings responsible for 50% of the UK's CO_2 emissions, the Centre for Alternative Technology demonstrates the very latest ideas in environmental building design.

Featuring the latest in energy conservation, heating, waste and water management, the building includes: the UK's largest array of roof mounted solar collectors; a community heat main using renewables, rain water harvesting; low flush and compost public toilets.

For further details, check: <www.cat.org.uk>

Boeing Satellite Sends Video Home

Following its successful launch from Kourou, French Guiana at the end of last year, PAS-1R, a Boeing 702 built for PanAmSat, has transmitted back photos from space.

The on-board cameras, which will also videotape the deployment of the spacecraft's solar arrays, caught these glimpses of the sun and the Earth as PAS-1R entered its orbit.

The first two frames (top and middle) show the Earth in the foreground, and the third photograph (bottom) is looking toward the sun.

PAS-1R is the second Boeing 702 in the PanAmSat fleet and will provide video, data and Internet services to four continents from its orbital slot over the Atlantic.

For further details, check: <www.boeing.com/space>

Hewitt Welcomes Independent E-Commerce Report

E-Minister Patricia Hewitt has welcomed the publication of the Better Regulations Task Force's report on e-commerce.

The report, 'Regulating Cyberspace', was undertaken by the Task Force to examine to what extent regulatory barriers were preventing UK businesses and consumers from engaging in e-commerce.

"I welcome this independent endorsement for the Government's light touch regulatory approach to e-commerce," said Hewitt.

"Over the last year there has been a surge in businesses getting online. However, while the results are promising, relatively few are exploiting the full power of e-commerce and consumers still lack confidence in buying online.

"This report makes some useful recommendations which will help overcome the barriers to achieving our goal of making the UK the best place in the world for e-business. We will consider these very seriously in our response."

A copy of the report is available at:
<www.cabinet-office.gov.uk/regulation/taskforce/index.htm>.

Liddell Starts Wind of Change

Helen Liddell, Minister for Energy, opened the first UK Offshore wind project at Blyth, Northumberland in December.

The £4 million wind project 1km off Blyth Harbour is the largest at any offshore site in the world and can produce enough power to supply 3,000 houses.

Speaking at the launch at Blyth Harbour Liddell said, "This is a major signal of the potential for a new energy source and a new industry for the UK.

"Rapid development of offshore windfarms over the years immediately ahead is a key element in the Government's strategy for renewable energy.

"The Government is making a total of £89 million available for offshore wind and energy crops projects. These projects need extra support, at the critical early stage, towards the costs of plant construction.

"The Renewables Obligation will move this important industry from the margins to the mainstream and give a significant priority to major technological development."

Congratulating the shared achievement of Blyth developers AMEC BorderWind, Powergen Renewables, Nuon UK and Shell Renewables Liddell said, "The offshore experience of oil and gas companies that are already household names will be invaluable as the UK offshore wind industry gathers momentum.

"We want to make it easier for companies such as these to invest in this exciting new industry and make progress with proposals.

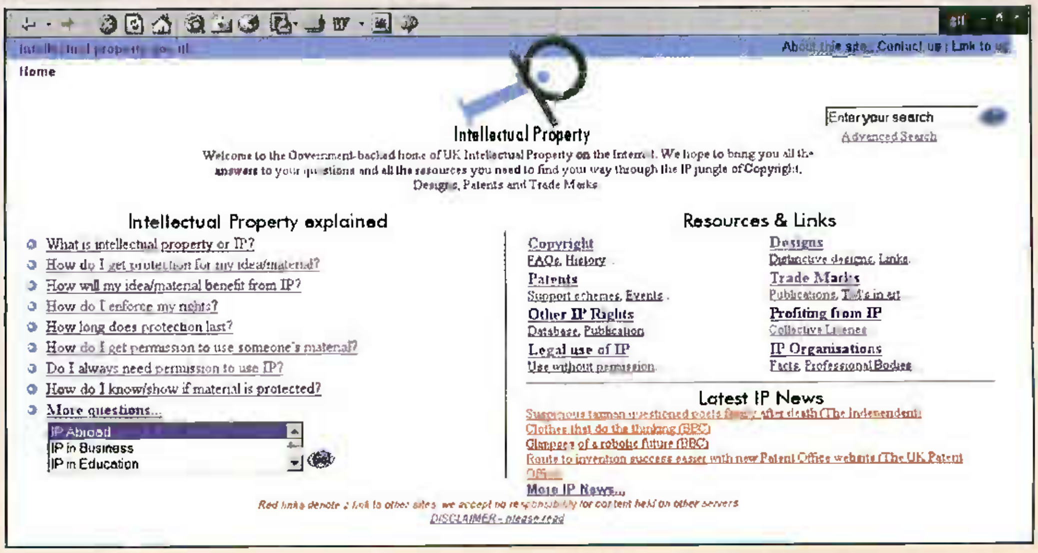
"We will be consulting the industry very soon to establish a co-ordinated procedure for companies to obtain the consents they need for offshore projects.

For further details, check:
<www.dti.org.uk>.

Web Portal Offers Helping Hand UK's Innovators

Budding innovators can learn how to make the most of their ideas and protect themselves from counterfeiters thanks to a new Intellectual Property (IP) Web site launched at **<www.intellectual-property.gov.uk>** by Minister for Consumer and Corporate Affairs Kim Howells.

The site provides a comprehensive resource for businesses and inventors, with information on copyrights, trade marks, patents and designs. Users will be able to find answers to frequently asked questions, view the latest news and link to other IP-related sites. Special sections deal with IP as it relates to business, education and entertainment and there is information on how to profit from IP.



The site will also help people with concerns about using the property of others, for example by signposting them to the correct place to obtain a licence. There is information for both people with little knowledge of IP and more experienced users.

Understanding COLOUR

by Mike Bedford

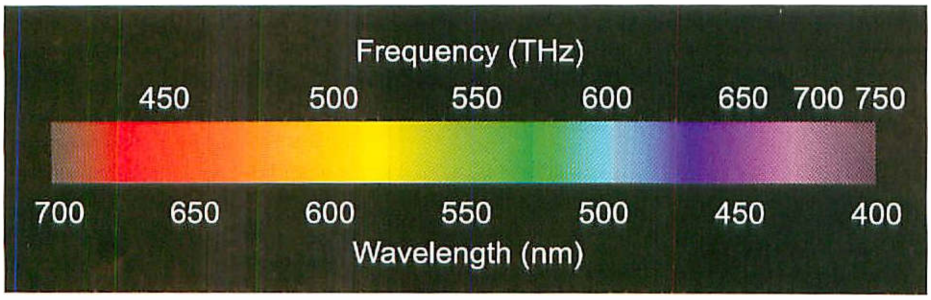


Figure 1.

Although it's a concept which most people think they understand, few people really have an in-depth appreciation of colour. Yet an understanding of certain elements of colour theory is essential in various areas. Traditionally it was artists, designers and printers who needed to appreciate colour. Increasingly, though, and of particular relevance to readers of Electronics & Beyond, it's in graphics programming and opto-electronic design where such knowledge is needed. Even power users of graphics and design packages will need this sort of appreciation of colour theory. My aim here is to provide a grounding in basic colour theory which can be applied in these application areas.

The Basics

Light is that portion of the electromagnetic spectrum which is visible to the human eye and is normally considered to lie in the approximate wavelength range 400nm to 700nm as shown in Figure 1. Normally, this, rather than frequency (actually in the range 430THz to 750THz), is quoted. The visible part of the spectrum is bounded by infra-red at the low-frequency end and ultra-violet at the high frequency end. Our eyes contains two kinds of receptors which are called rods and cones. The rods allows us to perceive shades of grey whereas the cones allow the brain to perceive different colours. There are actually three types of cones which are sensitive, respectively, to red-orange, green, and blue-violet light. When a single cone is stimulated, the brain perceives the colour associated with that cone. So, for example, if the eye receives light at a wavelength of 550nm, the green cones are stimulated and we see green. Clearly this is a simplification since we can actually perceive many millions of colours, not just the three which correspond to the different types of cone.

Additive Mixing

At this point, since it's a key to many of the methods of defining colour, let's think about colour mixing. By colour mixing, I'm talking about the sort of thing we were taught in school physics lessons, as opposed the type of mixing we learned in art lessons – we'll come onto this a bit later. In Figure 2 we see what happens if we project circles of red, green and blue light onto a screen in a darkened room. Where the red and green overlap we get yellow, the overlap between red and blue gives magenta, that between green and blue gives cyan, and in the central portion, where red, green and blue all overlap, we get white. In fact, by varying the amounts of red, green and blue we can produce any colour the eye can perceive so these three colours are referred to as primary colours. Similarly, the three colours cyan, magenta and yellow are called secondary colours. To be more precise, and to differentiate them from the subtractive primaries and the subtractive secondaries which we'll see shortly, we should really refer to red, green and blue as the additive primaries and cyan, magenta and yellow as the additive secondaries. Similarly, the type of mixing we've been looking at is called additive mixing.

Since you have a grounding in electronics, many of you are probably now considering why red plus green gives yellow and so forth. And that knowledge of electronics may well cause you to think in terms of frequency mixing like that employed, for example, in a superhetrodyne radio receiver. But a few quick calculations shows that this can't be the explanation. The mixing products of signals with frequencies f1 and f2 are f1+f2 and f1-f2. Since the frequencies of red and green light are, say, 462THz (650nm) and 577THz (520nm), if any appreciable frequency mixing were to take place, the mixing products would be at 1039THz and 115THz, neither of which are in the visible portion of the spectrum let alone the frequency which corresponds to yellow. In fact, mixing red and green to give yellow is purely an artefact of the way the brain processes the information – an optical illusion if you like. Although we can perceive an image with different colours in different parts of that image, we can only differentiate a single colour at a single point. So, when the brain is presented with signals indicating multiple colours at a particular point, it perceives this as a single different colour. In other words, the brain cannot differentiate a mixture of red and green light from yellow light. And in the case of mixing red, green, and blue light, this is clearly the case since, spectrally, there's no such thing as "white", it's all in our brains. Having said that the eye cannot differentiate yellow light from a mixture of red and green light there are exceptions. In the early days of high brightness LEDs, before the widespread availability of white LEDs, people experimented with a mixture of red, green and blue LEDs to produce white light for high reliability torches. Although the light appeared to be white, in much the same way as sunlight, the effect was very different when illuminating primary coloured objects. Since the light contained

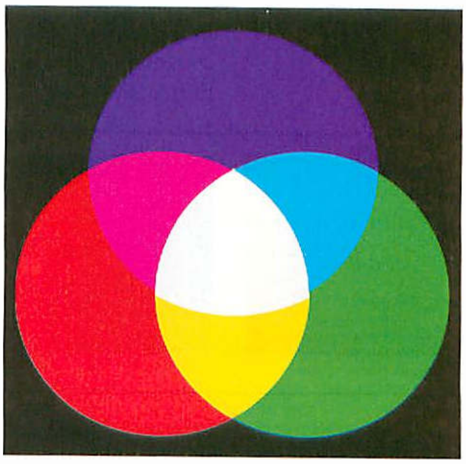


Figure 2.

just three spectral bands, any object of a *similar colour* to one of these bands would appear to glow in the light of the torch.

Subtractive Mixing

In the previous section I referred to another type of mixing, that which we were taught in art lessons – this is summed up in Figure 3. Here we see the effect of mixing three colours of paint – cyan, magenta and yellow (art teachers tend to talk about blue, red and green but this isn't strictly correct) – on a piece of paper. Now we see that mixing cyan and magenta gives blue, cyan and yellow gives green, magenta and yellow gives red, and that mixing all three gives black. The explanation lies in an understanding of how paints and pigments work. Clearly pigments don't actually emit light since they don't glow in the dark. Instead, they selectively reflect light by absorbing their complementary colour. Cyan paint, for example, absorbs red light so, when illuminated with white light, allows green and blue light to be reflected. And, as we already know, adding together green and blue light gives cyan. Cyan paint can, therefore, be thought of as minus red. Similarly, magenta is minus green and yellow is minus blue.

We can now return to mixing paints or inks and see that it makes perfect sense. Since cyan paint absorbs red and magenta paint absorbs green, when the two are mixed together we end up with something which absorbs both red and green. When the mixture is illuminated with white light, therefore, only blue is reflected. Because this form of mixing works by subtracting colours from the light illuminating it, the process is called subtractive mixing. Cyan, magenta and yellow are the subtractive primaries and red, green and blue are the subtractive secondaries.


Figure 3.

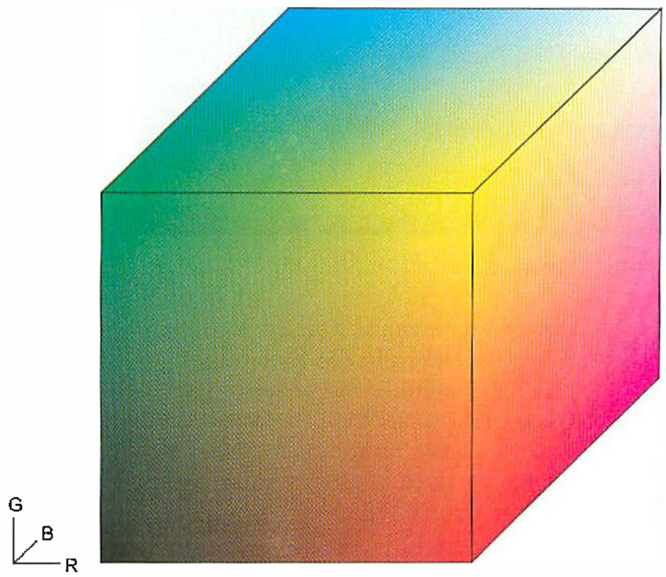


Figure 4.

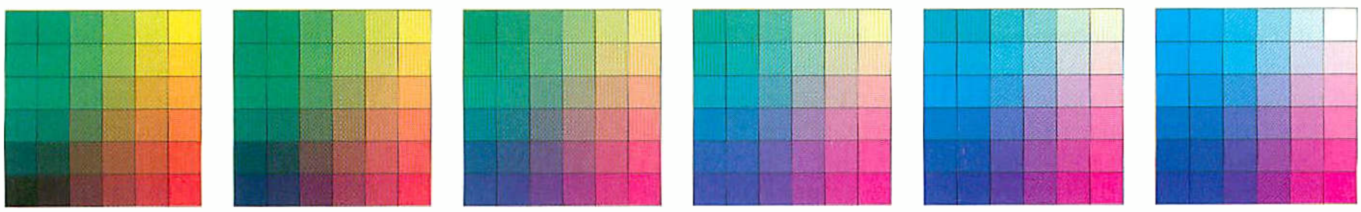


Figure 5.

Defining Colour

Officially, the colours of the rainbow are red, orange, yellow, green, blue, indigo and violet as in the well-know aide memoire "Richard of York gained battles in vain". This is interesting since it suggests that the rainbow contains just seven discrete colours whereas in reality, of course, it contains an infinite number of which many thousands can be differentiated by the human eye. And when there are so many colours, coming up with names for them all can be a daunting task. There are, of course, many names of colours in addition to the rainbow colours – cerise, turquoise, aquamarine, lemon, crimson, mauve, purple and scarlet for example – and many colours can take descriptive adjectives so we have lime green, bottle green, leaf green and so on. But these an imprecise and too few to name all the available colours. In the printing industry, books of standard colours are produced by companies specialising in colour matching. A popular colour matching scheme is Pantone – customers pick colours for logos etc. from a Pantone booklet and specify these colours to the printer using the corresponding Pantone number. This way, irrespective of which printing company is being used, the colours should be identical. Many PC graphics packages also allow Pantone colours to be selected. But although there's a clear benefit of using a colour matching method like this, the numbers assigned to the colours (e.g. Pantone 5415 CV) appear to be largely arbitrary. No doubt there is some sort of rationale to the numbers but this isn't something Pantone feel the customer needs to be concerned with.

In the early days of computer graphics, none of this was a problem. Since the first colour displays had just eight colours, the three additive primaries: red, green and blue, the three additive secondaries: cyan, magenta and yellow, plus black and white, using names was perfectly adequate. And even when the number of colours increased, perhaps, to 64, names were still used by some companies. So, the progression from yellow to green might be yellow, greenish yellow, yellow-green, yellowish green, and green and these would indicate 100% yellow, 75% yellow / 25% green, 50% yellow / 50% green, 25% yellow / 75% green, and 100% green respectively. Eventually we come to a point, though, at which attempting to use names just isn't feasible and we have to turn to numbers. Not only does using some mathematical definition of colour solve the problem of colour definition, but the numbers can also be manipulated directly by software.

RGB and CMY

One of the most common ways of defining colour is by the proportion of each of the three additive primary colours red, green, and blue. This is called the RGB method. The proportion is normally defined either as a value in the range 0-1, a percentage or as a number in the range 0-255. This latter method is appropriate for typical colour displays which are capable of showing 16.7 million colours since this is the number of

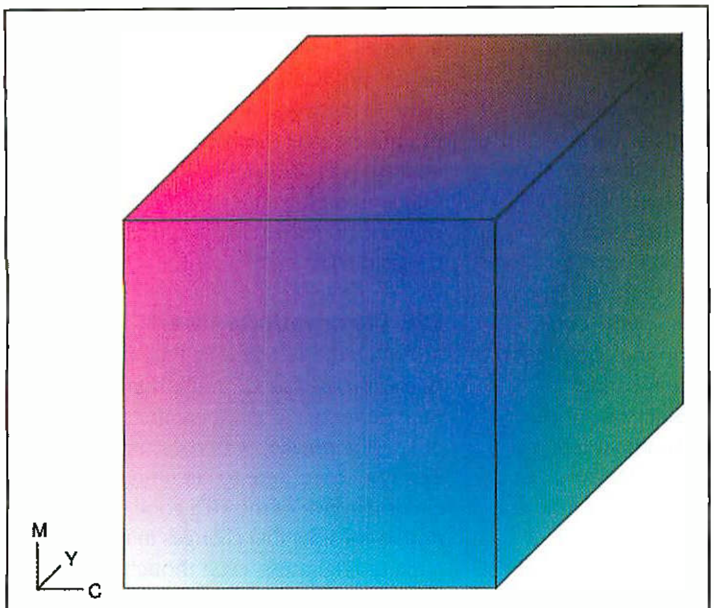


Figure 6.

possible combinations of 265 levels of red, green and blue. The RGB colours are often visualised as a cube – the RGB colour cube – which is shown in Figure 4. Here the amount of red, green and blue increases along the x, y and z-axes, respectively, starting at the bottom left hand corner. Sometimes this cube is shown differently, perhaps with the black corner at the back or the top right but the basic principle is the same. All possible colours can be found somewhere inside this cube. However, since this diagram only allows you to see the colours on three of the faces, and even if you could rotate it you'd still only see the colours on the other three faces, we show a number of slices through an RGB colour cube as Figure 5. Specifically the cube has been sliced from front to back as viewed in Figure 4. Note also that this particular version of the colour cube is far from the idealised one which contains all possible colours. Instead of the infinite number of shades in the theoretical colour cube, this one has six levels for each of red, green, and blue so includes just 216 colours. All practical imaging systems will be capable of displaying a limited number of colours.

Since they operate by additive mixing, RGB is a useful way of thinking about colour on a display screen, but less so colour printing which operates by subtractive mixing. A close relative to the RGB colour cube is the CMY colour cube. Now, instead of the x, y and z-axes representing red, green and blue, they represent the subtractive primaries cyan, magenta and yellow. The CMY colour cube is shown as Figure 6 and you'll notice that it is, in fact, an RGB colour cube with each point reflected about the centre of the cube. You won't be surprised to learn, therefore, that colours can easily be converted between the two colour models using the following simple relationships:

$$C = 1.0 - R$$
$$M = 1.0 - G$$
$$Y = 1.0 - B$$

Where C, M, Y, R, G and B are values of cyan, magenta, yellow, red, green and blue, respectively, in the range 0-1. If working with values in the range 0-100% or 0-255 rather than 0-1, each of the constants 1 in the formulae should be changed to 100 or 255, respectively.

CMY is important in the printing industry since inks combine according to the subtractive mixing model. Traditionally, a colour original would be split up into the three subtractive primaries by photographing it through coloured filters. Plates are then made for each of the primaries and these are used, one at a time with the appropriately coloured ink. The full colour image is, therefore, built up progressively. Today, the process of splitting a full colour image into the subtractive primaries (which is called colour separation) is normally done by software, especially if the artwork is being mastered

Figure 7.

digitally. In fact, I've over-simplified things by suggesting that colour printing is based on the CMY model; in fact full colour reproduction is referred to as four-colour printing and conforms to the CMYK model where K stands for blacK (because B would be confused with Blue in RGB). Although perfect cyan, magenta and yellow inks will overprint to produce black, most printing inks aren't perfect primaries so blacks would appear as muddy browns. However, by extracting the black content and using this information with a pure black ink, a better full colour image results. The conversion of a colour defined in CMY to CMYK (which should really be C'M'Y'K to differentiate the different cyan, magenta and yellow contents in the two models) is given by the following equations:

$$K = \text{minimum}(C, M, Y)$$
$$C' = C - K$$
$$M' = M - K$$
$$Y' = Y - K$$

Figure 7 is a full colour original and Figures 8a, b, c and d are the C, M, Y and K contents separated digitally. Then, in the parts of Figure 9 we see the image being built up as it would be in lithographic printing. Note that the printing normally takes place in order of increasing density, that is yellow, magenta, cyan and black.

HLS and HSB

Although the RGB and CMY colour models are, perhaps, the most obvious ways of

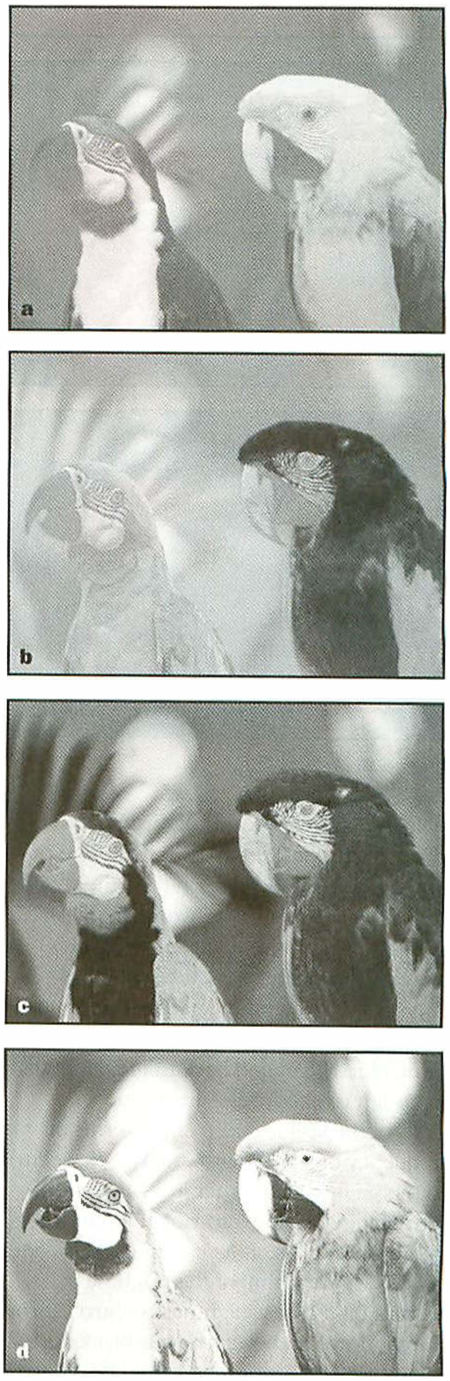


Figure 8.

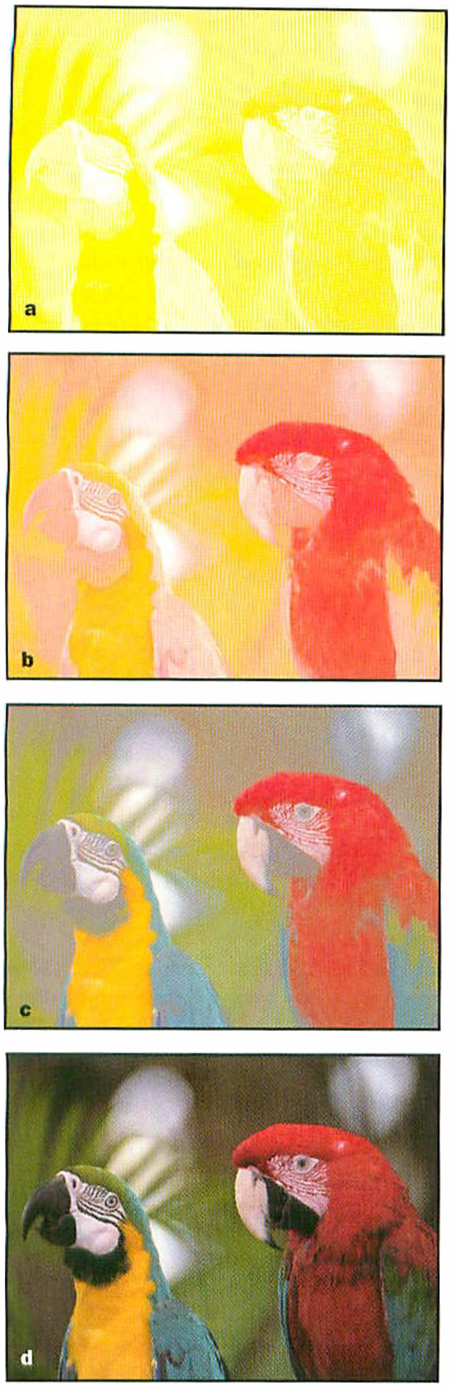


Figure 9.

defining colour in terms of mixing, they don't really conform to our perception of colour. The HLS model, on the other hand, uses concepts, if not the words themselves, which we can more easily relate to. H stands for hue and is best described as "colour", by which I mean the continuum from red through orange, yellow, green, cyan, blue, violet and back to red. Note that although red and violet are at opposite ends of the visible spectrum in terms of frequency or wavelength, the two do seem to merge into each other just as red does into orange or blue into violet. L stands for lightness and has, as its extremes, black and white. You can think of the brightness control on a TV as a lightness control. Turn it right down and everything is black, turn it right up and everything would be white if it wasn't for the fact that TV manufacturers place a limit before this point. S stands for saturation and is the property which is influenced by the colour control on a TV. Turn it right down and everything is a shade of grey, turn it right up and the colours are all vibrant. Hue takes values of 0°-360°, whereas lightness and saturation both take values of 0-1, 0-100% or 0-255. HLS colour space is represented as a double cone as shown in Figure 10. Hue is the angle around the spine of the cone, lightness is the distance up the cone with 0 at the bottom and 1 at the top, and saturation is the radial distance from the spine. At first you might find it surprising that it's this particular shape. However, as you study it and as you note, for example, that a lightness of 0 is always black irrespective of hue and saturation and that a lightness of 1 is always white irrespective of hue and saturation, it should make more sense. As with the RGB colour cube, we've also shown a few slices through the HLS colour cone in Figure 11 so that you can see some of the internal colours. This is particularly important here since you can only ever see the colours with a saturation value of 1 on the outer surface of the cone. The following formulae shows how HLS values (0-1) can be obtained from RGB values (0-1):

IF minimum colour is B then

$$H = 120 * \frac{G - B}{R + G - 2 * B}$$

ELSE IF minimum colour is R then

$$H = 120 * \left(1 + \frac{B - R}{B + G - 2 * R}\right)$$

ELSE

$$H = 120 * \left(200 + \frac{R - G}{R + B - 2 * G}\right)$$

ENDIF

$$L = \frac{MAX(R,G,B) + MIN(R,G,B)}{2}$$

IF L < 0.5 THEN

$$S = \frac{MAX(R,G,B) + MIN(R,G,B)}{MAX(R,G,B) - MIN(R,G,B)}$$

ELSE

$$S = \frac{MAX(R,G,B) - MIN(R,G,B)}{2 - MAX(R,G,B) - MIN(R,G,B)}$$

ENDIF

Another colour model, which obviously has quite a bit in common with HLS, is the HSB model which is represented as a single cone as shown in Figure 12. Here, H stands for hue as in HLS, similarly S stands for saturation, and B stands for brightness. Occasionally, this colour space is called HSV, in which case V stands for value but is defined just the same way as brightness. Hue is defined in exactly the same way as in the HLS model, but saturation is defined rather differently and brightness is not the same as lightness. In this model, the 100% brightness level is achieved if any of the additive primaries are at 100% so all the fully saturated colours are at a brightness value of 1.0 rather than a lightness value of 0.5 as in HLS.

CIE Chromaticity Chart

Although the HLS and HSB colour models purport to be based on the human perception of colour, there are some very obvious anomalies with these schemes. For example, if we were to circumnavigate the circumference of the HLS cone, we'd notice considerable changes in the apparent lightness, even though all are colours we'd encounter have lightness values of 0.5. In particular, the colours in the yellow region appear very much lighter than those in the blue region. So although there's a clear theoretical basis to the colour models we've seen so far, we really need to adopt something else if we're genuinely interested in the human perception of colour.

A colour model which was devised back in 1931 but is still in widespread use is the CIE colour space which includes all the colours which can be perceived by the human visual system. It is based on the spectral power distribution of the light emitted from a coloured object and then calibrated by the sensitivity curves for the human eye. Effectively, colours are represented by the proportion of three primary colours, referred to as X, Y and Z, which correspond to the sensitivities of the three types of cone sensors in the human

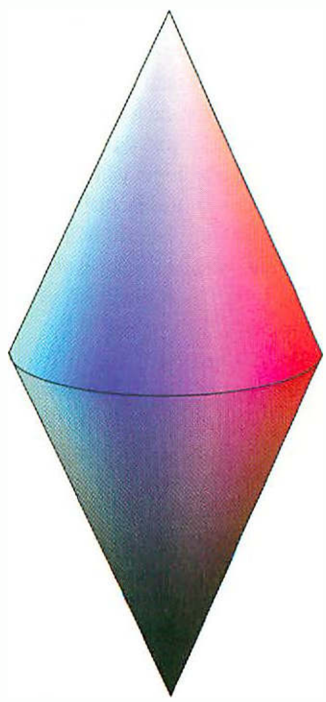


Figure 10.

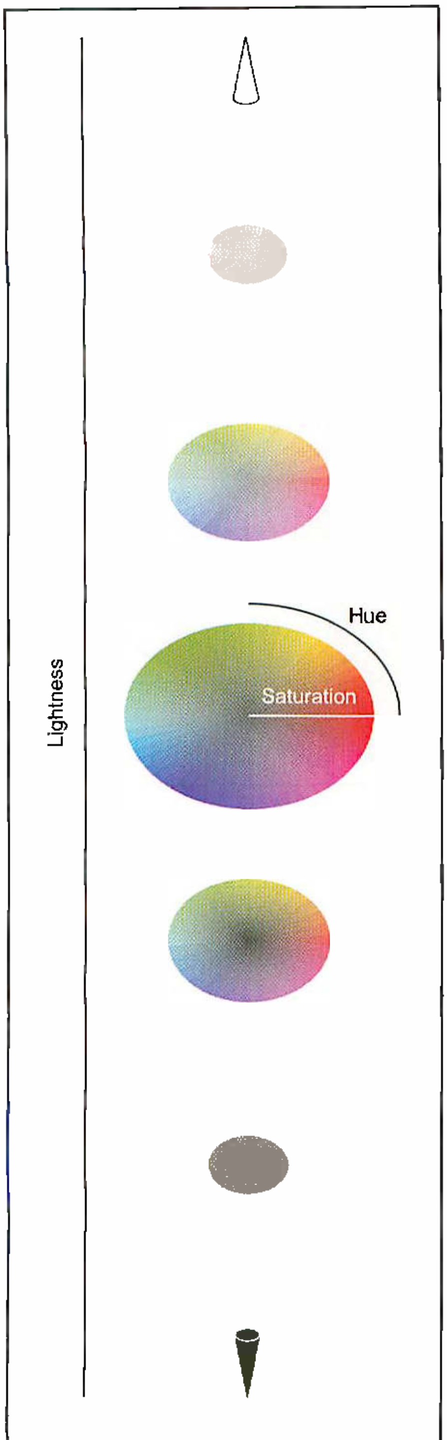


Figure 11.

eye. Furthermore, Y represents the perceived brightness and is referred to as luminance. This differs from the lightness in the HLS and HSB models, or the intensity of the three primaries in the RGB or CMY models, each of which are proportional to the physical power level measured in a unit such as watts per square metre. Figure 13 shows the spectral curves for the three CIE primaries. You'll notice that the blue curve is taller than the others because the eye is less sensitive to blue light. Rather than showing the full colour space, this model is normally shown as the CIE chromaticity diagram which appears as Figure 14. This is a slice through the colour space which has equal luminance – specifically the slice for X+Y+Z = 1. In other words, the X and Y primaries are normalised according to the following formulae to give the co-ordinates x and y which are shown on the diagram.

$$x = \frac{X}{X = Y + Z}$$

$$y = \frac{Y}{X = Y + Z}$$

In fact, it turns out that all hue and saturation combinations can be represented in terms of x and y alone. Y can, therefore, be used to represent luminance alone so giving the Yxy colour space. It's interesting to note that the colours round the curved edge of the CIE chromaticity diagram are pure colours, that is spectral colours. The corresponding wavelengths are indicated on the diagram. However, the straight line section of the perimeter, the so-called purple line, includes those shades of magenta or purple for which there is no equivalent monochromatic light.

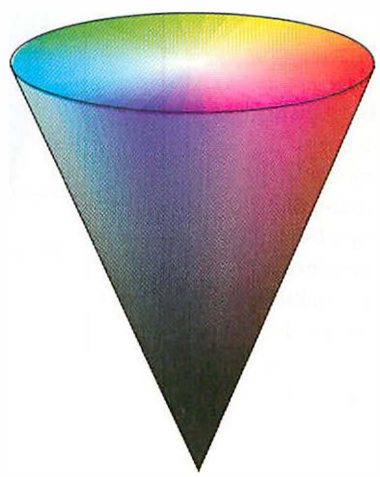


Figure 12.

