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**Electronic World - May 2001**

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**Killing fields - recognition at last**

The NRPB’s recently published report on ELF Electromagnetic Fields and the Risk of Cancer confirms a weak association between power line electromagnetic fields and childhood leukemia. This should be no surprise to readers of Electronics World who may recall a series of “Killing Fields” features in the 1990s by independent researchers investigating the effects of power lines on those living and working nearby.

What is important is that over the intervening years the NRPB has slowly shifted from outright denial of any possible link to a grudging recognition that further research is needed to determine the exact mechanism linking power lines and cancer processes.

As one of those researchers and an EW feature writer I am pleased that the door to further research has crested slightly ajar. Nevertheless, there’s still a mountain to climb to make sure that future research is directed into those areas where it is likely to shed most light.

The main problem is one of definition. The eminent research group chaired by Sir Richard Doll was only briefed to investigate the effects of non-ionising ELF radiation emanating from electric power systems. This led to an obsessional concentration on the electromagnetic fields emanating from power lines.

There has been no interest in extending power line electromagnetic and electromagnetic field research to interactions with other known harmful radiations, involving natural charged particles and background ionising cosmic radiations.

In some ways it’s remarkable that the Committee found any link at all, bearing in mind that over a century of domestic and industrial electric power has more or less preserved that power system magnetic fields per se are unlikely to be directly harmful.

The problem facing regulatory like the NRPB is a relative to range across the EM spectrum to actively research interactions that may be harmful. This is partly due to NRPB resources being hijacked to allay public disquiet about selling mobile phone masts near schools, while ignoring broadcast transmitters generating far higher field strengths in the same bands and areas.

As I write, Vatican Radio faces shutdown by the Italian Government for massively exceeding ELF field safety limits in urban areas near its short wave transmitters. If threatened by local TV transmitter shutdown and loss of soap, public concern about transmitter safety is likely to wane in the UK.

The same goes for ionising radiation. Nuclear paranoia has ensured that radiation risk assessments has failed to grasp the reality that there may be no lower safe limit for human ionising radiation exposure, and that some public risk has been accepted, as it is with road traffic accidents.

While the scientific jury is out, the precautionary principle has led to power companies in the USA buying up properties close to power lines deemed unsaleable, and planning codes and guidelines advising against domestic housing close to overhead lines.

In the meantime, the likelihood of a link between electromagnetic fields and human disease through background ionising radiation interactions is strengthened by the numbers of papers reporting solar cycle disease curves for cancers at high magnetic latitudes and high altitude urban locations where natural background radiation flux is intensified by location.

The NRPB must get away from its comfortable preoccupation with ELF non-ionising fields, and actively investigate ionising radiation interactions with all electromagnetic fields.

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**Anthony Hopwood**
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Anthony Hopwood
Poll reveals serious concern over electronics skills shortages

A survey of electronics executives by City consultancy KPMG shows there is serious concern over skills shortages in the industry in the UK. In a survey of executives from firms such as ARM, BT Colnet, IBM and Motorola, 98 per cent of respondents in the survey said their major concern was over skills shortages.

"Much more active investment is needed in centres of learning," said KPMG's head of electronics, Crispin O'Brien. "If you compare what we have with partnerships in Cambridge, for example, we're a long way behind other countries." According to O'Brien, a recent IDC report says that the shortage of skilled labour in Europe could reach 3.8m by 2003. "You could probably say that just under one million of those could be in the UK," he said.

However, he stressed that KMPG's report did not try to blame any one party for the situation and insisted that the industry must also do more.

"The Government is listening, we just have to wait and see how effective their measures will be," said O'Brien, commenting on the recent publication of the Enterprise, skills and innovation white paper.

The report by KPMG, announced mid-February, also highlights the lack of R&D funding and the industry's relationship with Government and education as key areas that need to be addressed.

Countries where R&D funding is high have a healthier industry and economy, said O'Brien. Competition in Europe for inward investment is much higher now, he said, and only five per cent of the UK electronics industry is actually UK owned, so the manufacturing base is not tied to Britain.

"Tax incentives are needed to keep them here. But although these incentives certainly help, the main reason that people invest in a country is the skills base," said O'Brien. "And right now, the biggest constraint is good quality people and access to a research base."

Firms team up to make superbhip

Firms Sony and Toshiba are to develop jointly a "super-computer on a chip." With a 300-person design centre in Texas, the three firms will invest $400m on the project over the next five years.

Called 'Cell,' the sub-0.1µm chip will combine technologies such as copper interconnects, silicon-on-insulator transistors and low-k dielectric materials.

Cell will be more powerful than IBM's Deep Blue supercomputer, the firms claim. Providing teraflops of processing power, it will be aimed at broadband consumer products.

Cambridge firm wins multilayer optical disk link up

Cambridge-based Plasmaion will use its experience in recordable optical media to set up a prototype production line for fluorescent multilayer disks (FLMDs), most probably in the UK.

"Our collaboration will focus on industrialization of the production processes, to provide future manufacturers of FLMD disks with efficient, low-cost and durable mass production techniques," said Nigel Speirs, CEO of Plasmaion.

FLMDs use fluorescence, rather than reflection, to sense data. Dye placed in the pit of the disk fluoresces when a laser is focused on it. Because the CD-sized FLMD is essentially transparent, multiple layers can be formed. A 20-layer disk is capable of storing up to 100Gb of data, the firm claimed.

"C-3D has demonstrated multilayer read-out using their unique FLMD technology at a level that is significantly greater than the two layers achievable with current reflective recording layers," said Street.

In January C-3D signed a deal with Lite-On to manufacture drives for the disks. Last November, it signed a similar deal with optical disc equipment supplier Steag Hanatch.

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Richard Ball

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Amstrad profits plummet due to e-m@iler losses

Amstrad's telephone with e-mail capability -- the e-m@iler -- is continuing to lose money for the company, which saw interim pre-tax profits fall by over 80 per cent to £1.5m. The consumer electronics manufacturer's e-mail business is operated through a joint venture with Dison known as Amserve. As the majority shareholder, Amstrad incurred a pre-tax loss of £3.9m in its Amserve business. Around 77,000 e-m@ilers have been installed since the launch last March. These are being sold at a loss in order to quickly build up a user base. It is hoped that they will then generate revenues through advertising and call charges. "With over nine months experience, e-mail usage is currently generating an income for Amserve which equates to £20 per phone per year or £1.5m per annum on the current installed base of 77,000 units," said Amstrad chairman Sir Alan Sugar. Sugar said that first advertising revenues were expected to start later this year when the installed base tops 120,000 units. "We are looking for growth of the installed base and as more e-m@ilers are sold losses from the Amserve business will continue but the future profit potential of the Amserve business will increase," said Sugar. Amstrad, which is one of five suppliers to satellite broadcaster BSkyB, also saw weaknesses in the digital TV set-top market.

Satellite mission investigates solar storm effects

The first results have been published from the four satellite Cluster mission which is measuring the Earth's magnetosphere. The bow shockwave, where the solar wind interacts with the magnetosphere, has been measured in detail for the first time. Findings from the mission enable designers to increase the ruggedness of communication satellites which have been destroyed by solar storms in the past.

New CO sensor stands to benefit from tighter gas laws

Full-cell sensor technology developed by Scipher spin-off firm Memos stands to benefit from potential steps to tighten CO pollution regulations in the US. The Swindon-based firm, a spinout from the Scipher intellectual property group, has developed a hermetic plastic carbon monoxide sensor -- the subject of 27 patents. It uses conductive plastic to transfer the output signal to conventional solder pins while an internal platinum/thorium electrode system deposited directly onto plastic minimizes precious metal use. Test gas passes into a sulphuric acid electrolyte via a semi-permeable membrane/wick system. The company has already received a £10m order for the new sensor, with more promised. A ruling in the US, although currently suspended, requires that all public buildings must have carbon monoxide (CO) detection alongside other fire detection systems. An attempt was made to enforce the regulation several years ago but, following a massive spate of false alarms from the sensor technology then available, the requirement for CO detection was put on ice. However, recent technology developments producing better sensors has excited legislators in Canada and the European Union to set much higher limits on CO detection -- and the US is under pressure to follow suit. New Canadian and European legislation requires reliable detection at gas concentrations down to 1ppm; a sensitivity which, while recently, could only be achieved with a conventional lead wire wire transducer. Frank Ogden

New technology will halve mobile antenna numbers

Quintel, the company that emerged from a deal between DERA, the research arm of the Ministry of Defence, and UK landlord, Rotch Group, was launched this week. The company is combining technology from DERA with properties owned by Rotch to halve the number of mobile phone antennas across the UK and Europe. Radio masts are often shared but several antennae are attached to them. DERA said its technology let each antenna receive up to five radio signals at once. This means the services of all five 3G licence holders could be combined on one roof-top or mast antenna. Quintel reckons that each operator will need up to 20,000 sites to complete the roll out of third generation mobile services.

Interactive audio plan

BountyQuest

BountyQuest has paid out $10,000 each to four people who may have found 'prior art' to break patents. The company was set up last year to make money by putting boosters on the patents that other companies do not want to exist. "Patents are a double-edged sword. While they encourage creativity and the introduction of new products that improve lives, they can also stifle competition -- particularly when they don't represent genuine innovation," said Charles Cella, founder and CEO of BountyQuest when it was set up. Patents are awarded only if there is no evidence that an idea has been thought of before. A search for evidence, or prior art as it is called, is made before granting the patent, but this search may not be exhaustive. Finding prior art can cause a patent to be withdrawn. BountyQuest has tapped into the world's knowledge base to uncover this hard-to-find information, which can be used not only to weed out bad patents, but also to validate good ones," Cella said. BountyQuest rewards start at $1000 and could go higher than $1m, depending on the value of the information to the client searching for it, said the company. Prior art, claims BountyQuest, has been found that challenges the following patents: a method for online music sampling, held by Intouch Group, a method controlling access to an event venue through alterable tickets, held by Walker Digital, a technology for database copying, held by Oracle, and a technology for single-chip network routers, held by Cisco Systems. Steve Bush

Software boost for WAP developers

Nokia's WAP Toolkit 2.1 is a free software tool that provides a PC-based environment in which developers can write, test and debug WAP applications. For this version, the company has added simulators for its 6200 and 7100 series phones. It also includes a June 2000 WAP Forum specification reference implementation simulator, which supports multifonks push among other new features. The simulator enables the prototyping of next-generation WAP services that will be supported in handsets coming to the market later this year and next.

Orange unveils the house of the future. A detached house in Hertfordshire is being used as a research centre to test, monitor and evaluate advanced services and products for the home. Dubbed 'Orange at home' the project is being led by mobile operator Orange. The house was adapted at a cost of £2m to include a range of services that can be controlled using 'wire-free' technology such as lighting, heating, security, curtains and baths.

UPDATE

May 2001 ELECTRONICS WORLD 326

ELECTRONICS WORLD May 2001 327
**Amstrad profits plummet due to e-m@ler losses**

Amstrad's telephone with e-mail capability - the e-m@ler - is continuing to lose money for the company, which saw interim pre-tax profits fall by over 80 per cent to £1.5m. The consumer electronics manufacturing e-m@l business is operated through a joint venture with Discos known as Amserve. As the majority shareholder, Amstrad incurred a pre-tax loss of £3.9m in its Amserve business. Around 70,000 e-m@lers have been installed since the launch last March. These are being sold at a loss in order to quickly build up a user base. It is hoped that they will then generate revenues through advertising and call charges. "With over nine months experience, e-mail usage is currently generating an income for Amserve which equates to £20 per phone per year or £1.5m per annum on the current installed base of 77,000 units," said Amstrad chairman Sir Alan Sugar. Sugar said that first advertising revenues were expected to start later this year when the installed base tops 120,000 units. "We are looking for growth of the installed base and as more e-m@lers are sold losses from the Amserve business will continue but the future profit potential of the Amserve business will increase," said Sugar. Amstrad, which is one of five suppliers to satellite broadcaster Sky, also saw weaknesses in the digital TV set-top market.

**Satellite mission investigates solar storm effects**

The first results have been published from the four-satellite Cluster mission which is measuring the Earth's magnetosphere. The bow shockwave, where the solar wind interacts with the magnetopause, has been measured in detail for the first time. Findings from the mission enable designers to increase the ruggedness of communications satellites which have been destroyed by solar storms in the past.

**New CO sensor stands to benefit from tighter gas laws**

FTel-cell sensor technology developed by Sciphir spin-off Filmex stands to benefit from possible changes to EPA (Environmental Protection Agency) regulations in the US. The Swiss-base firm, a spinout from the Sciphir intellectual property group, has developed a hermetic plastic carbon monoxide sensor - the subject of 27 patents. It uses conductive plastic to transfer the output signal to conventional solder pins while an internal platinum/rhodium electrode system deposited directly onto plastic mimics precise metal use. Test gas passes into a sulphuric acid electrolyte via a semi-permeable membrane/nickel system. The company has already received a $1m order for the new sensor, with more promised. A ruling in the US, although currently suspended, requires that all public buildings must have carbon monoxide (CO) detection alongside smoke detectors and other fire detection systems. An attempt was made to enforce the regulation several years ago but, following a massive spate of false alarms from the sensor technology then available, the requirement for CO detection was put on ice. However, recent technology developments producing better sensors has caused legislators in Canada and the European Union to set much higher limits on CO detection - and the US is under pressure to follow suit.

**New technology will halve mobile antenna numbers**

Quintel, a company that emerged from a deal between DERA, the research arm of the Ministry of Defence, and UK landlord, Rother Group, was launched this week. The company is combining technology from DERA with properties owned by Rother to halve the number of mobile phone antennas across the UK and Europe. Radio masts are often shared but several antennas are attached to them. DERA said its technology let each antenna receive up to five radio signals at once. This means the services of all five 3G licence holders could be combined on one roof-top or mast antenna. Quintel reckons that each operator will need up to 20,000 sites to complete the roll out of third generation mobile services.

**Interactive audio plan**

Broadcaster Capital Radio has teamed up with US digital radio technology firm Cella, and Command Audio to launch on-demand interactive audio through the UK's digital audio broadcasting (DAB) network. A joint venture company also including UBC Media, Command Audio-UK (CA-UK) will produce on-demand interactive programmes and licence other programmers and service providers. According to the firm's website, the service will launch in the UK in 2003. Capital's radio stations already include Classic FM, the BBC's 5 live, LBC London, and Smooth. The 'interactive' service, which will be available through a new software package for cars, will offer a range of programmes and allow listeners to choose from a range of programmes and listen to them whenever and wherever they want.