Figure 15 is another version of the CIE diagram onto which the colours of red, green and blue LEDs and of the red. green and blue phosphors on a CRT are indicated. In each case, the triangles bounded by the three "primary" colours contain all the colours which can be produced by mixing the three colours. The colours within the triangle are referred to as the gamut of a LED-based display or of a CRT. The LED gamut is the smallest and quite clearly there is a significant number of colours which cannot be mixed from red, green and blue LEDs – basically because they're not perfect primaries. Most notably, the traditional green LED is a very yellowish green. You'll notice, though, that a so-called "pure green" LED is also shown. This is a newer type of LED which uses a similar semiconductor to that which made blue LEDs possible and is much closer to a true primary green. Now the range of colours is much improved, even over the CRT. Also shown on this diagram are the gamuts of four-colour printing and photographic film. You'll notice that the gamut of four-colour (CMYK) printing is particularly limited. For this reason, for high quality work, additional colours are sometimes used in addition to cyan, magenta, yellow and black – the so-called process colours. One common approach is to add a further two "primary" colours, specifically an orange and a green to give six-colour printing. Another option is to add one or more "spot" colours. A spot colour isn't used in mixing, instead it allows a single colour, which cannot faithfully be mixed from the primaries, to be printed. This might be used, for example, in a glossy brochure showing a red car. If four-colour printing wouldn't do justice to the red of the car, the exact shade would be printed as a spot colour after the four process colours.

YUV Colour Space

So far we've looked at five colour models in some detail and there are dozens of others. Many are effectively obsolete, though, or applicable only to very specialised areas so we're not going to go through them all here. However, there is one other we should look

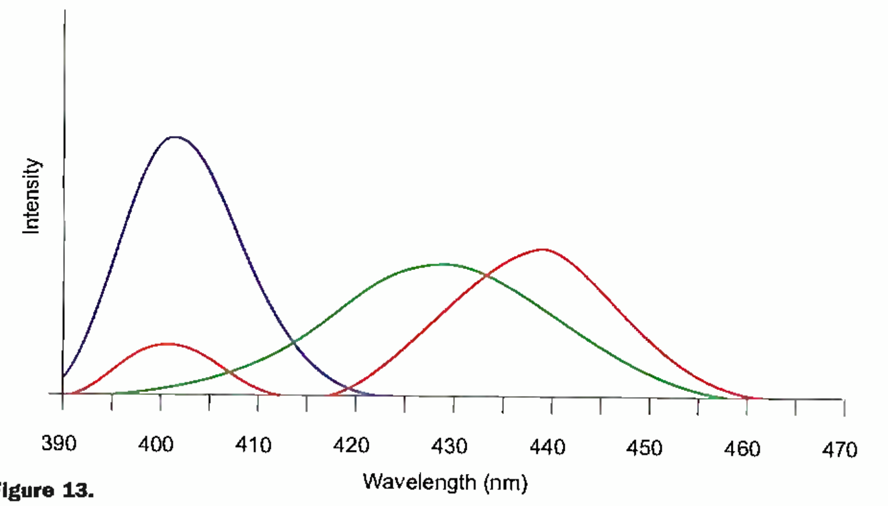


Figure 13.

at because of its importance in colour TV and video. This is the YUV colour model.

The YUV colour model separates luminance from colour. I'll explain later why this is useful for broadcast TV and in MPEG encoding. Y represents the luminance but, despite numerous reports to the contrary, it is not the same as Y, the luminance in the CIE Yxy. In fact, the YUV model was originally referred to as the Y'UV model in order to make the distinction but the prime has now been dropped. Y in YUV is a gamma corrected luminance value and is sometimes referred to as luma in order to reduce confusion. Gamma correction involves applying a non-linear transformation to the luminance value to take into account the non-linear relationship between the voltage applied to a CRT and the perceived lightness which results. Failure to apply this gamma correction before transmitting a video signal results in the inefficient use of bandwidth. Luma is determined by gamma correcting each of the additive primary colours, R, G and B, and then combining them with different weightings which correspond to the sensitivity of human vision to each of the additive primaries standardised for video. This is shown in the following formulae:

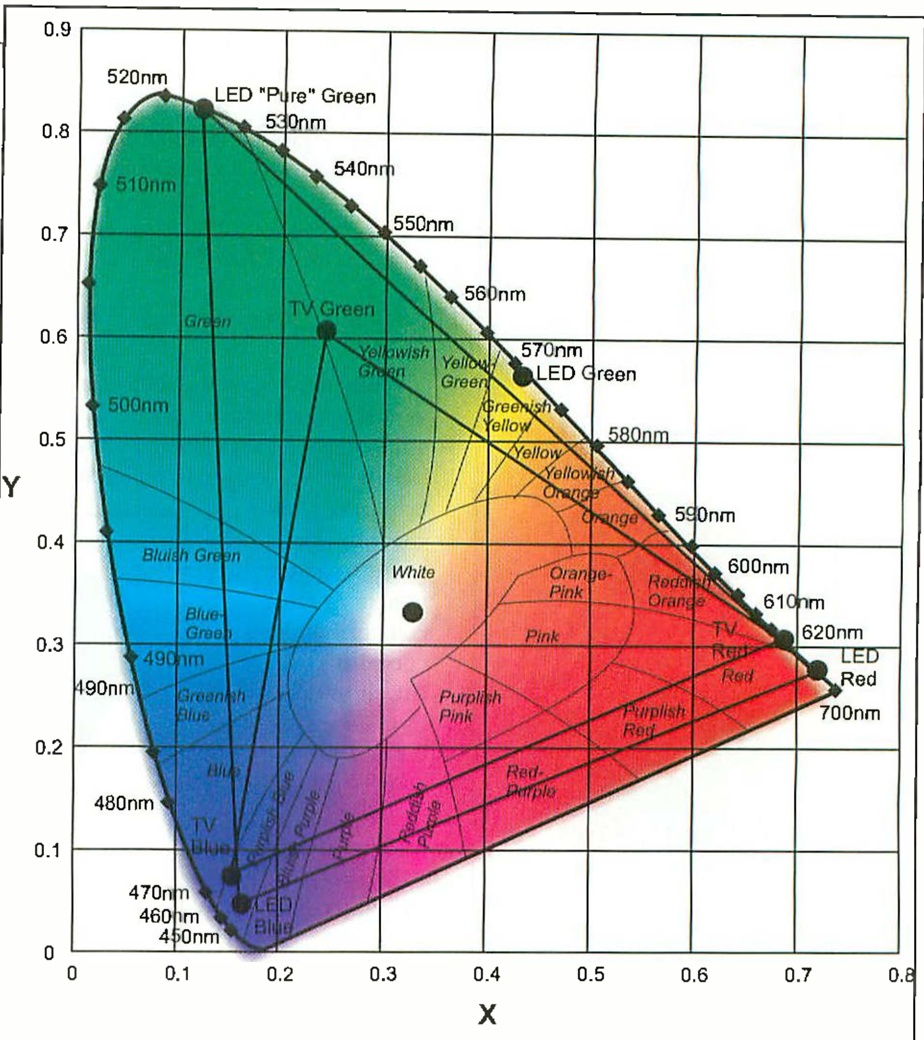


Figure 14.

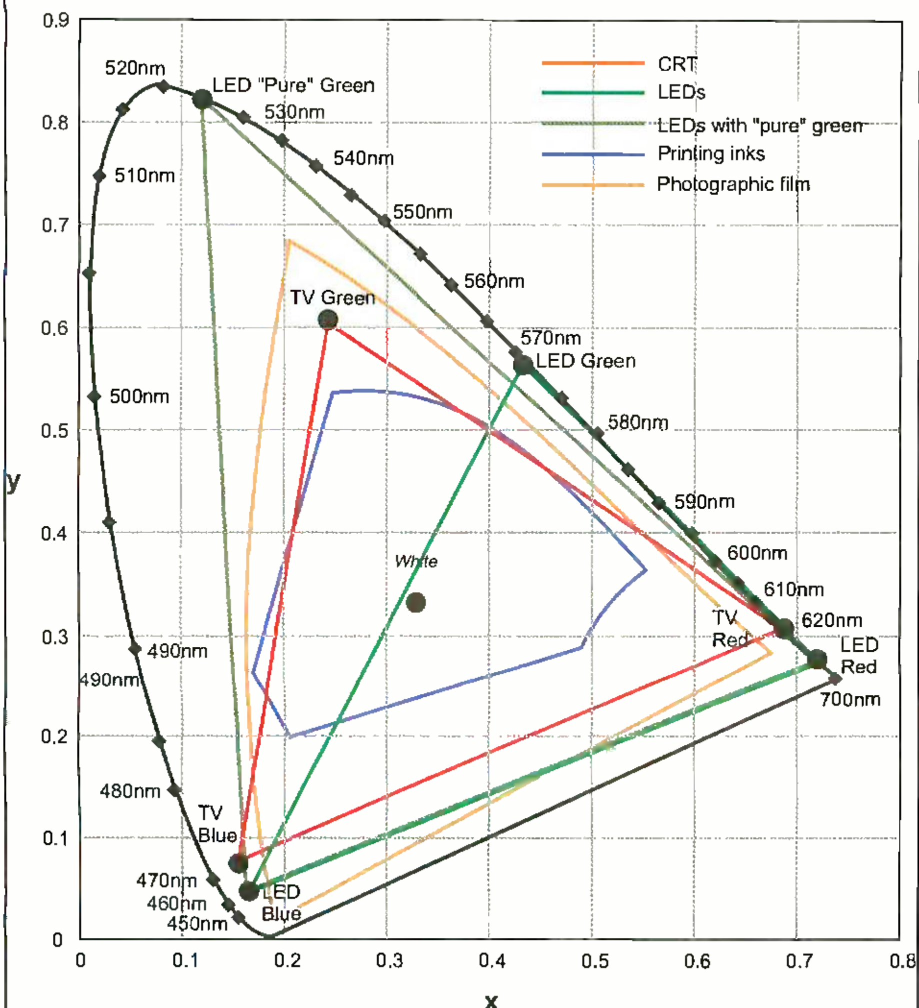


Figure 15.

$$R_{gamma} = 1.099 \times R^{0.45} - 0.099$$

$$G_{gamma} = 1.099 \times G^{0.45} - 0.099$$

$$B_{gamma} = 1.099 \times B^{0.45} - 0.099$$

$$Y' = 0.288\, R_{gamma} + 0.587\, G_{gamma} + 0.114\, B_{gamma}$$

The U and V values, which are, in fact, colour difference signals (i.e. the difference in intensity between two of the primaries and the luma value) are now calculated according to the following formulae:

$$U = 0.493 * (B - Y')$$

$$V = 0.877 * (R - Y')$$

If the signal is being transmitted as component video, such as from a DVD player to a TV on separate cables, no more encoding is necessary. However, for analogue broadcast TV the U and V values are combined to produce a chroma signal, C, by quadrate modulation. The reason for the strange looking coefficients in the above equations is so that the composite

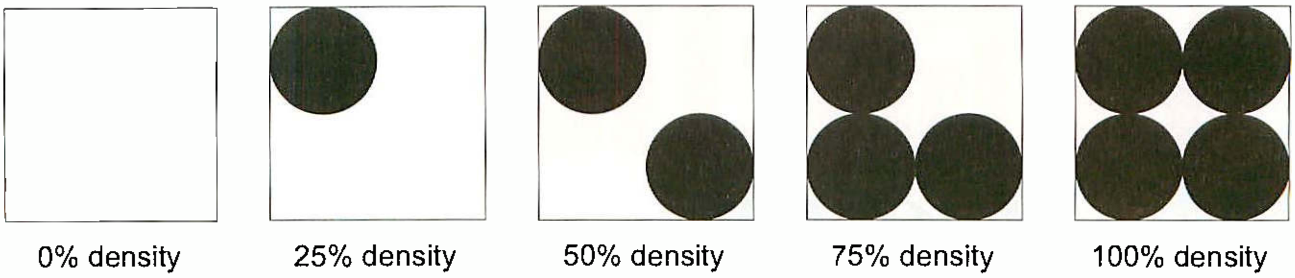


Figure 16.

PAL signal (luma plus modulated chroma) is contained within the range -1/3 to +4/3. These limits reflect the capability of the composite video recording or transmission channel.

And finally, before leaving the topic of the YUV colour model I need to explain the rationale for separating the colour information from the luma. The eye is more sensitive to detail in colour than in luminance. In PAL TV, therefore, the U and V values are sampled at half the horizontal frequency as the luma. This provides a useful decrease in the bandwidth. A similar technique is employed in video compression, in the MPEG-2 standard, for example.

Practical Colour Mixing

We started off by looking at colour mixing and this is also where we'll conclude. For although it's possible to continuously alter the amount of the additive primaries red, green and blue on a CRT tube by controlling the voltage on the tube, this is not possible on paper. In most forms of printing a dot of ink is either present or it isn't. So the only way of altering the perception of darkness is to alter the size of the dot and/or its separation from its neighbours. Since lithographic printing really doesn't have much of a bearing on electronics and computing, I won't describe the solution adopted here. However, this is something which is relevant in desktop publishing so you may like to read up elsewhere on the subject. You should look for a book on printing or DTP, or search the Web for information on half-toning or screening. In most colour printers intended for use with PCs (e.g. inkjet printers), though, a technique called dithering is used. If a printer has a 1200dpi x 1200dpi resolution it can deposit dots of ink on a 1/1200th of an inch grid. But since it only has four colours of ink (cyan, magenta, yellow and black) and since it can overprint to produce another three (red, green, and blue) it can only print at this resolution in seven colours plus the white of the paper. Fortunately, for a photographic image, the eye generally won't notice if the actual resolution is much less than 1200dpi. So a block of printer dots can be used to represent one pixel in the image. Figure 16 shows how this can be useful and, for simplicity, I've used a small 2 x 2 dot block to represent a pixel. Since this contains four dots, 0, 1, 2, 3 or 4 dots can be printed thereby giving an overall density of 0%, 25%, 50%, 75% or 100%. And at a normal viewing distance, the individual dots will not be resolved so the eye will just see the shade of grey represented by the density. By increasing the size of the block, the number of shades of grey is increased at the expense of resolution. But this just relates to greyscale printing. Since we can do the same for each of the subtractive primaries, a 2 x 2 dot block actually allows 125 colours to be printed, 3 x 3 dots allows 1,000 colours and with 4 x 4 dots this rises to almost 5,000. In Figure 17 a few colours mixed by dithering are shown. The scale is large enough to allow you to see how they've been made up from individual dots in one of just 8 colours but from a distance you'll be able to perceive the colours.

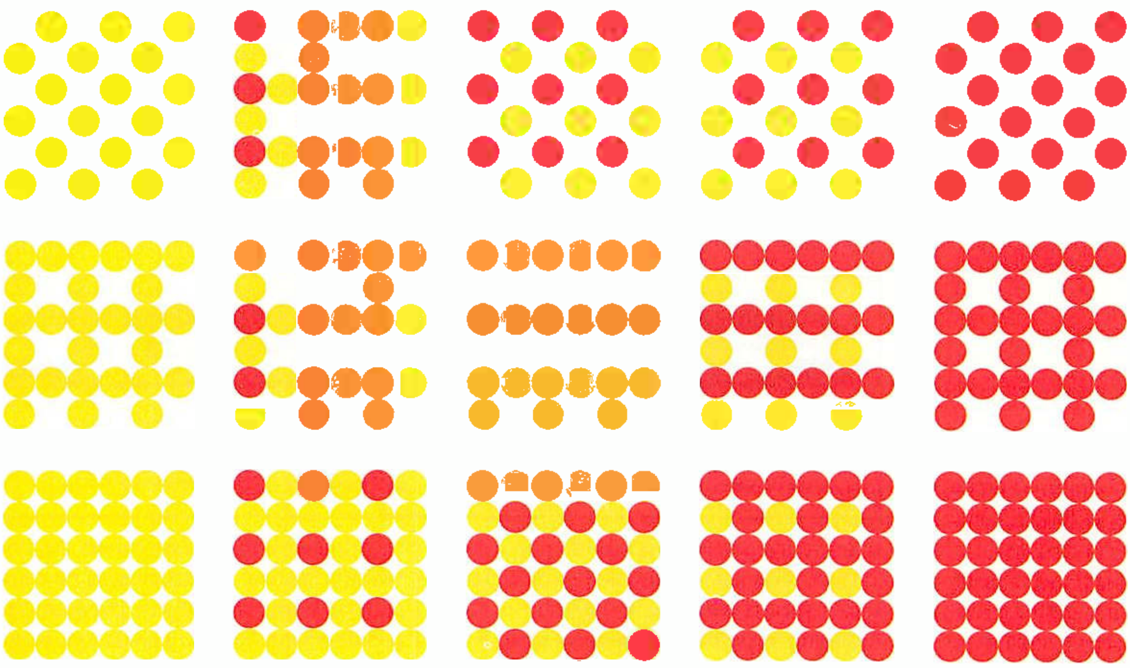


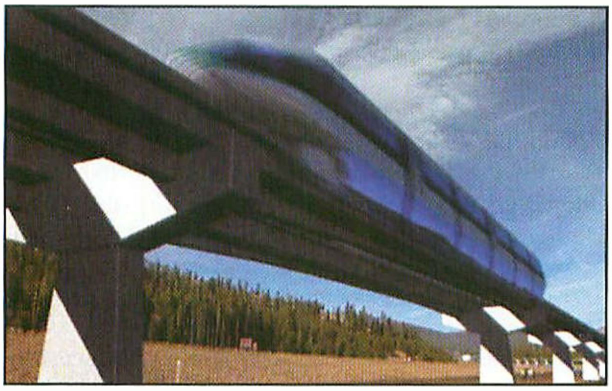
Figure 17.

This is the way that inkjet printers have operated in the past but some of the newer so-called photographic quality printers have less of a trade-off between the number of colours and the resolution. Some printers achieve this by having an extra two colours of ink – pale cyan and pale magenta. HP have an alternative technology which, for the first time, actually allows the size of the ink droplet deposited on the paper to be altered. For this reason, comparing headline resolutions alone isn't a good way of judging the quality you're likely to get from a printer for photographic work.

MAGNETIC *Trains*

By Reg Miles

The US Department of Energy's Sandia National Laboratories magnetically powered train development project has been allocated the funding necessary for work to continue.



In mid-September 2000, Sandia received an appropriation of $1 million, to build a full-scale prototype of its Segmented Rail Phased Induction Motor (Seraphim). Subsequently, the 2001 Transportation Appropriations Bill passed by Congress and signed into law by President Clinton on 23 October allocates $2 million to Sandia for further motor testing and design of its Seraphim technology, which relies on magnetic repulsion to push a vehicle forward.

Key parts of the work to be completed in the year ahead include analyses of system energy efficiency, construction costs, and operating costs. Should these analyses lead to a system design that is economically attractive to one or more transit agencies, a working system could be operational at the Pueblo, Colorado, Transportation Technology Center in about 5 years (where a magnetically powered vehicle was tested at speeds of up to 400kph in the 1970s).

The same 2001 bill allocates an additional $2 million to the Colorado Intermountain Fixed Guideway Authority (CIFGA), a state planning agency, to perform cost and technical analyses on a quiet, magnetically powered, monorail transit system for the Denver metropolitan area (see artist's impression). CIFGA's and Sandia's intent is to develop an urban system robust enough to reach from the Denver International Airport through 'downtown' Denver to the more mountainous western suburbs.

Other regions in which Seraphim could be used as part of a cost-effective transit system include Los Angeles, Seattle, Atlanta, San Francisco, and other locations 'where the terrain and distances make it important to travel at high average speeds within existing rights-of-way.' says Bruce Kelley, the project leader at Sandia.

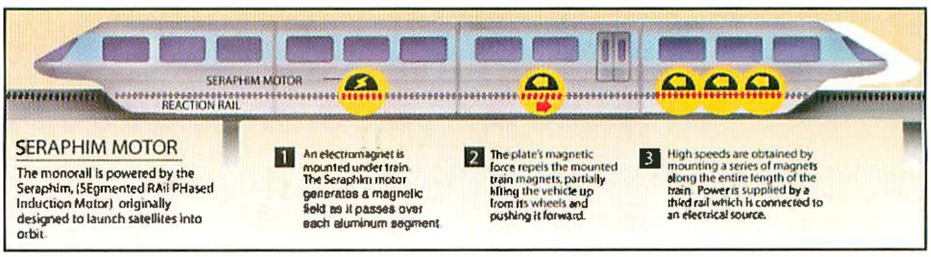
The science behind Seraphim was originally developed for the Strategic Defense Initiative ('Star Wars'), to launch projectiles at 20 Mach! So the first challenge for Seraphim researchers was to moderate the force of propulsion. In the mid-1990s, Sandia researchers demonstrated a Seraphim motor prototype that accelerated a 60cm tall aluminium plate mounted on rails to 55kph in only a distance of over 3m. However, no funding was then forthcoming to build a motor suitable for testing on a vehicle. Now the researchers will design and test a prototype motor that will be capable of powering a train at speeds of up to 200kph. This it is said should permit actual transit speeds averaging 95-110kph; including stops, over gradients of up to 8.5 percent even in periods of snow and ice accumulation. Conventional trains are limited to gradients of a few percent in good weather conditions, because the reliance on friction between steel wheels and steel rails limits the gradient a conventional train can safely climb.

The Seraphim motor is a modular, high-performance extension of the conventional linear induction motor (LIM). It works by sequentially powering a series of electromagnetic coils mounted on the train (see Figure). The powered coils induce associated eddy currents and magnetic fields of opposite direction in passive coils incorporated in the guideway. The resultant repulsion of the magnetic fields accelerates the train. Sensors monitor the location of the coils on the train with respect to the coils in the guideway and control the sequential firing of the powered coils to produce either acceleration or braking.

The motor also generates vertical forces in addition to the horizontal propulsion forces and is considered to be a form of magnetic levitation. However, the completed train is likely to rely on wheels for support - which are a lot cheaper. According to Barry Marder, principal inventor of Seraphim technology, 'Conventional magnetic levitation is possible, and fascinating to the public, but costly. The main limitation to high-speed trains is air resistance, not rolling friction. So why add all the complexity needed for levitation? The TGV train in France has demonstrated that wheels are perfectly good at speeds up to 250 miles per hour.' (400kph)

Preliminary cost studies have shown that a Seraphim-powered transit system with the equivalent carrying capacity of 6-8 lane roads could be deployed for $12-$22 million per mile depending on corridor geography and construction conditions (although preliminary cost studies are notorious for their inaccuracy). This cost apparently compares favourably with the cost of an equivalent capacity of new roads in many urban areas. The system, operated on a guideway such as an elevated monorail, would operate within existing rights-of-way and is expected to provide significant reductions in congestion for corridors where the cost of building additional roads is prohibitive. Its backers expect the system to decrease the construction of new roads, vehicle noise, atmospheric pollution, and other environmental degradations that are the inevitable results of more roads and cars, not to mention the deaths and injuries that are also the inevitable results of more roads and cars.

'For 2001', says Kelley, 'expect continued development of Seraphim's motor and controls, as well as work on the safety, surety, and systems controls aspects of the project.'



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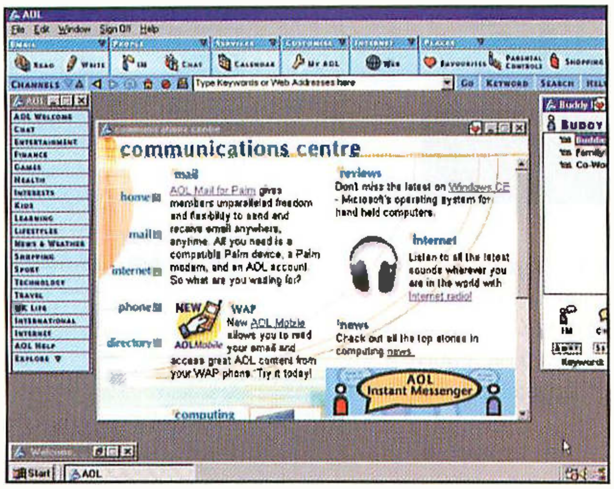
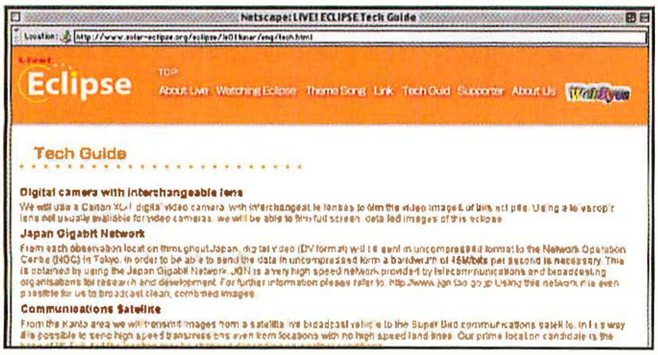
AOL

The brand new version AOL 6 has been released, which brings with it a plethora of new features and services. While being the most popular Internet service provider in the world, with some 28 million users, AOL doesn't rest on its laurels, as this new version shows.



The AOL 6 software gives all the old features that previous versions offered, albeit some in slightly different places. Many of these features have been improved too. For example, users now have the ability to create up to seven screen names, each with their own email account. This makes AOL even more appealing to families — even quite large ones — where each family member wants her or his own email address. AOL 6 takes full use of the latest pricing policy introduced by AOL recently, where for a flat-rate price of £14-99 a month, users can enjoy totally free Internet access (that is, without telephone charges). This is another bonus for families of all descriptions. Screen names can be longer than before, too — up to 16 characters in length.

Other new and improved features are AOL Mail for Palm (which allows Palm-based personal digital assistants to connect to AOL to send and receive mail messages), AOL Mobile (which allows WAP-based mobile telephones to connect to AOL for mail and other content), and a PC to SMS messaging service (that allows users to send SMS text messages to mobile telephones directly from their AOL client program).



Eclipsed

The recent lunar eclipse was watched live by many millions of people in Europe, Africa and Asia, and it brought with it a hive of activity on the Internet. Several Web sites followed events closely and shows just how powerful a tool the Internet can be in promoting international cooperation.

One of the best resources when it comes to locating information about eclipses is NASA and the Goddard Space Flight Center's eclipse Web site, at: **<http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html>**. Significant information about the lunar eclipse can be found, as well as details of upcoming eclipses over the next few years — such as the total solar eclipse which will occur on June 21 of this year over southern Africa.

Another good eclipse Web resource is Klipsi's Web site, at: **<http://eclipse.span.ch/>**, where Webcams can be accessed which feature recent and future eclipses. Klipsi intends to be in Lusaka in Zambia on June 21, so the site's Webcam will feature possibly the best view of it you can get — apart from being there, that is.

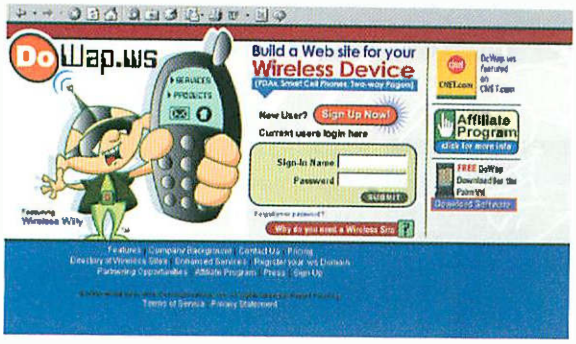
Finally, the Live! Eclipse Executive Committee (a non-profit, volunteer organisation whose members are amateur astronomers, professional astronomers and related workers, workers involved with the SOHO observatory, network engineers, and students) has a Web site, at: **<http://www.solar-eclipse.org>** which is well worth a look.

Live! Eclipse broadcast the first ever live internet of a solar eclipse from multiple locations in March 1997, and has broadcast a total of 8 solar and lunar eclipses and meteor showers so far, using the Internet as its main method of communication.

QuickTime 5

Apple has released the second public beta version of its upcoming QuickTime multimedia player and utility. While the previous public beta was available for Macs only, this second version is available for both Macs and Windows-based computers. Download it for free, from: **<http://www.apple.com/quicktime/>**. Once installed, QuickTime gives users access to much of the multimedia content that's available on the Web sites of the Internet, as well as the ability to download and view movie trailers and QuickTime TV channels live on the desktop. As QuickTime is being used as the basis for future generations of MPEG video compression, it's certain that more and more multimedia content will be based on QuickTime, so it's a worthwhile download. Even though it's still only a public beta version, it appears very stable and works well.

Build a Wireless Web Site with Wireless Willy



DoWap.ws has launched a new Web site at DoWap.ws at <www.dowap.ws> for the purpose of developing a Web-based, easy-to-use publishing tool that would enable businesses and individuals to create Web sites that can be viewed on mobile devices such as mobile phones and personal digital assistants (PDAs).

The company's strategy – in addition to using DoWap.ws as an independent, revenue generating application – is to develop custom operator and platform independent applications for both business and individual users. The focus is on user-generated content, interactive services and business or personal applications.

This is in contrast to most other wireless applications that focus on broadcasting content such as news, TV listings, sports scores, financial information and weather.

The core component of the site is a patent-pending, Web-based publishing tool called Wireless Willy. Wireless Willy enables individuals and businesses to develop a site quickly and easily.

As users build their site, they can actually see what it will look like each step of the way, and as soon as they finish, the site is immediately live and can be viewed on any wireless device.

Streaming Media Usage Spikes 65% Over Past 12 Months

Nielsen//NetRatings at <www.nielsen-netratings.com> has revealed that streaming media consumption rocketed to an all-time high in November 2000, with 35 million Web users accessing streaming content, a 65% increase from 21 million during the same month last year.

36% of all Web surfers accessed some form of streaming media in November 2000, as compared to 28% during the same time last year.

CompuServe 2000 Members Get Upgraded

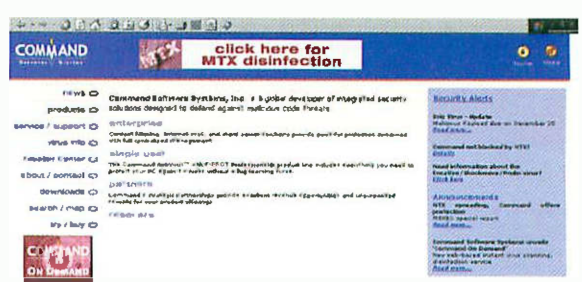
AOL subsidiary, CompuServe at <www.compuserve.com> has announced the introduction of new features designed to bring greater value and convenience to CompuServe 2000 and CompuServe 2000 Premier members.

The new layout of the CompuServe 2000 and CompuServe 2000 Premier Main Menu offers greater personalisation, allowing for quick access to information and services that members care about most throughout the day.

Also new, members will be able to take advantage of the new CompuServe Radio feature, which offers 17 channels of popular music formats, directly from the main menu, which is powered by Spinner.com.

Additionally, members can easily purchase the music they are listening to directly from the CompuServe Radio feature.

Command Software Unveils Web-Based Virus Scanning

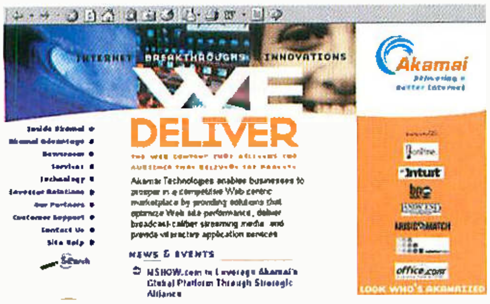


Command Software Systems at <www.commandcom.com> has introduced Command On Demand, the Internet's first online instant virus scanning and disinfection service for ISPs and Web portals that is fully portable to UNIX, Mac, O/S, Linux, NT, Windows 2000 and Windows ME.

Unlike other anti-virus services, this 100% portability makes Command On Demand fully hostable from an ISP's or Web portal's internal site, keeping the customer base secure.

The company also announced that Virus.com at <www.virus.com>, a portal for virus information, will be using Command On Demand on its Web site under the name Virus Striker.

Akamai Selects Fireclick to Speed-up Web Site

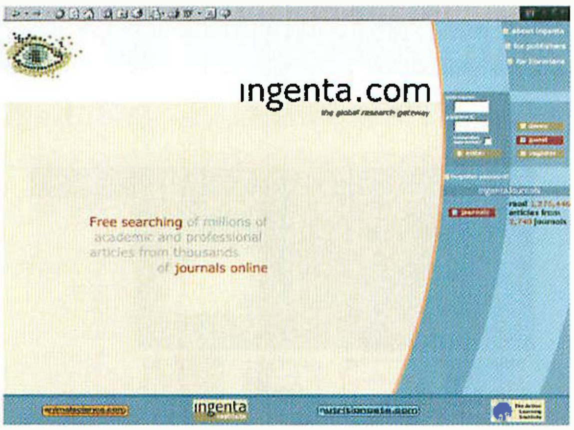


Akamai Technologies is using Fireclick's Netflame technology to further accelerate the thousands of page views per day on its Web site at <www.akamai.com>.

Netflame at <www.netflame.com> turbo-charges Web sites by using proprietary algorithms to track and analyse end user clickstream patterns. The application service pre-downloads content elements to the user's browser cache that are most likely to be requested with the next mouse-click.

As a result, Web pages are delivered with split-second timing, generating increased individual page views, thus resulting in higher revenues and more satisfied customers for e-commerce and content Web sites.

Ingenta Enhances Academic Search Service

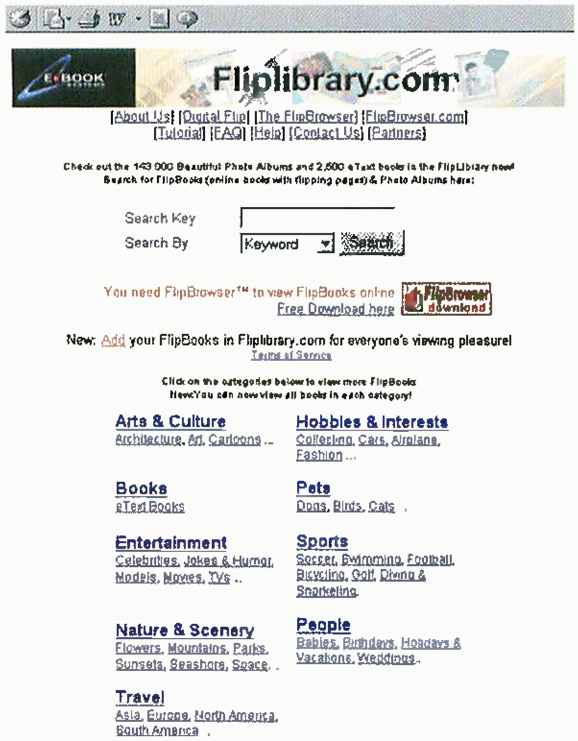


Building on the acquisition of the UnCover in March of 2000, ingenta has announced that access to the UnCover database is now live and available through ingenta's Web site at <www.ingenta.com>.