**Patent bounty hunters pay out $40,000**

BountyQuest has paid out $10,000 each to four people who may have found 'prior art' to break patents. The company was set up last year to make money by paying bonuses on the patents that other companies do not want to exist. "Patents are a double-edged sword. While they encourage creativity and the introduction of new products that improve lives, they can also stifle competition - particularly when they don't represent genuine innovation," said Charles Cella, founder and CEO of BountyQuest when it was set up. Patents are awarded only if there is no evidence that an idea has been thought of before. A search for evidence, or prior art as it is called, is made before granting the patent, but this search may not be exhaustive. Finding prior art can cause a patent to be withdrawn.

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Metallic superconductor works at 39K

Japanese researchers have found a single metallic compound that superconducts at twice the temperature of previous materials. Magnesium diboride (MgB2) superconducts at 39K, claims Tokyo’s Aoyama Gakuin University, twice that of the previous best metallic material.

“It’s certainly a new type of semiconductor,” said Dr Mark Blamire, a materials scientist researching superconductivity at Cambridge University. “But it doesn’t really compete with high temperature superconductors.” Blamire’s group at Cambridge has already repeated the Tokyo experiments, creating 99-99 per cent pure MgB2, with a Tc of 39.5K.

Ceramic and other intermetallic compounds remain much better superconductors, working at over 100K, but they are potentially harder to manufacture than metallic varieties.

The Tokyo work may open up new avenues of research, using less exotic and expensive elements than niobium, the current favourite. At Cambridge and other research centres, scientists are at the stage of making bulk materials by sintering powders, said Blamire.

Work is under way to make useful electronic components which would involve laying down thin films on substrates.

All new European Ford cars to have electronic telematics within 5 years

Ford aims to put electronic telematics systems in all its European cars within five years. The car maker has stepped up its plans for in-car electronic systems through a partnership with mobile communications operator Vodafone with the intention of bringing in-car security and information services to its range of European vehicles by 2006.

The first production Ford Focus cars with telematics will appear in Germany next week. A UK launch using Vodafone’s mobile network will follow shortly after, said a company spokesman.

“We anticipate that within five years nearly all new Ford vehicles will be fitted with some type of telematics system,” said David Thursfield, president and CEO of Ford Europe.

The in-car communications links supporting GPS-based location, security and information services will be provided by Vodafone’s UK mobile network and its D2 subsidiary in Germany.

Services are expected to include providing emergency and roadside assistance, traffic information and dynamic re-routing as well as an operator and voice controlled service.

For example, the driver will be connected with the emergency services, who will also be automatically alerted if the airbag is deployed. Also, the vehicle’s position will be calculated using the GPS location system.

“Telematics is an integral part of our strategy,” commented Vodafone’s Thomas Oelker.

Typical additional cost to the first Ford Focus being fitted in Germany will be £845.
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1kHz to 30MHz oscillator IC

Linear Technology has produced the LTC1799, a handy 1kHz to 30MHz oscillator in an eight-pin SOIC-23 package.

Frequency is set between 100kHz and 30MHz with a single resistor (if there is a linear relationship to R), and an output divide ratio of 1:10 or 1:100 is selected with a single external pin.

Claimed frequency error is plus or minus one part per cent or under between 1MHz and 20MHz (0°C to 70°C) with a 0ppm/°C temperature and 0.05%/V supply instability.

The chip operates from 2.7 to 5.5V, although it will not reach 30MHz on lower voltages.

Typical supply current is 1mA and output impedance is 100Ω. Linear uses the chip driving charge pumps, clocking switched capacitor filters and replacing crystal and ceramic oscillators.
Chip cap flaws investigated

If a ceramic chip capacitor fails, don't automatically blame the assembly process. The mechanism of failure may have been built in at the factory.

Ceramic chip capacitors are among the least expensive of electronic components, and among the simplest in design. A ceramic chip capacitor consists of alternating layers of metal plates, or electrodes, and ceramic insulating layers.

At each end of the capacitor, one set of plates -- positive or negative -- joins together in a termination. Properly built and installed, a ceramic chip capacitor will store and release a charge thousands or millions of times per second without incident.

The primary function of a capacitor is to block DC voltages, while passing AC signals. As such they are often used in a variety of circuit designs. By virtue, they are most often used as "bypass" components on voltage supply or bus line circuits, where they filter out unwanted high-frequency noise. In these applications, random circuit "glitches" are shorted to ground, thus preventing inadvertent errors from being generated.

However, the most common failure modes for a ceramic capacitor are the development of a resistive short. This causes AC signals to also be shunted to ground -- i.e., a short circuit condition -- resulting in the failure of the product.

Most ceramic chip capacitors sell for relatively low prices. If they were not made and tested to the exacting standards of, say, a high-speed microprocessor, they would be more reliable, but they would also be exorbitantly expensive. Still, a failed ceramic chip capacitor can be an annoyance at the very least.

For example, it is typical for automotive air bags to contain a test circuit. If a capacitor in the test circuit becomes defective, a leakage current may flow around it. What should be a closed circuit is now open, and the driver will be looking at an erroneous "Air Bag Failure" message.

On a given printed circuit board, it's usually not difficult to tell that a ceramic chip capacitor has failed -- there may be a spike in the power supply for example. It may be more difficult to tell by electrical testing which of many capacitors has failed.

Without resorting to relatively heroic measures, it is nearly impossible to tell why the capacitor failed. Examining a capacitor visually doesn't give you much information unless the capacitor has sustained gross damage that is visible on the exterior.

Often -- but not always -- the failure is the result of an internal manufacturing defect that eventually reached a critical state. The most common internal defects are voids in the dielectric layers.

A void is a bubble of air -- or possibly another gas -- that became trapped in the fluid ceramic before the capacitor was fired. If you sliced a capacitor open at just the right point, the void would look like a tiny flattened bubble. It might lie entirely within one layer of ceramic, or it might be in contact with one or both of the adjacent plates.

Saving open a capacitor to examine a void is something not often done, because of the labor and time involved. In most applications, the condition of a single ceramic chip capacitor isn't truly critical. But in some systems -- those that go into earth-orbiting satellites or marine vessels, for example -- every capacitor has to be flawless. For those applications, capacitors are often inspected by acoustic micro imaging, which scans internal defects non-destructively. Voids and the other frequent defects, cracks and delaminations, are usually too small to be imaged by x-ray.

Detecting flaws via acoustic imaging

Acoustic micro imaging uses high-speed imaging transducers that scan over the capacitor. Several thousand times a second, the transductor switches between pushing ultrasound and receiving the return echoes from the interior of the capacitor.

The return echoes are used to make data points. The whole collection of data points from a capacitor shows its internal structure, including defects.

Ultrasound is reflected only by interfaces between different materials. The stack of electrodes and dielectrics in a capacitor presents a great many material interfaces, but these are basically low-contrast interfaces, at least when compared to defects.

The three common defects -- voids, cracks, and delaminations -- amount to an interface between a solid material and the air or other gas inside the defect. Technically, what occurs is a difference in acoustic impedance, which is the density of a material multiplied by the speed of ultrasound through that material.

Since the density of a gas is extremely low compared to the density of a solid, the difference in acoustic impedance between either a metal or a ceramic and air is huge, and results in a very high-contrast data point.

In the completed acoustic image, defects are very easy to spot. The ordinary acoustic view, looking straight down into the acoustically transparent capacitor, shows the x-y outline of defects, but there are other kinds of acoustic views, including a non-destructive cross-section that shows feature depth.

Cracks in ceramic chip capacitors usually extend more or less vertically through several layers of ceramic and metal. Since they provide a direct pathway between plates, cracks create short circuits. Voids can also cause shorts, by a slightly more indirect route.

Ralph Carbone and Tom Adams provide a unique insight into the failure modes of ceramic chip capacitors.
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COMPONENTS

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Delaminations are horizontal separations between layers. Capacitors having one delamination are likely to have several more delaminations at various layers, since delaminations are the result of a lack of bonding between layers. Companies involved in high-reliability applications tend around a million ceramic chip capacitors a year to the applications laboratory at Sonoscan (www.sonoscan.com) for acoustic impingement. The lab’s acoustic imaging accesses the capacitors into good and bad categories: for expensive high-reliability uses, this is far cheaper than having a system become impaired or fail outright in an inconvenient or impossible location. The lab sometimes sees capacitors open too, chiefly so that customers can see defects optically. Sawing an exactly the right place in a simple business because the acoustic image has already shown exactly where the defects are. Because acoustic micro imaging primarily operates in the reflection mode—pulse the ultrasonic, receive the return echoes—ceramic chip capacitors are imaged acoustically equally well when they are still mounted on a board. This became important recently at Hewlett-Packard, where a circuit board used in a medical product began to experience field failures. The problem was identified electronically at a single ceramic chip capacitor on the board. The lab could have removed the capacitor from the board for acoustic imaging, but this would have created the possibility that the removal process had caused whatever defect was present—and at least in the eyes of the capacitor manufacturer. Instead, capacitors on failed assemblies were imaged right on the board.

The results show two types of defect—large delaminations between layers, and cracks resulting from the firing process. No voids were found, suggesting that manufacturing flaws were related to firing, and did not involve the fluid ceramic material. The board assembler was then able to set up a screening process for incoming capacitors, and the capacitor manufacturer was able to adjust his processes to make delaminations and cracks less frequent.

Peter Marlow
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Readership: Professional service engineers, same college courses.
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To Jackie Lowe, Room LS14, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

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— Separate jack for 10A current measurement.
— 1MHz input impedance
— 220V DC or RMS AC maximum overload for 2000V DC range, 600V RMS AC on other DC ranges

Voltage and current and resistance

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<th>Accuracy</th>
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<td>±1% of rdg, ±2dig.</td>
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For a PDF file of the meter’s manual, e-mail e-world.orders@rbi.co.uk with the subject heading “Meter manual”.

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Peter Marlow
Contents: Introduction; A-Z of manufacturers and models
Readership: Professional service engineers, same college courses.
Pages: 400pp
Price: £22.50

TV Fault Finding Guide
Unique expert authorship and trusted Television magazine identity. Fault repair and troubleshooting info — not just statistics from manufacturers’ data sheets. Ease of reference — this book is an essential repair tool, not just another volume for the shelf. Television magazine’s TV Fault Finding volume is a wide scope for practical servicing tips, with the U.K’s leading service engineers and servicing writers contributing their observations and recommendations month by month, but try making those faults reports for the Annual TVT/C2200 that’s on your beach.

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- 11 functions: measures sound level, light, humidity, resistance, DC voltage, AC voltage, DC current, resistance, transistor, diode and continuity test.
- 3-segment LCD with indicators for lux, °C, %RH and dB.
- Sound level: from 35dB to 102dB with C weighting, 0.1dB resolution.
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- Separate jack for 10A current measurement.
- 1MHz input impedance.
- 220V DC or RMS AC maximum overload for 2000V DC range, 600V RMS AC on other DC ranges.

Voltage and current and resistance

<table>
<thead>
<tr>
<th>DC Voltage</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
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<tbody>
<tr>
<td>200.0V</td>
<td>±0.3% of rdg, ±2μg</td>
<td>±0.5% of rdg, ±2μg</td>
</tr>
<tr>
<td>600V</td>
<td>±1% of rdg, ±2μg</td>
<td>±1% of rdg, ±2μg</td>
</tr>
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AC values

| 200.0V     | ±1% of rdg, ±2μg |
| 600V       | ±1% of rdg, ±2μg |

DC current

| 200μA     | ±1.0% of rdg, ±2μg |
| 10μA      | ±2% of rdg, ±2μg |

Resistance

| 200Ω      | ±0.5% of rdg, ±2μg |
| 20μΩ      | ±0.8% of rdg, ±2μg |

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Fig. 4. Optical view of a nearly vertical firing crack first detected acoustically. The dimensional accuracy of the acoustic image simplifies and speeds up accurate physical sectioning. Photo courtesy Hewlett-Packard.
Design competition

Devis a useful and/or ingenious application for the ZXF36L01 versatile high-Q bandpass filter with integral mixer and you could win a £500 voucher redeemable at Farnell. There's two runners up prizes of £100 vouchers too.

Rules
- Electronics World reserves the right to publish submitted entries. All designs published will be attributed to their designers. A minimum payment of £50 will be made for each design published.
- Submission of an entry does not remove your right to exploit your design, but it does give Zetes the right to use the entry as an application note, or as the basis thereof, effectively making the design public domain.
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- No employee of Reed Business Information, Zetes and Farnell, or any of their associated companies, may enter this competition, nor may members of their families.
- No entry will win more than one prize, multiple entries may be submitted.
- Prizes are as stated above and not negotiable.
- Entries arriving after the closing date will be void.
- No purchase in necessary to enter this competition.
- Winners will be notified by post, and the results may be publicised.
- For a list of winning entries, send an SAE to the editorial office.
- Submitting an entry for the competition implies acceptance of these rules.

Win a £500 voucher redeemable at Farnell.

For more information visit
http://www.farnell.co.uk for details of the ZXF36L01 development kit or http://www.zetes.com/pdf/zxf36L01.pdf for more data on the filter chip.

This Electronics World competition is sponsored by UK semiconductor manufacturer Zetes and distributor Farnell Electronics Components.

You don't need to buy this new development board for the ZXF36L01 in order to enter the competition, but if you do, and your entry meets the competition criteria, you will receive a Farnell voucher for £15 to help cover the cost.

Launches this year, the ZXF36L01 is a versatile high-Q bandpass filter requiring a minimum of external components. In addition to the variable-Q analogue filter there is also a mixer block, making the device suitable for a wide range of applications.

All you have to do in order to enter the competition is send a design concept incorporating the ZXF36L01 to the address below. Entries will be judged on ingenuity, originality and usefulness. All entries must be subject to the rules set out below.

Entry of a designer's kit is available from Farnell and you can find full details on the kit in Farnell's web site http://www.zetes.com/pdf/zxf36L01.pdf. It is not necessary for you to prove your design, and buying the kit is not a condition of entry into the competition. The design you submit has to work in practice but you will not be penalised for not having built a prototype.