The addition of UnCover's content puts ingenta at the forefront of the research community by offering one of the largest Web article databases to date – over 11 million article citations and full text articles from journals and publications across the world – all available from one single point, and archived back to 1988.

ingenta's content can now be delivered in multiple formats; with expanded full-text delivery, users now have the option of PDF or HTML delivery direct from the popular UnCover database as well as the traditional fax article delivery.

FlipBrowser Gold Organises Web Pages into e-Book



FlipBrowser Gold users can easily compile e-books on their computers, choose their upload Web sites and then have FlipBrowser Gold automatically publish the e-books for public viewing. FlipBrowser Gold can even inform your friends via e-mail, of these published e-books.

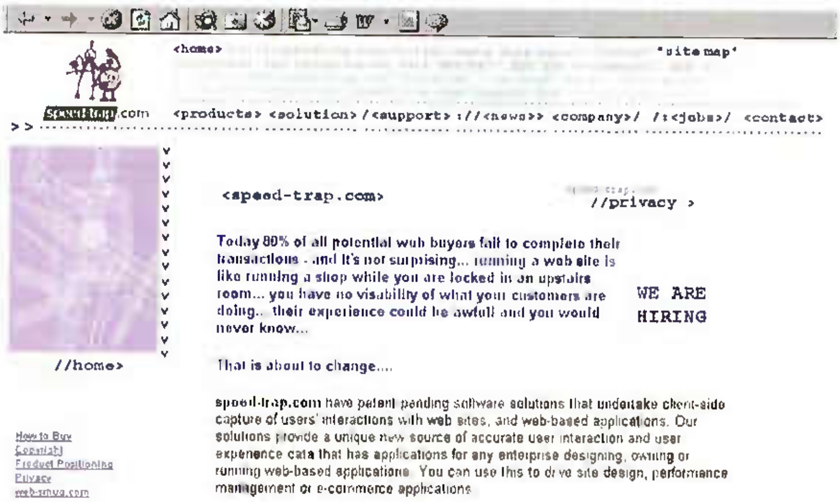
Internet users can view their favourite Web pages in a book-like format, with real 3D turning pages. Users can also read novels, magazines, view photo albums, browse catalogues, all in a turning-page, electronic book form. E-Book Systems calls such online e-books, FlipBooks.

FlipBrowser automatically organises all of the Web pages that you have viewed into a book-like form with separate pages that can be navigated through as you would any book. This allows users the ease of flipping to previously visited pages with a simple turn of a page. You can even add bookmarks, which appear at the side of the pages of the e-book.

As an e-book or FlipBook viewer, FlipBrowser Gold can view anything that has a book-like form – such as photo albums, product catalogues, manuals, magazines and novels. You can use FlipBrowser Gold to read a novel, browse a product catalogue or view a friend's photo album stored at a remote Web site. Any of these books will now be viewable electronically as if looking at a traditional book with a cover page, flipping pages and bookmarks.

As an online sharing tool, FlipBrowser Gold can open a folder of HTML and image files and automatically compile the files into a FlipBook with a thumbnail overview and table of contents. You can manually re-order the pages by drag and drop, upload the complete FlipBook to the Web for sharing and even get FlipBrowser Gold to e-mail your friends to inform them of the location of the online FlipBook. You can also choose to have your FlipBook listed at <www.fliplibrary.com> for search and retrieval by the general public.

Tool Monitors Online User Experience



speed-trap.com at <www.speed-trap.com> has launched its Prophet software application, which is a Java-based, active client-side toolkit for use by Internet Web site operators to monitor, analyse and replay actual client Web usage in order to optimise site design for a better user experience.

Prophet provides a complete insight into the actual user experience of individuals coming to a Web site because it collects real-time data on user interaction with Web pages. The software then permits a wide variety of data analysis – from simple clickstream to page audit trails to real-time replay of actual user sessions on a Web site.

It does this with bespoke technology that downloads a Java applet onto the user's PC as part of Web pages which are to be monitored and analysed. This applet then converses with the Prophet server application, co-located with the Web server, to collect all events that occur while the user interacts with the Web site. In this way, each Web page monitors its own use.

Competitive Web monitoring applications attempt to provide usability data by watching the Web servers or network management systems themselves. They typically deploy computer scripts or even volunteer Web surfers to hit a Web site and report results. At best, these only provide anecdotal information on usability or performance, based on crude statistical mechanisms derived from sparse or inappropriate data. None provides actual factual results as to where and how users moved around individual pages, frames or forms, what buttons they clicked on or what data they entered.

By contrast, Prophet allows Web site operators to specify the level of detail they want to record, including individual mouse and cursor movements, clicks, keystrokes, buttons, selections and submits on a page-by-page, minute-by-minute or frame-by-frame basis. Prophet even detects and reports user environment details such as browser window size, browser type and version number.

Web site for Fujifilm WebAward

FujifilmMediaSource.com at <www.fujifilmmediasource.com> has won a WebAward for its ability to demonstrate leadership on the Internet, quality of Web development, and an advanced level of user interactivity.

The Web Marketing Association, a consortium of Internet experts formed to assess and establish standards for the Web, produces the WebAwards.

Adobe GoLive 5 Enables Dynamic Web Sites

Once upon a time a picture on a Web site was special; and an animated GIF was jaw-dropping. Nowadays, Web-savvy surfers are looking for animated graphics, streaming audio, videos, and animations.

Web sites have become more intricate to create and manage. Now there's Adobe GoLive at <www.adobe.com>, a tool for creating Web sites and taking them live on the Web.

GoLive is tightly integrated with other Adobe products such as Photoshop, Illustrator and LiveMotion. The application includes site planning and management tools for designing and maintaining dynamic and compelling Web sites.

New Engineering-Community Sites Launched

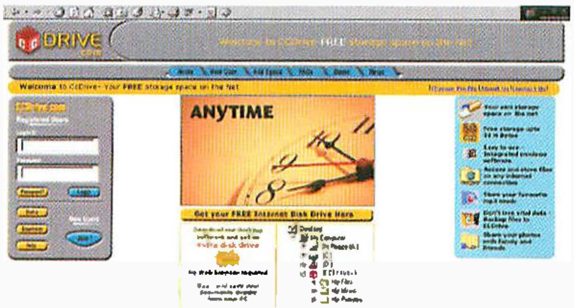
CMP has launched EDTN Europe, an online news, information, and design services portal for the European electronics industry.

In addition, the Electronics Group has created two, specialised engineering community sites – CommsDesign.com at <**www.commsdesign.com**> and Silicon Strategies at <**www.siliconstrategies.com**>.

EDTN is a global online network comprised of CMP Media's Electronics' 17 news and technology publication sites, dedicated engineering community Web sites, and exclusive commerce, content and technology partner sites.

Visitors to EDTN Europe at <**www.edtneurope.com**> can access all of the online resources of the Electronics Design Technology and News (EDTN) Network, all CMP Electronics publication sites, and a proprietary news page for Europe.

Net Tech Release Virtual Hard Drive



Net Tech has become the first UK company to release a virtual hard drive system. CcDrive at <**www.ccdrive.com**> is an online file storage system with a unique interface that allows users access to their own online data.

CcDrive also gives users free software that integrates their online storage into their Windows PC making CcDrive appear as an extra disk drive. This means that CcDrive can be accessed directly from Windows Explorer or any PC application.

CcDrive is FREE with up to 50MB of disk space. Options to rent larger amounts of internet space are available from £2.99 per month.

Browser War Lights Up Again

Opera Software at <**www.opera.com**> has unleashed Opera 5.0 for Windows, making its Web browser available for free for the many millions of surfers around the world that are looking for a faster, better Internet experience.

With this move the popular browser enters the re-ignited Browser War in full force as a third player besides AOL/Netscape and Microsoft's Internet Explorer.

Opera has long been known as the third browser for Windows, with around 1.5 million users. Opera Software is now making the browser available for free as a download, but you must be prepared to tolerate a banner ad constantly inside the browser window.

The Opera Web browser has been developed over a period of 5 years into the fastest, best Internet experience available in the market. The speed is achieved both through how fast it renders pages, but also in its functionality.

XStreamVoice Breaks Audio Streaming Code

XstreamVoice has developed an audio streaming technology solution available today that allows users of the Internet to receive streaming audio directly to mobile phones or other WAP-enabled devices.

The XStreamVoice solution is voice activated and allows customers to personalise a menu of all streaming audio content directly to their wireless device. The solution, using integrated voice recognition technology, allows for hands-free, mobile Internet access to the latest streaming content available.

A demonstration of XStreamVoice's audio streaming technology is available and a can be viewed at <**www.xstreamvoice.com**>.

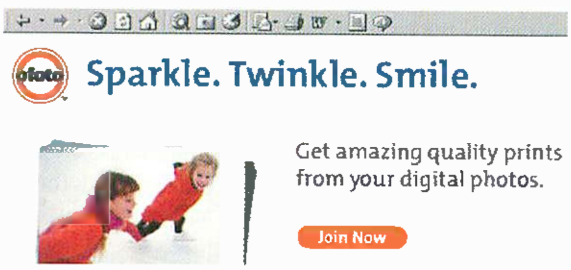
GEO Interactive Partners With ITN to Deliver News Videos

GEO Interactive Media has entered into an agreement to conduct trials with ITN.

Under the agreement ITN will stream its video reports to handheld wireless devices via MPEG-4 compliant clips – using GEO's Emblaze Wireless technology. Further, ITN will provide live video feeds, as well as video-on-demand headlines, to customers chosen by GEO to participate in the trials.

ITN is the UK's leading commercial news and information provider across all media platforms. The Web site at **<www.itn.co.uk>** is known for the quality of its coverage and its innovative use of multimedia in providing breaking news and analysis to the latest new media platforms, from digital television to wireless devices.

Image Enhancement Software Available for Mac



The Mac version of OfotoNow provides essential photo enhancing and editing tools to help everyone to get better looking photos and makes uploading digital pictures to Ofoto.com at **<www.ofoto.com>**.

The new image manipulation application allows members to visually select their favourite digital pictures from any source, view the pictures one at a time, look at collections of pictures all at once or view them in a slideshow.

OfotoNow also makes it easy to zoom-in, rotate, trim and remove red eye from photos. Once photos are selected and enhanced, OfotoNow enables its members to quickly upload any number of photos.

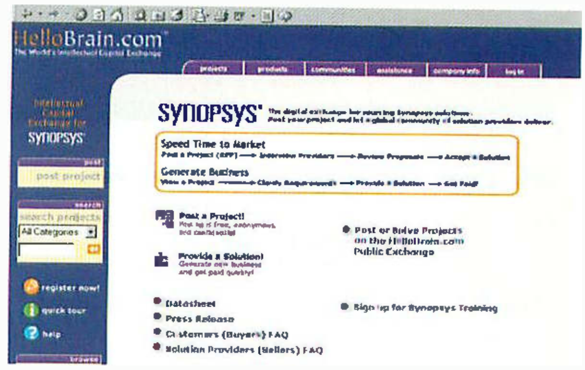
LookSmart Expands AltaVista Relationship

LookSmart has been chosen to provide directory services for AltaVista Europe. LookSmart has also extended its relationship with AltaVista in the US and will integrate its directory listings into AltaVista's search index.

BTLookSmart at **<www.btlooksmart.com>**, LookSmart's global joint venture with BT, will become the exclusive Web directory for AltaVista United Kingdom, Germany, France, Sweden, Spain, Italy and the Netherlands, which together are used by more than 10 million people in Europe.

LookSmart will also provide its popular Express Submit and Subsite Listings products to businesses wanting to be found on the top-ranked European search engine.

Synopsys and HelloBrain.com Launch Site for Complex Chip Design



Synopsys and HelloBrain.com have announced an alliance to enable Synopsys customers to accelerate electronic design projects.

The two companies have jointly launched an online exchange where Synopsys customers can post project requirements and source third-party solutions for complex IC design, such as test bench creation, simulation model development and intellectual property.

The exchange is accessible immediately at **<synopsys.hellobrain.com>.**

The Synopsys exchange uses the Internet to provide electronic design companies access to a global network of third-party solution providers to help them accelerate their products to market. The exchange gives these solution providers an efficient way to find new business worldwide, and a means to leverage their proven knowledge of Synopsys tools and IC design methodologies.

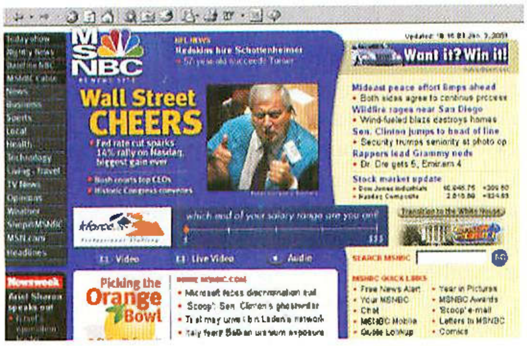
Red-M Launches Bluetooth News Service

Red-M has launched an online news service dedicated to Bluetooth called m-news at **<www.red-m.com/m-news>**. Designed to provide industry-watchers with the latest information on Bluetooth, m-news will be live from 18th December and is free of charge to registered users.

Red-M has teamed up with global online news service, Lexis Nexis, to deliver this first of its kind service. Via e-mail, users will receive regular updates with hotlinks leading to m-news, which will be hosted on the Red-M Web site.

M-news will provide information on the latest developments in Bluetooth technology, new products, industry comment and breaking news.

MSNBC.com Rated the Leading News Site



MSNBC.com at <www.msnbc.com> is the leading news site for the month of November according to the most recent data compiled by Media Metrix. MSNBC.com set a new record for total monthly users with more than 12.3 million unique users logging onto the site through the course of the month for continuing coverage of the Battle for the White House.

According to Media Metrix, MSNBC.com maintained its standing as the primary source for news on the Internet over the competition in the combined Home/Work audience. Total traffic for the month represents a 30% growth in audience from the previous month and a new record for total monthly traffic. MSNBC.com remains at the top of the General News category with 12.3 million unique users in November, ahead of CNN.com.

AOL Launches Upgraded Version of AOLbyPhone

AOL at <www.aol.com> has announced the launch of new features and functionality for its AOLbyPhone service, giving AOL members even more ways to communicate, transact and stay informed while they are away from their computer.

This new version of AOLbyPhone now includes enhanced e-mail, shopping, sports, finance and international weather.

AOLbyPhone enables AOL members to check their e-mail and access other popular AOL features conveniently through simple, spoken commands from the most ubiquitous of communication devices, the telephone.

An important component of the AOL Anywhere strategy, AOLbyPhone provides simple and convenient access to popular AOL applications like news, stock quotes, weather, and e-mail from any phone.

Euroseek and RealNames Help Navigate the Web

A co-operative deal between Euroseek and RealNames gives the users of Euroseek.com the ability to search for specific Web sites using Internet Keywords; an Internet navigation system that transports people directly to locations on the Web.

To use Internet Keywords in the Euroseek.com search engine, users simply type an Internet Keyword into the search box. If an Internet Keyword is available, Euroseek.com will feature the RealNames result at the top of its search results. The user simply clicks on a selected Internet Keyword to go directly to the Web page for the information they are seeking.

Euroseek at <www.euroseek.com> is one of the leading European Internet services. Euroseek provides Internet access with wireless/fixed broadband connection, portals with their own search engines, information, multimedia, entertainment, services and e-business for all Europeans.

RealNames at <www.realnames.com> is a market leader in Internet Keyword navigation, develops and markets products and services that simplify Web navigation, transform brands into interactive response vehicles, and increase relevance of search results.

Shopping While You Work

Almost half of all online shopping is done from work, according to Nielsen/NetRatings at <www.nielsen-netratings.com>.

The study points out that if employers were to crack down on personal computer use in the workplace, the fledgling e-commerce sector could suffer a major blow. Certainly many work-shoppers would adjust to browsing online stores at home, despite the lower connection rates delivered by typical dial-up access.

But those shoppers who access the Web only through work because they have no PC at home would be cut off completely, resulting in a possible 30% drop in e-commerce revenues.

Siemens Researchers Develop New Software Technology

Scientists at Siemens at <**www.siemens.com**> have developed a filter technology for Web browsing able to translate HTML-based documents into audio. The user dials up a number using a phone and listens to ZYX's Web site.

Perhaps the greatest benefit of this new software technology is that it holds promise for increasing access to the Web for the blind and visually impaired.

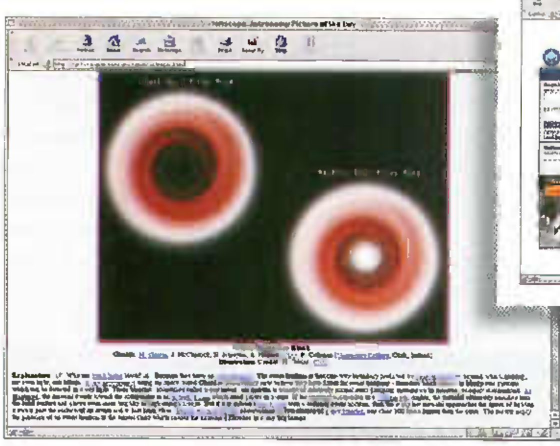
VoxPortal is believed to be the first standards-based voice browsing system with a generic solution for dynamic HTML (HyperText Markup Language)-to-VoxML (Voice Xtended Markup Language) conversion. VoxML is a standard markup language, first developed by Motorola, for specifying the dialogs of interactive voice response applications that feature speech synthesis and recognition technologies.

For Web Site publishers or content providers, this means that rather than translate their HTML content and services to VoxML, the VoxML converter will bridge that gap between voice and Web domains. In addition, interactive voice browsers offer an alternative to those who are blind to access the Web.

Also, voice browsers offer mobile access to the Web using a wide range of consumer devices. This technology can facilitate a safe, hands-free browsing session, important to both car drivers and others.

Site Survey

Destinations of the month



Astronomers among our readers might appreciate NASA's Astronomy Picture of the Day Web site, at: <**http://antwrp.gsfc.nasa.gov/apod**>. The picture is changed, daily, and features an explanation describing what the picture is.

Several Internet sites have sprung up that allow users to store files in a personal storage area — the idea being that files can then be accessed from anywhere worldwide with an Internet connection. Some of these sites are good, some not so good; some are free, and some not free. One of the best (and free, to boot) is i-drive.com, where each registered user has a personal space of 50Mb. You can create your free i-drive account at: <**http://www.idrive.com**>. You can also allocate part of your storage space as publicly accessible, which means that friends and associates can also access the allocated files.

If you're thinking of buying a new car, first stop is to locate the one you want. Checkout What Car? Online, at: <**http://www.whatcar.co.uk**> for such details. You'll probably be selling an older car at the same time, so need some information about how much you can expect to get for it. Try Carprices, at: <**http://www.carprices.co.uk**> where you'll find details of some 150,000 cars. It's also worth checking out Parker's Online, at: <**http://www.parkers.co.uk/**>.

TRANSISTOR *Tales*

by Gregg Grant

PART 2

Sussing out Silicon

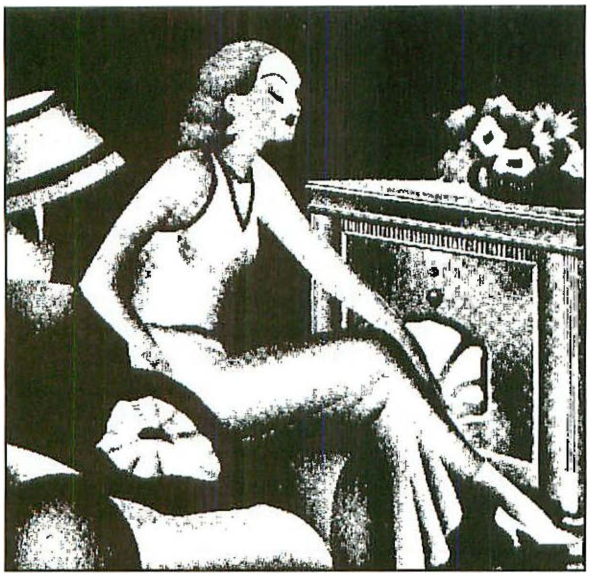


Figure 1.

The 1920s and 1930s are remembered - if at all - for the Great Depression and the myriad problems it brought. One such problem was that there was virtually no capital available for investment in technical developments and, even if there had been, it's questionable if it would have been allocated for projects aimed at reducing the size of things.

At this time the valve was king, new types of the component being brought out on a fairly regular basis. The Pentode for example - developed by Tellegen and Hoist at Philips in Eindhoven - was a child of this period. More to the point the valve, for its purpose, was considered satisfactory by both the radio manufacturing industry and the general public.

For those fortunate enough to be in work during this period, the cosy relationship between manufacturer and customer worked to the advantage of both. One of the most potent symbols of the importance of a job was the radio set in the living room. As Figure 1 illustrates, this was a large unit, frequently amounting to a piece of furniture.

Figure 2 illustrates one of the advertising slants of the period, much of which revolved around the 'more is better' theme, where the number of valves in the equipment signified but one thing: quality. Therefore developing smaller components using less power - whether a valve, capacitor or anything else - sent entirely the wrong indicator to the marketplace, in fact the sort of signal the crystal set radiated: poor quality.

Nevertheless, the period was not entirely barren where scientific and technical advances were concerned. It was in this period for example that the theory behind what would later be called semiconductors was developed and the first transistor patents were filed.

The Theory Men

Between 1926 and 1932, a number of able physicists published a series of papers on the quantum electron theory of metals. Among the authors were the Nobel Prizewinners Felix Bloch, Werner Heisenberg and Wolfgang Pauli as well as Rudolf Peierls and Arnold Sommerfeld.

As a result, there developed a basic quantum theory of solids, which became the bedrock on which future advances were built. The next generation of theorists began to examine the properties of what would shortly be termed semiconductors.

In the US, the principal centres of this research were evolving by the early 1930s, one at the Massachusetts Institute of Technology, the MIT, the other at Princeton.

In the UK, there were also two centres where this sort of research was carried out. One location was Bristol University, where Neville Mott and Harry Jones were the principal investigators. The other was at Cambridge University, where Alan Wilson was also examining the physics of semiconductor materials.

Both Mott and Wilson began by attempting to understand the action of the metal/semiconductor rectifier, of the type invented by Grondahl and Geiger .

Wilson thought that the action was a quantum mechanical one, in which the charge carriers 'tunnelled' through the narrow 'response curve' - a mere 10^{7} cm wide - of Figure 3. This concept seemed to indicate that the direction of low resistance to current flow - what would come to be termed the Forward direction - was from metal to semiconductor.

In fact this prediction by Wilson was exactly the opposite to that observed and later experiments indicated that the barrier width was around 10^{5} cm. which suggested that tunnelling was not the explanation for the rectifying action. Mott - and independently the German research engineer Walther Schottky - put forward a different explanation, that the majority carriers were thermally agitated over a wider barrier, one in the region of 10^{4} to

Figure 2.

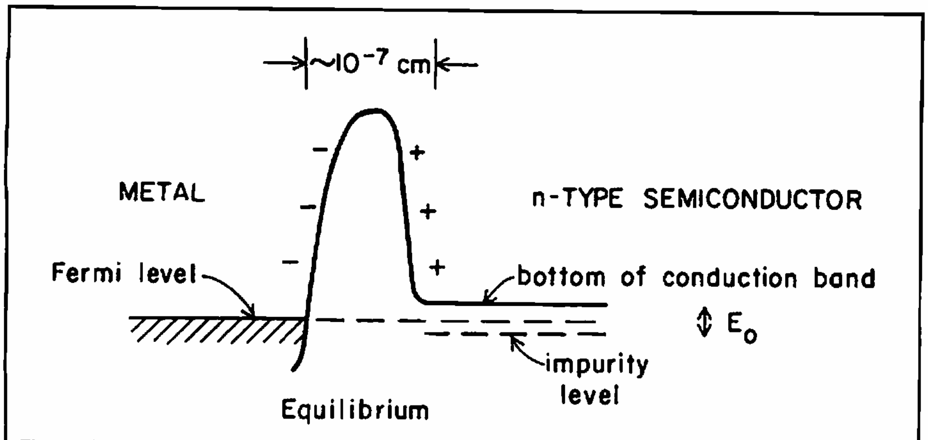


Figure 3.

10^{-4} cm. Their concept is illustrated in Figure 4. This is essentially a ramp in which - in equilibrium - the electrons on both sides of the divide see the same barrier height. When, however, a negative voltage is applied on the metallic side as Figure 4b, it raises the electron energy levels in the metal relative to those in the semiconductor.

The result is an increase in the barrier space charge and the semiconductor electrons 'see' an increase in barrier height. Therefore electron flow from the semiconductor to the metal decreases.

Conversely, the application of a positive voltage to the metal as in Figure 4c, decreases the metal's electrons energy levels in comparison to those of the semiconductor material, so that its conduction electrons 'see' a barrier that has been lowered. The result is a considerable increase in current flow in the forward direction, from semiconductor to metal.

Although both the Wilson and Mott-Schottky theories had their faults - one of which was that both hypotheses took no account of the role of minority carriers - they were among the earliest attempts to explain the metal/semiconductor forward-reverse conduction mechanisms. This then paved the way for the later, American work on the development of the transistor.

In fact by 1931, Alan Wilson was using '. . the so-called band theory to study the processes by which conduction occurs' [1] in semiconductors and this groundbreaking work remains the basis of our understanding of semiconductor operation. His theory gave us the concept of doping semiconductor material with precisely measured amounts of impurities, which produced what he termed defect and excess types of semiconductor.

Ten years after Wilson's research Jack Scaff, a Bell Laboratories (Bell Labs) metallurgist, renamed these substances p-type and n-type, the names by which they are known today.

By early 1935, Bell Labs had decided to carry out research into electronic conduction in solids, the Bell believing that '. . the knowledge of materials and processes acquired will ultimately be of value in the solution of engineering problems.' [2] This research triggered a new interest in crystal detectors, Bell wishing to develop '. . a crystal detector for microwaves because vacuum tubes would not work at those frequencies.' [3]

Consequently one of Bell's radio engineers, George Southworth, asked his metallurgist and chemist colleagues if they could produce silicon whose properties would be more controllable and predictable than that used in the 'cat's whisker' radio detectors. Whilst Bell Labs concentrated on silicon, a research group at Purdue University, led by Professor Karl Lark-Horovitz, investigated germanium, with a view to using the material as a radar detector. Yet this period was not one of theory entirely. Two German researchers actually applied for patents for solid state devices at this time, one in the US, the other in the UK.

The Patent Men

In March 1928, Dr. Julius Lilienfeld filed a patent application with the US Patent Office for what he termed "a device for controlling electric current."

Patent No. 1,900,018 was subsequently granted on the 7th of March 1933 for the device illustrated in Figure 5. This has had the letters G, S and D added, mimicking the current field-effect transistor terminology of Gate, Source and Drain.

The materials used were unusual, to say the least. The Gate - 10 in the illustration - is made from aluminium and insulated by a film of aluminium oxide, 11. The p-type semiconductor - 12 - is made from cuprous sulphide and is of molecular thickness at the point shown as 13. The Source and Drain contacts are shown as 14 and 15 and are electrical conductors. Both they and the semiconductor were vacuum evaporated. How well did this early quasi-transistor work?

In 1964 J. B. Johnson, the discoverer of 'Johnson Noise,' who was - at that time - a physicist with the Instrument Division of Thomas A. Edison Industries attempted to find out whether Lilienfeld's device would indeed work.

Johnson had his doubts since - despite his having carefully followed Lilienfeld's

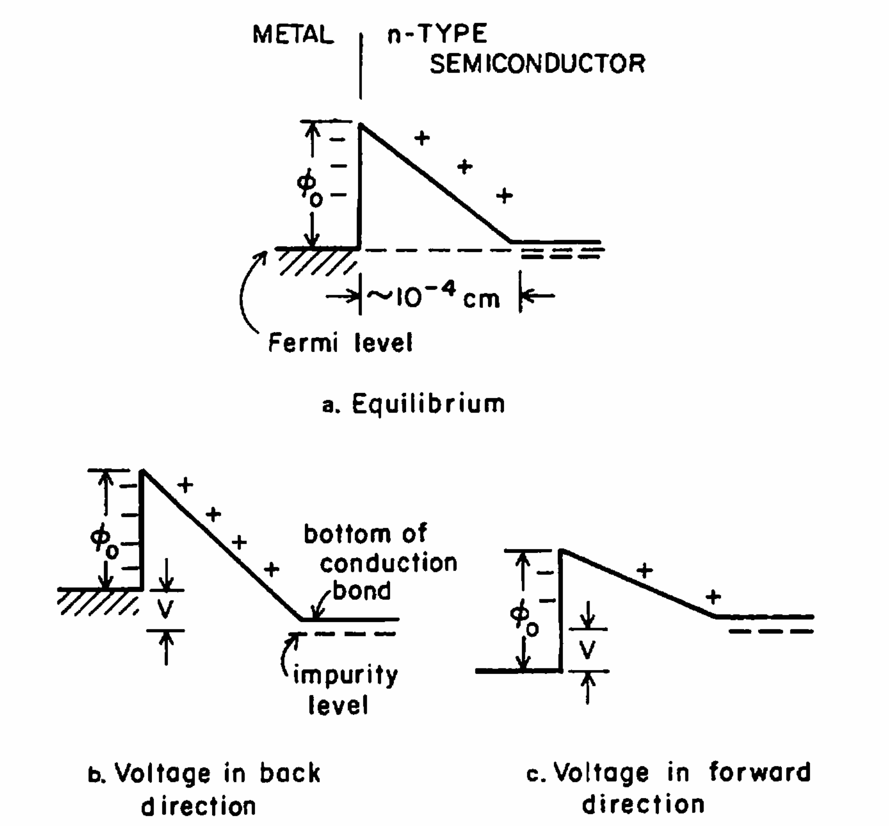


Figure 4.

specifications - he noted that no amplification or even modulation took place. He thought that one reason for this '. . was probably the very low mobility of holes in the Cu_2S (~ $1cm^2$V-sec), and the effect of surface states on the free surface of the film.' [7]

In 1991, another experimental effort was made to create the device outlined in the Lilienfeld patent. In his Master of Science thesis for the University of Vermont, entitled Th invention of the transistor, Bret Crawford set out to reproduce the original using the same materials as had been available in the late 1920s.

Faithfully adhering to the patent, Crawford did produce working models, although their performance was less that spectacular, they being unstable. Cuprous Sulphide as a semiconductor was simply no match for the present-day, purified and carefully doped silicon. Nevertheless, Crawford suggested that Lilienfeld actually did manufacture the device he described in the patent, as well as theorising about it because his - Crawford's - own observations were close to those of Lilienfeld, as described in the patent application.

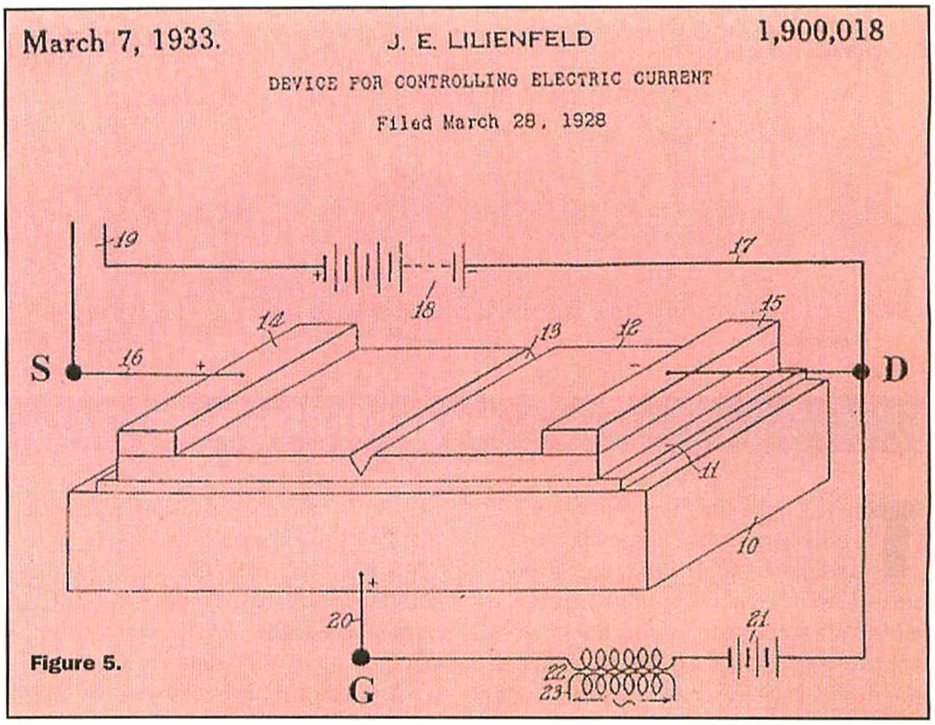


Figure 5.

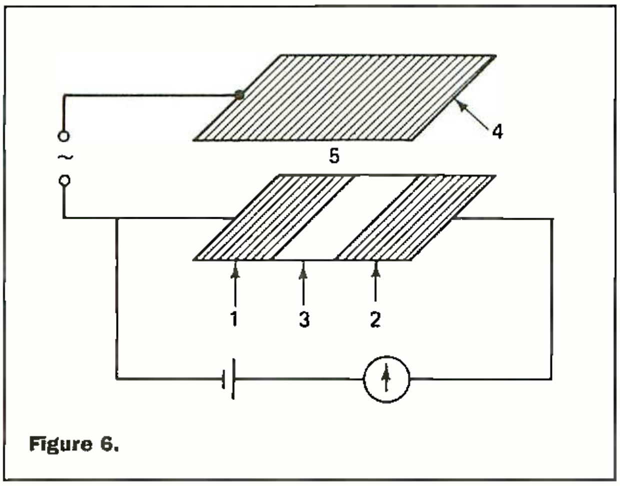


Figure 6.

Four years later another American physicist, Joel Ross, looked into the Lilienfeld device. At the Spring meeting of the American Physical Society, Ross presented his paper Reconstruction of a Lilienfeld transistor, in which he - like Crawford - followed the prescriptions of the original patent. The devices Ross produced, whilst they remained stable over a considerable period and did indeed demonstrate the field effect, had poor conductance due - he thought - to surface states.

In 1935 the University of Berlin's Oskar Heil filed a patent application in the UK for what he termed Improvements in or relating to Electrical Amplifiers and other control arrangements and devices. His concept is illustrated in Figure 6.

The section annotated 3 in the drawing is a very slim area of semiconductor material such as cuprous oxide, iodine, vanadium pentoxide or tellurium, whilst the even smaller areas designated 1 and 2 are ohmic contacts.

The area above the semiconductor material annotated 5 is a metallic control electrode which is insulated - 4 - from the semiconductor. In his explanation, Heil outlined how a signal applied to the control electrode modulated the semiconductor's resistance, producing an amplified signal, which is registered by the current meter.

Today, this device would be termed a Unipolar field-effect transistor having an insulated gate or, to give it its common abbreviation, an IGFET.

In 1939, William Shockley at Bell Labs wrote in his workbook that it '. . occurred to me that an amplifier using semiconductors rather than vacuum is in principle possible.' [5] Yet another decade would pass before the transistor was invented and it would be the early 1960s before a commercial field effect transistor became available to the electronics industry. Why?

The most obvious problem was the material itself. The first thing to note about silicon is that it is NOT a metal. It comes from silicon dioxide, in its familiar form of quartz, and is produced in electric arc furnaces. The silicon produced, via the reducing agents wood chippings and coke, is over 95% pure. The ubiquitous silicon chip is created by crushing the product of the furnace '. . to a powder and then [leaching it] in hydrochloric acid, forming the compound $SiHCl_3$. The compound is then treated with hydrogen; extremely pure silicon is formed.' [6]

The above of course is the modern method of producing the material on which the electronics industry has depended for the last half century or so. In 1939 however Russell Ohl, an electro-chemist turned radio engineer working at Bell Labs, found that contact between the silicon material and a 'cat's whisker' rectified in one direction and then, suddenly, in the opposite direction.

Ohl decided that the way ahead lay in purifying silicon by melting it, and he became the first engineer to discover that special furnaces would be needed to do this.

In the autumn of 1939, Ohl turned to two metallurgist colleagues, Henry Theuerer and Jack Scaff, and asked them to purify the silicon. In the course of doing this, Scaff and Theuerer confirmed what Ohl had already discovered, namely that the direction of rectification varied from one silicon ingot to the next. Obviously, more research was needed on this, at times strange, material.

References

1: Atherton, W.A. (1984): From Compass to Computer. San Francisco Press Inc., San Francisco. Ch 10, Page 240.
2: Hoddeson, Lillian (1981): The Discovery of the Point Contact Transistor. University of California. Page 48.
3: Weiner, Charles (1973): How the Transistor Emerged. IEEE Spectrum Article, January 1973. Page 28.
4: Johnson, J.B. (1964): More on the Solid-State Amplifier and Dr. Lilienfeld. 'Physics Today' article, May 1964, Page 61.
5: Ibid [2], Page 60.
6: Street, Arthur & Alexander, William (1998): Metals in the Service of Man. 11th Edition. Ch 23, Page 214.

COMMENT

by KEITH BRINDLEY

There's no doubt that DVDs (digital versatile discs) are becoming more and more popular. They are, if you are not aware already, a means whereby movies are recorded on a disc, the same size as a conventional CD. To view them, you need a DVD player and television, or a computer with a DVD drive of some description. To say that DVDs are becoming popular is actually a huge underestimation. Like videocassette movies, millions of DVD movies are being sold worldwide each year. Unlike videocassettes however, sales of DVDs are increasing rapidly, so it won't be long at all before videocassettes are regarded as old technology and virtually worthless. All the major movie rental organisations now stock DVDs, and just about every high-street outlet has sales stands of DVDs at least as large and prominent as their sales stands for videocassettes. Many public libraries now even hire out DVDs.

But DVDs aren't the only way to view movies on computer. There is another method, based on a little known standard called Video CD (VCD), which allows ordinary compact discs to be used to hold movies (or any other form of video content). As the Video CD standard uses ordinary CDs, virtually any computer that has a CD drive can access and play the movies (a computer needs a DVD drive to play DVDs, of course). Also, many standalone DVD players can access and play Video CDs. So, as far as the end-user is concerned, cost can be held to a minimum. Video CDs are actually quite popular in Asia, where most movies are available on the format but, as yet, it's not too popular here, and that's a shame. Perhaps it's time for the format to become more popular, as it has some very important advantages.

There are differences in quality between DVDs and Video CDs that need to be considered. Both are based on the use of MPEG compression to create the two formats. DVDs use MPEG-2 compression, while VCDs use MPEG-1. Ultimately though, it's not the compression type that makes the difference in quality, it's the fact that DVDs use a larger frame size of up to 720 x 476, while VCDs use 352 x 288 (these sizes are for PAL-based movies — NTSC movies vary a little). DVDs use interlaced video. As such, with around twice the resolution horizontally and vertically DVD videos hold something like four times or so the information that their VCD counterparts hold.

Naturally, this information difference has a direct impact on the picture quality the viewer perceives. Put bluntly, whereas DVD allows excellent quality reproduction, VCDs have a picture quality which is capable of being superior to videocassette — but still nowhere near as good as DVD. So they might not stack up against DVD quality, but they have a distinct advantage over videocassettes in that the image — being digitally recorded — doesn't deteriorate with time.

But quality isn't everything if you look at what VCD is capable of. The VCD format means that a standard 650 Mb CD can hold up to 74 minutes of video, while a 700 Mb CD can hold up to 80 minutes of video (most movies therefore require two VCDs). Of course, these are ordinary CDs, so theoretically anyone with a computer and CD-writer can produce their own VCDs. On the other hand, it takes a significantly greater investment in equipment to produce DVDs.

The technique to creating VCDs is actually quite straightforward. Often CD burning software has the standard built in. Adaptec's Easy CD Creator (Windows-based software) for example, as well as the company's Toast (Mac-based software) both allow the creation of VCDs, as do many other CD creating programs. All the user has to provide is the video content in the correct MPEG-1 format.

This, unfortunately, isn't quite as easy as it sounds. In general, computerised video is created in a format native to the computer. Windows computers might store video in AVI format, for example, while Macs generally use the QuickTime format. Thus, any video that is created on a computer by recording from a camcorder, say (there have even been reports of people using the video from DVDs!) would normally have to be encoded after creation and prior to writing the VCD. Encoding to the MPEG-1 format isn't necessarily a difficult task, but it does tend to be very slow unless you throw money at it. The cheapest methods are based on software encoders (many of these are freeware, or shareware). However, a software solution is not ideal. Given that a typical computer might encode something below 5 frames a second, and that there are 25 frames for each second of movie, then it doesn't take a genius to work out that at least 5 hours of processing is required to encode each hour of video into the MPEG-1 format. Couple this with any other processing tasks that are necessary, such as multiplexing separate audio and video files into a single file, decoding any already existing MPEG files into a native computer standard and it's not hard to see that creating a VCD is not a task to be taken lightly.

There are hardware solutions, in the form of MPEG encoder cards that fit inside a computer. These can greatly speed up the encoding process, and there are some hardware products that can even do the encoding in real-time (that is, an hour's worth of video will encode in one hour). However, these generally require a powerful computer to drive them, so they are not the cheapest of methods and to a large part, counteract the advantage of cheapness of VCDs in the first place.

Nevertheless, the Video CD format is a viable proposition for many people. They are relatively easy to create, and they are definitely easy to use. The VCD standard, on the one hand, cannot produce a particularly high quality display. On the other, it is sufficiently good that many users might not even notice the difference between VCDs and DVDs — particularly if the television used to display the movie isn't of a particularly good make. For many people VCD may be all that's required.

The opinions expressed by the author are not necessarily those of the publisher or the editor.

Flat Panel DISPLAYS

by Reg Miles

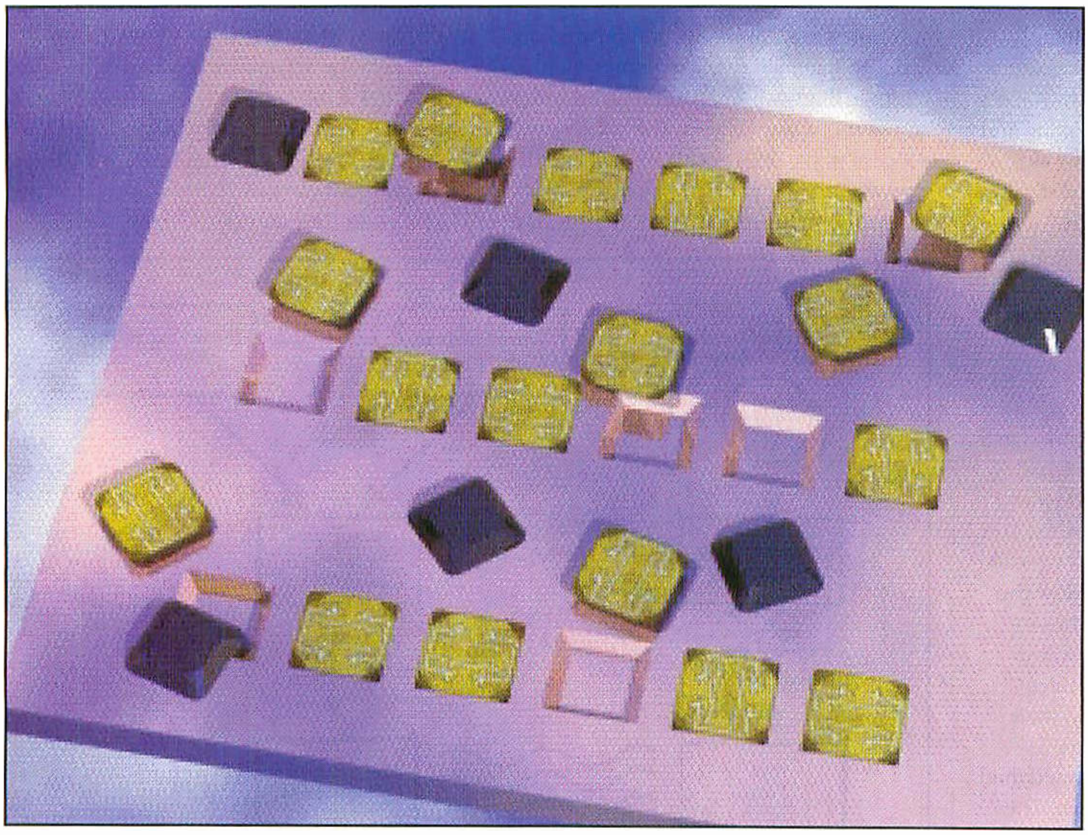


Figure 1. Artists impression of FSA NanoBlocks and receptors.
Picture: Alien Technology.

The flat panel display (FPD) market is beginning to get lively, with companies springing up and doing deals with or being taken over by existing, larger companies. At the same time the technology is diversifying, with new ways of doing old things or completely new technologies. Much of the latter is coming out of the universities, and either going to existing companies or into companies spun-off from the universities themselves. The large companies have their own research programmes, but these tend to reinforce what is already being produced - a refinement of the product and the production processes - rather than devising something that is novel. This is hardly surprising given the investment that exists in plant and machinery, the skilled workforce, and the contracts to supply the existing products to customers.

The reason for all this activity is plain for anyone to see. Small displays are appearing on everything from camcorders and still cameras, mobile phones, personal stereos, remote controls, various types of meters, to travelling clocks. The larger displays have made portable computers possible, and are now being sold as space-saving alternatives to desktop monitors; while still larger displays are providing large TVs of reasonable proportions, and information and advertising displays of all kinds. The profits that are being made today are as nothing by comparison with the potential profits from the replacement of the CRT and the realisation of all the possible applications that the CRT cannot address.

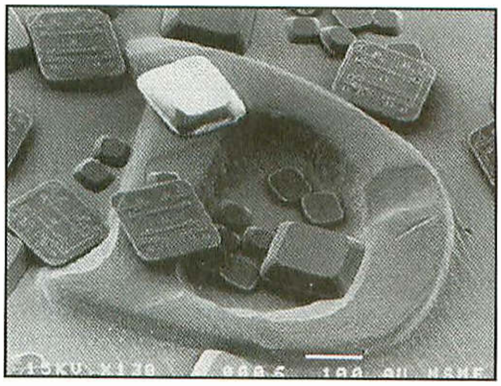


Figure 2. NanoBlocks on a Dime.
Picture: Alien Technology.

Potentially, just about everything could have a display - whether it was necessary or not. It will be a case of 'if it can be done, it will be done'; it may be irrational but that, as they say, is progress! It may really prove to be an advantage over existing methods or provide a display where there were no existing methods.

One such application is smart card displays. Apparently over 650 million microcontroller-based cards were produced in 2000, and twice that many would be produced in 2002. Gemplus is the market leader with a more than 40% share of the market; and they and Alien Technology have signed an agreement to produce smart cards with displays.

This is made possible by Alien's Fluidic Self-Assembly (FSA) technology. The FSA process allows transistors and integrated circuits produced on standard wafers to be micromachined apart and literally floated into place across a large surface area. This makes it possible to employ continuous flow roll-to-roll (web) processing, while still meeting the physical demands of smart card applications. The Gemplus display will be Alien's first volume product. Alien is designing a high volume, web factory that will begin operation in 2001. Production for Gemplus is scheduled to begin in late 2001.

The FSA process is similar to the child's' educational toy, with shaped blocks that fit into correspondingly shaped holes. Only in this case what Alien has termed a 'NanoBlock' varies in size from just ten to several hundred micrometres, and the holes, or receptors, can number in their thousands (Figure 1 shows an artists impression of the NanoBlocks and surface receptors). The wafers are produced for Alien in commercial

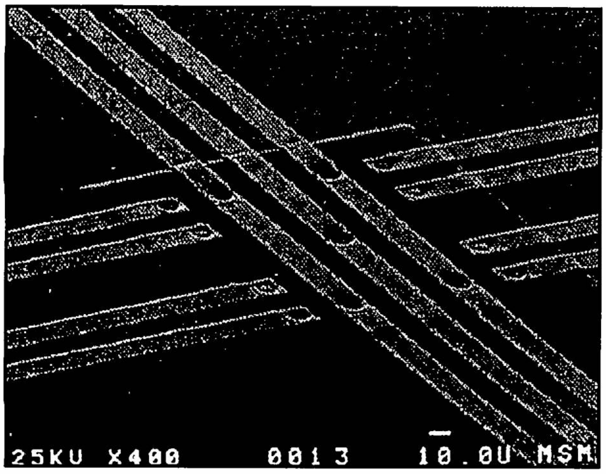


Figure 3a. Metallised NanoBlock.
Picture: Alien Technology.

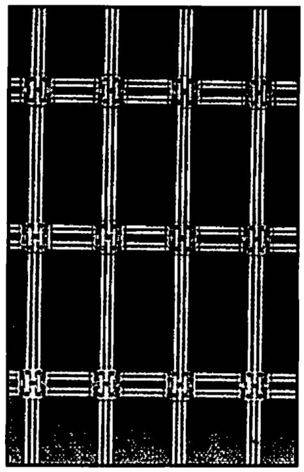


Figure 3b. 3x4 subsection.
Picture: Alien Technology.

CMOS foundries; with each containing hundreds or even millions of devices. These are tested. Then separated by Alien's proprietary process of etching, shaping and freeing into NanoBlocks having specific three dimensional shapes (Figure 2 shows a microphotograph of 70 and 185μm NanoBlocks laid on a Dime coin). In a separate process the substrate has receptors punched, etched or laser drilled into it, according to the medium, that correspond to the shapes of the NanoBlocks.

The NanoBlocks are then suspended in a fluid, which is run over the prepared substrate, and the NanoBlocks drop into the correspondingly shaped receptors. The ratio of NanoBlocks to receptors is typically in the range of 5-10:1 - fewer will slow the rate of fill, while more will only achieve diminishing returns (the filling process typically takes 30 seconds to 2 minutes). Those NanoBlocks that do not find their way into receptors are collected up, drained, cleaned, and put into cleaned fluid to be sent through the system again. The fluid is water-based (although, not essentially so), with additives that are secret but act to adjust the viscosity of the fluid, preventing the NanoBlocks from clumping together, and bond the NanoBlocks in the receptors when the substrate is removed from the fluid and dried. The NanoBlocks are then electrically connected using standard metallisation techniques to produce the fully integrated system (Figure 3a, shows a Microphotograph of a passivated metallised NanoBlock and Figure 3b, a 3x4 subsection of a metallised array of NanoBlocks on a glass substrate). These can be used as they are, or go through the process again to produce larger, composite NanoBlocks.

Figure 4 shows the complete FSA process. This has been proven on small substrates - Alien has been able to consistently fill a 3in square substrate with 11,000 IC sites; and it is believed to be easily scalable and able to fill much larger substrates in a full production process. In order to maintain the filling times then multiple fluid delivery heads will be spread across the substrate area. The subsequent process steps, of depositing metal over the NanoBlocks and patterning interconnects to produce a functional active matrix, have also been successfully demonstrated. 140 pixel flexible display demonstrators have been produced on a PET substrate using a polymer dispersed LCD (PDLCD) material. This low power, high contrast, highly reflective display does not rely on polarisation to achieve tonal gradations - which would be unsuitable for a flexible display because colour and contrast would change with the viewing angle, but instead uses the alignment of molecules.

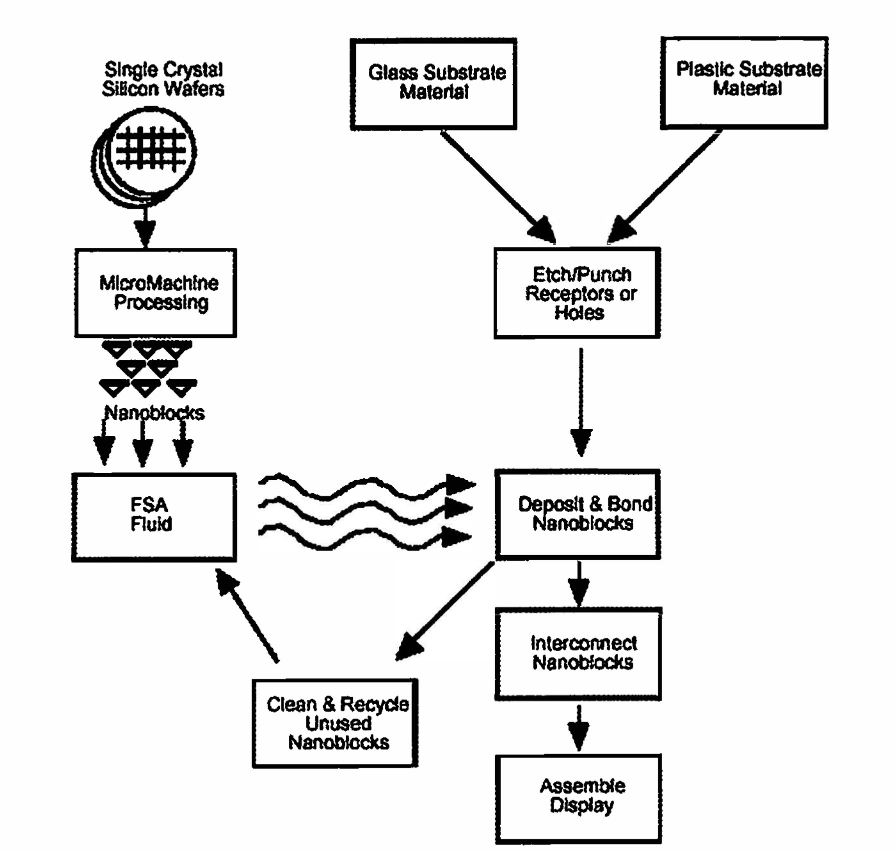


Figure 4. Complete FSA process. Picture: Alien Technology.

Depending on the size and complexity of a display anything from dozens to thousands can be produced from a single 6in CMOS wafer. And it is not confined to LCDs, any type of display that can overlay an active matrix is suitable. The FSA process is also not confined to displays; but can be used wherever a lot of small components need to be relatively quickly and inexpensively assembled to produce completed systems.

Flexible plastic substrates and web produced displays have been sought for some time, because they obviously open the way to all sorts of new applications or refinements of existing ones - and to high volume production. But there are other means of achieving them.

Philips Research has demonstrated a display in which each thin film transistor (TFT) in the active matrix is based on a polymer semiconductor. Again, there is also a cost advantage, with fewer production steps required, and not quite such a clean 'clean room'. In this Philips display only the semiconductor part of the transistors consists of polymer and the transistors are produced on a solid substrate. However, the same research group has already demonstrated all-polymer transistors on flexible substrates; and all-polymer TFTs are currently being incorporated into the next prototype display.

The present one is a 1.5in square reflective PDLCD type, with the 64x64 pixels either scattering light when the molecules are not aligned or being

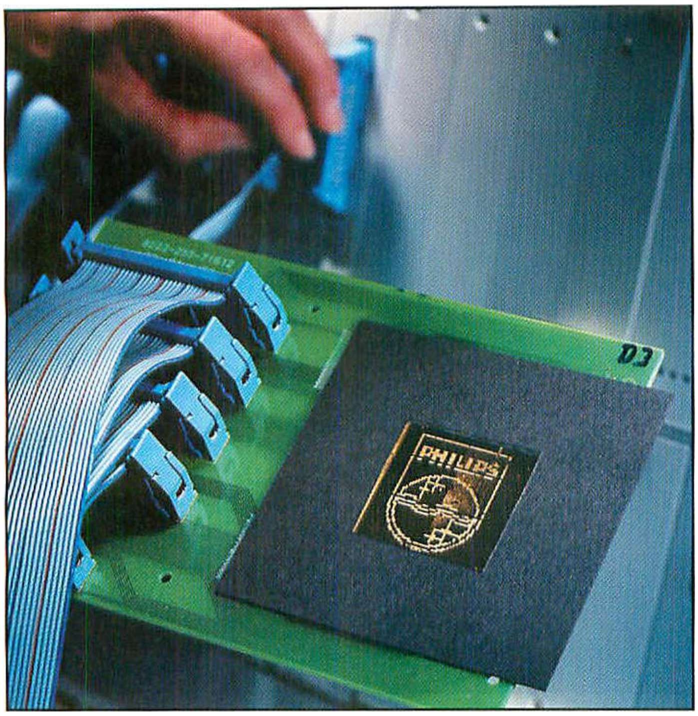


Figure 5a. Polymer transistor PDLCD display. Picture: Philips Research.

Figure 5b. Polymer transistor PDLCD display. Picture: Philips Research.

transparent when the molecules are aligned by an electric field (Figures 5a and 5b show the display in two of its complementary states). The relationship between applied voltage and resulting contrast prevents multiplexing and, thus, passive matrix driving - hence the TFT active matrix (which represents a major part of the cost with conventionally produced TFTs). However, it does enable direct control of each pixel, whereas with passive matrix the pixels are addressed by the intersection of rows and columns only.

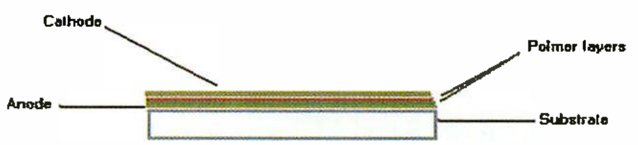


Figure 6. Light Emitting Polymer construction.

Polymer transistors tend to be larger and slower than their silicon cousins. The speed is perfectly adequate for display use. The size, however, will reduce the active area of the pixel in transmissive displays, reducing the light output. Reflective displays and those that generate their own light are not affected.

Philips is also working on emissive PolyLED displays (short for polymer LED, which is also known as PLED), or Light Emitting Polymer [LEP] by the inventors Cambridge Display Technology - a spin-off company to commercialise research work done in the University. All the names for the organic electroluminescence display technologies can be lumped together under the generic title of organic LED [OLED]).

Both CDT and Philips have shown LEP displays in which the conjugated polymers have been printed onto a substrate using an inkjet process, instead of the more usual spin coating. This printing process is limited only by the size of the substrate; which can be rigid or flexible (being an emissive technology there is no problem with the viewing angle in the latter case). It is also greater than LCD in any case. The CDT prototype is a 2.5in display consisting of 200x150 pixels with 16 grey scale levels. Produced in conjunction with Seiko-Epson, the display consists of two organic polymer layers, one a conducting layer covering all the pixels, the other, the light emitting layer consisting of red, green and blue pixels. It is an active matrix display, with each pixel addressed separately by a digital driver using pulse width modulation.

Conjugated polymers provide light emitting and charge transporting/injecting layers in the LEP. Adjusting their material properties gives colours from blue to red. The light emitting layer is sandwiched between an anode - normally a thin, transparent layer of indium tin oxide coated onto the transparent substrate at the front, and a cathode - which can be made of any conducting material (see Figure 6). In operation the anode and cathode inject holes and electrons respectively into the light emitting layer, where they form excitons which release photons as they decay and recombine. The second polymer layer acts as an electron transport layer.

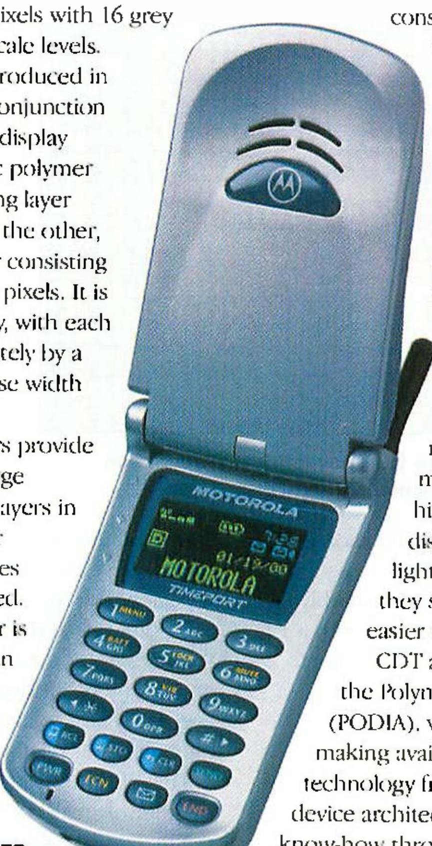


Figure 7. Mobile phone with OLED display. Picture: Motorola.

LEP technology offers a number of advantages over LCD. Only a low voltage is required (the display is current driven); and the power consumption is considerably less than an LCD with a backlight (LEP can also be used as a backlight for LCD - rigid or flexible). Of course, no backlight is required for LEP; and with homogeneous light emission effective use is made of the pixel size.

The brightness and contrast are greater. Its response times are faster - measured in microseconds rather than milliseconds, thus allowing higher refresh rates. The displays are slimmer and lighter than baclit LCDs. And they should be quicker and easier to produce.

CDT and Covion have formed the Polymer Display Alliance (PODIA), with the intention of making available all the necessary technology from polymer materials, device architecture and process know-how through to device prototyping to companies wishing to evaluate LEP display technology.

Incidentally, going back to inkjet printing of displays, polymer transistors have also been inkjet printed, in a co-operative effort by Cambridge University, the Cavendish Laboratory, Plastic Logic (another University spin-off) and Seiko-Epson. So both the active matrix and the light emitting layer will be printed onto the substrate in future developments. In the present case the source, gate and drain were printed using polyethylene dioxythiophene, while the semiconductor layer of fluorine bithiophene copolymer and the insulating polymer of polyvinylphenol were spun onto the substrate - and the 5μm gate was lithographically defined in advance.

OLEDs in general are causing great interest among manufacturers. Kodak and Sanyo have jointly produced a 5.5in active matrix display, with 320x240 pixel resolution, using the Kodak invented sublimed molecular films organic luminescence technology combined with Sanyo's expertise in low temperature polysilicon TFT technology. The principle is similar to that of LEP, with the injection of electrons and holes that recombine in the RGB emissive layer to produce photons. Between the organic emissive layer and the indium tin oxide anode there are organic hole injection and hole transport layers, and between the cathode and emissive layer an organic electron transport layer. The organic materials may include 'small' molecules or 'macro' polymers: in the former case the display will be constructed using vapour sublimation for thin film deposition; in the latter case solvent coating techniques will probably be used. The emissive layer is doped with a small amount of fluorescent molecules to enhance the efficiency of the electroluminescent process and control the colour output.

OLEDs are expected to take an increasing share of the small screen market in camcorders and still cameras, personal digital assistants, and mobile phones from

Figure 8. Tiled AMLCD display. Picture: Rainbow Displays.

LCDs (Motorola has recently launched a phone with an OLED colour display sourced from Pioneer - see Figure 7. And it is anticipated that in 2005 between 30-40 percent of 3G phones sold will have OLED colour displays). Colour being necessary to provide the legibility for all the additional services that will be provided on mobile phones. And single colour passive displays, those for clocks and instruments, can be easily and inexpensively achieved. While further developments in full colour displays will allow screen sizes that encompass sub-notebook and notebook computers, then desktop displays; with further improvements bringing small, medium and eventually large widescreen TVs - and, ultimately, high definition wall-hung TVs.

This lucrative potential has led to a number of small companies that possess the technological know-how being taken over by large companies who desire to have it. One such being UNIAX Corporation, a company that was formed to commercialise the early work that was being done on polymers at University of California, Santa Barbara. Its new owner, DuPont Displays, will combine its own flexible substrates, barrier coatings, web manufacturing, polymer synthesis and manufacturing, electronic materials and pixellation technology with the intellectual property of UNIAX to develop flexible displays.

But LCD technology is not standing still. And OLED, in its various guises, is not the only technology whose proponents claim it to be the replacement for both LCD and the CRT.

LCD is the more vulnerable of the two because, although prices are falling, it is inherently expensive to manufacture. The picture quality has also been wanting; but various developments in that area have brought noticeable improvements of late. And the technology (that also comes in various guises) encompasses all screen sizes from small to large. LG.Philips has developed a 29in active matrix LCD high definition TV, to prove the point. Larger sizes are possible through the use of tiling.

This was first employed by Sharp to produce large screen displays from smaller segments, and they recently demonstrated a 40in model composed of two tiles. One company that specialises in this process is Rainbow Displays Inc. (RDI). They have

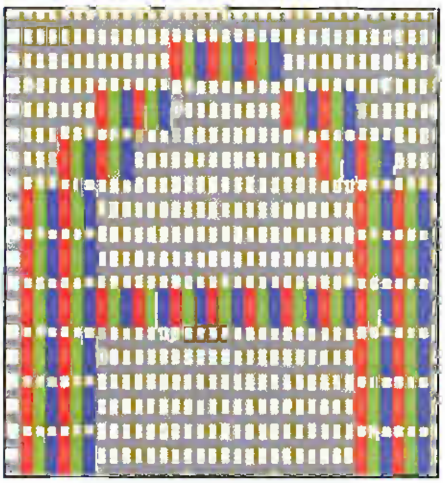


Figure 9a. Conventional Plasma line arrangement. Picture: Fujitsu.

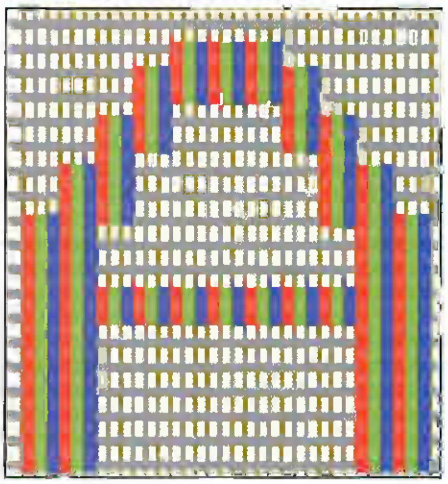


Figure 9b. High definition Plasma line arrangement. Picture: Fujitsu.

demonstrated an active matrix 38.6in 4:3 prototype, of 800x600 pixels, composed of four tiles (each holding one quarter of the pixels); and, in a joint effort with Philips Flat Display Systems, a 37.5in 16:9, 852x480 active matrix display employing three tiles, and are developing an HDTV model. Tiling is an important step, because, without it, LCD technology would not be able to share in the still small but growing market for large displays of various types in airports, conference rooms (see Figure 8), TV studios, pubs and clubs, and the homes of those who can afford home cinema in the grand style. The difficulties and cost of manufacturing a one piece LC display of that size would make it a non-starter.

RDI is able to produce seamless displays with its proprietary tiling technology. The criteria for this are pixels with constant pitch and visual characteristics maintained across the seams, those seams must be light-tight, and two or more tile edges must be accessible for matrix addressing. Requirements that RDI has achieved, despite pixel pitches of under 1mm. The tiles are produced on a conventional manufacturing line. The only differences being a pixel layout designed with space for joining, the fabrication of an LC seal with a width of about 100µm, and the control of the LC cell gap to better than 0.5µm. The tiles are then tested, and assembled into the display between optical glass plates using transparent optical adhesives. Microfabricated aperture masks on the insides of the glass plates prevent light leakage from the seams. The light comes from a fluorescent backlight with a quasi-collimated light output - with a diffusive screen on the front glass to regain the viewing angles reduced by the collimation process. When completed the seams are actually visible and there are minor differences in brightness and colour between the tiles. However, these are addressed by digital signal processing and individual settings of row and column voltages for each tile. After this the variations are said to be in the order of 1 percent.

The two companies are planning to produce displays in screen sizes from 30 to 60in. Thus competing directly with plasma display panels (PDP).

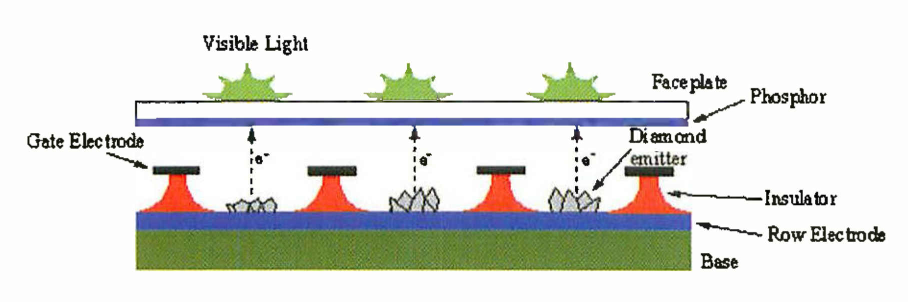


Figure 10. Diamond FED construction. Picture: School of Chemistry, University of Bristol.