If you do submit a design that meets the competition criteria and you have bought the kit, then you will receive a Farnell voucher for £15, courtesy of Zetes. Send your entry to Filter Design, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Note that it is not necessary to send your prototype Simply send a circuit diagram and a concise description of the circuit. It will help if you describe why you think that your circuit should be among the winners. You can also email your entry to jackielowe@rbi.co.uk, but unless the email has a subject heading that reads 'Filter Design' it will not be eligible. Please attach diagrams and text separately and include a daytime phone number with your entry if possible. The closing date for the competition is 30 April.

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you are browsing the Internet looking at your car’s own web page. The screen is full of messages and indicators telling you all about your car, but an orange flag tells you there is something that requires your attention.

You look at the various gauges: clutch, brake fluid, they seem OK. Oil looks a bit low though, so you place a tick under one of the oil brands in the ‘garage reminder’ memo pad. You wonder how people did this in the past; did people actually open the bonnets and look inside their own cars? Then the door bell rings, the washing machine repairman is at your doorstep... “Your dishwasher just e-mailed us to say in drive belt is just about to go.”

Whether you think the concept of networking your possessions is a good thing or not, it may be of some use knowing how it all works. In any case, this article is for you because it will at least put you on the first step of the “I am not afraid of the technology,” ladder.

On the other hand, you may have already thought of network-enabling your own product or application, but been put off by the apparent complexities involved. This article will give you an insight into the expertise and effort involved.

What’s more, a readily available preprogrammed chip to be described in the next article will give you a head start on the prototyping stage.

Why use Ethernet?

As a consultant, I am sometimes asked about the Internet and its potential extended uses. Boring as the subject may be, the conversation sometimes ends in optimistic discussions about the need for Internet fridges and microwaves that e-mail you when the noodles are ready.

Nevertheless, there are some interesting possibilities for considering the use of a local-area network as a serious interface between a personal computer and external input/output devices. For one, the interface can be remote from each other as needed be anywhere in the world in theory. You can also share a device among several users, say a rooftop web camera or weather monitoring station accessed by all users in a building or school – or even from home. These are benefits at the practical level too. Remote data logging and controlling equipment becomes much easier when it can all be interfaced using standard and well-tested networking components, cabling and connectors.

New network models such as Real Time Publish Subscribe, or RTPS for short, are also making Ethernet more suitable for real time systems, data logging and control. Interacting possibilities arise too when interfacing to other proprietary networks such as Home Automation, X10, CEBus or Lon.

But then, it can all sound very complicated: the protocols, the stacks, and so little information published. But is it? The answer is not really, and it is certainly not out of reach.

Embedding is the word

Internet-enabled hardware products are slowly becoming commonplace. From vending machines dialling up to report their stock, to pinball machines publishing their high scores on the Internet for all to see. Internet appliances – the term used for devices that do not use a computer – are predicted to overtake PCs for Internet use within the next four years. A new addressing scheme for the Internet (version 6) allows for a staggering 2^128 times the number of addresses currently available. The address field used is 128 bits. Each nut and bolt in your washing machine will be able to have its own unique Internet address.

Many modern products are driven by internal microprocessors. These small devices are quite powerful, but one generally omitted fact is that in order to implement the functionality required for Internet and network access, a lot of program code space is required. Gone are the days of simple ASCII dial-up interfaces, simple 25MODEM or Kermit protocols. Nowadays your processor has to deal with PPP, ARP, IP, ICMP, TCP and a host of others. More on this later.

Of PCs and interfaces

PCs are well known for their lack of suitable interfaces into the real world. They were not originally designed with many facilities for driving external equipment, or to act as data gathering stations. Many alternatives using the parallel and serial port have been on offer, but this approach is becoming less practical nowadays – especially with NT and Windows 2000 where special low-level software systems drivers are required. Worse still, parallel and serial ports are now called ‘legacy’ devices, which is computer jargon for obsolete. The newest machines from the shops just do not have these ports any more. These are all being replaced by USB.

Eventually, USB devices may be accepted as the standard method for general-purpose direct, local interfacing to a PC.

The advantage of using an Internet, as opposed to a direct connection, is distance. Most PCs will have a local network connection. Low cost Ethernet cards are readily available and easy to install – even in older and non-PC machines. From this point of view, using Ethernet for I/O external access is an attractive, cheap alternative. Furthermore, different brand, newer and older machines with different operating systems can access the devices. PCs, Linux, Unix and portable hand-held devices can all be used, Figs. 1 & 2.

Software at the PC end

If you develop a piece of network hardware, you will need to think about how to drive it from the PC. You may not need to write any software at the PC end at all. Your device could for example emulate a web page, and be accessible as if it...
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Remote PC

Enabling TCP/IP communications via the LAN

Ethernet PC ISA card

Fig. 2. It is possible to buy Network cards for well under £10 now so interfacing via Ethernet is convenient, fast and reasonably cheap. 16/882 Ethernet cards interconnect via coaxial cables. Many cards can be daisy-chained, each end of the chain being terminated with a 100Ω terminator.

Fig. 1. A cheap PC network card plus microcontroller forms the basis for a simple unit that allows a PC access to external I/O devices via a local area network.

User Interface, including sensors and data gathering hardware

Connecting external devices to your PC via a local-area network card is not as difficult as it may seem. Eddy Insam explains how it all works and what you need to know. In a second article, Eddy will describe a development device that can get you going in no time at all.

Interactive publishing!

Interfacing via Ethernet is a complex topic involving new concepts for those of you used to RS232 and the like. If you have any queries regarding interfacing with Ethernet, e-mail martin.eccles@rbi.co.uk using the subject heading 'Ethernet interfacing'.

Any queries that are of general interest will be published in next month's article, together with their replies. We'd do our best to answer all your questions, but as the time available to prepare answers is finite, we cannot guarantee you a reply. Ed.
were a normal Internet page.

If you used more dedicated control, standard API libraries are available for network communications. The one in Windows is called Winsock, which is a family of API calls contained in a DLL file.

There is also higher level support in the form of ready made OCS components, add-ons for Visual Basic and C. List 1 shows a simple "C" driven application program showing how Winsock calls can be used to send and receive data from a remote on the network.

How do they do that?

Figure 3 shows a block diagram of the business end of a simple Ethernet embedded device. It consists of a small dedicated microprocessor connected to a custom Ethernet interface chip, which is in turn connected to the local area network via a suitable electrical isolation transformer.

The Ethernet interface chip acts like a sophisticated serial-to-parallel converter. Its job is to read serial packets of data from the wire, check their header bytes with an internal address, perform checksum calculations, and then push the block into a user accessible first-in, first-out data buffer. This " FIFO" queues the data blocks for processing by the application.

The job of the microprocessor is to retrieve the blocks, and according to the information within, perform a few more data calculations. checksums, then push the "clean" data on to another device or system. The micro should be quick enough to retrieve frames from the FIFO buffer before it overflows. If it isn't, packets may be lost.

During transmission, the opposite takes effect. The microprocessor sees data blocks coming from the Ethernet chip then adds any required headers and checksums, performs the parallel-to-serial conversion and then push the serial stream into the wire. At the same time, it checks for possible collisions in that is all there is to it. The rest is all done in the software.

What does the micro do?

The microprocessor's job is very simple. Take data from a buffer, do some conversions and then do whatever with it. Easy! Well, not quite.

A far bit of housekeeping needs to be done along the way. Functionality needs to be included to communicate packets in the background, and setup timers so the user knows who and where we are for example. There are various established "protocols" that describe exactly how and when this should be done.

Protocols, as camels designed by committee, are by definition complicated. The following valves give a rough idea of the amount of program code required to implement an average Ethernet application. Values are for a P16 110 MHz computer, with an Ethernet card, 1.5K IP, and ICMIP, another 1.5K TCP, another 2.5K PPF (for modem access) 3.5K.

If you want to enable Ethernet to your project, you may need to dedicate quite a bit of program space to handling the protocols. But do you need to use these complex communications protocols? Isn't it possible to just talk directly to other workstations using your own simple private peer-to-peer system?

The answer is yes. Each Ethernet packet carries a frame identifier that describes the protocol format used by its payload. Pick a number of your choosing and send that data format you like.

The rest of the network will just ignore the privately encoded packets — but first check with www.tlsw.in/ standardization/ether-net-work-numbers/ to ensure the number you have chosen has not been already allocated.

Of course, you will need to program your protocol closely to the Ethernet card, and your packets will not be able to get past a router come to roost on for example on the Internet. There may be real advantages in using alternative network modes to simplify the need to maintain speed and response times.

Isn't that much software available at great cost? Expect little support from software vendors.

For real flexibility, you will need to use Internet protocols, and until dedicated TCP/IP interfaces are built in to the microchip in hardware, you will need to live with the complexity of handling the protocol in software.

There's already a number of products in the market offering different levels of functionality. The best way to find out about these is to look at web sites maintained in the separate. Which follows is just a simple summary.

The complete lowdown comes in the form of complete PCB cards with built-in micro, RAM, PROM and user defined Ethernet interface driver chip. Units range in size from the smaller 8051 based, to larger, 386 embedded Linux-based cards.

"The Ethernet chip buffers incoming serial stream and presents the data in parallel form to the micro controller via a circular first-in-first-out data buffer. The microcontroller performs all necessary high level addressing and decoding. Cleaned data is then transferred to the user application, which can be embedded in another microprocessor."
PC INTERFACING

Network functionality is usually supplied in the form of a "C" library or module that the user compiles or links with their existing code. This is sometimes a cut-down or trimmed version of the standard sockets library.

If you do not want to use a readymade card, there is nothing much available at the single chip level. Notable exceptions are the IChip systems from ConnectOne and Selica. Originally offered as a set of software-licensed intellectual property (implemented in ASIC form), this is now available in single-chip form (PN 7600/7610). A US company, Iplist, has just announced another single chip device. More devices are expected to appear in the future.

I have found some of the claims made for these products to be the 'flexible with the truth' class. This is reflected in the unnecessarily long times taken to get the software to work properly and reliably. These difficulties are possibly due to the smallness of the technology, but it is a hard way for you to learn.

Roll your own or build the bag?

If you want to network your application, depending on how complex it is, you will need to decide whether to go for a readymade route, i.e. buy cards, modules or components in, or roll your own. If you are starting from scratch, the initial learning curve is pretty steep. The most obvious decision that may be your only option is to pointlessly re-invent the wheel. If you are considering quantities or reliability, a deeper knowledge of the product and its performance may be important. In practice, this means that you could spend as much time trying to get an external offering to work properly and reliably – especially one that doesn't perform as well as advertised – as you would developing your own from scratch.

Again, depending on your requirements, you will need to evaluate how many functions are necessary for your application. It is pointless to include the full TCP stack into a product that would be happy to communicate using simple UDP packets. This is a waste of code space, components and resources. Is speed of access important? Is your field of work in real-time systems? If so, you should consider alternative network models.

As I mentioned earlier, the ready-made controller described in the next article may help you a little bit with this decision process. It will allow you to evaluate and try possibilities and use it in prototyes. Because the controller provides access to the data stream at various levels, it can also be used as a teaching tool, and as a component in a more advanced network tester or server. It was originally designed as a tool for evaluating network stress.

I have used two processors for this controller. One handles the protocol interactions and another, supplied and written by the user, handles the application.

Data transfer between the two processors is via simple serial commands. The overheads such as checksums and framing are completely handled by the main controller.

Still confused?

If you have managed to get this far, and still you think you have not understood networks, don't despair. The next few sections will unravel some of the theory, and explain what you need to know.

No article on Internet basics can do without a guided tour of the technology, from the bit-shifting protocols to the higher level scripts.

I am not going to go into any in-depth detail, as there is plenty of information around in books and magazines. What I have done is give a quick tour of the basic concepts involved, with special relevance to a microcontroller-based implementation.

Readers mentioned later in this article will find the address to the topic. You can find RFCs on the Internet by searching under 'RFC'.

Ethernet

You may already have a network controller on the back of your computer. Look for a BNC socket with a coaxial cable (remember 802.5/87), or a flat cable ending in something looking like a plastic telephone connector.

In most offices, these wires just disappear down the back of the desk. Just as on today's motorways, you can expect to see bunches of house holds-ups at the most obscure times and for an unprecedented length of time.

Anybody designing equipment using a network for data transfer must be well aware of this situation.

As a conservative estimate, just one PC with one interface and no other traffic should be able to exchange data at between 70% and 90% of the full advertised speed. Throughput does decrease drastically when more users are on the network at the same time. The 'twentieth' article in the series, compatible with some charts and calculations plus a pointer to an Excel spreadsheet for estimating these delays.

In terms of hardware support, there are dedicated Ethernet interface chips available from various manufacturers. Most are compatible with a standard generic architecture, known as NE2000. They have a standard 8 or 16-bit data bus interface, compatible with most CPU addressing schemes.

Access to the chip is via a number of internally pagged registers, usually arranged as sixteen I/O or memory locations. Most chips can have directly connected to a CPU memory bus, or even directly to a framework controller. The blocks of data being transferred are stored in FIFO memory, as a buffer

area for the different speeds between the LAN and the rest of the system.

Using the chip involves first setting up your network environment, and then setting up your protocols. You must set up addresses for all the devices on the network, and communicate addresses.

Every Ethernet frame has a header containing a 6-byte sees address, a 6-byte destination address, and a 2-byte protocol identifier. The first byte of the payload, which addresses mentioned, tends to have only between 46 and 1500 bytes.

On receipt of a frame without errors, this address is usually reset to all zeros and passed on to the rest of the system. The protocol identifier field specifies which type of protocol the payload is carrying. For example, 0x806 denotes an Internet protocol, or "IP" message.

The payload will have its own header and payload part, which are dealt with by the next layer in the stack. This is the concept of transport layer 'layer 5', Fig. 5.

It is important to know that Ethernet data packets or frames are completely independent of each other. Frames are fired like bullets out of a gun, and, apart from a collision detection mechanism during transmission, what happens to them afterwards is of no further concern to the transmitter. In other words, the Ethernet network layer does not provide for any global form of flow control or error prevention.

At the other end, received frames are checked for consistency by multiplying their CRC bytes. Frames arriving with errors are simply dropped or ignored. It is up to the higher layers to provide for any form of error control and reports.

![Fig. 4. Ethernet frames comprise a 6-byte destination and source addresses, plus a field word indicating the type of payload carried. The two most common payload relevant to the TCP/IP world are shown in the figure. The preamble is a string of 52 bits used to synchronize the internal clock generator. A 4-byte header contains the Internet address comparison and checks for CRC validity before placing the data block in the RAM buffer.](image-url)
Network functionality is usually supplied in the form of a "C" software library or module that the user compiles or links with their existing code. This is sometimes a cut-down or version of the standard socket library.

If you do not want to use a ready-made card, there is nothing much available at the single chip level. Notable exceptions are the 1Chip systems from ConnectOne and Seiko. Originally offered as a set of software-licences implemented in ASCII form, this is now available in single-chip form (28-pin DIP, part number 760D). A US company, IpLit, has just announced another single chip device. More devices are expected to appear in the future.

I have found some of the claims made for these products are too "promising" to be become the "brass ring" class. This is reflected in the unnecessary long times taken to get the software to work properly and reliably. These difficulties are possibly due to the newness of the technology, but it is a hard way for you to learn.

Roll your own or boil the bag?

If you want to network your application, depending on how complex it is, you will need to decide whether or not to go for the ready-made route, i.e. buy cards, modules or components in, or roll your own. If you are starting from scratch, the initial learning curve is pretty steep and some room for error may be your only option. It is pointless to re-invent the wheel.

If you are considering quantities or reliability, a deeper knowledge of the product and its performance may be important. In practice, this means that you could spend as much time trying to get an external offering to work properly and reliably - especially one that doesn't perform as well as advertised - as you would developing your own from scratch.

Again, depending on your requirements, you will need to evaluate how many functions are necessary for your application. It is pointless to include the full TCP stack into a product that would be happy to communicate using simple UDP packets. This is a waste of code space, components and resources. Is speed of access important? Is your field of work in real-time systems? If so, you should consider alternative network models.

As I mentioned earlier, the ready-made controller described in this article may help you a little bit with this decision process. It will allow you to evaluate and try possibilities and use it in prototypes.

Because the controller provides access to the data stream at various levels, it can be used as a teaching tool, and as a component in a more advanced network tester or server. It was originally designed as a tool for evaluating network stress.

I have used two processors for the main controller. One handles the protocol interactions and another, supplied and written by the user, handles the application.

Data transfer between the two processors is via simple serial commands. The overheads such as checksums and framing are completely handled by the main controller.

Still confused?

If you have managed to get this far, and still you think you have not understood networks, don't despair. The next few sections will unravel some of the theory, and explain what you need to know.

No article on Internet basics can do without a guided tour of the technology, from the bit-shifting protocols to the higher level scripts. I am not going to go into too much detail, as there is plenty of information around in books and magazines.

What I have done is a quick tour of the basic concepts involved, with special relevance to a microcontroller-based implementation. References mentioned later in this article all contain the extra detail you may ever need. The main sources for detailed work in real-time systems are 'RFCs' or 'requests for comments'. The text contains the references that relate to the topic. You can find RFCs on the Internet by searching under "RFC".

Ethernet

You may already have a network controller on the back of your computer. Look for a BNC socket with a coaxial cable (remember RG-58/U), or a flat cable ending in something looking like a plastic telephone connector.

In most offices, these wires just disappear down the back of the desk. This is usually a good thing, for reasons of hold-ups at the most obscure times and for aesthetic reasons. Anybody designing equipment using a network for data transfer must be well aware of these constraints.

As a conservative estimate, just one PC with one interface and no other devices should be able to handle 10Mbps in this form. This is because collisions and other users sharing the network.

There are many good and bad statistics around showing relationships between usage and throughput. Just as on today's motorways, you can expect gridlock and hold-ups at the most obscure times of the day. The main Ronnie sampling article in the reference section contains some charts and calculations plus a pointer to an Excel spreadsheet for calculating these delays.

In terms of hardware support, there are dedicated Ethernet interface chips available from various manufacturers. Most are compatible with a standard genetic architecture, known as NE2000. They have a standard 8 or 16-bit data bus interface, compatible with most CPU addressing schemes.

Access to the chip is via a number of drivers that allow connection to the network. Usually arranged as 16-bit I/O or memory locations. Most chips can be directly connected to a CPU memory bus, or even directly to a network card. The blocks of data being transferred are stored in FIFO memory, as a buffer connected to each other. Rather, they need to be connected to a central "hub", which acts more or less like a repeater or distributor. Other methods are available working on similar electrical principles.

In terms of speed, two main flavours are available, 10Mbps and 100Mbps. In many small office and home networks, 10Mbps is usually the most popular. It is easy to install, and the cables are easily cut and crimped. You will only be considering the 10Mbps version from now on.

How fast will it go?

A speed of 10Mbps sounds appealing when considering using a LAN for interfacing to external I/O devices. Reality is different though; you have to consider the inefficiencies of any start-stop burst protocol, plus grief/lock effect caused by collisions and other users sharing the network.

This form of Ethernet is simplicity itself; all workstations are connected together in a peer-peer fashion with a 1:1 termination at each end of the chain.

Data packets are just bursts of raw data fed into the impedance of the wire, and are re-adapted by the receivers.

Transmitters fire bursts more or less without the knowledge of any other transmitters. Collisions - i.e. when two generators feed the wire at the same time - are detected by an abnormal rise in the voltage on the wire due to two or more currents superimposing. Each transmitter then waits for a certain random time before trying to transmit again.

The flat, or twisted, cable used is known as 10Base-T - use separate right-and-left wires for transmit and receive; this gives better immunity and transmission quality.

Access to the chip is via a number of drivers that allow connection to the network. Usually arranged as 16-bit I/O or memory locations. Most chips can be directly connected to a CPU memory bus, or even directly to a network card. The blocks of data being transferred are stored in FIFO memory, as a buffer.

A 4-byte frame comprises a 6-byte destination and source addresses, plus a field word indicating the type of payload carried. The most common payloads are TCP/IP and UDP. The frame is a string of 52 bits used to synchronize the internal clock generator. A 4-byte header precedes the data to allow the integrating circuits to check for CRC validity before placing the data block in the RAM buffer.

Etherometrics has a header consisting of a flat MAC address, a 6-byte destination address, and a 2-byte protocol identifier. This provides the data carried by the payload, which as mentioned before, may only have between 46 and 1500 bytes.

The payload contains a set of data in another part of the RAM buffer, and sets a flag, which is usually reset at the end of transmission.

More detailed information on the workings of Ethernet interface chips can be found in manufacturers' data sheets. Unfortunately, an Excel spreadsheet for estimating these delays.

In terms of hardware support, there are dedicated Ethernet interface chips available from various manufacturers. Most are compatible with a standard genetic architecture, known as NE2000. They have a standard 8 or 16-bit data bus interface, compatible with most CPU addressing schemes.

Access to the chip is via a number of drivers that allow connection to the network. Usually arranged as 16-bit I/O or memory locations. Most chips can be directly connected to a CPU memory bus, or even directly to a network card. The blocks of data being transferred are stored in FIFO memory, as a buffer.

Protocols, addressing and payload

Ethernet data packets - better known as frames - cannot be of just any size. If you were to do some simple calculations involving the maximum distance between workstations, the speed of light in coaxial cable and various other time considerations about collision detection, you would work out that frames cannot contain fewer than 46, or more than 1500 payload bytes each, Fig. 4.

Every Etherometrics frame has a header consisting of a flat MAC address, a 6-byte destination address, an 8-byte protocol identifier, and a 2-byte payload length.

On receipt of a frame without errors, this is passed to the next layer in the stack. The protocol identifier field specifies which type of protocol the payload contains. For example, 0x806 denotes an Internet protocol, or "IP" message.

The payload will have its own header and payload part, which are dealt with by the next layer in the stack. This is the concept of protocol 'layers', Fig. 5.

It is important to know that Ethernet data frames are defined completely independently of each other. Frames are fired like bullets out of a gun, and, apart from a collision detection mechanism during transmission, what happens to them afterwards is of no further concern to the transmitter. In other words, the Ethernet network layer does not provide for any form of flow control or error detection.

At the other end, received frames are checked for consistency by Describing their CRC. Frames arriving with errors are simply dropped or ignored. It is up to the higher layers to provide for any form of flow control and error.
protection.

It is also relevant to note that the source and destination addresses are "hardware" addresses. Known as media access control, or "MAC", numbers, they refer to 6-byte patterns uniquely associated with each Ethernet card and usually assigned at manufacture.

In practice, the address is stored in a separate EEPROM on the PC card. A network of addresses are assigned by the IEEE to each manufacturer, so when you buy a PC card, it will have its own unique number stored in it.

You can change this number if you want to. Apart from some simple restrictions, such as the first byte in the sequence must have a '1' and a '0' as its least-significant bits, any number can be used as long as there are no clashes with other cards in your network.

It is not practicable to rely on fixed hardware addresses when managing a real computer network. Therefore, a more flexible form of addressing is used. This addressing scheme consists of four byte sequences, known as "IP" addresses. They are displayed for human consumption as four decimal numbers, e.g. "192.168.0.1".

In a computer network, each workstation is allocated its own IP address, maybe once only by the network manager, or dynamically at various times by a program in the network server. Each workstation with an Ethernet card will also have its own hardware MAC address. The four-byte IP address means nothing to the Ethernet card. Ethernet frames contain only MAC addresses as destinations. Sending a packet of data to a remote location requires knowledge of its MAC address. If you connect a black box into a network containing a controller and data logger for example, you must allocate an IP address, and notify everybody else of it. But how does the rest of the network know what our hardware MAC address is, and how to access the controller? You need to know about ARP to answer this one. For more on Ethernet and IP, see RFC840.

ARP

If I mentioned earlier, the payload in an Ethernet frame can carry formats other than IP. One such simple query-response packet protocol used to match workstations hardware addresses, and an ARP address stands for an address-resolution protocol.

In a typical network, computers spend a small part of their time sniffing each other, that is, sending short probe packets too see who else is around. This is usually done on a regular, or even a "need to know" basis. The ARP protocol is used just for that. It makes use of a special MAC "broadcast" destination address (0-FF-FF-FF-FF).

All Ethernet stations on the network access broadcasts. The broadcast message basically says, "Hey out there, anybody with IP address 190.168.0.15?" The one and only station having this IP address allocated will then reply with a packet stating its hardware MAC address.

In a Windows network each workstation builds up and maintains a local table of IP versus MAC address pairs. Before sending a message to another station, the table is consulted. If there is no entry, an ARP query message is sent out. The table is dynamically maintained, refreshed and refreshed every few minutes.

Windows provides a number of tools and facilities, mainly supplied as DOS programs, which you can use to see this in action. Open an MS-DOS command box in your Windows, enter "C:\ARP\ARP" and the program is not available in your machine, try installing these components from the new version. Any programs/communications tools Wizard. The program will show you a tree of the programs/communications tools Wizard. The program will show you a tree of your machine components.

Remember that the tables are dynamic and refreshed every few minutes.

Next, enter: C:\ping 192.168.0.15 -t. Then you will see all replies, then try "C:\ccump" again. Assume that your prototype controller is connected to the network, the action will show you the delay, the response time, and the echo time for the route to be taken.

In order to use the echo, the controller must include some form of ARP relay processing in order to respond to echo messages sent by other stations on the network. The controller also needs...
Fig. 6. Commands are available from the DOS prompt that allow you to check your network interfaces. A PC workstation maintains a local cache of other network addresses, which is dynamically updated every two minutes or so. Network stations regularly transmit ARP packets to each other to maintain their caches up to date. The DOS command arp is used to display and/or update your local cache.

ping 192.168.0.1

Fig. 7. Ping sends a probe packet to a remote IP destination, which just echoes the packet back. The sender can use the information collected on the way to deduce aspects of the path, delays, users, route taken, etc. The name ping is derived from submarine echo sounders. Ping is a very useful facility for advanced network users. The material described in this article can be used to generate custom ping type packets.

It is also relevant to note that the source and destination addresses are "hardware" addresses. Known as media access control, or "MAC", numbers, they refer to 6-byte pairs usually associated with each Ethernet card and usually assigned at manufacture.

In practice, the address is stored in a separate 48-bit EPROM on the PC. The blocks of 8-byte MAC addresses are assigned by the IEEE to each manufacturer, so when you buy your PC card, it is likely to have its own unique number stored in it.

You can change this number if you want to. Apart from some simple restrictions, such as that the first byte in the sequence must have a '1' and a '0' at its least-significant bits, any number can be used as long as there are no clashes with other cards in your network.

It is not practicable to rely on fixed hardware addresses when managing a real computer network. Therefore, a more flexible form of addressing is used. This addressing scheme consists of four byte sequences, known as "IP" addresses. They are displayed for human consumption as four decimal numbers, e.g., "192.168.0.1".

In a computer network, each workstation is allocated its own IP address, maybe once only by the network manager, or dynamically at various times by a program in the network server. Each workstation with an Ethernet card will also have its own hardware address.

The four-byte IP address means nothing to the Ethernet card. Ethernet frames contain only MAC addresses as destinations. Sending a packet of data to a remote location requires knowing its MAC address.

If you connect a black box into a network containing a controller and data logger for example, you must allocate it an IP address, and notify everybody else of it. But how does the rest of the network know what our hardware MAC address is, and how to access the controller? You need to know about ARP to answer this one. For more on Ethernet and IP, see RFC904.

ARP

As I mentioned earlier, the payload in an Ethernet frame can carry various Ethernet protocols. One such format is ARP, which is a simple query-response packet protocol used in match workstations hardware addresses and IP addresses. ARP stands for address-resolution protocol.

In a typical network, computers spend a small part of their time sniffing each other, that is, sending short probe packets too see who else is around. This is usually done on a regular, or as a 'need to know' basis. The ARP protocol is used just for that. It makes use of a special MAC 'broadcast' destination address (0XFF FF FF FF FF).

All Ethernet stations on the network advertise broadcast messages. The broadcast message basically says, "Hey out there, anybody with IP address 192.168.0.1?" The one and only station having this IP address allocated will then reply with a packet stating its hardware MAC address.

In a Windows network each workstation builds up and maintains a local table of IP versus MAC address pairs. Before sending a message to another station, the table is consulted. If there is no entry, an ARP query message is sent out. The table is dynamically maintained, flushed and refreshed every few minutes.