This has quickly become accepted as the large screen, direct view alternative to projection, and wherever a slim display is required. However, the technology is not without its disadvantages: the panels consume a lot of electricity for their light output and require cooling fans. The panels consist of glass plates separated by barrier ribs and filled with an inert gas. This is converted into a plasma where x and y electrodes cross by applying a voltage between two parallel discharge electrodes; this produces ultraviolet light that excites the red, green and blue phosphors. The perceived intensity of each pixel is controlled by pulse width modulation, switching the plasma discharge on and off, since it cannot be directly varied.

Until recently all the displays were standard definition (the US 480 vertical lines) and used progressive scanning. Fujitsu, however, has developed a high

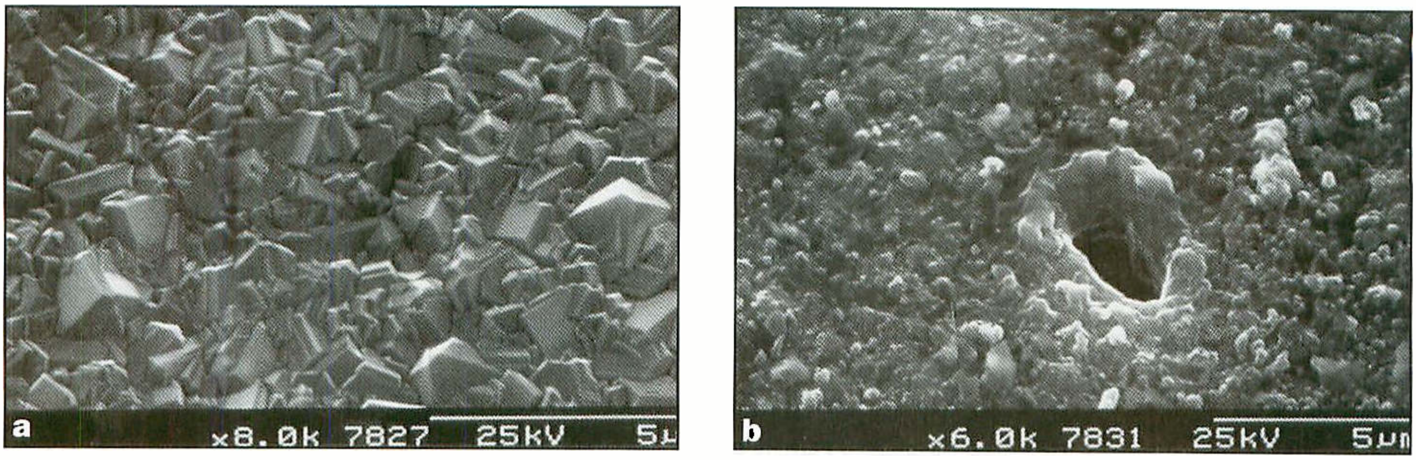
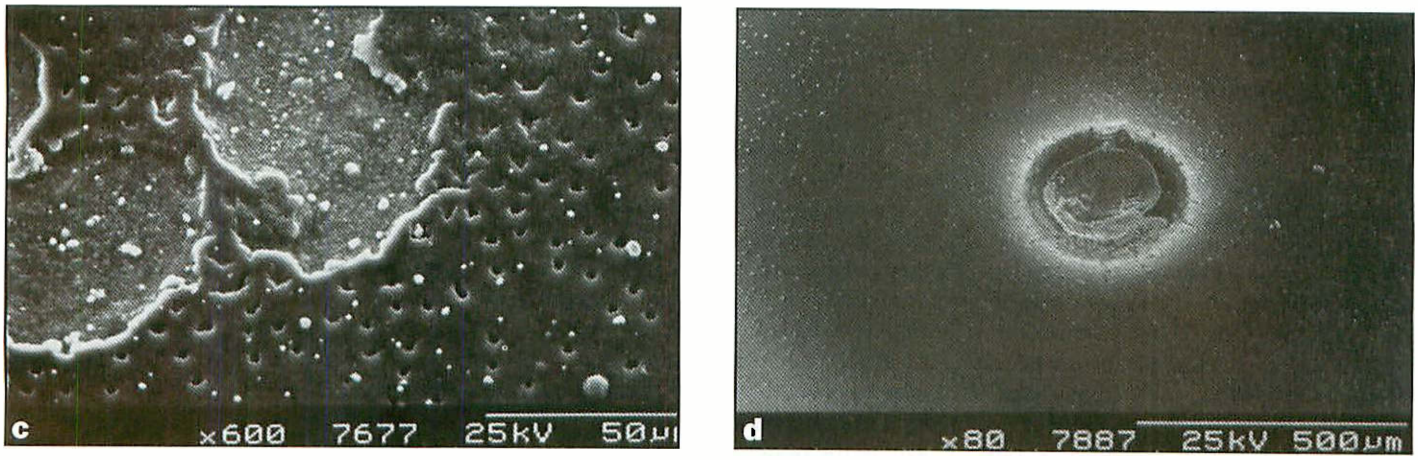


Figure 11a/b/c/d. Testing CVD film for Field Emission. Picture: School of Chemistry, University of Bristol.



definition version by employing what they term Alternate Lighting of Surfaces (ALiS). This makes use of what was the unused area between the lines to produce an interlaced display of 852 lines on the 32in model and 1024 on the 37in one - both having a 1024 horizontal resolution (a 42in version has also been demonstrated with 1024x1024 resolution). Figure 9a shows the complete frame of a conventional PDP display; Figure 9b shows the complete frame of the ALiS display. In addition to the greater resolution the brightness is increased by half, and flicker is reduced.

However, plasma is suited to medium and large screens. Another emissive display has the potential to cover small to large, because it is the nearest relation to the CRT - this is the Field Emission Display (FED). Like the CRT it produces electrons that excite phospors; but each pixel has its own microspcopic emitters, typically an array of microtips probably numbering in their thousands. In Figure 10 the microtips have been replaced by diamond emitters, but the principle is the same: the voltage difference between the row (cathode) and gate electrodes extracts electrons that pass through the vacuum and go on to strike the phosphor. With diamond, whether real or diamond like carbon, the voltages can be a lot lower than molybdenum and silicon, and so too, can the vacuum. It can also be coated on by chemical vapour deposition making a fairly simple display.

A number of universities in the UK are experimenting with diamond like carbon (and carbon nanotubes) for FEDs - such as Bristol, Cambridge, Oxford, Surrey and University College, London. At Bristol most of the work is now concentrated on the actual cathode material itself - such as doping DLC with various exotic elements to see if this improves the FE performance. Figure 11a shows an electron microscope image of a CVD diamond film before FE testing, 11b shows what can happen after extracting 1μA for 30 minutes, 11c after extracting 10μA and 14d after 100μA - both for 30 minutes). Oxford, conversely, has a new spin-off company called Nanox that is developing nanoparticle phosphors that can work at lower voltages than conventional phosphors - at 500V the Nanox phosphors are said to be five times more efficient than conventional ones at much higher voltages. Not surprisingly, a number of manufacturers are testing them.

One of those is Sony. Who, at the end of last year, extended its partnership with Candescent Technologies, one of the companies that are developing FEDs. In this case a high voltage type. The two companies have demonstrated a 5.3in model.

Another user of phosphors is the photoluminescent LCD (PL-LCD). This was invented at Cambridge University, and is being commercially developed by another spin-off, Screen Technology. The device employs near visible UV collimated illumination, which shines through the LC display and onto phosphors. The LC display just varies the brightness of the light and, hence, that of the phosphors. 12in monochrome and colour PL-LCDs have been demonstrated. Philips has been experimenting with a similar display, but they call it an emissive LCD. This differs from the PL-LCD by having the phosphors within the LC layer and using a plain UV backlight, plus a wavelength selective mirror between the phosphors and the LC layer to reflect wrongly directed emitted light to the viewer (this is a dielectric stack of 36 metal oxide layers).

A rather older technology is that of the Suspended Particle Device. This was invented in 1934 by Edwin Land, the founder of Polaroid; and, ironically, that company has acquired a licence to manufacture SPD film from Research Frontiers who have been developing it to perform a variety of applications, including 'smart' windows. The technology is based on suspensions of light-absorbing colloidal particles encapsulated within a thin plastic film, placed between glass or plastic plates. When in the off state the particles are randomly aligned and block light, when an AC voltage is applied they align and light is transmitted or reflected (see Figure 12). At present the response is slower than an LCD, with times of 150ms, but the times are continuing to be improved and they are aiming to achieve video speeds of 25ms or less. They also require a greater voltage than LCDs. But they are superior in terms of contrast ratio (and they do not require polarisers).

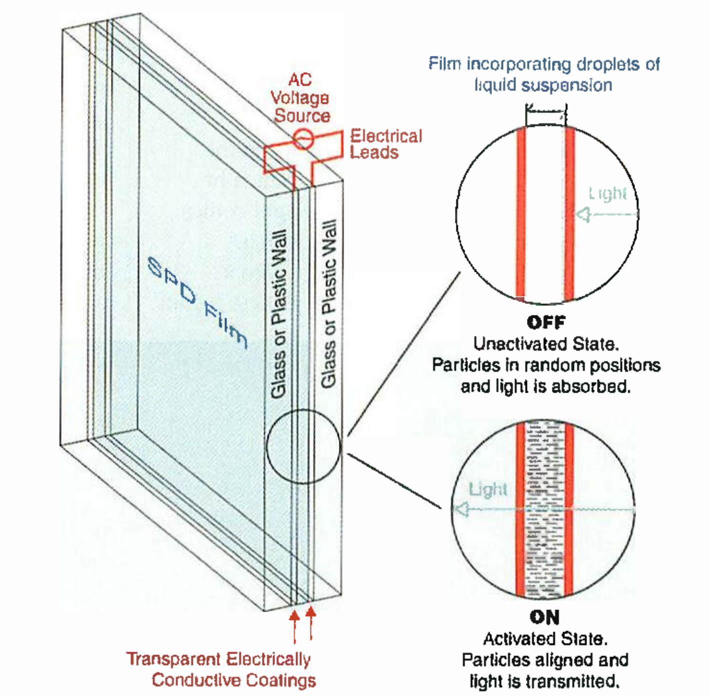


Figure 12. Suspended Particle Display operation.
Picture: Research Frontiers.

In addition to obvious similarities with PDLCs, SPD also bears some relationship to Electrophoretic Image Displays (EPID), which rely on particle suspension in a cell. However, EPID uses a DC voltage, and the particles are made to migrate between the electrodes: the electrodes on one glass plate are the widths of the pixels so that the particles spread out and block the light. On the opposing plate they are narrow and the particles leave the pixels largely clear. The particles are also light scattering, not absorbing; and a dark dye is used to hide them from view (which is why the latest developments employ microlenses to maximise the light).

There is also a variation on EPID technology, called Reverse Emulsion Electrophoretic Display (REED). This uses a mixture in which coloured droplets are suspended in a clear liquid (the reverse of an emulsion); and these respond to electric fields. Actually, the reverse emulsion is a microemulsion, which is thermodynamically stable and forms by itself given the right constituents. The technology is a new one being developed by Zikon. And so far only simple monochrome displays have been demonstrated. Both electrophoretic addressing and frequency addressing have been tried. The latter causes the emulsion to exhibit different properties with different frequencies, varying the colour and transparency of the pixels.

REED would seem to be a long-term effort. But a number of companies are anticipating their technologies changing from development to production either this year or next. This should give their investors something to celebrate finally.

Entangled PHOTONS

By Reg Miles

A joint research team from NASA's Jet Propulsion Laboratory (JPL) and the University of Wales has discovered a means to potentially enable the fabrication of smaller and faster computer chips without changing present day manufacturing processes.

This is done by photolithography, with laser light being shone through a mask onto a polymer photoresist that has been coated onto the silicon, which after development leaves behind a hardened image that protects those areas of the silicon from etching. And the end result is an array of transistors and resistors.

As manufacturers continually reduce the size of the transistors and squeeze greater numbers into smaller ICs so the distance that the electric current has to travel is reduced and the operating speed is increased. Unfortunately, this reduction in the size of transistors will be stopped well short of the theoretical minimum size that traditional computers can accept by the limitations of the optical process. The functional minimum for a computer is about 25nm; modern fabrication methods are achieving sizes of 180-220nm. This is using light with a wavelength of 248nm. It becomes increasingly difficult to use light with shorter wavelengths to produce transistors with smaller dimensions. And, according to a central principle of optics called the Rayleigh criterion, which sets a limit on resolution relative to the wavelength, 248nm light cannot create features smaller than 124nm. Smaller transistors have been produced experimentally, down to 20nm, but using different designs.

This new research, still in its theoretical stage, could enable the Rayleigh criterion to be 'side-stepped' and conventional designs to be scaled down. The research team proposes to use the intermingled properties of two or more photons to obtain subwavelength spatial resolutions. This 'entanglement' of photons would allow the use of existing sources of laser light of 248nm to produce computer chips with dimensions of one quarter of the wavelength (62nm) or smaller rather than the present day half-wavelength.

Einstein referred to this intermingling of photons as 'spooky action at a distance' because the particles can immediately influence each other over huge distances - according to the press release, 'even halfway across the Galaxy'.

Optical spontaneous parametric down conversion (SPDC) is the most effective mechanism to generate an entangled two-photon state. In this process an optical pump beam is shone through a birefringent crystal: the light is intense enough for non-linear effects to convert pump photons into pairs of photons. In this quantum lithography proposal, a pair of entangled photons enters a set-up with two paths. While the two particles travel together and act as a single unit, it is impossible to determine which of the two paths the pair has taken. In an effect of quantum mechanics, however, each photon actually travels down both paths.

On each path, the photons act like a rippling wave with peaks and troughs. After traveling on their own path for a while, the two photons converge on a surface. Because the light particles making up each wave were originally entangled, the result of adding the photon waves together is to create patterns on the surface equivalent to those made by a single photon with half the wavelength.

This process, in essence, enables the entangled photon pair to produce patterns half the size on each side of a chip's surface as can be created by single photons in conventional photolithography. Entangling more than two photons would improve results even further.

While a number of technical challenges remain, researchers are already working on developing materials that would be required for quantum lithography. According to JPL researcher Dr. Jonathan Dowling, 'Our economy constantly depends on faster and faster computers. This research potentially could enable us to continue upgrading computers even after traditional manufacturing procedures have been exhausted.'

Entanglement is becoming fashionable. There is a European Project devoted to it, for example: Entanglement in Quantum Information Processing and Communication (EQUIP), 'To advance the theory of bi-partite entanglement and to develop a theory of multi-partite entanglement which would ultimately provide the basis for the future technological application of quantum mechanics in information processing and communication.' It has also been suggested as the means for achieving teleportation.

However, photon, and more generally quantum, entanglement has been a contentious issue in quantum mechanics ever since the Einstein, Podolsky and Rosen (EPR) 'thought experiment' paper of 1935 used the principle of entanglement, mathematically formulated by Schrodinger, to demonstrate an inferred lack of completeness in QM theory. Instead of instantaneous action at a distance, they postulated local hidden variables with each of the 'twinned' particles having more information about each other than QM allowed for. Bohr defended the completeness of QM by suggesting that EPR were interpreting the theory too literally. A test, 'Bell's inequalities', was formulated in 1964 to determine which of the two sides was correct. But although QM has generally been ascendant, a number of research results have been marred by suppression of data, and the arguments rumble on.

Contact:

Gia Scafida Tel: (818)354-0372

WEB CRIME

Are consumer fears about fraud on the Internet unfounded? Here we report on the fear of crime that leads shopper Web worries.

The new report reveals that UK householders are more than twice as likely to have their homes burgled than to fall victim to Internet fraud.

Just 2% of online shoppers - less than one in 50 of the Web population - say they have been victims of Web fraud, compared to more than four per cent of home owners who will this year suffer the trauma of a break-in at their homes.

Ironically the report 'E-privacy issues among European consumers' suggests fear seems to escalate according to Internet usage. According to the survey, the fear of crime is highest among experienced Web users.

David Petraitis, director of e-privacy at PricewaterhouseCoopers, says, "Fraudulent use of personal information on the Internet is less than expected. The result of the pan-European research stands in stark contrast to the fear of 95% who said they were reluctant to release their credit card details into cyberspace. Interestingly, two out of three prefer to give bank details over the phone - ignoring the fact that they may be prone to eavesdropping - than via the net.

"That perception of fear, reinforced by the occasional media scare story, seems to be at the heart of the matter and e-businesses have a long way to go to win the trust of consumers.

"Fortunately, there are some e-privacy solutions."

The survey points to the fact that consumers are increasingly looking for a well-rounded security and e-privacy solution, which suggests that technology providers, business and government will have to work together. Around one third remains sceptical relying upon various security technologies only. This may explain the seemingly illogical finding that experienced surfers (33%) worry more about security breaches than newcomers (27%).

PricewaterhouseCoopers identified that intrusion and misuse of information is one of the biggest concerns amongst consumers. Nearly one European Internet user in three rated his/her level of concern as 'high'. To avoid 'surveillance', 75% indicated that they opt out of providing information when given the choice.

Petraitis explains, "This paranoia is not entirely unfounded as over half (55%) of consumers suffer from unwanted email, and around a fifth (20%) find that their personal details have been passed on to others without their knowledge.

"However opting out of providing personal information is a double-edged sword, which leaves permission based e-marketing at an unsophisticated stage. The less personal information available the more e-business will have to rely upon more or less random advertising methods which aim for an occasional response by a potential customer."

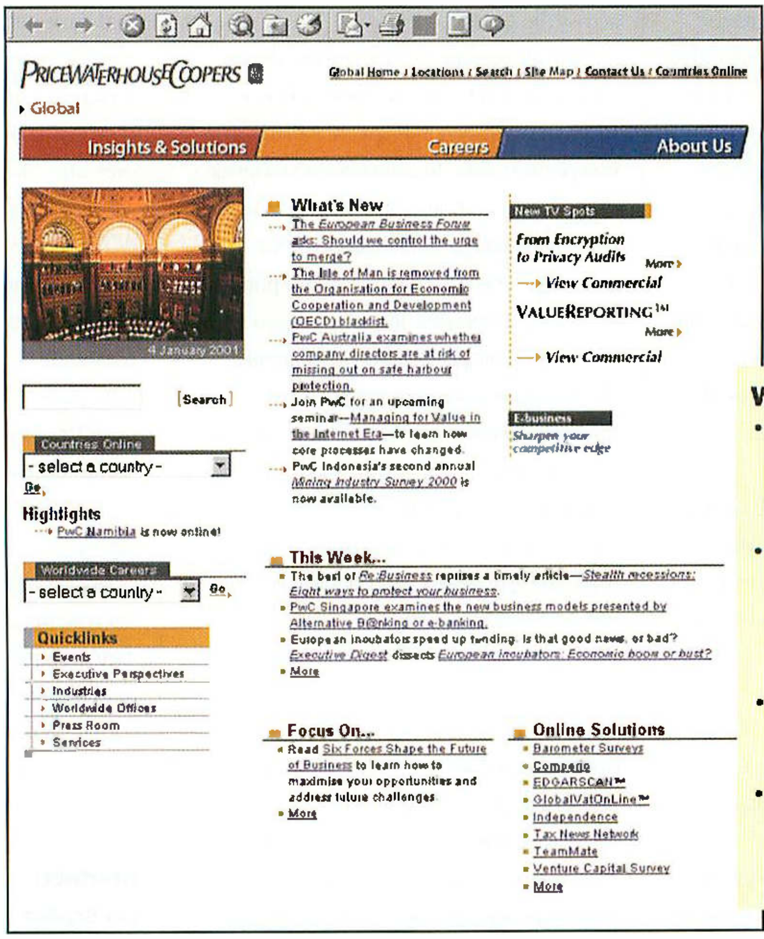
In order to survive in cyberworld and gain the consumers' trust, responsibility is clearly on the side of e-business. The degree to which this is achievable will differ from country to country, as the cultural divide is wide. For example:

- Concern about privacy when using the Internet is highest in Spain, South Africa and the UK. Whereas the Scandinavians - being among the highest Internet users in the world - seem to be least concerned
- Italian (19%), French and Spanish consumers are the most sceptical about privacy protection on the Internet
- Scandinavians, Belgians and Dutch feel that their privacy is most protected
- German consumers were most unwilling to disclose any personal information in general (26%)
- Italians were the most comfortable in disclosing brand and product preferences (68%)
- UK net users are the most willing to disclose credit card details at 12% but in Germany and Italy the figure drops to a mere 2%

Petraitis concludes, "Creating channels of dialogue is vital both for business and for consumer associations. Businesses have to make privacy more of a priority and make sure consumers are aware of their effort to resolve this issue.

"At the same time consumer rights organisations and data protection representatives should ensure that consumers have a voice."

For further details on the PricewaterhouseCoopers' report and information about Internet security, please check: **<www.pwcglobal.com>.**



Web fraud highlights

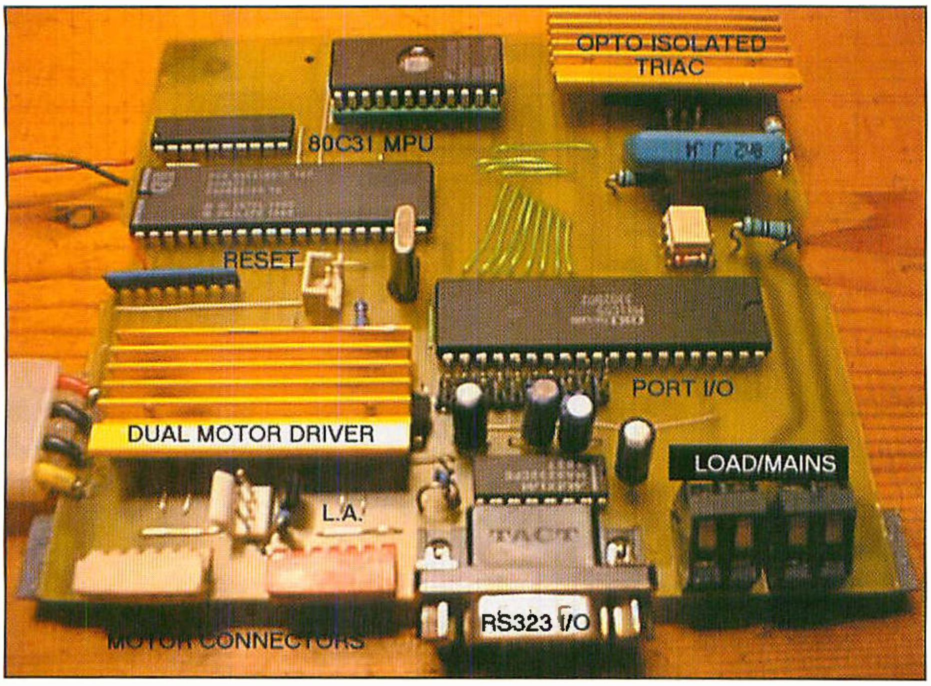
- High Street banks and public health authorities are most trusted by just over a third of those surveyed (33%)
- Foreign companies and small businesses are the least trusted with only 13% of the respondents willing to give them information
- Internet Service Providers (ISPs) are among the least trusted institutions (21%)
- Consumers appear unaware of legal protection, but would turn to the police in the first instance to report fraud.

RS232

IO Control Board

PROJECT

Part 1: by R.Grodzik



This project is in essence a distributed embedded control system comprising of a PC, a serial RS232 communication link and a 8031 micro-controller based autonomous controller board housed in a low profile enclosure. From a PC mouse-driven menu, you are able to independently control 2 stepper motors: forward/reverse, fast/slow, stop/go; switch on a mains lighting circuit and control 16 switch outputs as well as monitor a simple alarm circuit with feedback to the PC.

Connections

As with any control board there are plenty of plug connections to interface to the outside world. These are:

(P1) This is a standard 90 degree PCB 9-pin D-type male plug mounted on the board which provides the RS232 communication link between the serial port (COM1) of a PC and the RS232IO board. The mouse should be either be connected to the PS2 socket, if available, or the COM2 port. In addition, the RTS hardware handshake line (pin 7) from the PC's serial port is used to switch an external standard PC power supply unit which provides a +12 volt supply for the 2 motors and a hefty +5 volt supply for the board and external interface circuitry e.g. indicator diodes. When the PC software driver (RS232IO.EXE) is executed, the serial COM1 port is opened and a +ve voltage appears on the RTS line. This is clamped to +5 volts by a 5V1 zener diode and used to switch an FET transistor (type BS170p). This results in a short between the two lines (usually black and white wires) of the logic activator connection to the PC PSU, and the PSU starts up, supplying power to the RS232IO board. Since the board contains a mains output, a breakdown in the RS232 communication link or a computer 'crash' will switch off the PSU and also disable the mains output (if enabled). Also, when program RS232IO.EXE is aborted, the serial port of the PC is switched off under software control, and again the eternal PSU is shut down.

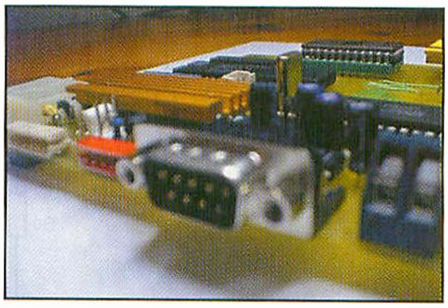
(P2) Consists of 2 9-pin D-type female sockets wired together with approx. 1 metre of 4 way cable to provide a connection between the PC's serial port and P1 of the RS232IO board. Wiring of the cable is as follows and can be either way round.

PIN 2	PIN 3
PIN 3	PIN 2
PIN 5	PIN 5
PIN 7	PIN 7

(P3)Consists of a 20 way IDC 0.1" header used to carry the following control outputs/inputs: 16 outputs labelled PA0-PA7,PB0- PB7 on IC7 (a programmable PIO IC. These lines can be switched on/off by simply clicking the mouse on the PC's menu. A facility is provided to switch BANK A or BANK B switches on or off together. The remaining lines carry an alarm input (a simple micro-switch) which is wired between the +5v line and the alarm input. When the micro-switch is activated, the Alarm mimic on the PC's screen will flash together with an audible warning, inhibiting any further control of the RS232IO board until the alarm is cancelled. Simultaneously on alarm condition line Pc5 will be asserted logic high allowing for external control of a transducer or an external alarm device. A +5 voltage and 0v line is provided on the remaining pins.(In Part II of this project the LED status array and interconnections for P3 will be described in further detail).

(P4)This is a square pin (3-way) header to which connects the logic activator lead from the power supply.

(P5)A simple press-to-make switch is connected to the 2 pin header via a small length of cable. This is the external reset switch for the system which is mounted on the completed enclosure. Pressing this switch will close down all the functions i.e. stop the 2 motors if running, kill the mains output and force all switch outputs of P3 off. Clicking the mouse pointer on RESET bar of the menu will similarly reset the RS232IO board.



(P6)A standard 4 pin PC PSU plug which is attached by 4 short leads the RS232IO board and secured by silicone compound: 2 black leads (0v), red (+5v), yellow (+12v).

(P7,P8) These are two 6 way pcb header pins to which the two stepper motors are attached.

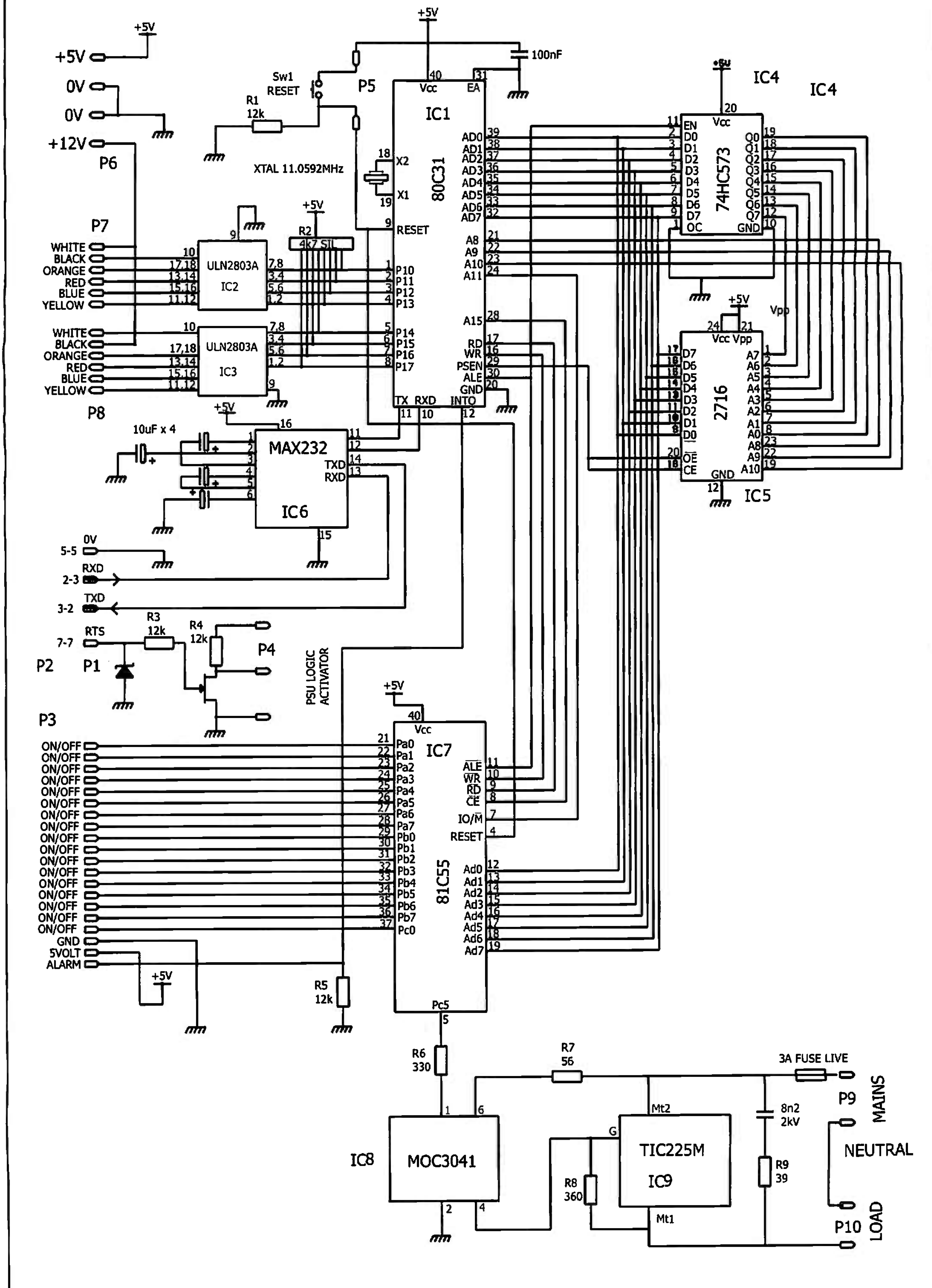


Figure 1. Complete circuit of RS232 IO Control Board

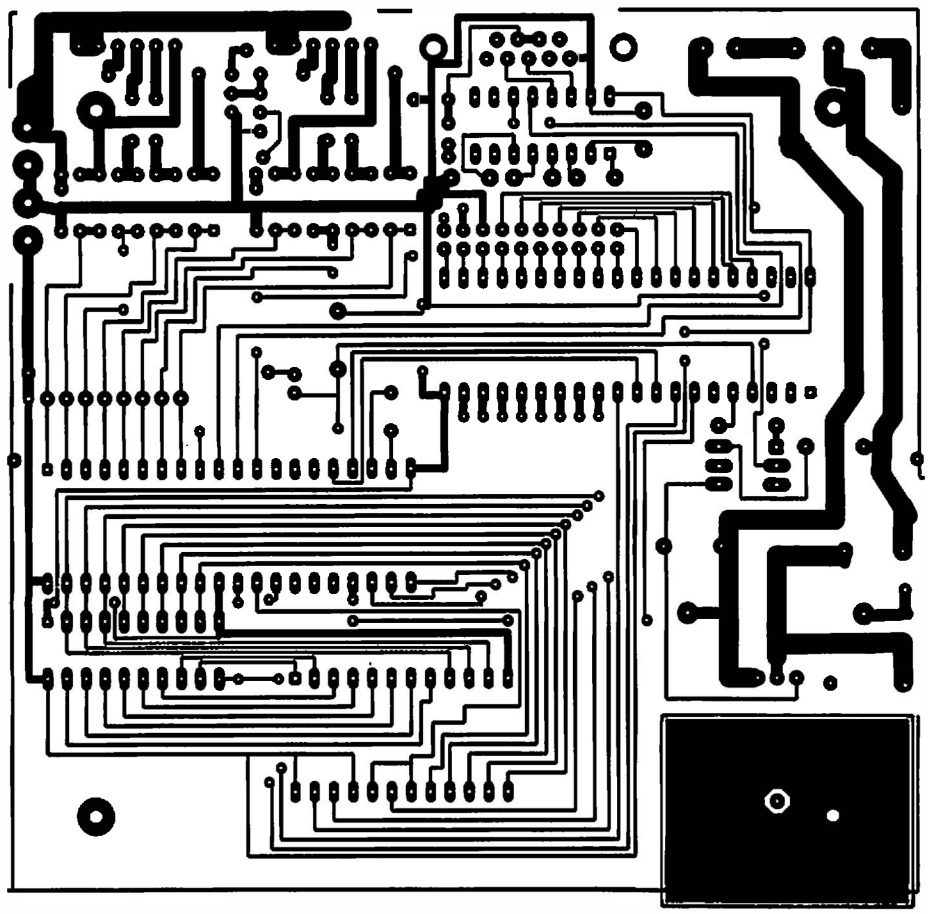


Figure 2a. Control board PCB bottom view

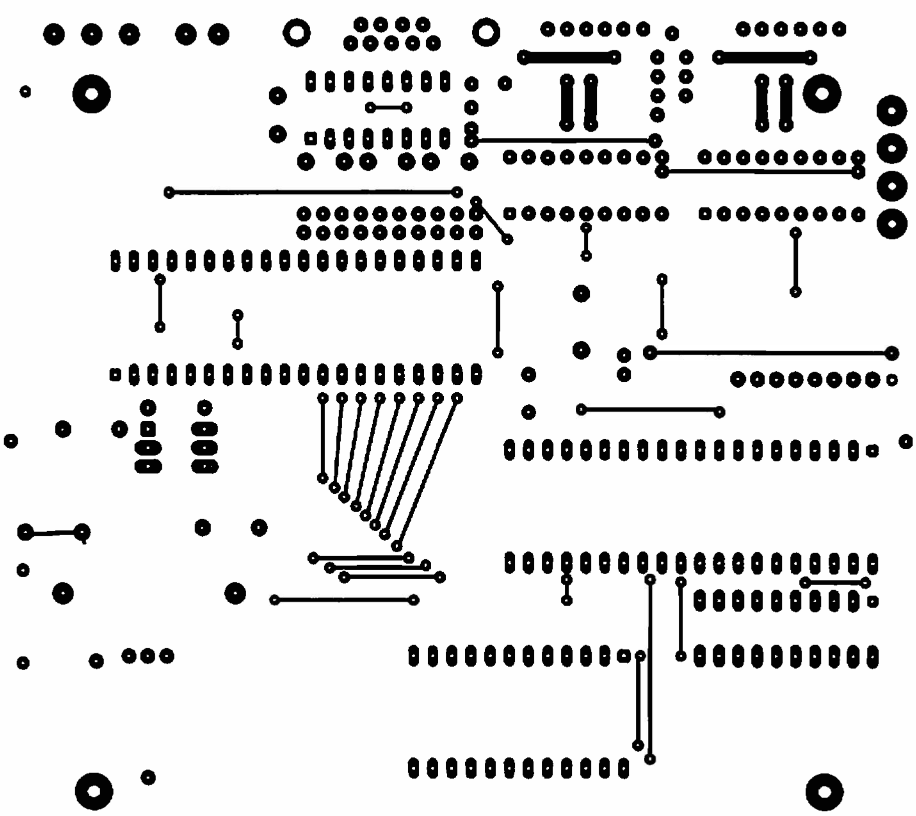


Figure 2b. Control board top view

(P9) is the mains input pcb terminal block.