Windows provides a number of tools and facilities, mainly supplied as DOS tools, for examining this ARP table, which you can use to see this in action. Open an MS-DOS command box in your system and enter "c:arps" as the program is not available in your machine, try installing these components from the new programs/communications tools Wizard. The program arp will store a copy of the table, which may be useful, especially if there was no recent network activity. Remember that the tables are dynamic and flushed every few minutes.

Next, enter "C:>ping 192.168.0.15" or the address of any other station on your network — and wait to see any replies, then try "C>:arp -a" again. Assuming that your prototype controller is connected to the network, the action will be immediately obvious. You can try other commands, e.g., "arp -s MAC_ADDR 192.168.0.15", or "arp -d 192.168.0.15".

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Internet Protocol

Internet protocol, IP for short, forms the backbone of all TCP and UDP messaging. Like the rest, each IP packet—better known as a datagram—has itself a header and a payload component. RFC 793 is the basic document describing IP. Within the IP header, the most important items of information are the source and destination IP addresses. For local communications between two stations in a local loop, the IP address in the IP header and the MAC address in the Ethernet frame header just preceding it will correspond to the same workstation computer. This may sound like unnecessary repetition, but this pairing is required for routers, where the fields may be different. There are other various fields including a checksum, a fragmentation pointer, a protocol code for the payload, and the payload itself.

Like Ethernet frames, IP datagrams are independent of each other and contain no built-in error protection or recovery. So why is IP necessary? Well, IP is the common layer above all hardware-dependent transport mechanisms. Irrespective of how the devices are electrically connected together—be it via fibre, radio or phone lines—all data blocks end up as comparable IP datagrams.

The job of IP is to get the data block to its destination. Its main contributions are addressing, routing and fragmentation.

Remember how Ethernet frames had a limited byte size range? Similar limitations also apply to other transport mechanisms: optical fibre, satellite links, etc. Internet protocol allows datagrams to be chopped (fragmented) into shorter sections of the right size for transmission and vice versa: short sections packed into single, longer datagrams.

The method employed for fragmentation is relevant for embedded systems. Fragmented datagrams include a 'pointer' indexing the position of the first byte of their data payload in an imaginary 64kb data buffer. Therefore, each IP datagram contains exact information about the position and size of their payload within this imaginary buffer. This allows for fragmented datagrams to be received out of sequence. A receiver accumulates datagrams until they all neatly fit into a contiguous block. It follows that fragmented IP datagrams are not really independent of each other. This will introduce an element in any system. A receiver for example, has to consider when to give up waiting for missing out of order packets, and dump any previously stored.

Fragmented datagrams cause problems with small embedded systems. In theory, a receiver needs to allocate a 64kb buffer for every first out of sequence datagrams received. This means one buffer for every different open socket (or channel) being serviced. This is impractical for small RAM limited systems.

One practical solution is to disallow or ignore fragmented IP datagrams. This may not be much of a problem if the transactions involved are small, e.g. for a small data logger. However, there may be problems for systems dealing with long streams of block-encoded data such as voice or video.

Fragmentation is not much of a problem with TCP (see later on) as TCP can be engineered to use small fragments.

In a typical situation, an embedded system needs to deal with many sources or originators. Datagrams may be arriving from more than one source at the same time. The microcontroller will need to keep track of all, keeping state variables for each connection, to ensure the right replies are sent back to the right originators. In a PC this is an easy task using concurrent threads. But small microcontrollers do not have such niceties.

Three types of IP payloads are of interest here: ICMP, UDP and TCP.

ICMP

ICMP stands for 'Internet control-message protocol'. This is not a protocol used to transfer messages, but rather to provide a kind of internal maintenance messaging service.

One of the most common uses for ICMP is a service known as 'pinging'. This is a method where a workstation queries another by transmitting a special short 'ping' massage and wait for an echo response, Fig. 7.

Any embedded implementation transfers. Think of telephone extensions working off a main private exchange number.

Document RFC 768 fully describes UDP. Sending a UDP message is somewhat like sending a postcard to a friend, a simple 'shout and forget'-type protocol can be very useful in networks that are reliable to start with such as LANs.

This method is normally used for simple file transfers and remote booting of PCs. It is also used anywhere where a failure to receive is not a disastrous issue, or one that can be simply compensated by a repeat transmission later on.

Because of this simplicity, UDP is a simple protocol to implement in an embedded application. Simple error recovery can be implemented at the user level. This can take the form of a timeout on receive or a simple acknowledgement with a repeat message.

Open a connection is done by sending a special 'echo request' to the target IP address. The response message is then sent back to the originator. It is also possible to send a query to be acknowledged if more than one computer is needed.

ICMP messages are typically sent as 'ICMP echo request' messages. Writing the software at the PC end is also easy, as the program in List 1 shows.

The controller described here uses UDP to demonstrate simple echo and write to a parallel and the analogue port. It also uses UDP for simple data connection so and from the serial port. UDP is an effective protocol for developing special user applications.

RFC 793. You will find additional information in RFC 896, 1122, 1232 and 2018.

Traditionally, error and flow control in telecommunications were handled at the lower layers. It was recently discovered that lower-layer error handling is not as effective as higher layer handling. This is one of the reasons why the layers below TCP do no need to provide any form of error or flow management.

In UDP, statistics just show packets at each other. TCP requires the two stations to establish a 'connection' first. Once the connection is established, data can flow from one station to the other. Opening a connection is done by sending a 'connection request' message to the target IP address. The response message is then sent back to the originator. It is also possible to send a query to be acknowledged if more than one computer is needed.

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Table: Data and UDP

<table>
<thead>
<tr>
<th>Data</th>
<th>UDP</th>
</tr>
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<tbody>
<tr>
<td>Uses</td>
<td>Goals</td>
</tr>
<tr>
<td>Segment</td>
<td>Transport Layer</td>
</tr>
<tr>
<td>Data</td>
<td>8-bit short integer</td>
</tr>
</tbody>
</table>

Fig. 8. Simplified diagram of a TCP connection. These stages are essential: setting up the channel, the actual data transfer process, and closing down the connection. State transition tables are generally used in the implementation to handle the overall process. One set of table data and memory buffers will be required for each open point connection. This is not practical for small microcontroller memory-limited applications.

Transmission control protocol (TCP)

TCP is a protocol used to ensure reliable transport of data over a network. It provides a connection-oriented service, which means that data is sent in a consistent order and is acknowledged by the recipient. TCP uses a three-way handshaking mechanism to establish a connection before data transmission begins. This ensures that both the source and destination have established a two-way communication link.

TCP segments are sent in a series of packets, which are then reassembled at the destination. Each packet contains a sequence number and an acknowledgement number. The sequence number indicates the order in which the segments were sent, while the acknowledgement number indicates the expected next sequence number.

TCP also includes error detection and correction mechanisms. It uses a sliding window mechanism to control the flow of data and to avoid congestion. If data is lost or delayed, TCP will detect the problem and request retransmission of the lost or delayed packets.

TCP is a reliable protocol, but it can be slow and resource-intensive. It establishes a connection for each end-to-end data transfer, which can be inefficient for short or small amounts of data.

Example of a transmission control protocol (TCP) connection:

- **Host A** sends a request to **Host B**.
- **Host B** sends a response, acknowledging the request.
- **Host A** sends data, followed by anACKnowledgment (ACK) packet.
- **Host B** acknowledges the data packet and waits for the next data packet.
- This process continues until all data is transferred.

TCP is widely used in the Internet, providing a reliable and efficient way to transmit data between hosts.
Useful web sites
National Semiconductors Ethernet Chip data sheet
www.national.com/doc/dsp430x.pdf
General X10 Home Control Information:
www.x10.com
More information on embedded Ethernet controllers:
www.embedded.com, www.chipcenter.com,
RFC papers are available from various websites in different formats. Try one of the search engines such as www.google.com and enter the search word "RFC".
Useful article on Ethernet throughput and RTSP
www.snomag.com/articles/110223/main.shtml

Further reading
TCP/IP Illustrated, Vol. 1, W. Richard Stevens, Addison Wesley, 2000. A very comprehensive guide for all aspects of TCP/IP. This is one of the best known books in the subject.

The author
Dr. Eddy Ismail is a consultant in innovative applications of telecommunications and specialises in graphics and signal processing. He can be reached on eddism@unisa.co.za.

PC INTERFACING

Table 1. Simple C code for the PC to use with the Winsock API to communicate with an external I/O device. Refer to the literature for more examples. This development program shows how Winsocks can be used for communicating between a PC and an embedded ethernet device. This is a Windows centric application to open, read a SDOS box, and then exit. The program was written in C++.

```
//hardcoding the message for this demonstration.
char prf[16];

// The actual TV call
SOCKET sta=socket(socket(AF_INET, SOCKET_STREAM, 0)); if (sta==-1) {
    printf("SOCKET ERROR\n");
    return(sta);
}
//Must initilize the sockaddr_in structure.
socklen_t len=sizeof(struct sockaddr_in);
//Must set the address, port and protoco... first before sending.
sta=socket(AF_INET, SOCKET_STREAM, 0); if (sta==-1) {
    printf("SOCKET ERROR\n");
    return(sta);
}
//Send the data packet, we now need to wait for a response before calling the receive function.
//We can use Winsock timeouts so if no data received
if (write(sta, prf, len)==-1) {
    return(sta);

//while no data in rx buffer, 
//Before we need to call initilize function.
//We can use Winsock timeouts so if no data received.
while (write(sta, prf, len)==-1) {
    printf("No data in RX buffer...
");
    // Again, no need to include this function in your program.
    // This is only here to show a possible way of sensing if there are no data.
    // Or, you can use the RX bytes left in the receive buffer before calling receive.
    if (recv(sta, prf, len)==-1) {
        printf("No data, exit!
");

//Close the receive socket... now data has been received.
if (shutdown(sta, 2)==-1) {
    printf("SOCKET ERROR\n");
    return(sta);
}
//Close the receive socket... now data has been received.
if (shutdown(sta, 2)==-1) {
    printf("SOCKET ERROR\n");
    return(sta);
}
```

In the next article, Eddy discusses ways of implementing a simple controller based on a PIC 16F877 and a standard LAN PC card. The controller can be used for demonstrations or as the basis for an embedded prototype interface project.


Closed. The state table is described in Table 793.

Implementing the full set of TCP requirements in an embedded system is not trivial. Including each and every combination of events, states and actions will readily inflate a micro's valuable program and memory space. In addition, threads are not easily implemented in the small CPUs used in embedded systems.

Furthermore, some simplifications can be made if the connection has been coherent for a long time, and it is resilient to repeated and random errors. Depending on the use it is put to, it is possible to implement a perfectly workable "bit-aware" version of TCP in an embedded processor.

Telnet, HTTP, FTP SMTP ...
Telnet, HTTP, FTP and SMTP are higher level application protocols. They were designed to be specific end-to-end purposes - FTP for file transfer, SMTP for mail, HTTP for web access.

These protocols have one thing in common. They work by sending and receiving streams of bytes, usually ASCII characters, down an already opened TCP connection.

In terms of implementation, these are relatively simple. One just needs to generate the right sequence of characters. As long as there is an existing TCP open channel to convey the characters, you could even use some BASIC-like programs.

Implementing a simple web server involves nothing more than writing a program that receives an ASCII serial stream, sends character sequences, and sends back another sequence of characters.

RTPS - real-time networking
A number of alternative network models exist. Most are designed for particular applications such as stream voice, video, and real time control.

An abbreviation for "real-time publish subscribe", RTSP is a good example of a recent innovation in networking models. Node owners send data onto a network or "subscribe" to any data from the network. Subscribers eliminate the need for request traffic.

The model is aimed at real-time control systems using the Ethernet, where speed of response and reaction has to be tightly controlled. A number of companies, among them General Motors, have evaluated the use of Ethernet in such schemes, and have found it a very reliable real-time transport medium.

RTSP technology is very recent, and typically a number of similar developments are moving away from the limitations of TCP. Companies such as RTI (www.rti.com) are offering components and toolkits under a $10k licence.

For some small real-time applications, a subnet cable technology is all that may be necessary. I have been looking at some implementation possibilities and can see that this is an area that will see a lot more development in the future.

The author
Dr. Eddy Ismail is a consultant in innovative applications of telecommunications and specialises in graphics and signal processing. He can be reached on eddism@unisa.co.za.

If you are considering a server application for this device, Eddy will endeavour to answer your queries via e-mail.
Useful web sites
National Semiconductors Ethernet Chip data sheet
General X-10 Home Control Information:
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www.embedded.com, www.chipcenter.com,
RF-C papers are available from various websites in different formats. Try one of the search engines such as www.google.com and enter the search word "RFC".
Useful article on Ethernet throughput and RTSP:
www.syscom.com/articles/110222/main.htm

Further reading
TCP/IP Illustrated, Vol. 1, W. Richard Stevens, Addison Wesley, 2000. A very comprehensive guide for all aspects of TCP/IP. This is one of the best known books in the subject.

The author
Dr Eddy Ismail is a consultant in innovative applications of telecommunications and specialists in graphics and signal processing. He can be reached on eddyismail.co.uk.
If you are considering a serious application for this device, Eddy will endeavour to answer your queries via e-mail.
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RS 446 personal mobile radio...

To celebrate its launch, new test and instrumentation company Tecstar is offering Electronics World readers two RS 446 personal mobile radios for just £75 excluding VAT and carriage.

Capable of transmitting and receiving voice over a distance of up to two miles, depending on terrain, the PMR 446 needs no licence. It offers eight channels, scanning – and with CTCSS up to 304 channel combinations. A backlit liquid-crystal display shows volume level, channel number, sub-channel number, battery level and transmit/receive or channel busy. A unique call feature enables the user to alert the person they wish to contact.

Transmission distance is up to 2 miles. The radio has an accessory socket for an external headphone, earpiece or vox-microphone/telephone combination. A keyless lock and battery save feature are also standard.

The unit measures only 120 by 50 by 20mm and weighs less than 150 grams – including batteries. It is supplied complete with instructions and belt/clip mounting.

Compact, lightweight and low cost, the RS 446 wireless personal-communications hand set has a wide range of applications. These include police, and events and rallies. Builders on building sites could benefit from these radios, as could exhibitors at exhibitions and staff at warehouses, winter activities, sports events, maintenance departments, schools and care homes. Of course you can also use the RS 446 just to keep contact with someone locally. The uses are almost limitless.

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- Backlit display for night time use
- Unique call function
- Headphone and microphone sockets allow discrete use
- Battery status indicator
- Auto battery save feature
- Keypad lock-out

What is CTCSS

CTCSS – or ‘continuously tone controlled squelch system’ – allows sub-channels of the main channels to be used. There are 38 sub-channels to each main channel. Using subchannels decreases the likelihood that someone else will be using the same frequency.

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The quest for performance in today's mobile world means that high power consumption is the curse of chip designers, but plenty of solutions exist. Richard Ball explains the traditional approach and looks at the latest attempts to keep pace with clock speeds.

Today's trends continue, by 2015 we'll all be carrying small nuclear power sources to keep our laptops going. Why? Because microprocessors will be consuming far more juice than a V8 dragster and spewing out more heat than a rocket nozzle. So claims Pat Gelsinger, CTO of Lanti's architecture group.

Mind you, such comments are a bit rich coming from the company that's done more than most in the race to push up clock speeds.

So why are we heading towards nuclear-powered laptops, and what are chip designers doing about it?

The quest for performance has often been at the expense of power consumption — witness Compaq's latest Alpha processor which runs at 1300MHz and produces 125W. Mind you, it has 130 million transistors.

One of the traditional routes to higher performance is increasing the number of pipeline stages in the processor. As each stage has less to do, the clock speed can increase.

Increasing the pipeline depth might increase the clock speed, but it's a dubious method of improving overall performance and is definitely bad for power consumption. Pentium 4 and its 20-stage pipeline, for example, processes fewer instructions per clock than Pentium III on conditional code, and hence its power/performance ratio is worse.

As IBM paper at this year's ISSCC conference nicely sums up pipelining: "A deeper pipeline could have yielded even higher frequencies, but at the expense of reduced instructions per clock (IPC). Processor performance is not proportional to frequency but rather the product of frequency and IPC."

Another well trodden route to performance is parallelism in the processor — placing two, four or more arithmetic units in parallel to do more work in a single clock cycle.

The problem with these superscalar designs is that if the pipeline code can't be written or reordered to take full account of the processing resources, then performance is wasted. And this happens a lot in systems with parallel architectures.

The end result is more heat for less useful work.

Plenty of solutions exist to the problem of high power consumption in processors and hence, to a certain extent, any system-on-chip. However, different solutions fit different markets and applications.

Dynamic clock and voltage management

Power consumption in a circuit is proportional to frequency, but it is also proportional to the square of the voltage. Therefore, the easiest way to cut power is to reduce the voltage.

This does mean a reduction in frequency, but if the loss in performance can be absorbed, then the reduction in current and power will be well worth the effort.

Intel has certainly taken this approach with XScale, its second generation successor to StrongARM. At one end the chip can run from 1.6V, limiting 800MHz and consuming 900W. Throttling back the voltage to 1.0V, however, sees the clock bandwidth reduced to 400MHz while power plummets to 180W. At the other end the power reaches just 10W at 0.75V and 500MHz.

XScale’s power restrictions in 'system-on-a-chip' devices

Hitachi has taken a fresh look at power restrictions in system-on-chip-based appliances and come up with a hardware-based on-chip power management system called ChipOS, writes Steve Rush.

Processors tend to draw power in bursts. Inconveniently, power supplies have to be sized to match the power peaks, or include chunky capacitors to meet peak demands. This problem is particularly bad in battery-powered devices where a high peak draw can bring a pair of AA cells to their knees and cause a system reset.

ChipOS tackles this by allowing the system designer to specify a maximum power draw from a system-on-chip. The same chip, running the same software, can be allowed to run free in a mains-powered application, and peak-limited when battery powered.

And this peak limit is accurate, rather than just the average reduction which comes from processor clock speed switching.

Hitachi claims to the detrimentChipOS could be used in a low cost 1W system or 10W high-performance system. When multithreading, one task may be given priority and allowed to have all the processor's capacity up to the imposed power limit during an activity burst. The other tasks will be slowed or stalled until power becomes available again.

Power limiting clamps the overall performance of the system, but Hitachi's figures for an undisclosed single-processor application show a 40 per cent reduction in peak power only results in 10 per cent slower system speed.

With four processors under the same ChipOS controller, an 81 per cent reduction in peak power was available with 14 per cent slowing. The penalty with ChipOS is additional hardware. Logic blocks have their clocks gated, and their power rails switched.

Associated with each block is a block-specific power driver, which controls clock gating, and rail switching. Running above this is a power scheduler that uses knowledge of block power requirements to allocate blocks to tasks.
The quest for performance in today's mobile world means that high power consumption is the curse of chip designers, but plenty of solutions exist. Richard Ball explains the traditional approach and looks at the latest attempts to keep pace with clock speeds

Power consumption runs wild

According to Patrick Gelsinger, chief technology officer of the Intel architecture group, increasing the absolute performance from the processor series has resulted in less and less performance per gate per megahertz. The law of diminishing returns has taken over and increasing power consumption is the result. Intel's current Intel trends continue chip power density will reach that of a nuclear reactor in 2007 and dissipation will be the same as the surface of the sun, 1300W/cm², in 2015. His solution is less brute force - so smarter branch prediction and pipelines - and processors designed for specific tasks. Perhaps Intel is waking up and breaking out of the Windows-PC mould.

Semiconductor process

Improving the semiconductor process is the simplest trick in the book for reducing power consumption. As the geometry size reduces, voltage is forced down - most of the time - and so power drops quickly.

Today the work-horse process is 0.18µm, but in R&D labs, firms are building circuits on 0.13µm or smaller. At this level some significant problems are beginning to surface.

As gate lengths decrease, then the gate oxide thickness must also reduce, and this defines the maximum voltage of the transistors. But for high performance devices, this thin gate oxide will result in high leakage current. For low power, a thicker gate oxide will impact performance. Therefore many firms, such as Toshiba, IBM and Motorola, are using different flavours of transistors in a single device.

Motorola's 0.13µm (130nm) process detailed at last year's IEDM conference has gate lengths from 80 to 110µm, and gate oxide thicknesses of 1.8nm, 2.5nm for low power, 5nm for 2.5V IO and 7nm for 3.3V IO.

Another way to reduce leakage current and parasitics is to use a so-called-in-silicon. Devices by IBM, this technology may well be used by AMD in its mobile PC processors.

Simultaneous multi-threading

SMT is not a new idea – it was first used by Cray in one of its chips over 30 years ago. However, the idea is only just appearing in mainstream devices, and it promises much, especially in the server or telecoms markets.

In a superscalar processor – even with the greatest compiler in the world – a single thread is hard pressed to keep all the execution units active. In deep pipelined devices, a cache miss or mis-predicted branch causes power restrictions in 'system-on-a-chip' devices

Hitachi has taken a fresh look at power restrictions in system-on-a-chip-based appliances and come up with a hardware-based on-chip power management system called ChipOS, writes Steve Rush.

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Associated with each block is a block-specific power driver, which controls clock gating, and rail switching. Running above this is a power scheduler that uses knowledge of block power requirements to allocate blocks to tasks.
Alchemy is a name to be reckoned with in the chip design world, having its ancestry in the original StrongARM team. Its first chip, the Au1000 (above), is back from the lab and undergoing testing. Like Xeactus, clock frequency and hence power can be dynamically scaled. Initial figures indicate that running at 1.25V and 200MHz, the chip dissipates 300mW, while at 1.3V and 400MHz power is up to 560mW.

Electromagnetic gun fires a pellet 20km in a second

Sandia Labs' Z machine electromagnetic pellet accelerator has boosted a projectile to 20km/s - i.e. 45,000m/h. Inside Z machine, 20 million amps produces a magnetic field that expands in around 200ns and generates "several million atmospheres pressure" on the pellet, according to Sandia. When fired up to 13km/s, the aluminium pellets are neither distorted or melted, but with the wick turned up to achieve 20m/s the aluminium reaches 2500K and liquefies. Research over the last year has been keep this temperature down as the pellet can no longer be accelerated once it vapourises. The picture shows researcher Mark Knudson holding two pellets in his right hand and the chambers of Z machine on his left.

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Large chunks of data to be flushed - wasting a considerable amount of power.

Multi-threaded processors can fill alms in the instruction issue with waiting threads. So the whole thing runs faster, or to look at it another way, the same amount of work is done with less wasted power. However, SMT doesn't come for free - it adds around ten per cent extra hardware.

SMT may be about to become mainstream, especially if, as is rumoured, Intel puts it in Pentium 4. It's already in the latest Alpha, described earlier.

Clock distribution

Better clock distribution design is also an avenue to reducing power dissipation, as a processor's clock tree can have a massive overall impact. For example, another IBM paper from ISSCC describes its POWER4 chip. This dual microprocessor device contains a staggering 170 million transistors. At 1.1GHz it consumes around 115W.

"Approximately 70 per cent of the power is burned in the clock distribution and latches," the firm says.

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Voltage or current drive?

Moving-coil loudspeakers are invariably driven by a voltage amplifier. Here, John Watkinson explores the alternative — current drive.

Generally the audio industry does nothing about this problem, even though the cone velocity becomes anti-phase to the input below resonance, making the output waveform a travesty of the input. Instead, new clothes continue to be made for the Emperor long after his death. With voltage drive, a number of other factors can affect the cone velocity and potentially cause distortion. These include non-linearity and coil inductance. If the coil inductance were constant, the result would just be an HF roll-off. Unfortunately, coil inductance changes with the cone position, so the effects of different amounts of the pole structure are within the coil. The inductance of the drive unit is also a function of coil temperature, which itself is a function of the power dissipated.

Implementing current drive

Effectively, the power amplifier has become a transconductance amplifier. Figure 2b) shows that current drive can be achieved by providing a sense impedance of the amplifier means that there is no electrical damping of the drive unit's fundamental resonance at all. The only damping is due to the drive unit's own structure, with a tiny amount due to sound radiation. The strong response is audible and the drive unit can easily over-drive. Consequently the designer is forced into making some active compensation for the drive unit fundamental resonance in the shape of an analogue computer-taped circuit or DSP. In fact this is no great drawback, because this has to be done with voltage drive if any degree of precision is required. The difference is that with voltage drive it is possible to dispense with resistance compensation if a lower quality is acceptable.

At low frequencies the drive unit becomes compliance controlled. Non-linearities in the suspension, and modulation of the driver product with coil position, will cause distortion, of voltage or current drive is used. In fact given good engineering and a correctly designed resonance-compensation mechanism, voltage and current drive would give exactly the same effect at low frequencies; the sound quality would be limited by the drive unit.

Inductance modulation is negligible at LF. The distortion there is dominated by magnet and suspension design, which amplifier topologies can't affect.

The main advantage of current drive would appear to be in tweeters, where the elimination of the effects of coil inductance can give a useful improvement in frequency response and linearity. Tweeters tend to be used well above their fundamental resonance, so the lack of damping there may not be an issue. At low frequencies, the use of current drive is less compelling because the problem comes down to one of precision drive unit design. If the suspension is non-linear, or if the HF product changes as the coil moves because of an asymmetrical flex pattern, the choice of drive topology is irrelevant.

As has been stated countless times, to make a fine loudspeaker it is necessary to have line drive units.

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Fig. 2. Current drive principles. In a) with infinite output impedance, current is independent of coil resistance and inductance (and back EMF). Figure 2b) shows how current drive can be achieved using a back-current sense resistor.

Fig. 1. Most loudspeakers don't recreate the input waveform. In a) the ideal system with a zero output impedance amplifier and zero coil resistance speaker. Fig. b) depicts a real system. Even though Vcoil is close to zero in a real amplifier, coil resistance and inductance mean that back EMF is not equal to Vback. Cone is not under control of input waveform.
Voltage or current drive?

Moving-coil loudspeakers are invariably driven by a voltage amplifier. Here, John Watkinson explores the alternative – current drive.

Traditionally, the moving coil loudspeaker drive unit has been connected to a voltage amplifier. Figure 1a) shows that an ideal voltage amplifier has zero output impedance such that the voltage at the output terminals is independent of the load impedance. In practical amplifiers this requirement is typically met with negative feedback, which simply compares the output voltage waveform with the input signal waveform. Figure 1b) also shows that an ideal drive unit would have zero resistance and zero inductance. The only factor controlling the coil current is the back EMF. Any difference between the amplifier output voltage and the back EMF would result in an infinite current, so the coil velocity would have to be proportional to the amplifier voltage.

Generally, the audio industry does nothing about this problem, even though the cone velocity becomes anti-phase to the input below resonance, making the output waveform a travesty of the input. Instead, new clothes continue to be made for the Emperor long after his death. With voltage drive, a number of other factors can affect the cone velocity and potentially create distortion. These include non-linearity and coil inductance. If the coil inductance were constant, the result would just be an HF rolloff. Unfortunately, coil inductance changes with the cone position and is different amounts of the pole structure are within the coil. The impedance of the drive unit is also a function of coil temperature which itself is a function of the power dissipated.

Implementing current drive

Figure 2a) shows an ideal current source driving a loudspeaker. An ideal current source has an infinite output impedance. The output current is proportional to the input voltage and is independent of load impedance.

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Fig. 2. Current drive principle. In b) with infinite output impedance, current is independent of coil resistance and inductance (and back EMF). Figure 2b) shows how current drive can be achieved using a load current sense resistor.
Power supply problems and solutions are the subjects of this second article describing Norman Thagard's high-performance, pick-up preamp, which exhibits 0.006% THD up to several kilohertz.

Phono preamp for the CD era

In the second part of this preamp project, you'll discover that paying close attention to good power-supply design and construction techniques offers its own rewards. I have favored on-board regulation since my digital design days. However, my amplifier designs have had discrete regulators located on their own separate circuit boards. This was partly because I used voltage-doubling techniques that added enough bulk to the double regulator that it was not practicable to place this circuitry on the preamplifier's PC board.

Here, I returned to my roots with small IC regulators located on the preamp circuit board.

Choosing a transformer

The current requirement for each preamp channel is only 20mA per rail, with another few milliamps required for the monolithic voltage regulator. Almost any transformer with sufficient secondary voltage should work.

I had a 48V, centre-tapped 150mA transformer in my parts bin. I also obtained a small 44V centre-tapped toroidal transformer at 73mA in case I decided to mount the power supply in the same enclosure as the preamp.