(P10) is the 2 way terminal block to which an ac lighting circuit is wired. The mains part of the RS232IO board is totally isolated from the logic and external connections by means of an optically coupled isolator (IC8) a MOC3041 which is used to switch a mains triac switch (IC9) a type TIC225M. Note that an earth connection is not provided since this circuit has been designed only for ac lighting with a maximum 500 watt load. The limiting factor of power output is the size of the heatsink that is of small dimensions, being limited by the size of the enclosure. If the box gets hot, reduce the load! Class II double insulated lead should be used to make all connections to P9 and P10.

Construction of the board

Readers of this magazine should recognize the 8031 SBC described in an earlier article, but this time a conventional 40 pin DIL 80C31 embedded controller is used in place of a PLCC package. This makes for easier fault-finding since the 8031 pins are readily accessible. Note that the ac circuitry consisting of IC8 and IC9 and associated resistors should initially be built and tested. Resistors R9 R7 R8 are all 1 watt power rating. Remove R6. Wire together 2 battery cells in series to provide a 3 volt source and connect the +ve end to pin 1 of the opto-isolator (IC8), the -ve end to pin 2 (ground). Connect in a dead mains supply to P9 ensuring that the Live mains lead is connected to the fused end of the terminal. The fuse is a wire-ended 3 AMP type soldered to the underside(copper side) of the board. Switch on the mains supply and measure the ac output on P10.This should read 240 volts ac Kill the mains and disconnect the battery from the opto-isolator. Re-connect mains and there should be no output on P10. Ensure safe working practice when working on live mains i.e. FOLLOW THE HAND IN

POCKET RULE. The mains must now be disconnected until the board logic circuitry build has been finalized and checked and the completed board has been installed in a plastic enclosure.

As with all micro-processor boards, several wire links are required on the component side of the board due to complexity of the copper artwork. A 0.5mm drill was used for the connecting pads and fine insulated single strand wire was used to make the links. All the IC's with the exception if IC5 (27C16- a 2Kbyte EPROM) are unsocketed and soldered directly to the board.

Heatsinking

The triac (IC9) and the 2 darlington motor driver ic's (IC2,IC3) generate heat when operational and need to be heatsinked. A simple method is to cut a standard low profile Pentium heatsink in half and epoxy one half to the two darlingtons and the other half directly onto the triac.

Final assembly and testing of the board will follow in Part II and a description of the firmware in the 27C16 EPROM will be given, together with details of using an EPROM Emulator to write short programs to test the completed board. In Part III details of the completed enclosure and LED monitoring board, together with interfacing the RS232IO board will be provided.

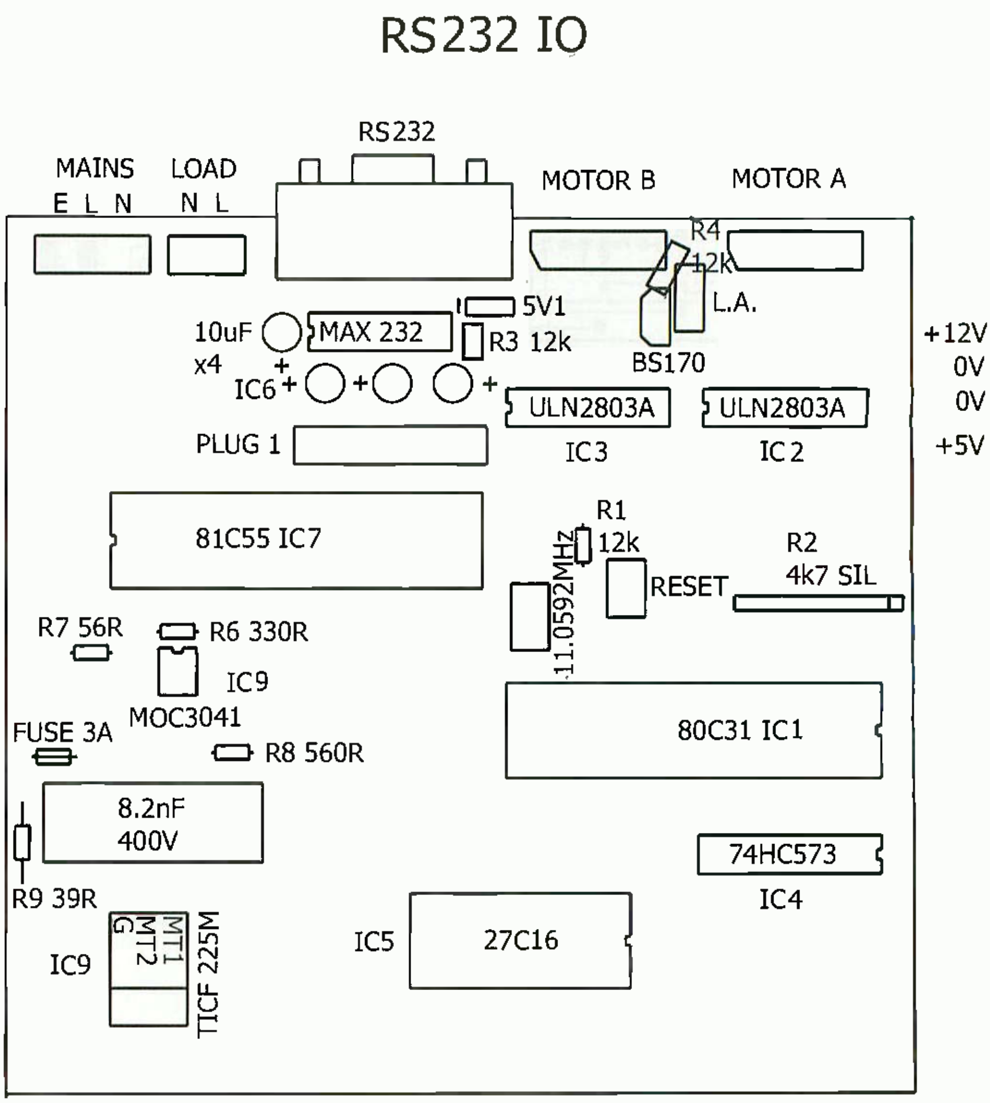


Figure 3. Component overlay of control board

Note: The PC software driver (RS232IO.EXE) on disc and pre-propgrammed EPROM is available from:

R.Grodzik (MICROS)
53 Chelmsford Road
Bradford
West Yorkshire, BD3 8QN
United Kingdom.
Email:<dgrodzik@netscapeonline.co.uk>

Screen grab of software showing status of ports

PARTS LIST

Semiconductors

IC1	80C31
IC2,3	ULN2803A
IC4	74HC573
IC5	27C16BQ200 (See Note)
IC6	MAX232CPE
IC7	81C55
IC8	MOC3041
IC9	TIC225M

Transistors

BS170p
Zener 5v1

Resistors

R1,3,4,5 12K
R2 4K7 SIL
R6 330R
R7 56R 1 WATT
R8 360R 1 WATT
R9 39R 1 WATT

Capacitors

4 x 10µf 16v

Sundries

SW1	PRESS TO MAKE SWITCH
XTAL	11.0592MHz

200 WATT PC Power supply with logic activator

Connectors

P1	PCB 90 DEGREE 9 PIN D-TYPE
P2	D-TYPE 9 PIN FEMALE X 2
P3	20 WAY IDC 0.1" HEADER
P4	SQUARE 3 PIN HEADER
P5	SQUARE 2 PIN HEADER
P6	4 PIN PC PSU PLUG
P7,P8	6 WAY PCB HEADER
P9,P10	2 WAY PCB TERMINAL BLOCK

Bending
INFRARED LIGHT

by Reg Miles

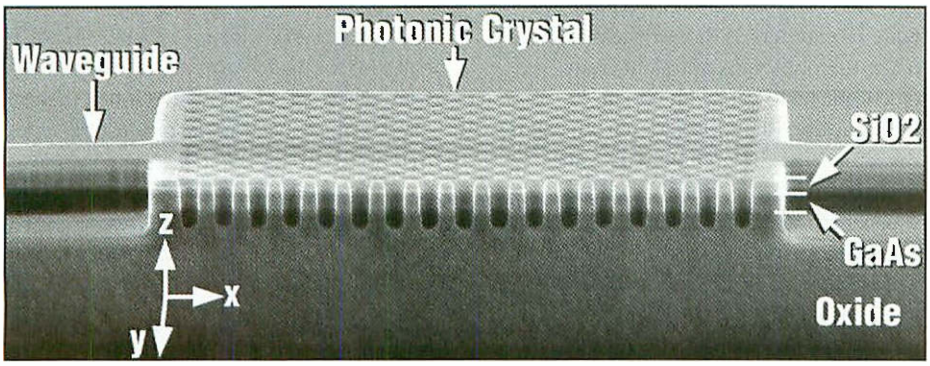


Figure 1. The perforated two-dimensional Gallium Arsenide shape of [Sandia's] Shawn Lin research team has proven unusually successful in bending infrared light with little loss.

Researchers at the US Department of Energy's Sandia National Laboratories have produced an efficient and inexpensive means of bending infrared light in confined spaces, with little measurable loss or distortion, using a perforated bar fabricated from Gallium Arsenide without metallic components.

In this two-dimensional photonic crystal the perforations provide a substitute for the spaces between molecules through which the light is channelled in real crystals (see Figure 1). The structure has its cell centres spaced at 416nm, with holes of only 200nm made by electron beam lithography. Natural crystals are restricted by their intrinsic molecular spacing and only allow certain wavelengths of light to pass through them. So the advantage to researchers with this artificial structure is that they can vary the spacing of the crystal components, thus allowing any frequencies (within tool limits) to pass while blocking others.

The effect opens the possibility that the essentially two-dimensional technique can considerably reduce the energy required to start and operate a laser - of which most of the input energy merely compensates for the large amount of light ordinarily dispersed uselessly in the lasing process. The crystal itself is 'easy to make,' according to Shawn Lin who, with Sandia researcher Edmond Chow, led the project. 'One can have the laser and guiding element in the same chip. There is signal binding and switching, all in one place.'

Because of the minimal light loss, the technique offers the potential of ultimately replacing electronic chips with faster, cooler photonic chips. Another possibility is using it to combine light with electrons in a single chip. It could also be used to relay as well as change the direction of optical signals coming through telecommunication lines.

According to Shawn Lin, 'Many people have realised the value of such a structure. The problem has been, how do you build it?'

It was thought that light would easily escape out the top and bottom of an essentially two-dimensional structure. However, that was resolved by using a covering of silicon oxide on the top and aluminium oxide on the bottom. This cladding provides a large difference in the refractive index that facilitates the ability of researchers to restrict the passage of light to the central portion of the photonic crystal.

The cladding's refractive index is higher than the refractive index of the material it encloses, thus preventing light from escaping from Gallium Arsenide. Which rather begs the question of how the cladding keeps the light stable as it passes through holes, since the refractive index of air is lower than the refractive index of semiconductors? (A higher refractive index prevents light from entering a substance.) The answer is that the distance across the hole is so small that quantum interference effects come into play, and the light merely

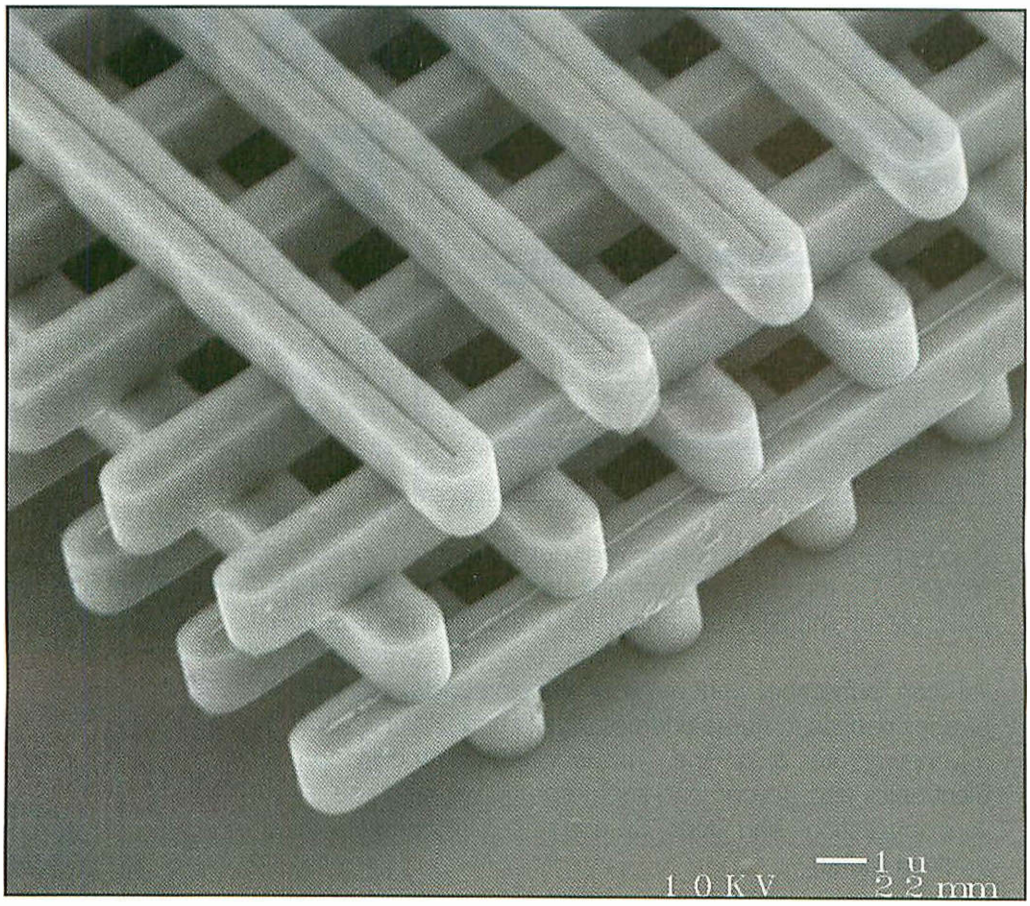


Figure 2. The photonic lattice acts like a crystal in guiding light because of its tiny, regularly placed silicon 'logs'. These are 1.2 microns wide. Control of different wavelengths is achieved by changing the lattice dimensions.

moves to the next confined substructure.

The cladding process, incidentally, was pioneered at Sandia as part of its work on the vertical cavity stimulated emission laser (see 'UV Laser' in the February issue).

This work on photonic crystals builds on that by the same research team who had earlier created three-dimensional, silicon, photonic crystals for the same theoretical purposes (as you might expect, two-dimensional crystals are cheaper and easier to fabricate).

Shawn Lin and Jim Fleming achieved the desired crystalline spacing in the three-dimensional structure using techniques perfected in building surface-etched micromachines - at which Sandia is a world leader, according to the press release. Gears that spin require spaces between parts. In this case, a silicon base is covered with an expendable coating in which a part can be etched, and then the expendable portion is removed by chemical and mechanical means, leaving the gear or axle unencumbered by surrounding material and thus able to spin freely.

Using a variant on the same technique, Fleming made an artificial crystal lattice. He took a silicon wafer, coated it with silicon dioxide, cut trenches into the silicon dioxide and then bathed the chip in polysilicon until it filled the trenches. Then he polished the surface until smooth and bathed the chip in another layer of silicon dioxide, into which he cut the same number of trenches as before, but so they lay across the trenches beneath them at right angles, and then filled those trenches with polysilicon. After repeating this process a number of times, Fleming removed the silicon dioxide, using hydrofluoric acid, and got 'micron layers of Lincoln Logs, orthogonal to each other, and joined where they touch.' See Figure 2.

The polysilicon 'logs' were 1.2 microns wide, 1.5 microns high, with a pitch of 4.8 microns. Proportions identical to that specified by Ames Laboratory and Iowa State researchers as those necessary to make the photonic equivalent of an electronic band gap, with certain frequencies of light forbidden from exiting the lattice. By designing the distance between the 'logs' carefully, a chosen wavelength was reflected instead of passing out of the space, as longer or shorter wavelengths could. The introduction of an impurity like air and much thicker polysilicon 'logs' provided routes for preselected wavelengths to travel along; thus following the impurity as it twisted or bent - no matter how sharp the turns. This made it well-nigh impossible for light of a frequency roughly in the middle of the band gap to escape. The lattices trapped and guided approximately 95 percent of the light sent within them. This compares with approximately 30 percent for conventional waveguides, and they took only one-tenth to one-fifth the space to bend the light (the turning radius was in the one wavelength range, rather than the traditional waveguide bend of more than ten wavelengths).

The idea of a "photonic band gap structure" was first advanced in 1987 by Eli Yablonovitch, now a professor at the University of California at Los Angeles. In 1990, he built the first photonic crystal, the size of a baseball (probably about the size of a cricket ball), to channel microwaves. In the mid 1990s, scientists at Ames Laboratory in Iowa built crystals the size of a table tennis ball, also for microwaves. The components were of a size that could be put together by hand, using straight metal pins (of the type that hold new shirts in place).

'The size reduction for current structures is a striking achievement that researchers have been attempting to achieve for a decade,' says Del Owyoung, Sandia manager for the project. 'The difference in frequency is comparable to moving from masers to lasers'.

Work on the current photonic crystal continues at Sandia.

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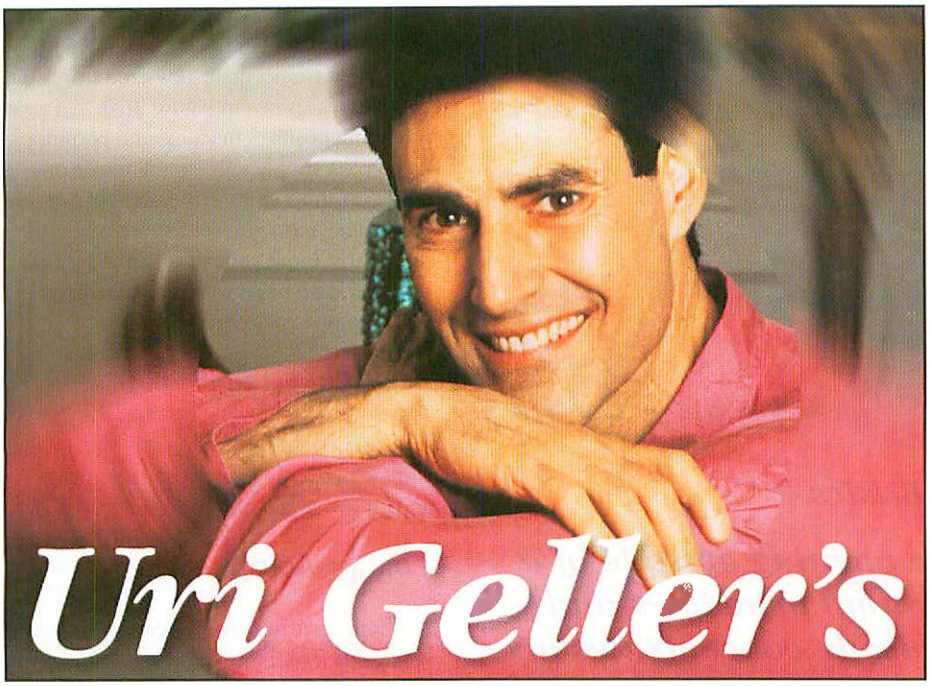


Uri Geller's EXTENDED REALITY

Manchester Meltdown

A reader asks me why I don't write more about myself in this column? Well, I write about what interests me, and there are a lot of things I find interesting enough to write about. However, as it happens I was involved in a very unusual incident recently, so here is my version of what happened.

The scene was the banquet held in Manchester last December to celebrate the 50th anniversary of the Jewish Telegraph, for which I write a regular column. Before we sat down, I was introduced to the lord Mayor of Liverpool, who was wearing his ceremonial gold chain and a very handsome diamond-encrusted gold and enamel medallion. On the back of this, a gold disc with an inscription had been fastened by six rivets.

I admired the piece as we shook hands, but joked that maybe I shouldn't get too near it just in case... Then we sat down at separate tables at least 20 feet apart, my neighbour being the Chief Constable of Greater Manchester for whom I bent a spoon. We had just begun our meal when there was a great commotion at the Mayor's table - at first I was afraid somebody had dropped dead.

However, all was well except with the Mayor's medallion. Here is what he told one of the reporters who were present: " I was just leaning forward to reach for the pepper when I heard and felt a rattle around my neck, and found the back piece of the jewel hanging outward and bending." All six of the rivets had somehow worked loose or melted, bending to the extent where the gold disc came loose in the Mayor's hands. It was also slightly bent.

The jeweller to whom it was taken for repair said "You might expect the odd rivet to come loose but for all of them to drop out and bend at once is bizarre... In my entire professional life as a jeweller I have never seen anything like this".

Nor have I. I have never bent a piece of gold before, the nearest I came being when I broke a silver spoon and bent the sword on a statue at Longleat, with the Marquess of Bath's permission. (The objects are now on display there). And I don't think I have ever bent even a teaspoon in front of so many reporters and distinguished witnesses.

The Mayor took it very well. He told reporters " I know some people say Geller is a magician but I don't. I accept that he has psychic powers. He had not touched the jewel at any time." True, but I don't think my psychic powers were responsible on this occasion - I suspect what happened was that when we met, I seeded his mind with the thought that something could happen and his psychic powers, not mine, did the rest. It was an example of what hypnotists call indirect suggestion, when you suggest something without actually saying it, and I've heard it said that this is far more effective than direct suggestion, because there is less resistance to it.

I would love to know exactly how incidents like this one can happen. There's certainly no explanation in terms of science as we know it. Maybe there will never be one, scientists finding it less trouble to write me off as a magician (like the Mayor, I suppose). However I reckon the Manchester meltdown was an example of just what the mind can do, even accidentally, and gave an idea of what it could do without destroying anything. I reckon scientists, especially psychologists, still have a lot to learn.

While I am blowing my own trumpet, I'd just like to mention an item that appeared in the November 16th issue of Autosport. Its columnist 'Pit Bull' had come across the account of how I bent a chrome vanadium spanner in the pits at Silverstone in 1998 in Guy Lyon Playfair's excellent book MindForce (available only from Tesco). Obviously he didn't believe it and asked readers if any of them had seen me doing it. One of them had indeed and described what he saw in the November 23rd issue: " I was about one metre away from Uri when he bent the spanner," he wrote. "It came straight from one of the mechanics' cabinets, and Uri had no way of having touched or even seen the spanner before he made it droop over to one side."

A similar spanner was bent recently on a strain gauge at Imperial College, London, and needed a force of more than 6 kilonewtons to get it to the same angle, about 30 degrees. That's the equivalent of more than half a ton, and whatever bent it was definitely not my physical powers.

Finally, a flashback to the 1987 edition of my book The Geller Effect, where I mention (page 365) meeting a group of U.S. senators including "a man who could well be a future U.S. president - Albert Gore" Well, he came close, and many believe he should be the current president, he does plan to stand in 2004.

Read Uri Geller's stunning online novel, Nobody's Child, at <www.uristory.com> Visit him at <www.urigeller.com> and e-mail him at <urigeller@compuserve.com>

Op-Amp COOKBOOK

PART 1

Op-Amp Basics

Ray Marston presents the opening episode of a new 4-part survey of op-amp principles and applications. This first episode concentrates on basic principles and configurations.

A conventional op-amp (operational amplifier) can be simply described as a high-gain direct-coupled amplifier 'block' that has a single output terminal but has both inverting and non-inverting input terminals, thus enabling the device to function as either an inverting, non-inverting, or differential amplifier. Op-amps are very versatile devices. When coupled to suitable feedback networks they can be used to make precision ac and dc amplifiers and filters, oscillators, level switches and comparators, etc.

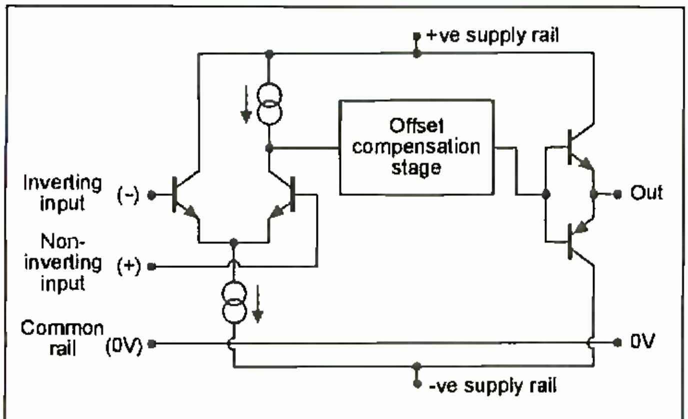


Figure 1. Simplified op-amp equivalent circuit.

Three basic types of operational amplifier are readily available. The most important of these is the conventional 'voltage-in, voltage-out' op-amp (typified by the popular 741 and CA3140 ICs), and this 4-part mini-series takes an in-depth look at the operating principles and practical applications of this type of device. The other two basic types of op-amp are the current-differencing or Norton op-amp (typified by the LM3900), and the operational transconductance amplifier or OTA (typified by the CA3080 and LM13700). These two devices will be described in depth in a couple of individual multi-part articles in some future editions of this magazine.

Op-Amp Basics

In its simplest form, a conventional op-amp consists of a differential amplifier (bipolar or FET) followed by offset compensation and output stages, as shown in Figure 1; all of these elements are integrated on a single chip and housed in an IC package. The differential amplifier has inverting and non-inverting input terminals and has a high-impedance (constant-current) tail to give a high input impedance and good common-mode signal rejection. It also has a high-impedance collector (or drain) load, to give a large amount of signal-voltage gain (typically about 100dB).

The output of the differential amplifier is fed to the circuit's output stage via an offset compensation network which, when the op-amp is suitably powered, causes the op-amp output to centre on zero volts when both input terminals are tied to zero volts. The output stage takes the form of a complementary emitter follower, and gives a low-impedance output.

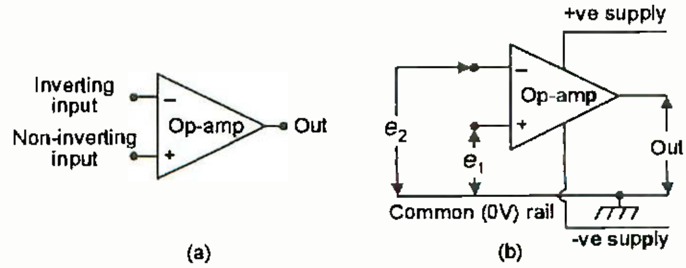


Figure 2. Basic symbol (a) and supply connections (b) of an op-amp.

Conventional op-amps are represented by the standard symbol shown in Figure 2(a). They are normally powered from split supplies, as shown in Figure 2(b), providing positive, negative and common (zero volt) supply rails, enabling the op-amp output to swing either side of the zero volts value and to be set to zero when the differential input voltage is zero. They can, however, also be powered from single-ended supplies if required.

Basic Configurations

The output signal of an op-amp is proportional to the differential signal voltage between its two input terminals and, at low audio frequencies, is given by:

$$e_{out} = Ao(e_1 - e_2)$$

where Ao is the low frequency open-loop voltage gain of the op-amp (typically 100dB, or x100,000, e_1 is the signal voltage at the non-inverting input terminal, and e_2 is the signal voltage at the inverting input terminal.

Thus, an op-amp can be used as a high-gain inverting dc amplifier by grounding its non-inverting terminal and feeding the input signal to the inverting terminal, as shown in Figure 3(a). Alternatively, it can be used as a non-inverting dc amplifier by reversing the two input connections, as shown in Figure 3(b), or as a differential dc amplifier by feeding the two input signals to the op-amp as shown in Figure 3(c). Note in the latter case that if identical signals are fed to both input terminals the op-amp should, ideally give zero signal output.

The voltage gains of the Figure 3 circuits depend on the individual op-amp open-loop voltage gains, and these are subject to wide variations between individual devices. One special application of the 'open-loop' op-amp is as a differential voltage comparator, one version of which is shown in Figure 4(a). Here, a fixed reference voltage is applied to the inverting terminal and a variable test or sample voltage is fed to the non-inverting terminal. Because of the very high open-loop voltage gain of the op-amp, the output is driven to positive saturation (close to the positive rail value) when the sample voltage is more than a few hundred microvolts above the reference voltage, and to negative saturation (close to the negative supply rail value) when the sample is more than a few hundred microvolts below the reference value.

Figure 4(b) shows the voltage transfer characteristics of the above circuit. Note that it is the magnitude of the input differential voltage that determines the magnitude of the output voltage, and that the absolute values of input voltage are of little importance. Thus, if a 2V0 reference is used and a differential voltage of only 200mV is needed to swing the output from a negative to a positive saturation level, this change can be caused by a shift of only 0.01% on a 2V0 signal applied to the sample input. The circuit thus functions as a precision voltage comparator or balance detector.

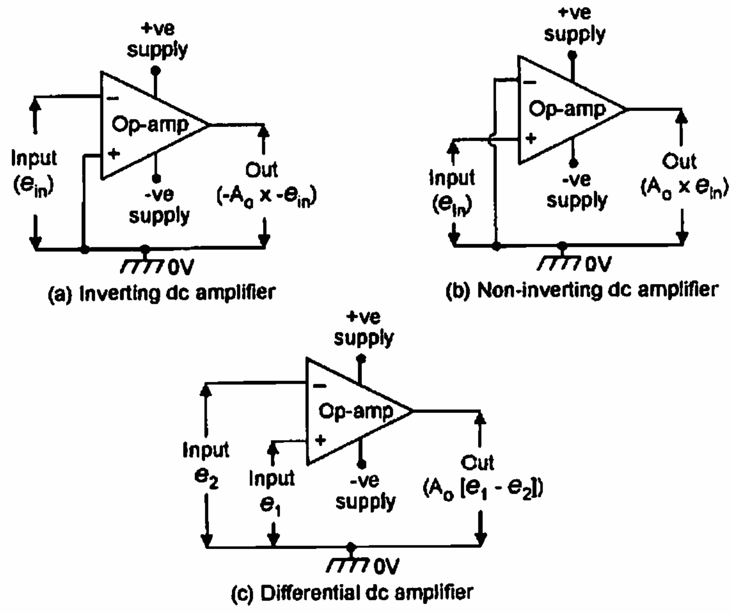


Figure 3. Methods of using the op-amp as a high gain, open loop, linear dc amplifier.

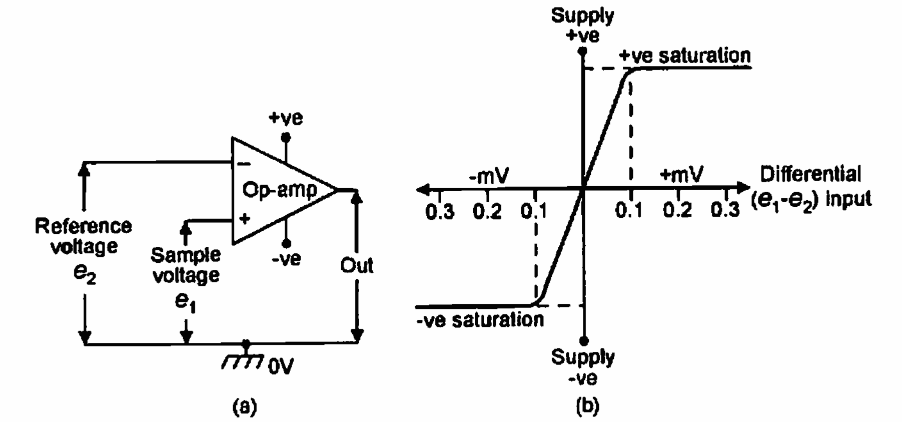


Figure 4. Circuit (a) and transfer characteristics (b) of a simple differential voltage comparator.

Closed-Loop Amplifiers.

The most useful way of using an op-amp as a linear amplifier is to connect it in the closed-loop mode, with negative feedback applied from the output to the input, as shown in the basic dc-coupled circuits of Figure 5. This technique enables the overall gain of each circuit to be precisely controlled by the values of the external feedback components, almost irrespective of the op-amp characteristics (provided that the open-loop gain, A_O, is large relative to the closed-loop gain, A).