In the end, I decided to take the conservative step of placing the power supply, Fig. 1, in its own enclosure with the unregulated DC output supplied to the preamp through a connecting cable. So, I used the old parts-bin transformer.

If you want two true high-current channels, I would recommend using two of the aforementioned toroids and duplicating everything. I opted for the dual mono configuration, where the transformer secondary is the last common component with everything downstream electrically and electronically separate.

A given power transformer can radiate at a level sufficient to induce hum in the preamp. In theory, a toroidal transformer would restrict such field to the iron core. Even so, it is probably better to locate the AC power portions of the system away from the signal paths. If that is infeasible or impractical, I recommend a small toroidal power transformer located as far from the preamp boards as possible.

This is more than a theoretical consideration, since the hum induced in this preamp when it was located immediately above the audio amplifier's power transformer was intolerable loud. This occurred even though the prototype phono preamplifier is in a steel cabinet and the power amplifier used two toroidal power transformers.

Electrostatic shielding with aluminum foil will clearly not prevent such hum induction. Simply locating the preamp away from intense alternating magnetic fields is the most cost-effective solution. Moving the preamp just 6 inches away from the amplifier reduced the hum below the audible level.

Filter design

With such a small current requirement, it makes sense to try for additional ripple reduction by using two stages of filtering. This takes advantage of very large, but still very compact, electrolytic capacitors, where the usual capacitor-input power-supply filter is followed by an RC low-pass filter.

My criterion for the capacitor values was the size of those most readily available to me — four at 2200uF, 50V, and four at 470uF, 35V. The smaller capacitors are positioned as conventional capacitor-input filters, with one each in the positive and negative power supplies for each channel.

Four 220uF capacitors connect the four 2200uF capacitors to the four 470uF capacitors. In this way, each positive and negative power supply of each channel follows the raw DC output across the 2200uF capacitors with an RC filter of 1.08kHz (30Hz) cut-off frequency. This corresponds to a filter cut-off frequency of (2102C) -1/2 = 1.05MHz. Capacitors of 470uF would be perfectly acceptable.

The total amount of ripple attenuation provided by the filter circuitry depends on whether you use half- or full-wave rectification. I know that this is almost always full-wave in high-end equipment. However, the amount of ripple attenuation is so high that either type is acceptable in this application. It may be that the 60Hz hum from residual ripple in a half-wave supply is less objectionable than any 120Hz hum from full-wave rectification.

The idea is, of course, that no audible hum be present no matter what rectification scheme you use. There is no audible hum produced by residual ripple in this preamp with the power supply described here — a supply that uses half-wave rectifiers.

Since ripple is attenuated by a factor of ten (20dB) for each decade that the ripple frequency lies above the filter cut-off frequency, the second stage of filtering here provides, 20dB/decade x 2 decades = 520dB of additional reduction where 60Hz = 390

0.154Hz = 1.05

number of decades is z, where: 10^z=390;

log10(10^z)=log390=2.6

For this application, I chose 2200uF for the filter resistors. I assumed that the unregulated, but heavily filtered, output voltage delivered to the preamplifier circuit board would be no less than about 18V under worst-case conditions. The above relationships show that if you select the full-wave rectifier, you will obtain 60dB more ripple attenuation from the RC filter.

Ripple blips

At 5mV/division, the ripple on an oscilloscope is barely visible, appearing almost as a pulse train of small "blips." The blips are probably due to the heavy current flow during the short period during which charging currents flow through the rectifier diodes to the 2200uF capacitors of the capacitor-input filter.

A small resistor between the diodes and the capacitors would reduce the amplitude of the blips, but there is already heavy overlap here.

As a matter of interest, if ripple were to be reduced to 10mV with a capacitor input filter alone, the charging current through the rectifier diode would be about 5A even though load current is mere 25mA. Charge is the product of current and time. The charge removed from the filter capacitor during the 16ms cycle time (7-0.3ms in a full-wave rectified supply) must be restored to the capacitor during the short (or, well-designed supply) recharge period, dz.

If recharge (diode) current is considered constant (it is not, but the approximate answer so obtained is sufficient), then,

Irecharge=n x Iload x dz

Solving this expression for charging current yields,

Iload=Irecharge/n x dz

This formula already suggests that charging current will be much greater than load current because the small charging interval dz is so short in comparison to the relatively long cycle period T.

Although diode conduction actually continues past the peak capacitor voltage Vcmax if you assume that conduction begins at time t before it ceases at Vcmin, then voltage magnitude at the onset of conduction is Vcmincos(dx).

The quantity dx is the diode conduction angle, and for a
Power supply problems and solutions are the subjects of this second article describing Norman Thagard's high-performance, pick-up preamp, which exhibits 0.006% THD up to several kilohertz.

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In the end, I decided to take the conservative step of placing the power supply, Fig. 1, in its own enclosure with the unregulated DC output supplied to the preamp through a connecting cable. So, I used the old parts-bin transformer. If you want to use two true monaural channels, I would recommend using two of the aforementioned toroids and duplicating everything.

I opted for the dual mono configuration, where the transformer secondary is the last common component with everything downstream electrically and electronically separate. A given power transformer can radiate at a level sufficient to induce hum in the preamp. In theory, a toroidal transformer would restrict its field to the iron. Even so, it is probably better to locate the AC power portions of the system away from the signal portions. If that is undesirable or impractical, I recommend a small toroidal power transformer located as far from the preamp boards as possible.

This is more of a theoretical consideration, since the hum indicated in this preamp when it was located immediately above the power amplifier's power transformer was inaudible to loud. This occurred even though the transformer's primary and secondary were not electrically connected. Simple locating the preamp away from intense alternating magnetic fields is the most cost-effective solution. Moving the preamp just 6 inches away from the amplifier reduced the hum below the audible level.

Filter design

With such a small current requirement, it makes sense to try for additional ripple reduction by using two stages of filtering. This takes advantage of very large, but still very compact, electrolytic capacitors, where the usual capacitor-input power-supply filter is followed by an RC low-pass filter.

My criterion for the capacitor values was the size of those most readily available to me — four at 2.200µF, 50V and four at 470µF, 35V. The smaller capacitors are positioned as conventional capacitor-input filters, with one each in the positive and negative power supplies for each channel.

Place 2202 resistors connect the four 2200µF capacitors to the four 470µF capacitor. In this way, each positive and negative power supply of each channel follows the raw DC output across the 2200µF capacitors with an RC filter of 1.03kHz cut-off frequency. This corresponds to a filter cut-off frequency of (2πf)C=0.154MHz. Capacitors of 470µF would be perfectly acceptable.

The total amount of ripple attenuation provided by the filter circuitry depends on whether you use half- or full-wave rectification. I know that this is almost always full-wave in high-end equipment. However, the amount of ripple attenuation is so high that either type is acceptable in this application. It may be that the 0.60Hz hum from residual ripple in a full-wave supply is less objectionable than any 120Hz hum from full-wave rectification.

The idea is, of course, that no audible hum be present no matter which rectification scheme you use. There is no audible hum produced by residual ripple in this preamp with the power supply described here — a supply that uses half-wave rectifiers.

Since ripple is attenuated by a factor of ten (20dB) for each decade that the ripple frequency lies above the filter cut-off frequency, the second stage of filtering here provides, 20dBdecade×2.6 decades=52dB of additional reduction where 60Hz/154Hz=0.154Hz.

This formula already suggests that charging current will be much greater than load current because the small charging current is so small in comparison to the relatively long cycle period T.

Although diode conduction actually continues past the peak capacitor voltage V_m, if you assume that conduction begins at time t before it ceases at V_m, then voltage magnitude at the onset of conduction is V_mcos(ωt).

Filtering is required with the power supply described here — a supply that uses half-wave rectifiers.

Solving this expression for charging current yields, I_CHARGE=T=M/ΔT.

This formula already suggests that charging current will be much greater than load current because the small charging interval δτ is so short in comparison to the relatively long cycle period T.

Although diode conduction actually continues past the peak capacitor voltage V_m, if you assume that conduction begins at time t before it ceases at V_m, then voltage magnitude at the onset of conduction is V_mcos(ωt).

The quantity τ is the diode conduction angle, and for a...
half-wave rectifier the ripple frequency is \(377\text{c}^{-1}\). The peak-to-peak ripple voltage is therefore, \[ V_{\text{ripple}} = V_{\text{peak}} \cdot \text{cos}(\omega t). \]

Remember that \(\sigma\) is intentionally made small to reduce ripple to that the trigonometric approximation, \[ \sigma = \frac{1}{2} \left( 1 + \frac{1}{4} \text{sech}^2 \right) \]
is valid. If the output voltage of the supply is to be about 21V, then you can solve for, \[ \Delta t = \frac{2 \text{V}}{V_{\text{ripple}}} \cdot \text{sin}(\omega t), \]

To find this, it follows immediately that,
\[ \frac{\text{I}_{\text{peak}}}{\text{I}_{\text{rms}}} \approx 0.0167 \quad \text{and} \quad 0.0254 \approx 0.994 \]

A pretty impressive number.

Output current \(I_{\text{output}}\) is constant at about 25mA and the capacitor discharges for almost the entire 16.7ms period. \[ \text{The formula for the discharge of a capacitor at a constant current} \]

\[ C_{\text{discharge}} = \frac{I_{\text{constant}} \cdot t}{(1 + \text{sin}(\omega t))}, \]

will give that, \[ C_{\text{discharge}} = \frac{0.025 \times 0.0167}{0.9189} \approx 0.82\text{mC}. \]

Surge current through the diode in the power supply is of the order of 1.2A. This is still a pretty shanty number, but the surge rating on even small rectifier diodes is well in excess of this.

For example, a 1N4002 diode has a 30A surge rating, but is sold as a 1A rectifier. It should be clear why surge ratings need to be so much higher than the average DC load-current rating.

A capacitor of about 4200\(\mu\)F would be required to reduce the ripple to 10mA. Using the additional RC filter reduces the almost 200mV ripple to less than 0.5mV with far smaller capacitors.

It is enlightening – even eye opening – to look at things like this. Many designers treat power supply design very casually. I used to, too, until I bit me.

Voltage regulators
Unregulated output voltage from the rectifier/filter will vary, depending on the power transformer secondary voltage under load. Measured voltage was 24V at a current draw of 25mA with the transformer that I used.

Once you’ve selected the actual transformers, you could simply increase the rectifier value as the RC filter gets better, you could add yet another stage of RC filter so that approximately 15V would be presented in the preamplifier under load. In either case, it would require no voltage regulator.

Voltage regulators are certainly free to use other schemes, the one chosen here was to use 78L15 and 79L15 IC voltage regulators on the preamplifier circuit boards to supply the needed 15V power rails. The regulators are part of the main preamplifier circuit shown in the last month’s issue. Voltages from the regulators were limited to a 15V magnitude because of the 30V drain-source voltage limitation of the 2SC1010 JFETs.

Some features of on-card regulator are discussed in National Semiconductor’s Voltage Regulator Handbook. This publication is a good general reference for power-supply design.

As always, there are constraints you must consider. If the unregulated voltage is too high, the voltage and/or power dissipation limits of the regulators will be exceeded. If this voltage is too low, then the regulator will “drop out.” This means that it will cease to regulate because some active device within is no longer in its active operating region.

The regulator output is for the average operating region, although these limitations are slightly different for the 78L15 and 79L15 regulators, the worst-case limits require an unregulated voltage magnitude in the range of 17.5VDC to 35VDC. These regulators are widely available from several manufacturers, including the replacement series manufacturers such as ECG, ITE, and RCA.

Since parts numbers will vary, be careful to select regulators whose output-voltage tolerances are guaranteed to be within ±5%.

There are even tighter tolerance devices available if you wish to go to the trouble and expense of finding them, but it really isn’t necessary to do so.

In the interests of stability, each regulator will require the input capacitor shown, unless you place the regulator immediately at the output of the unregulated supply. With the recommended value for the 78L15’s input capacitor, there was an intermittent, low-amplitude, high-frequency oscillation. This was increased by increasing the capacitor value to 1000pF. For consistency, I also used 1000pF input capacitors for the 78L15 regulators.

A case could be made for deriving first-stage supplies from the output of the 78L15/79L15 regulators by using yet another RC filter, or perhaps a zener. This would mean that the first stage would operate at some lower voltage. This should be no problem, however, given that the output swing demanded from the first stage is significantly less than the required from the second.

Putting it together
Layout and construction details are reasonably well described in Figs 2-4. Nonetheless, I should elaborate on a few of the details.

As a designer, I always think about the possibility of modification or repair of the device, especially for the prototype version. For that reason, I liberally employ quick-disconnects (QDs) as well as transistor and IC sockets. The JFETs are not socketed here because of their unusual pin-out.

The power cable between power supply and preamplifier enclosure has QDs at both ends. If you use QDs on this cable, be sure that it has male connectors at the power-supply end and female connectors at the preamplifier end. In this way, even if you use Molex header-type connectors, the “hot” connector pins are reversed.

I have some reservations about claims of sonic effects of QD metals. Given this, I favour gold connectors because of past experience with other types’ reliability problems due to corrosion.

I mounted chassis-mount RCA jacks to the edge of the PC board, and used unstriped wire to both strip and ground the sleeve (outer portion) of each jack to the board.

The same mounting arrangement of the jacks, it was necessary to drill holes only in the front panel of the preamplifier enclosure, allowing the RCA jacks to protrude.
half-wave rectifier the ripple frequency is \(2 \times 377 \text{Hz}\). The peak-to-peak ripple voltage is therefore, \(V_{pk} = V_{dc} \times \sin(\pi \times \text{frequency}) \). Remember that this is intentionally made small to reduce ripple to that the time-average approximation, can be simplified as \(V_{pk} = \frac{2}{\pi} \times V_{dc} \). 

From this, it follows immediately that, 
\[
I_{	ext{ripple}} = I_{	ext{peak}} \times \frac{V_{dc}}{V_{pk}} = \frac{I_{	ext{peak}}}{2} \times V_{dc}
\]

A pretty impressive number.

Current \(I_{dc} \) is constant at about 25mA and the capacitor discharges for almost the entire 16.7ms period. Thus, the formula for the discharge of a capacitor at a constant current leads to \(V_{dc} = V_{dc} \times \frac{I_{dc}}{V_{dc}} \). For the 2200\(\mu F\) filter capacitors then, 
\[
V_{dc} = 0.025 \times 0.045 \times 6.180V
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Surge current through the diode in the power supply is of the order of 1.2A. This is still a pretty astounding number, but the surge currents on even small rectifier diodes are well in excess of this. 