Figure 5(a) shows how to wire the op-amp as a fixed-gain inverting dc amplifier. Here, the gain (A) of the circuit is dictated by the ratios of R1 and R2 and equals R2/R1, and the input impedance of the circuit equals the R1 value; the circuit can thus easily be designed to give any desired values of gain and input impedance.

Note in Figure 5(a) that although R1 and R2 control the gain of the complete circuit, they have no effect on the parameters of the actual op-amp. Thus, the inverting terminal still has a very high input impedance, and negligible signal current flows into the terminal. Consequently, virtually all of the R1 signal current also flows in R2, and signal currents i_1 and i_2 can (for most practical purposes) be regarded as being equal, as shown in the diagram. Also note that R2 has an apparent value of R2/A when looked at from the inverting terminal, and the R1-R2 junction thus appears as a low-impedance 'virtual ground' point.

Figure 5(b) shows how to connect the op-amp as a fixed-gain non-inverting amplifier. In this case the voltage gain equals (R1+R2)/R2, and the input impedance approximates (A_O/A)Zin, where Zin is the open-loop input impedance of the op-amp. The above circuit can be made to function as a precision voltage follower by connecting it as a unity-gain non-inverting amplifier, as shown in Figure 5(c), where the op-amp operates with 100% negative feedback. In this case the input and output signal voltages are identical, but the input impedance of the circuit is very high, approximating A_O x Zin.

The basic op-amp circuits of Figures 5(a) to 5(c) are shown as dc amplifiers, but can readily be adapted for ac use by ac-coupling their inputs. Op-amps also have many applications other than as simple linear amplifiers. They can be made to function is precision phase splitters, as adders or subtractors, as active filters or selective amplifiers, and as oscillators or multivibrators, etc. Some of these

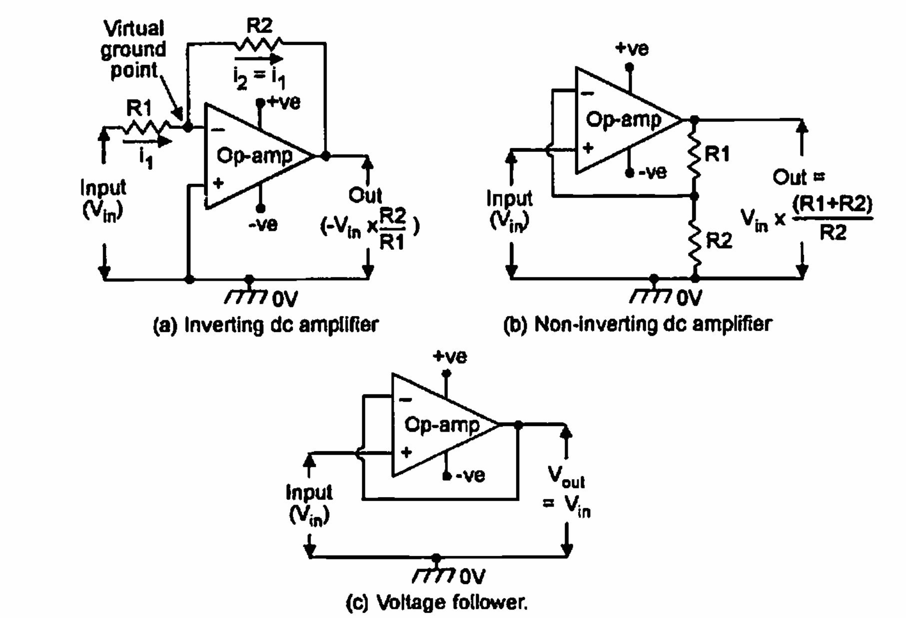


Figure 5. Closed-loop linear amplifier circuits.

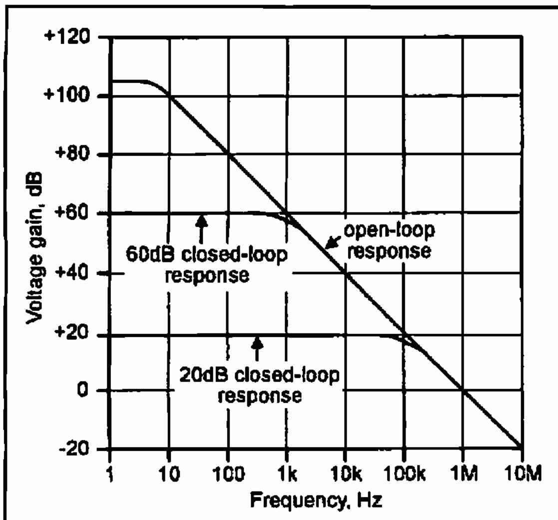


Figure 6. Typical frequency response curve of the 741 op-amp.

applications are shown later in this article; in the meantime, let's look at some important op-amp parameters.

Op-Amp Parameters.

An ideal op-amp would have infinite values of input impedance, gain, and bandwidth, and have zero output impedance and give perfect tracking between input and output. Practical op-amps fall short of all of these ideals. Consequently, various performance parameters are detailed in op-amp data sheets, and indicate the measure of 'goodness' of a particular device. The most important of these parameters are detailed below.

1. A_O (open-loop voltage gain). This is the low-frequency voltage gain occurring between the input and output terminals of the op-amp, and may be expressed in direct terms or in terms of dB. Typical figures are x100,000, or 100dB.

2. Z_{IN} (input impedance). This is the resistive impedance looking directly into the input terminals of the op-amp when used open-loop. Typical values are 1M0 for op-amps with bipolar input stages, and a million Megohms for FET-input op-amps.

3. Z_O (output impedance). This is the resistive output impedance of the basic op-amp when used open-loop. Values of a few hundred ohms are typical of most op-amps.

4. I_b (input bias current). The input terminals of all op-amps sink or source finite currents when biased for linear operation. The magnitude of this current is denoted by Ib, and is typically a fraction of a microamp in bipolar op-amps, and a few picoamps in FET types.

5. V_S (supply voltage range). Op-amps are usually operated from split (+ve and -ve) supply rails, which must be within maximum and minimum limits. If voltages are too high the op-amp may be damaged, and if too low the op-amp will not function correctly. Typical limits are ±3V to ±15V.

6. V_i(max) (input voltage range). Most op-amps will only operate correctly if their input terminal voltages are below the supply line values. Typically, Vi(max) is one or two volts less than VS.

7. V_{io} (differential input offset voltage). Ideally, an op-amp's output should be zero when both inputs are grounded, but in practice slight imbalances within the op-amp cause it to act as though a small offset or bias voltage exists on its inputs under this condition. Typically, this V_{io} has a value of only a few mV, but when this voltage is amplified by the gain of the circuit in which the op-amp is used it may be sufficient to drive the op-amp output well away from the 'zero' value. Because of this, most op-amps have some facility for externally nulling out the effects of this offset voltage.

8. CMMR (common mode rejection ratio). An op-amp produces an output proportional to the difference between the signals on its two input terminals. Ideally, it should give zero output if identical signals are applied to both inputs simultaneously, i.e.,

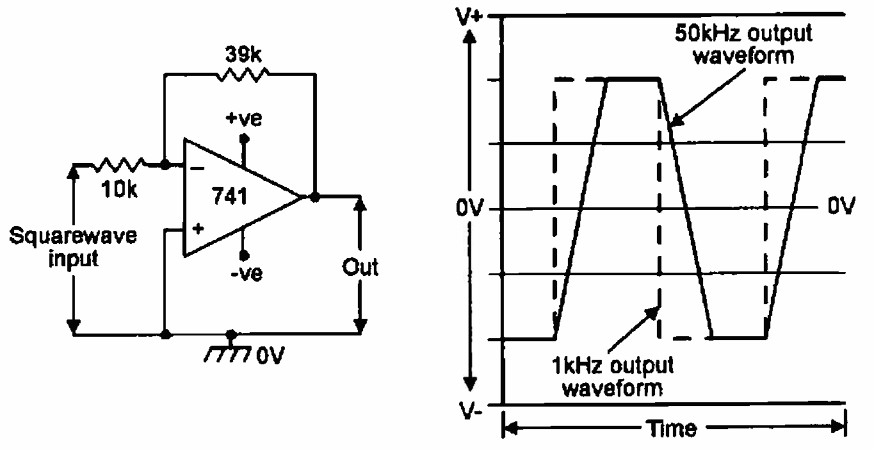


Figure 7. Effect of slew-rate limiting on the output of an op-amp fed with a squarewave input.

PARAMETER	Bipolar op-amps		MOSFET op-amps		JFET op-amps			
	741	NE531	CA3130E	CA3140E	LF351	LF441	TL081	TL061
Supply voltage	±3V to ±18V	±5V to ±22V	±2V5 to ±8V (5 to 16V	±2V to ±18V (4 to 36V	±5V to ±18V	±5V to ±18V	±5V to ±15V	±2V to ±15V
Supply current	1.7mA	5.5mA	1.8mA	3.6mA	0.8mA	1.8mA	1.8mA	0.2mA
Input offset volts	1mV	2mV	8mV	5mV	5mV	0.8mV	5mV	3mV
Input bias current	200nA	400nA	5pA	10pA	50pA	50pA	50pA	5pA
Input resistance, Ω	1M0	20M	1.5T	1.5T	1.0T	1.0T	1.0T	1.0T
Voltage gain, A_o	106dB	96dB	110dB	100dB	88dB	106dB	106dB	76dB
CMMR	90dB	100dB	90dB	90dB	100dB	100dB	100dB	86dB
f_T	1MHz	1MHz	15MHz	4.5MHz	4MHz	4MHz	3MHz	1MHz
Slew rate (V/µS)	0.5	35	10	9	13	15	13	3.5
IC outline	b	a	c	c	b	b	b	b

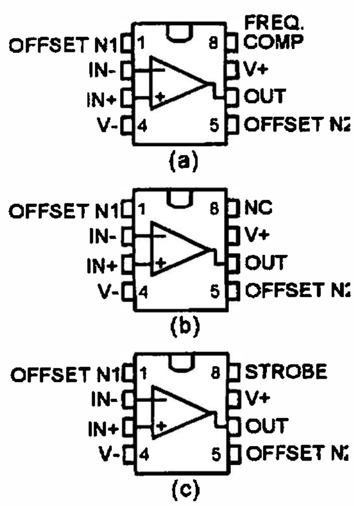


Figure 8. Parameter and outline details of eight popular 'single' op-amp types.

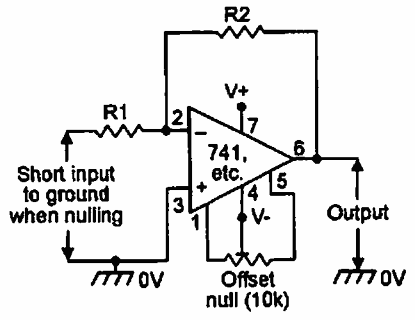


Figure 9. Typical offset nulling system.

in common mode. In practice, such signals do not entirely cancel out within the op-amp, and produce a small output signal. The ability of an op-amp to reject common mode signals is usually expressed in terms of CMMR, i.e., the ratio of the op-amp's

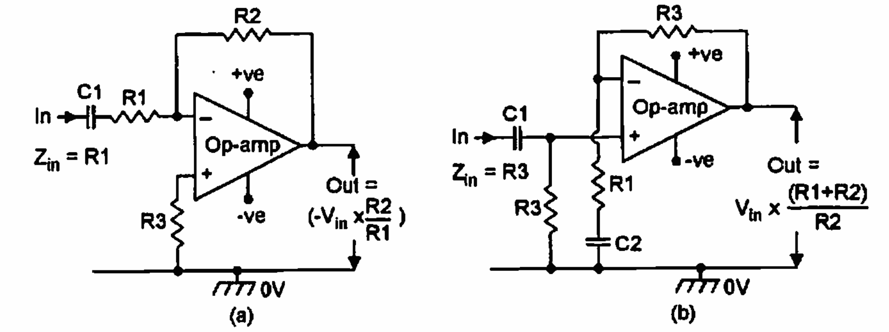


Figure 10. Basic inverting (a) and non-inverting (b) ac amplifier circuits.

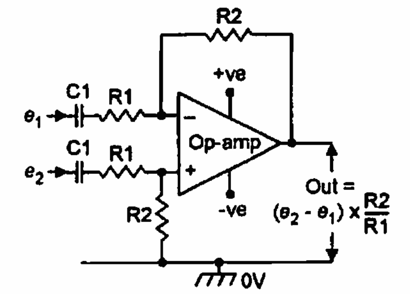


Figure 11. Differential amplifier or analogue subtractor.

gain with differential signals versus the gain with common mode signals. CMMR values of 90dB are typical of most op-amps.

9. f_T (transition frequency). An op-amp typically gives a low-frequency voltage gain of about 100dB, and in the interest of stability its open-loop frequency response is internally tailored so that the gain falls off at a rate of 6dB/octave (= 20dB/decade), eventually falling to unity (0dB) at a transition frequency denoted f_T. Figure 6 shows the typical response curve of the type 741 op-amp, which has an f_T value of 1MHz and a low frequency gain of 106dB. Note that, when the op-amp is used in a closed loop amplifier circuit, the circuit's bandwidth depends on the closed-loop gain. Thus, in Figure 6, the circuit has a bandwidth of only 1kHz at a gain of 60dB, or 100kHz at a gain of 20dB. The f_T figure can thus be used to represent a gain-bandwidth product.

10. Slew rate. As well as being subject to normal bandwidth limitations, op-amps are also subject to a phenomenon known as slew rate limiting, which has the effect of limiting the maximum rate of change of voltage at the op-amp's output. Figure 7 shows the effect that slew-rate limiting can have on the output of an op-amp that is fed with a squarewave input. Slew rate is normally specified in terms of volts per microsecond, and values in the range 1V/m$_S$ to 10V/m$_S$ are usual with most popular types of op-amp. One effect of slew rate limiting is to make a greater bandwidth available to small-amplitude output signals than to large-amplitude output signals.

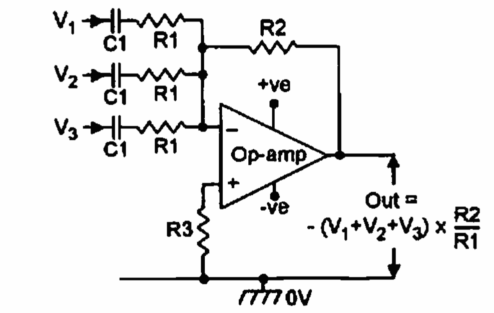


Figure 12. Inverting analogue adder or audio mixer.

Practical Op-Amps.

Practical op-amps are available in a variety of types of IC construction (bipolar, MOSFET, JFET, etc.), and in a variety of types of packaging (plastic DIL, metal-can TO5, etc.). Some of these packages house two or four op-amps, all sharing common supply line connections. Figure 8 gives parameter and outline details of eight popular 'single' op-amp types, all of which use 8-pin DIL (DIP) packaging.

The 741 and NE531 are bipolar types. The 741 is a popular general-purpose op-amp featuring internal frequency compensation and full overload protection on inputs and output. The NE531 is a high-performance type with very high slew rate capability; an external compensation capacitor (100pF), wired between pins 6 and 8, is needed for stability, but can be reduced to a very low value (1.8pF) to give a very wide bandwidth at high gain.

The CA3130 and CA3140 are MOSFET-input type op-amps that can operate from single or dual power supplies, can sense inputs down to the negative supply rail value, have ultra-high input impedances, and have outputs that can be strobed. The CA3130 has a CMOS output stage, and an external compensation capacitor (typically 47pF) between pins 1 and 8 permits adjustment of bandwidth characteristics; the CA3140 has a bipolar output stage and is internally compensated.

The LF351, LF411, TL081 and TL061 JFET types can be used as direct replacements for the 741 in most applications; the TL061 is a low-power version of the TL081.

Offset Nulling.

All of the above op-amps are provided with an offset nulling facility, to enable the output to be set to precisely zero with zero input. This is usually achieved by wiring a 10k pot between pins 1 and 5 and connecting the pot slider (either directly or via a 4k7 range-limiting resistor) to the negative supply rail (pin 4), as shown in Figure 9. In the case of the CA3130, a 100k offset nulling pot must be used.

Applications Roundup.

Operational amplifiers are very versatile devices, and can be used in an almost infinite variety of linear and switching applications. Figures 10 to 22 show a small

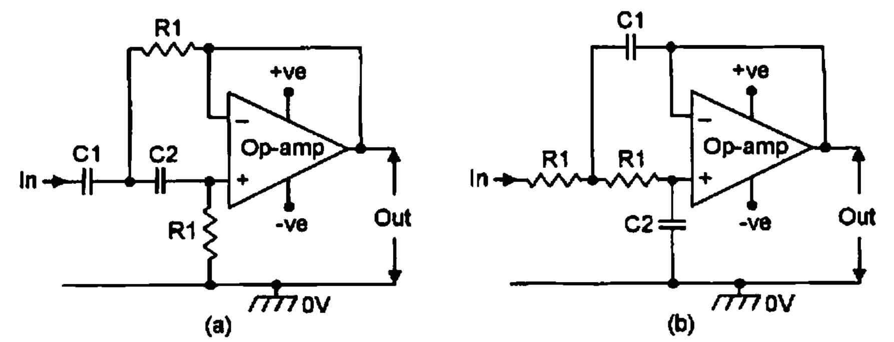


Figure 13. High-pass (a) and low-pass (b) 2nd-order active filters.

selection of basic 'applications' circuits that can be used, and which will be looked at in greater detail in the remaining three episodes of this 'Op-Amp' mini-series. In most of these diagrams, the supply line connections have been omitted for clarity.

Figure 10 shows basic ways of using op-amps to make fixed-gain inverting or non-inverting ac amplifiers. In both cases, the gain and the input impedance of the circuit can be precisely controlled by suitable component value selection.

Figure 11 shows how to make a differential or difference amplifier with a gain equal to R2/R1; if R1 and R2 have equal values, the circuit acts as an analogue subtractor.

Figure 12 shows the circuit of an inverting 'adder' or audio mixer; if R1 and R2 have equal values, the inverting output is equal to the sum of the input voltages.

Op-amps can be made to act as precision active filters by wiring suitable filters into their feedback networks. Figure 13 shows

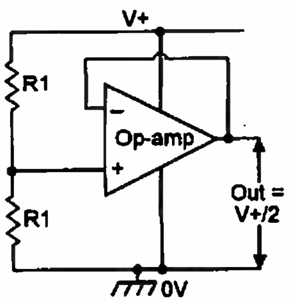


Figure 14. Supply-line splitter.

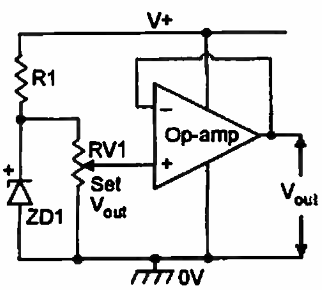


Figure 15. Adjustable voltage reference.

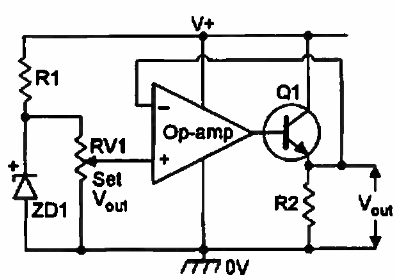


Figure 16. Adjustable-voltage DC power supply.

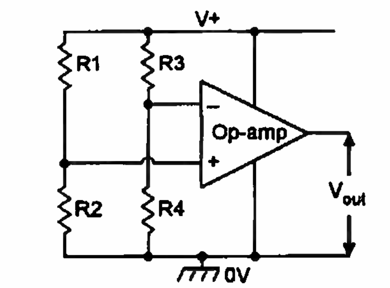


Figure 17. Bridge-balancing detector/switch.

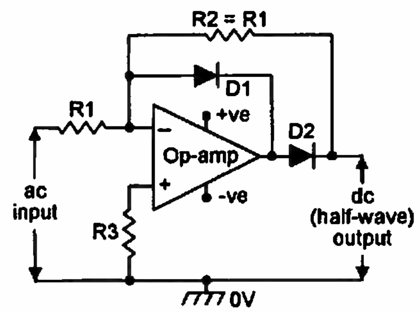


Figure 18. Precision half-wave rectifier.

the basic connections for making 2nd-order high-pass and low-pass filters; these circuits give roll-offs of 12dB/octave. Next month's episode of this mini-series will show more sophisticated versions of these basic circuits.

Figures 14 to 16 show some useful applications of the basic voltage follower or unity-gain non-inverting dc amplifier. The Figure 14 circuit acts as a supply line splitter, and is useful for generating split DC supplies from single-ended ones. Figure 15 acts as a semi-precision variable voltage reference, and Figure 16 shows how the output current drive can be boosted so that the circuit acts as a variable voltage supply.

Figure 17 shows the basic circuit of a dc bridge-balancing detector, in which the output swings high when the inverting pin voltage is above that of the non-inverting pin, and vice versa. This circuit can be made to function as a precision opto- or thermo-switch by replacing one of the bridge resistors with an LDR or thermistor.

Figures 18 and 19 show how to make precision half-wave rectifiers and ac/dc converters. These are very useful instrumentation circuits.

Finally, to complete this opening episode of this mini-series, Figures 20 to 22 show some useful waveform generator circuits. The Figure 20 design uses a Wien bridge network to generate a good sinewave; amplitude stabilisation is obtained via a low-current lamp (or thermistor). Figure 21 is a very useful squarewave generator circuit, in which the frequency can be controlled via any one of the passive component values. The frequency of the Figure 22 function generator circuit can also be controlled via any one of its passive component values, but this particular design generates both square and triangle output waveforms.

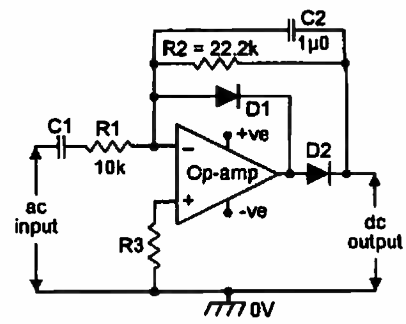


Figure 19. Precision half-wave ac/dc converter.

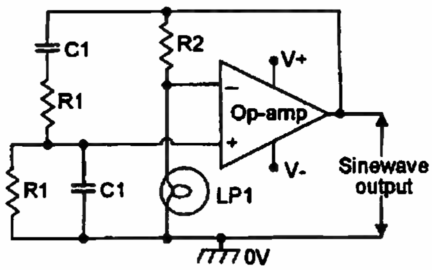


Figure 20. Wien-bridge sinewave generator.

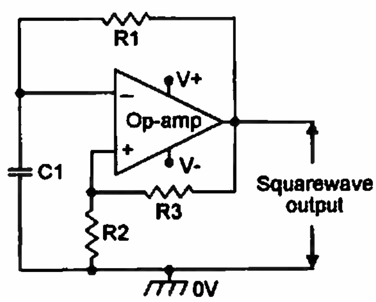


Figure 21. Free-running multivibrator.

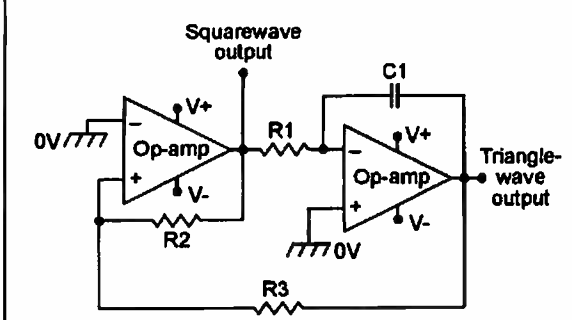
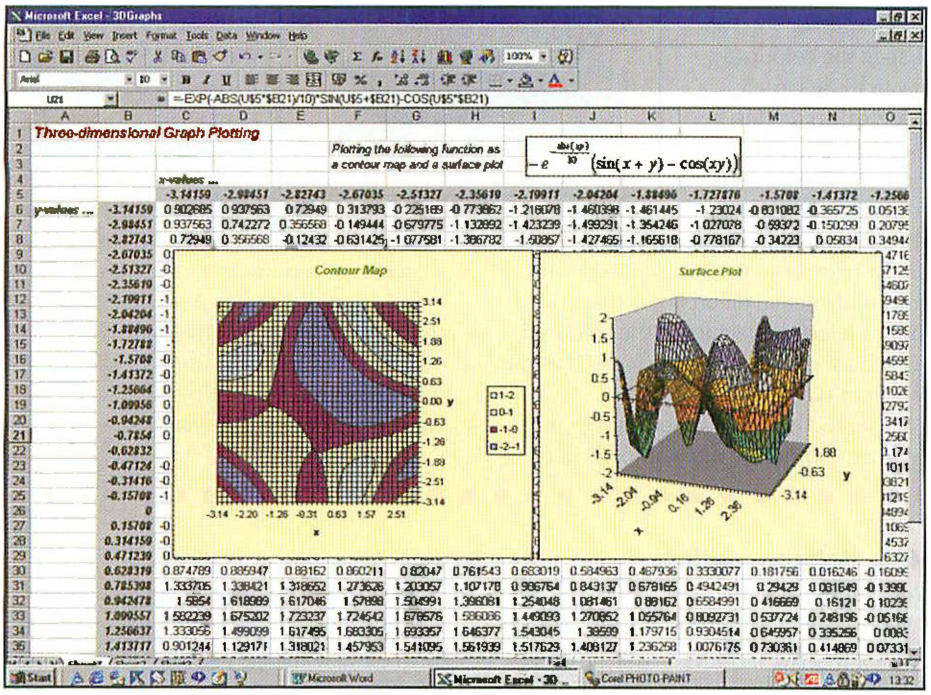


Figure 22. Sine/square function generator.

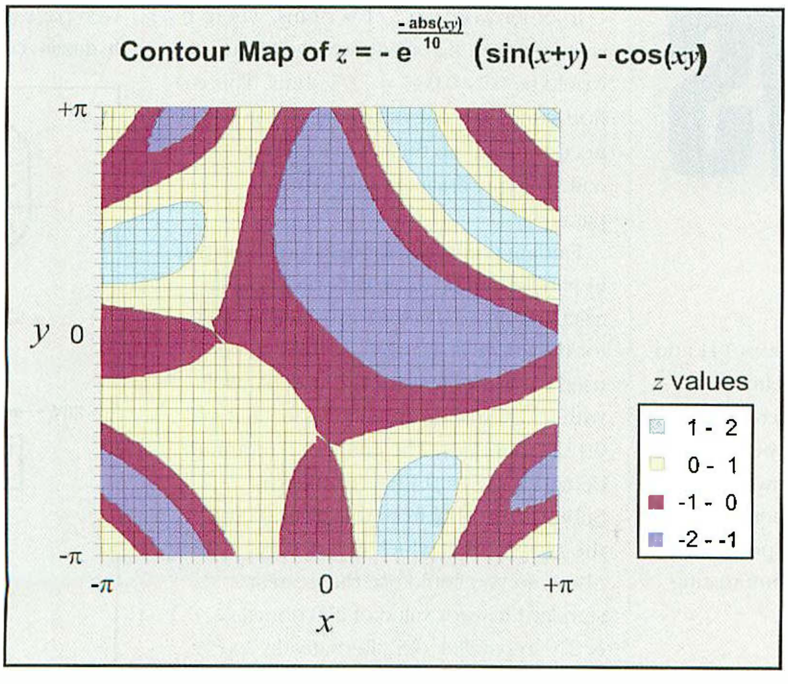
Excursions INTO EXCEL

PART 5

by Mike Bedford



In its usual guise as a package for business-oriented tasks, comparatively little use is made of Excel's graph plotting capabilities. And when graphs are plotted they tend to be just the bar charts and pie charts which are so common in business for displaying sales trends, market share and the like. All our examples so far have involved graph plotting but in three out of four cases, these were simple line graphs – the mainstay of technical data visualisation – and in the one remaining case it was an XY plot. But although a plot of one or more dependent variables against an independent variable on linear axes is common, technical applications sometimes need more sophisticated graphs. In this month's column, we'll take a look at some of Excel's facilities for plotting functions of two variables – specifically contour mapping and 3D surface plotting.



Generating Some Figures

Before we can investigate methods of creating these types of graph, though, we need some suitable figures to plot. Clearly the figures could relate to experimental data but for this month's example I chose a mathematical function. Specifically, I generated figures for the following mathematical function and then plotted the data in various ways:

$$z = -e^{-\frac{abs(xy)}{10}}\left(\sin(x+y) - \cos(xy)\right)$$

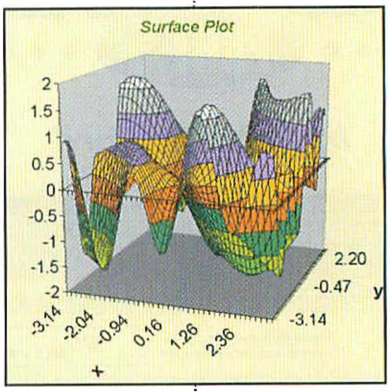
In this formula z, the dependant variable, is a function of the two independent variables x and y. So, the method of generating the figures is to create an array in which each cell represents one combination of x and y and then, in each cell of that array, we calculate z. We're going to plot the function from -p to +p in steps of p/20 for both x and y so the array will have 41 x 41 elements. The top-left hand corner of the array is at C6 but we also need row and column headings to the left of the 41 x 41 elements of the array itself (for y values) and above the array (for x values). These are easily generated. For the x values, for example, "=-PI()" goes into C5, "=C5 + PI()/20" goes into D6, and this formula is copied right into all rows up to and including AQ5.

Having got the labels for x and y it only remains to enter the formula for z into each of the 41 x 41 cells of the array. And each of these formulae must refer to the column and row headings that contain the appropriate values of x and y respectively. However, a bit of caution is required here or things will go badly wrong. Naively, you might assume that we can put the formula "=-EXP(-ABS(C5*B6)/10)*SIN(C5+B6)-COS(C5*B6)" into the first cell (C6) and then copy it right and down to populate all the other cells. This will give the correct result in C6, since the x value for this cell is, indeed, contained in the cell C5 and the y value is contained in B6. However, having copied the formula to the rest of the array, virtually every other cell will contain an invalid formula and it will become obvious why if you try it out. As you copy a formula right, Excel increments the column value of any cell references it contains and, as you copy it down, it increments the row value of any cell references. Normally this is what we want, but not in this case. Specifically, we want the x value always to refer to a cell in row 5 and we want the y value always to refer to a cell in column B. To do this, we have to employ cell references which have a relative column value and an absolute row value for x whereas for y we need an absolute column value and a relative row value. This means that the formula which should be entered into C6 and copied right and down to the rest of the array should actually be "=-EXP(-ABS(C$5*$B6)/10)*SIN(C$5+$B6)-COS(C$5*$B6)". Note the use of the dollar signs to turn the normally relative column or row values into absolute ones. If you've not come across the concept of absolute and relative references in Excel you can find out more about this important feature in Excel's help.

Contour and Surface Plots

Perhaps the most obvious way of plotting a function of this sort is as a contour map. In fact we can do better than this – rather than having numbered contour lines like those on an Ordnance Survey map, we can use different colours to represent different ranges of z values just as altitudes are represented on a topographic map. To do this, select the whole 41 x 41 array of cells with C6 at its top left and then click on the chart wizard. Under "Chart type:" select "Surface" and for "Chart sub-type:" pick the picture of the coloured contour map which, in Excel 97, is the bottom left of the four sub-chart types shown. I won't guide you through all the remaining options since they're much the same as with the 2D graphs we've already looked at and, after all, the best way to learn is just to try things out.

An alternative way of representing this data graphically is as a 3D surface plot. Now, rather than looking down on the terrain represented by the function, we see it in 3D with high z values appearing as hills or mountains and low z values as valleys or plains. Once again, colour coding is used but you can turn this off if you want, or you can change the colours to match more closely those which tend to be used in topographic maps. In fact, this is what I did in my workbook.



The 3D surface plot is generated in a very similar manner to the contour map – the only fundamental difference is that you should select the picture of the coloured 3D surface plot (top left in Excel 97) as the sub-chart type.

Presented here is a screen shot of the pertinent portion of the workbook, a close-up of the 3D surface plot in the workbook, and the contour map alone. You'll notice that this graph doesn't look exactly the same as in the screen shot – this is because I'd imported it to a separate drawing package for tidying up as I described in a previous article in this series. One thing I had to change was the labelling of the x-axes since Excel's automatic labelling isn't always particularly logical. It might have been possible to persuade Excel to produce something more acceptable but, in my opinion, it's far easier, and certainly more flexible, to do this sort of thing outside Excel. Note also that I've made an effort to format the workbook so that it's easy to read and have included some explanation as to what it does. This is important if you want to share it with others or even to understand it yourself at a later stage and was the topic I discussed in last month's column. Also, don't forget that you can download this, and all the other Excel workbooks used as examples in this series, from our Website at <www.electronicsandbeyond.com>

AIR your VIEWS

Sir,

In Electronics and Beyond issues 141 and 149 you had articles by Mike Holmes on valve power amplifiers, these incorporated "Current Generators". Would it be possible to obtain the information on how to calculate the values to enable them to work at different currents, I would appreciate any information you have on these interesting circuits.

Regards Peter Rush

Mike Holmes replies:

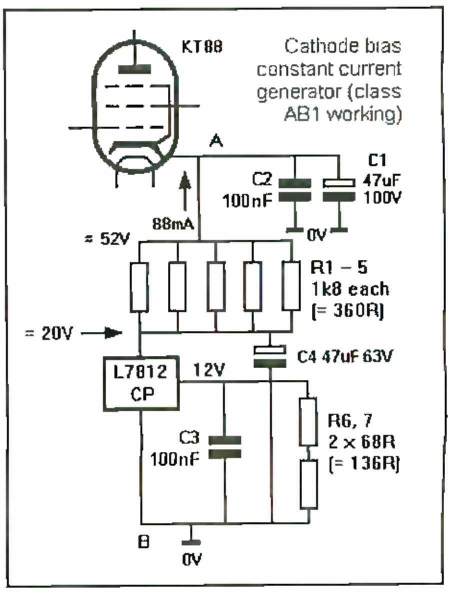
Hello Peter,

Basically this is nothing more mysterious than Ohm's law. If the Vbe (voltage drop across base-emitter junction) of the low power transistor that controls the base of the main transistor is 0.7V (approximately!), then you only divide this by the current you want.

In other words: 0.7 / I = ohms, where I is in amperes. E.g. if you wanted 88mA, it would be 0.7 / 0.088 = 7.95 ohms. This is a non-standard value of course so you will need to make up this resistance by combining resistors in series and/or parallel.

Finding the values for resistors to be put in parallel can be done with reciprocal calculations, i.e. the nearest standard value for the above is 8.2 ohm, & this can be used if another resistor is put in parallel with it. The reciprocal of 8.2 is: 1 / 8.2 = 0.122 (rounded). The final value required being 1 / 7.95 = 0.1258 (rounded), Subtracting 0.122 from this gives 0.0038; the reciprocal of which is 1 / 0.0038 = 263 ohms, so you could use the nearest standard resistor value of 270 ohms, i.e. 8.2 & 270 in parallel. (Or alternatively, 2 x 3.9 ohms in series!)

Incidentally I have since upgraded this biasing method to use instead a L7812 CP 12V constant voltage regulator chip (diagram below). The principle for determining the current flow by resistance is exactly the same, the only difference being that the constant voltage is here 12V instead of 0.7V. This drawing is from my web page **http://www.mc-h.demon.co.uk/kt88bias2.html**



TECHNOLOGY WATCH

With Martin Pipe

We got the power!

It seems incredible as we tuck into the 21st century, but the physical property we know as 'superconductivity' was discovered way back in 1911, by the Dutch physicist H. Kamerlingh Onnes. At least he won a Nobel Prize in 1913 for his efforts. To recap, superconductivity is the characteristic of certain materials to conduct electricity with no resistance and no losses, when cooled to extremely-low temperatures. Kamerlingh Onnes discovered that the electrical resistance of mercury disappeared when the metal was cooled down to 4K (-452°F/-269Celcius). Superconductivity depends on three interdependent properties. The first is the 'critical temperature', which is defined as the maximum temperature below which a superconductor shows superconductivity at zero magnetic field and current. The second is the 'critical current', or the maximum current below which a superconductor demonstrates superconductivity at a given temperature and magnetic field. The critical current is defined by means of an electric field or resistivity (i.e., 1 μV/cm). Finally, we have the 'critical magnetic field', which specifies the maximum magnetic field below which a superconductor shows superconductivity at zero current and temperature. Figure 1 shows how the three are inter-related.

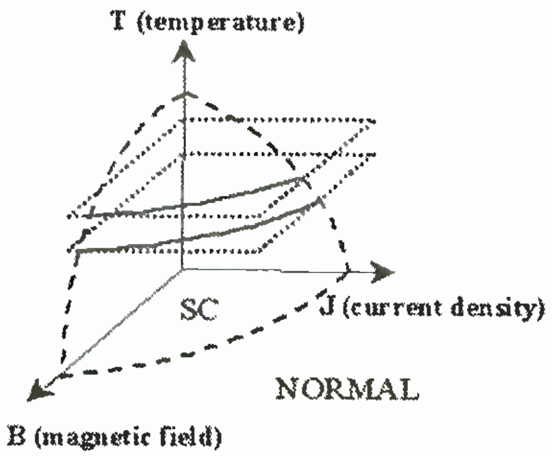


Figure 1. The interrelationship between critical current, critical temperature and critical magnetic field.

There has been significant research into superconductivity since this initial discovery, because there are obvious electrical engineering advantages. One can imagine electrically-powered public transport systems where energy wastage is reduced considerably. Another obvious contender is power distribution, which would be made vastly more efficient if superconductors were to be called into effect. Annually, megawatts of power are lost over the 13,891 km of power transmission lines operated by the National Grid company. It's much the same story elsewhere around the world. With natural energy resources dwindling, cutting down those losses makes a lot of sense. Superconductivity was only completely described in 1957, thanks to research conducted by J. Bardeen, L.N. Cooper and J.R. Schrieffer. The importance of their work was recognised in 1972, when they received a Nobel Prize Much research was subsequently devoted into investigating materials that would exhibit superconductivity at higher temperatures. The practical implication is that less expensive cooling systems are required. K.A. Muller and J.G.Bednorz won the Nobel Prize in 1987 for discoveries made the previous year. Also in 1987, P.Chu and M.Kuev Wu discovered a new ceramic compound $YBs_2Cu_3O_7$-x. This material allowed cooling temperatures to be increased from 4Kelvin to 77Kelvin. Today, high-temperature superconductors (HTSs) that exhibit superconductivity at temperatures ranging from 20K (-423°F) to 130K (-225°F) are available.

Pirelli is a company best known for its tyres. The company also happens to be a major player in the power transmission cable market, and its products are supplied

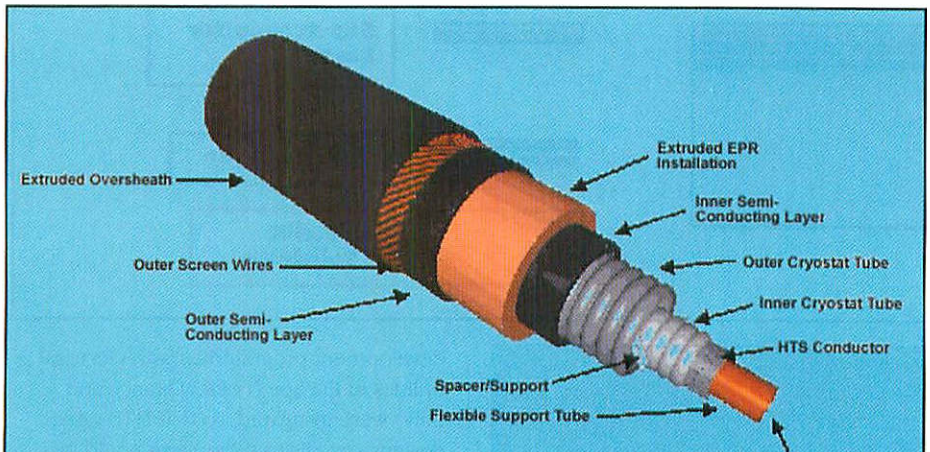


Figure 2. Component view of 'warm-dielectric' superconductor cable.

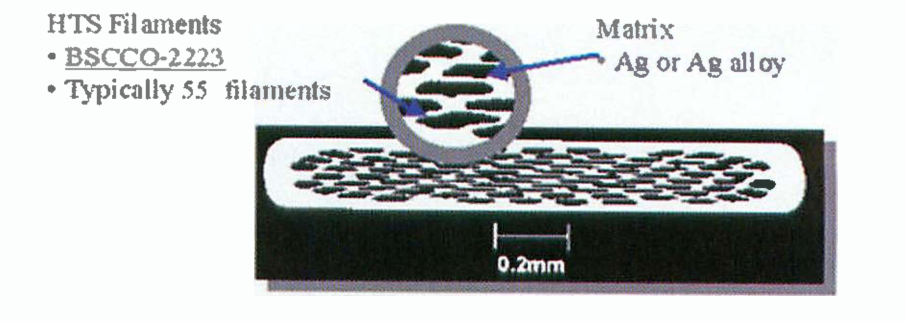


Figure 3. Construction of tape based around BSCO2223 HSC material

Figure 4. Construction of BSCO2223 HSC material.

to the National Grid amongst others. The discovery of HTSs prompted Pirelli to start its own HTS research programme with the eventual aim of commercially exploiting them as lossless power transmission lines. There were three phases, the first of which was to educate a new generation of researchers and engineers in the investigation of HTSs. They would then be encouraged to develop technologies for incorporating them into practical wires. Emphasis was given to the development and manufacturing of HTS 'tapes' that could stranded using machinery derived from that used for conventional cables. These tapes must be manufactured in long continuous lengths, and possess the mechanical and electrical characteristics to withstand cabling operations. In 1994, the second phase of the programme began. Pirelli completed the design of a 115kV, 400 MVA superconducting cable based around these tapes. The cable could be retrofitted to existing ducts with a diameter of 8 inches.

In 1995, Pirelli - together with the California-based Electric Power Research Institute and US Department of Energy - worked to develop this cable design into a working prototype. The temperatures involved are still extremely low (a few tens of K), and for this reason the ceramic superconductor is surrounded by a liquid nitrogen coolant. The cable in question was a 'warm-dielectric' type, shown in Figure 2. Here, only the HTS conductor assembly is enclosed in a cryogenic environment. An electrical insulation is applied over the flexible 'cryostat', which encloses the superconducting core and coolant. In addition to the required cryogenics, the partnership also worked on suitable joints and terminations. Similar

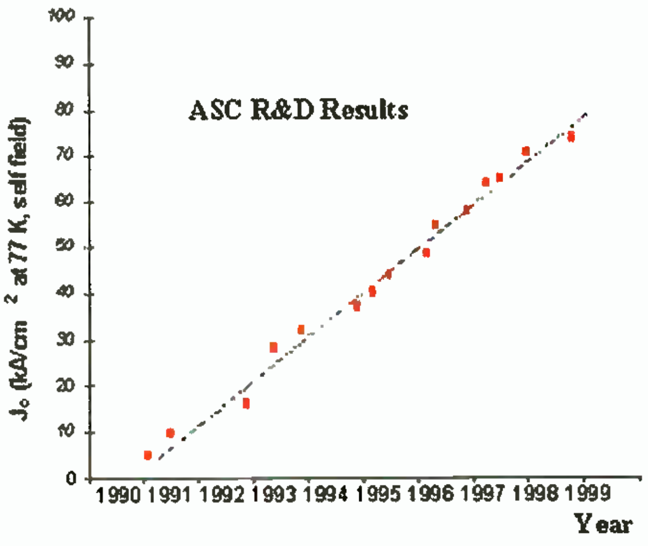


Figure 5. How American Superconductor Corporation's research has improved critical current density over time.

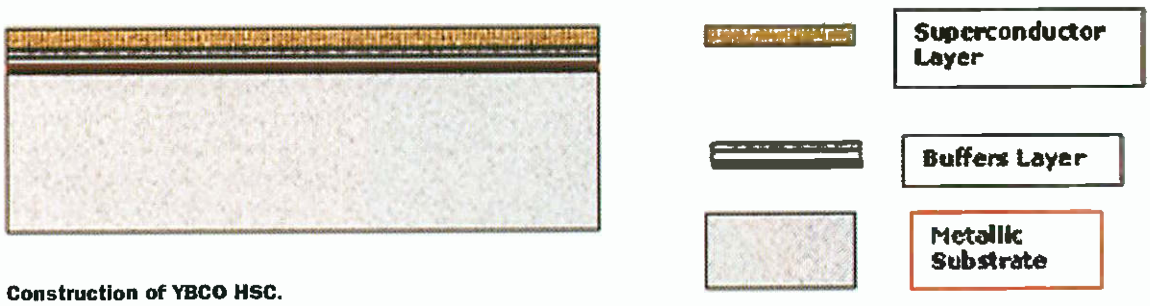


Figure 6. Construction of YBCO HSC.

development programmes with electrical utilities in Europe (notably France and Italy) were instigated, so that HTS cable designs specific to their needs could be developed. In 1998, the third phase began. This centred around setting up the first 'real world' HTS field trial in the US. A three-phase HTS system, currently being installed in Detroit Edison's electrical grid, is planned to start operation by the summer.

In this trial, a single three-phase cable circuit will replace three parallel sets of conventional three-phase cable. Superconductors can be thinner than conventional cables, on account of their lossless nature. Set against this, of course, is

Figure 7. Could conventional overhead cables be on their way out?
Photo courtesy National Grid Company

refer to Figure 5. Development of the second material, YBCO, was started in 1999 - again in conjunction with ASC. YBCO, shown in Figure 6, is a 'coated conductor' - a ribbon-shaped wire, made by depositing thin films of intermediate materials (such as cubic zirconia) on ribbons of metals, followed by deposition of a thick (> 1μm) superconducting layer.

A disadvantage of the current Pirelli HTS cables is that they're designed for laying in stable ducts or 'pipes'. It's unlikely that they'll withstand the forces that overhead cables - strung from pylon to pylon - have to sustain. The major stress points would be the pylon-mounted moorings at either end of the cable. Then there's the practical upshot of getting the coolant up there. Unless the technology is developed further, this leaves the power distribution industry in a bit of a dilemma. The obvious place to lay pipes would be underground, but digging up the landscape is an extremely expensive process. Then there are the practical upshots. It might be difficult to obtain permission to lay these cables along the most logical route - and underground cables run the risk of being accidentally severed! Here in the UK, major power distribution cables - notably the cross-country 132kV ones that link rural power stations to urban substations - are overhead, obviously for ease of maintenance and speed/relative cheapness installation. Effectively, this section of the network would have to be completely replaced. Although the switch to underground cables would undoubtedly

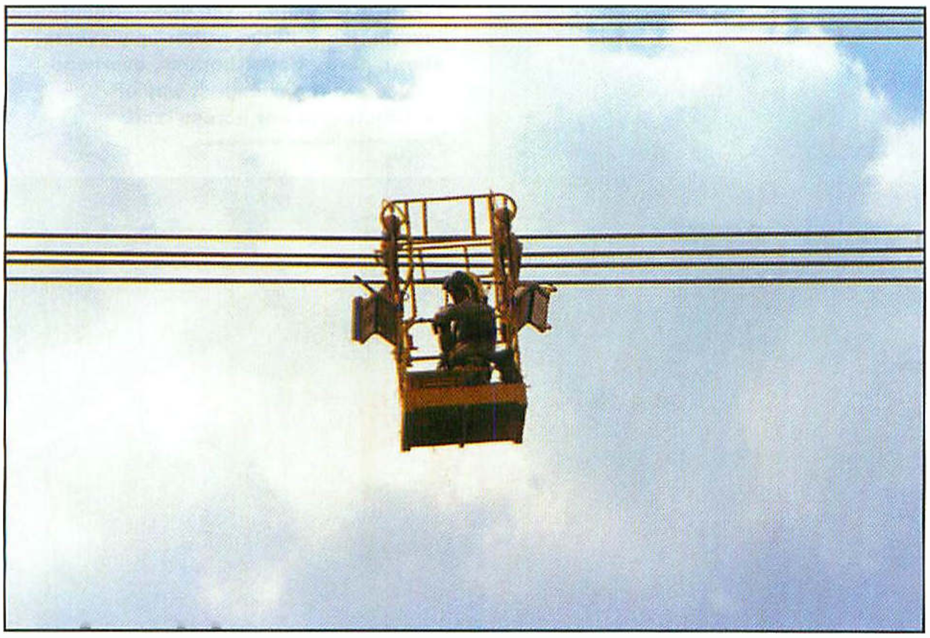


Figure 8. Checking conventional overhead cables. This job won't be as easy if they're buried underground!
Photo courtesy National Grid Company

Thickness	0.305 (+/-0.02mm)
Width	4.1 (+/-0.2mm)
Ic*	>100A
Je*	>8kA/cm2
Jc*	>37kA/cm2
Max Stress (@77K)	>300MPa
Max Stress	>265MPa
Max Strain**	>0.4%
Min. Bend Dia. **	<70mm

Ic = critical current, or the maximum current below which a superconductor exhibits superconductivity at a given temperature and magnetic field

Je = Engineering critical current density, or the ratio between critical current and tape cross-section

Jc = critical current density, or the ratio between critical current and superconductor cross-section

* at 77K ** With 95% Ic Retention

Table 1. BSCCO-2223 specifications

all that cryogenic plant! Pirelli have developed two HTS materials. The first, BSCCO-2223, was developed in conjunction with the American Superconductor Corporation (ASC). It consists of HTS elements made up from a composite structure, where the superconductor filaments are embedded in a metallic matrix - refer to Figure 3. Power distribution cables need to be mechanically robust, and so tapes produced from BSCCO-2223 are reinforced by a thin layer of stainless steel on both sides of the HTS element as shown in Figure 4. Over time, research has improved the critical current density, or the ratio between critical current and superconductor cross-sectional area -

Figure 9. One cannot deny that underground installation of power transmission plant doesn't have its advantages in areas of natural beauty.
Photo courtesy National Grid Company

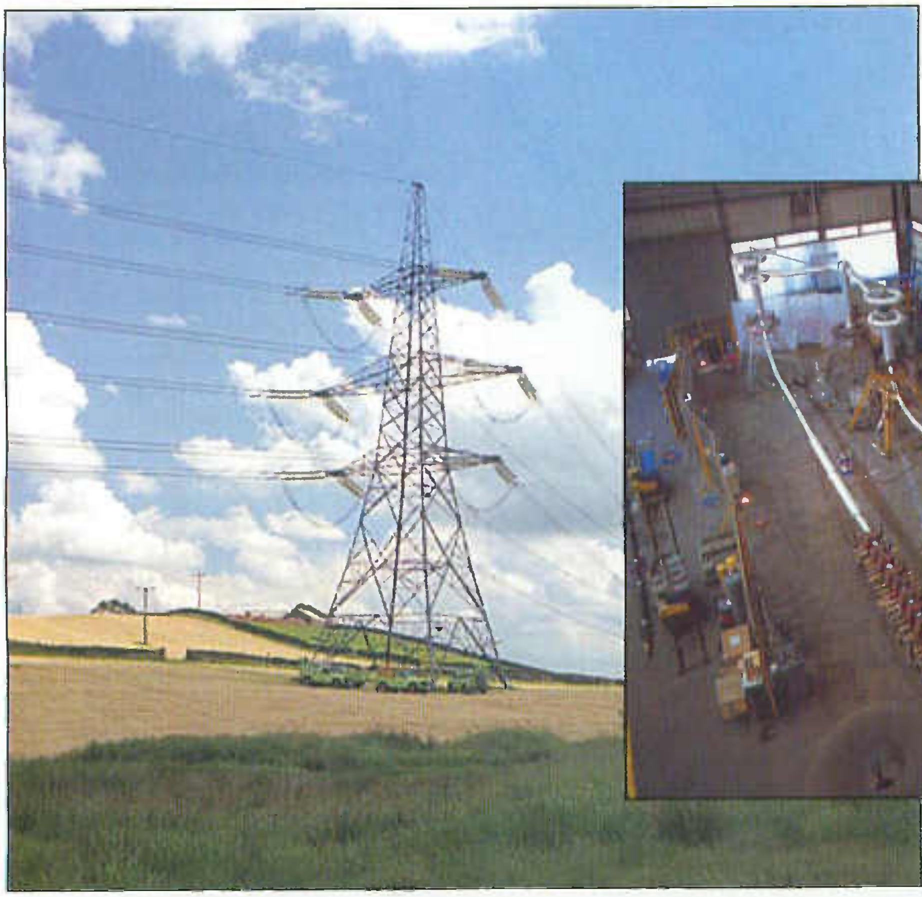
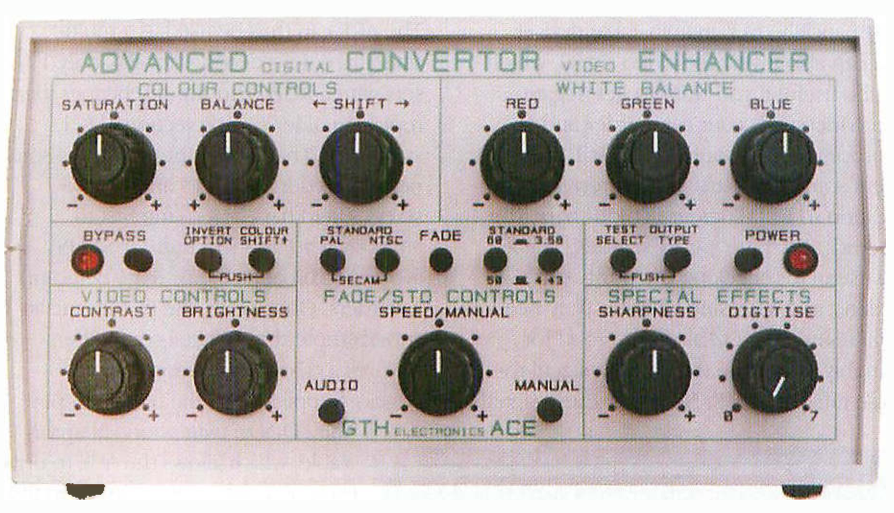


Figure 10. Compare the underground installation with the rather ugly pylons shown here. Nevertheless, overhead cables are the cheapest way of distributing power across land.
Photo courtesy National Grid Company

Figure 11. A length of finished superconductor power transmission cable, undergoing test.

make the landscape prettier, the costs would be astronomical. Would the privatised electricity industry be prepared to takes such steps? Although the increased efficiency - and elimination of some step-up/down transformers - would undoubtedly save money, the payback times would run into thousands of years! The cables alone aren't cheap. Pirelli's YBCO coated-conductor tapes have a projected cost of around $5/kA/m.

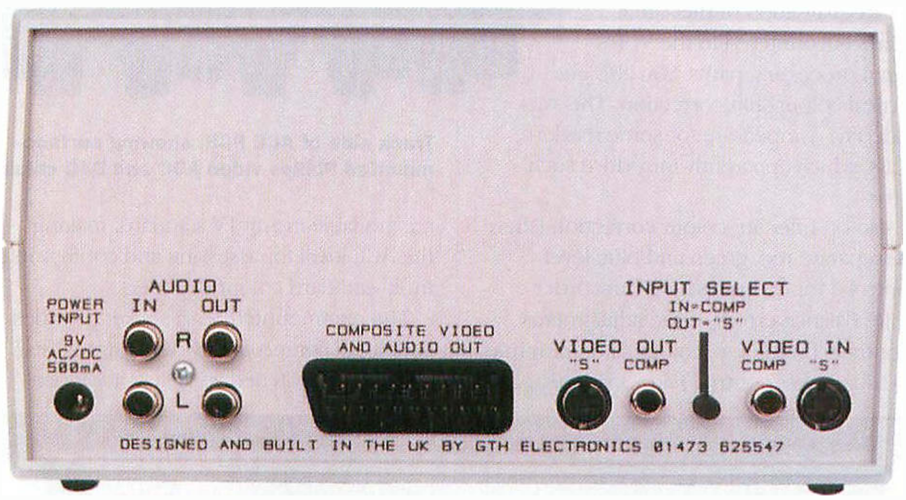
Figure 12. Applying the mylar insulation over the cryostat during cable manufacture.



ACE front panel, showing the wide variety of controls

2. Video variety

I frequently get to test various items of AV gadgetry for consumer electronics, but it's rare that I actually choose to buy any of them. The £300 ACE (Advanced Converter Enhancer) video processor from small Ipswich-based GTH Electronics proved to be an exception, however. This digital video processor is packed to the gunnels with all kinds of features that will appeal to moviemakers, home cinema enthusiasts and anybody who wants to make decent copies of tapes. It's not much to look at, having a definite home-constructor appearance with its Verobox-type enclosure and functionally-designed front panel label. It's well made, though - inside, you'll find decent-quality components and glass-fibre PCBs. Where DIL ICs are specified, GTH has mounted them in sockets. The unit is powered by a 9V 500mA AC source, courtesy of a rather hefty transformer unit built into a mains plug. Round the back is a comprehensive bank of input and output sockets, including 4-pin mini-DIN connectors for S-video, phonos for composite video and audio, and a Scart socket that can be configured to work in various ways. A rear-panel switch allows you to specify whether your video source is composite or S-video. The processed output is available in several formats (composite, S-video and/or RGB or even YUV).



The well-connected ACE rear panel.

All of the ACE's features are controlled by a sizeable quantity of knobs and push-buttons on the front panel. The most important feature is undoubtedly full standards-conversion between PAL (50Hz, or the 60Hz variety generated by some VCRs when playing NTSC tapes), SECAM, and both 3.58MHz and 4.43MHz 'flavours' of NTSC. The feature can be very useful if you want to swap tapes with overseas video enthusiasts, watch NTSC DVDs or laserdiscs on older TVs, or record foreign TV programmes from satellite TV. Combine the ACE with a multi-standard VCR (Thomson do a good £400 one with hi-fi sound and a stereo tuner) and you've got a pretty-flexible worldwide video solution. Note that the input standard is selected automatically, but I've had no problems here. Four buttons allow the output format to be selected. Two on the left select the colour standard (NTSC, PAL or SECAM), while the pair on the right selects the refresh rate (50 or 60Hz) and NTSC/PAL colour subcarrier frequency (3.58MHz or 4.43MHz). Although some other domestic-grade standards converters are available, none of the ones I know of will convert to SECAM! Although one or two have a SECAM input, they will only convert to PAL or NTSC.

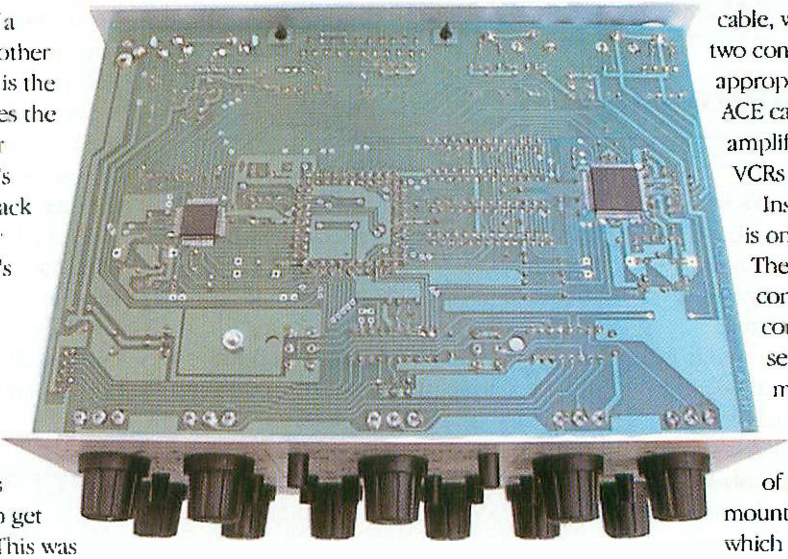
Standards conversion works by digitising the Y, U and V components of each field and storing them in a high-speed memory. It's then read out at the desired field rate, which is generally 50Hz for PAL or SECAM, and 60Hz for NTSC. At the same time, scanning lines are removed (when going from 625 to 525 lines) or added (when going from 525 lines to 625 lines). The processes involved here are rather complex, to prevent the aspect ratio from being screwed up. Adding lines in particular is rather difficult, and most converters employ an interpolation process to fill in those missing lines. The converted Y, U and V components are then recombined. Professional standards converters offer various tricks to reduce motion 'judder', which can be rather noticeable if scenes containing fast motion are converted. A common trick is predictive compensation, which borrows heavily from work carried out on MPEG video compression systems. The ACE doesn't have such tricks - after all, it costs £300 against the £10,000-plus of broadcast-standard converters. That said, results are excellent - the ACE delivers the best pictures of any consumer-level standards converter I have seen, including a Taiwanese one that sells for

Figure 13. Pirelli's first pilot line circa 1996, dedicated to HTS conductor 'stranding'

twice the price and misses out on most of the ACE's features. Pictures are crisp, and miss out on colour bleed. Note that the ACE has 8Mb of field memory, against the 2 or 4 of competing units. As a result, it will cope with a full-resolution frame without the need for compression.

Note that if the output standard is selected to match that of the input, the ACE will act as a timebase corrector. Such devices are very useful if you're trying to make stable copies from worn tapes that exhibit obvious drop-outs. As an added bonus, it will also defeat the Macrovision copy-protection, which is good news if you want to make a 'back-up' of a damaged pre-recorded tape. Another very useful feature for 'copyists' is the colour shift control. This modifies the horizontal position of the colour relative to the brightness, and it's thus possible to bring the two back into registration with each other and thus avoid colour 'bleed'. It's provided to correct multiple-generation copies, where displacement between the chroma and luminance signals isn't uncommon, owing to poor equalisation of the signal delays encountered in the VCR's signal processing paths. You also get vertical colour-shift correction. This was added to compensate for some modern VCRs, which apparently introduce such errors!

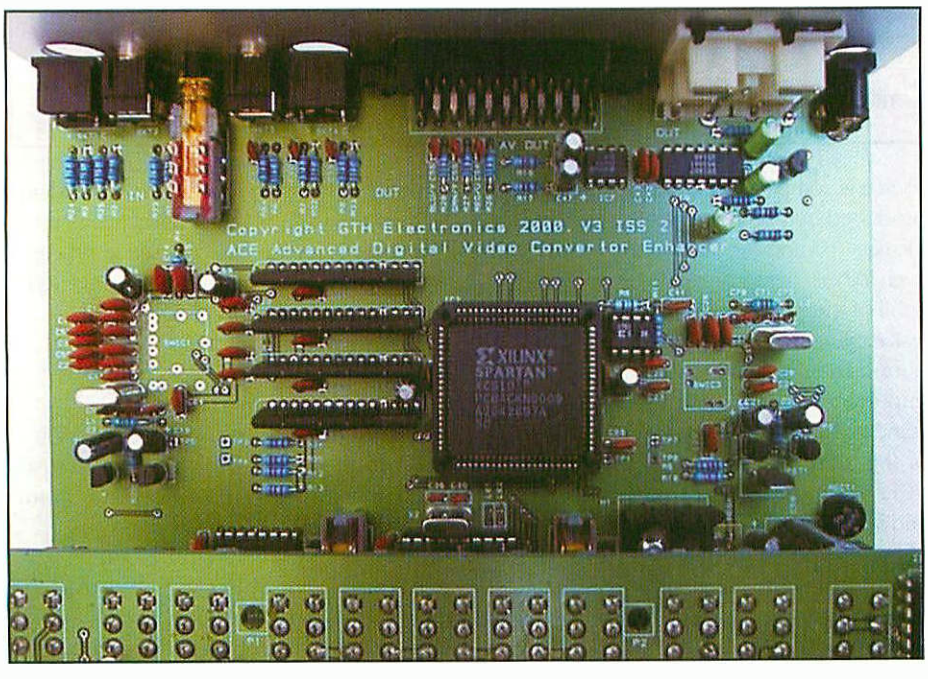
Also on offer are colour correction (there are separate red, green and blue level controls) for compensating camcorder white balance errors, video adjustments (contrast, brightness, colour saturation/hue and sharpness controls) and a video/audio fader that can be operated manually, or automatically over an adjustable period. You can also invert the video signal, which can be useful if you want to get negatives onto video with your camcorder and an appropriate light source. The ACE also offers some 'standard' test patterns. In addition to EBU-standard colour bars, you get 'red' and 'blue' purity screens. These are useful for checking the purity of TV screens, and assessing whether they need degaussing. They're also very good for (roughly) assessing the chroma signal-to-noise ratio of a VCR. Note that these signals are available in any TV standard, making the ACE ideal for assessing and configuring multi-standard colour decoders.



Track side of ACE PCB, showing surface-mounted Philips video ADC and DAC chips.

The rear-mounted Scart socket provides additional composite/S-video outputs, and can also be switched to deliver additional RGB or YUV (component) video outputs. The ACE can thus be used as a multi-standard colour decoder for PAL-only TV sets with a RGB Scart input (cheaper than replacing older rear-projection TVs, I suppose!). The YUV output can drive some new projection monitors and plasma screens, and has obvious interest to anybody who wants to transfer S-VHS footage to broadcast-spec (e.g., Betacam) recorders. Once again, the picture quality is superb (note that a digital comb filter ensures a crisp picture with no fuzzy edges). Supplied with the unit is a 4-pin mini-DIN to twin phono adaptor-cable, which allows the ACE to drive two composite video outputs in the appropriate mode. As a result, the ACE can act as a distribution amplifier capable of feeding up to 4 VCRs or monitors.

Inside the ACE, all of the circuitry is on two neatly-designed PCBs. The first is the main board, which contains most of the circuitry, controls and socketry. The second board, which is mounted on the front panel, contains an extra row of controls. On the underside of the main PCB are the surface-mounted video ADC and DAC, which are sourced from Philips. Both of these chips are commonly encountered on video capture cards, of the type used for PC-based non-linear video editing. According to GTH, these chips - which have an exceptionally-fine lead-pitch - were carefully hand-soldered to the board. As the photos show, an excellent job was done. There's hope then for the rest of us, who are forced to use surface-mounted components because their through-hole equivalents simply do not exist! On the component side of the board is a (socketed) Xilinx 80MHz DSP, which has been programmed to provide many of the more complex video features. The controls and operation of the unit are looked after by a PIC. In all, the ACE is a fabulous piece of equipment - and proof that a small and innovative company is capable of beating the major corporations at their own game!



Inside the ACE video processor. The Xilink DSP chip can be seen towards the middle of the picture - the four 2 megabit RAM chips are immediately to the left of this device.

Further reading

Pirelli superconductors
www.pirelli.com
GTH ACE
www.gthelectronics.com
Phone: 01473 625547

Martin Pipe welcomes comments and ideas. E-mail him at:
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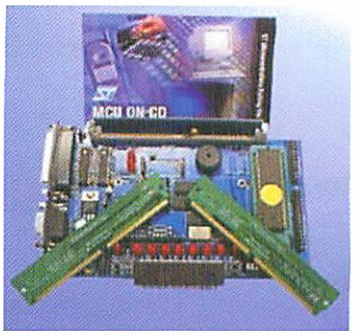

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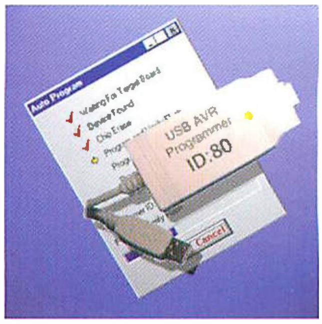

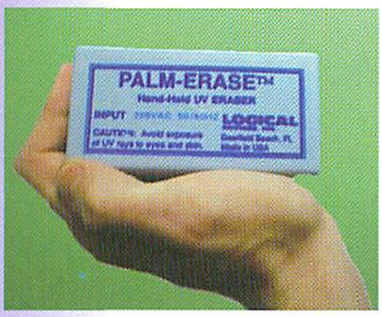

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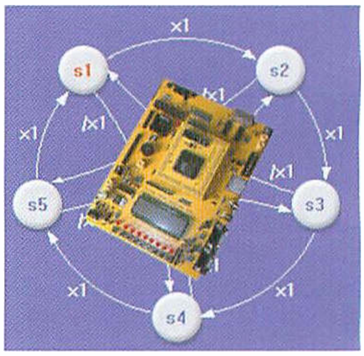

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