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A capacitor of almost 4200\(\mu F\) would be required to reduce the ripple to 10mA. Using the additional RC filter reduces the almost 200mA ripple to less than 0.5mA with far smaller capacitors. It is enlightening to see the essentially zero-voltage diodes and then to look at things like this. Many designers treat power supplies very casually. I used 2, too, until it hit me.

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Unregulated output voltage from the rectifier/filters will vary, depending on the power transformer secondary voltage under load. Measured voltage was 24V at a current draw of 25mA with the transformer that I used. Once you've selected the actual transformer, you could simply increase the resistor value as the RC filter gets bigger, and you could add yet another stage of RC filter so that approximately 15V would be presented to the preamplifier under load. In either case, it would require no voltage regulator.

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As always, there are constraints you must consider. If the unregulated voltage is too high, the voltage and power-dissipation limits of the regulators will be exceeded. If this voltage is very low, then the regulator will 'drop out.' This means that it will cease to regulate because some active device within is no longer in its active operating region. These constraints are slightly different for the 78L15 and 79L15 regulators, the worst-case limits require an unregulated voltage magnitude in the range 17.5V to 25V. These regulators are widely available from several manufacturers, including the replacement service manufacturers such as ECG, NTE, and RCA.

Since parts numbers will vary, be careful to select regulators whose output-voltage tolerances are guaranteed to be within ±5%. There are even tighter-tolerance devices available if you wish to go to the trouble and expense of finding them, but it really isn't necessary to do so.

In the interests of stability, each regulator will require the input capacitor shown, unless you place the regulator immediately at the output of the unregulated supply. With the recommended value for the 78L15's input capacitor, there was an intermittent, low-amplitude, high-frequency oscillation. This was cured by increasing the capacitor value to 1\(\mu F\). For consistency, I also used 1\(\mu F\) input capacitors for the 79L15 regulators.

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I have serious reservations about claims of sonic effects of QD metals. Given this, I favour gold connectors because of past experiments with other types' reliability problems due to corrosion.

I mounted chassis-mount RCA jacks to the edge of the PCB board, and used stranded wire between QDs and ground the sleeve (outer portion) of each jack to the board. However, to drill holes only in the front panel of the preamp enclosure, allowing the RCA jacks to protrude.
almost completely outside the enclosure. To do this, the front edge of the PC board must contact the inner side of the front panel of the enclosure.

The front-panel holes for the jacks must be sufficiently large that neither the jack nor the shielded connector portion of any connected RCA plug contacts the front panel. Also be sure that other PC board components or traces contact the front panel.

You could achieve the same effect more easily by using PC-mate RCA jacks. If you use such jacks, you must modify the board’s trace pattern accordingly.

Avoiding grounding problems

Some attention to the grounding scheme is required. For one thing, there are differences among various turntable tonearms, and even cartridges in the way grounding is handled. For that reason, the actual interconnections may be different depending on the manufacturer’s specific system and its components. It will probably be true that most builders will be very familiar with the schemes that work best in their systems.

I emphasize again that the RCA input and output connectors are insulated from the enclosure. It is important that the input connectors be grounded to chassis only through the 10Ω capacitors shown.

While I understand that isolating the input connector ground from the chassis prevents a ground loop, I have never seen a reason given for the capacitors. I assume they are for RF bypass, given the demand for low-resistance connections. These capacitors may be disc-ceramic types. Voltage rating is probably not critical, but since 10V, 0.1μF disc-ceramic capacitors are used in the power supply, it is convenient to make all of these capacitors the same and perhaps save on quantity purchases.

A ground loop can occur anyway if the cartridge or phonoarm cable connects both ground rails at the turntable end. If a continuity check indicates this situation, then break the potential loop by opening the shield connection at the turntable end for one channel only. If that is not possible, you can try simulating one shield connection to the PC board at the preamplifier end for one channel only.

I am not sure whether, if, itself, will give satisfactory results, but I do know that ground loop is what then comes circuittously from the other channel to the power supply and back to the first channel. I have seen amplifiers oscillograph with such ground loops.

As an alternative, after breaking one shield connection for the PC-board RCA input jack, connect the ground trace of both shield and ground at the turntable end to the ground return to the power supply for one channel only.

Some turntable/base measurement conditions offer an optimum ground loop for connection to the preamplifier chassis. Accommodation of this option is the reason for the binding post labeled "Turntable GND" on Fig. 3. The decision whether or not to connect this optional ground loop is based empirically on the situation that results in the best hum.

For my system, the SME9009 tonearm cable provides this optional ground loop, which, at the tonearm end, is connected to the turntable platform of a Thorens TD125. Connection of the amplifier to the preamplifier binding post is the preferred configuration in my case, since this reduces hum below the audible level.

At the power supply only a chassis interconnection point should exist. This is nicely illustrated in Fig. 4, which also indicates what is meant by such terms as "Star GND."

Setup and adjustment

No adjustments are required. It is a good idea, as mentioned on the tonearm, to verify the differential amplifier currents by measuring the voltage across current source resistors R1 and R2. Unless you used severely mismatched BJTs in the current mirrors, cascode current should be OK.

I always check the power-supply voltages before I connect the rails to the circuit. Circuit limits the power supplies for breadboard work, and a Variac for initial power up and check-out of the prototype version of a new design or after repairs.

The presence of the 220Ω resistors in the power supply afford short-term protection against short circuits downstream, but in the long term, their resulting power dissipation would exceed their rating. The IC voltage regulators are internally protected against short circuits.

In summary

I think that plenty well covers the whys and wherefores of this circuit. It is a satisfying approach from the standpoint of precision in a relatively simple discrete design. The THD was only about 0.006% for several kilohertz, rising to 0.025% at 20kHz with a 0.5V RMS output.

Obviously, it is possible to achieve significantly lower levels of THD with higher op-amp bandwidths by more direct feedback. It is difficult to do so, however, with the precise active-passive equalisation scheme realised through just two one-stage op-amps, as I did here. The proponent of "less is better" — and especially those sceptical of the benefits of negative feedback — will appreciate this trade-off.

As for listening attributes, the sound is open and dynamic. One hears no striations, even on massed strings. The bass is convincing, and I have no explanation for this. I do not know about the Adcom or Marantz preamps, but otherwise it is true that there are no coupling capacitors in the signal path — even at the input of the power amplifier currently in use. This was possible because the servo limited DC offset at around 60kHz. Still, there should be no perceptible difference in bass, even when coupling capacitors, as long as the low-frequency cut-off is well below the lower limit of hearing.

It is simply amazing how many good recordings there were in the days of vinyl. The ambience in the few Mercury Living Presence records available is uncanny; one is surprised at the number of golden ear's claims of magical qualities of amplifiers and preamplifiers and I attribute none to this design. I simply assert that this phone is good enough to accurately reproduce the information that is in the recording medium.

I believe you will thoroughly enjoy its use, provided that other components in the stereo system are equally good. I continue to be impressed with the sound even after several weeks. The need to use it is not a very serious handicap, particularly with the enthusiasm fading after the first few listenings. I am listening at high volume levels than before. This may be a sign of lower apparent distortion, since there is a tendency to adjust volume to a level just below that at which distortion begins to be objectionable.

References

1. Manny Harowitz, "How to Build Solid-State Audio Circuit," Table Books No. 606, 1972, (pp. 31-12).
7. Obviously, the output power is limited by the power supply current capability. In this case, the power supply is limited to 0.5V output.

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almost completely outside the enclosure. To do this, the iron or point of the PC board must contact the inner side of the front panel of the enclosure.

The front-panel holes for the jacks must be sufficiently large that neither the jack nor the shield connector portion of any connected RCA plug contacts the front panel. Also be sure that other PC board components or traces contact the front panel.

You could achieve the same effect more easily by using PC-mount RCA jacks. If you use such jacks, you must modify the board's trace pattern accordingly.

Avoiding grounding problems
Some attention to the grounding scheme is required. For one thing, there are many different among various turntable turntables, and even cartridges in the way grounding is handled. For that reason, the actual interconnections may be different, depending on the builder's specific system and its components. It will probably be true that most builders will be very familiar with the schemes that work best in their system.

I emphasize again that the RCA input and output connectors are insulated from the enclosure. It is important that the input connectors be grounded to chassis only through the 10pF capacitors as shown.

While I understand that isolating the input connector ground from the chassis will avoid a ground loop, I have never seen a reason given for the capacitors. I assume they are for RF bypass, given the capacitors shown.

These capacitors may be disc-ceramic types. Voltage rating is probably not critical, but since 10, 15, 1nF (ceramic) capacitors are used at the AC line, it is convenient to make all of these capacitors the same and perhaps save on quantity purchases.

A ground loop can occur only if the cap or turntable cable connects both output channels at the turntable end. If you check your ground and ensure that these channels come circuittously from the other channel to the power supply and back to the turntable, you have seen amplifiers oscilute with such an arrangement.

As an alternative, after breaking one shield connection for the PC-board RCA input jack, connect the ground trace of both channel and break the ground return to the power supply for one channel only.

Some turntable/turntable combinations offer an optional ground lead for connection to the preamplifier chassis. Acceptance of this option is the reason for the binding post labelled "Turbulent GND" on Fig. 3. The decision whether to use or not to connect this optional ground lead is based empirically on the situation that results in the least hum.

For my system, the SME909 amplifier cable provides this optional ground lead, which, at the turntable end, is connected to the turntable platform of a Thorens TD125. Connection of the amplifier to the preamplifier binding post is the preferred configuration in my case, since this reduces hum below the audible level.

As the power supply is only a chassis interconnection point should exist. This is nicely illustrated in Fig. 4, which also indicates what is meant by such terms as "Star GND."

Setup and adjustment
No adjustments are required. It is a good idea, as mentioned in the text, to verify the differential amplifier currents by measuring the voltage across current source resistors $R_7$ and $R_8.$ Unless you used severely mismatched BJTs in the current mirrors, cascade currents should be OK.

I always check the power-supply voltages before I connect the rails to the circuit. I use the limited benefit power supplies for breadboard work, and a Variac® for initial power up and check-out of the prototype version of a new design or after repairs.

The presence of the 22u2 resistor in the power supply affords short-term protection against shot circuits downstream, but in the long term, their resulting power distillation would exceed their rating. The IC voltage regulators are internally protected against short circuits.

In summary
I think that this is a very well written the words of the designer of the circuit. It is a satisfying approach from the standpoint of precision in a relatively simple discrete design. The THD was only about 0.005% for several kilohertz, rising to 0.02% at 20kHz with a 0.5V RMS output.

It is obvious, however, to be satisfied to achieve significantly lower levels of THD with higher operates. I did therefore measure more feedback. It is difficult to do so, however, with the precise active-passive equalisation scheme realized through just two one-stage op-amps, as I did here. The potential of "bias is better—and especially those scopical of the benefits of negative feedback—will appreciate this trade-off. As for listening attributes, the sound is open and dynamic.

You hear no intricacy, even on massed strings. The bass is even, and I have no explanation for this. I do not know about the Adcom or Manfatz preamps, but otherwise it is true that there are no coupling capacitors in the signal path—neither at the input of the power amplifier currently in use, nor at the output. This was possible because the source limited DC offset at around 60kHz. Still, there should be no perceptible difference in bass, even under coupling, even at the lowest frequency cut-off is well below the lower limit of hearing.

It is simply amazing how many good recordings there were in the days of vinyl. The ambience in the few Mercury Living Presence recordings I am familiar with is one of many golden ears" claims of magical qualities of amplifiers and preamplifiers and I attribute none to this design. I simply assert that this phone is very good and is accurately reproducing the information that is in the recording medium.

I believe you will thoroughly enjoy its use, provided that other components in the stereo system are equally good. I continue to be impressed with the sound even after several weeks. The overall output is very high, as expected, with the enthusiasm fading after the first few listenings.

I am listening at higher volume levels than before. This may be a sign of lower apparent distortion, since there is a tendency to adjust volume to a level just below that at which distortion begins to be objectionable.

References

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Power for the new generation

Sources of energy can have massive implications for all sectors of life, from the environment to lifestyles, but one alternative energy source is making waves. Chris Evans-Pughe looks at fuel cells.

1839 by a Welsh judge called Sir William Grove, but the technology wasn't really used until the sixties, when the US space program chose fuel cells for the Gemini and Apollo spacecraft.

Nowadays there are many variations of fuel cell around. At the high end are industrial systems using phosphoric acid and molten carbonate. At the very alternative end are entertaining concepts such as University of South Florida's microbial fuel cell. This can be powered by food, preferably meat because of its higher energy density. Within the fuel cell are bacteria that speed the breakdown of its food-fuel, releasing electrons that charge a battery.

The systems of most interest for electronics are proton exchange membrane (PEM) - the technology being used by firms such as Ballard for cars - and direct methanol fuel cells (DMFC). Both systems can operate at relatively low temperatures - from 40 to 60°C - have high power densities and can vary their output quickly to meet shifts in power demand.

PEM systems include a fuel reformer so they can use the hydrogen from any hydrocarbon fuel. DMFCs are less efficient but have the advantage that the anode catalyst draws the hydrogen directly from methanol, eliminating the need for a reformer.

Development work going on in Los Alamos, New Mexico looks to be the most significant for portable applications. Companies including Motorola, 3M and Honeywell are working with Los Alamos National Laboratory to develop miniature DMFC devices to replace batteries in laptop computers and mobile phones.

Motorola's fuel cells are two to three years away from a market launch. The company says its liquid methanol-powered cell will be able to last up to ten times longer than existing rechargeable batteries. Fuel cell powered cell phones could be fuelled by a small mechanical reservoir about the size of an ink-pen cartridge.

Energy Related Devices - ERD - for short - is another Los Alamos-based firm working on miniature DMFCs for cell phone power supplies. ERD's micro fuel cell is made with multiple layers of thin films. The alcohol side of the film contains a catalyst that breaks the alcohol down into hydrogen ions and carbon dioxide.

The firm says in fuel cells can be made inexpensively using a printing process similar to the manufacture of ICs. It hopes to have production prototypes this year.

ERD is funded by New York-based Manhattan Sciences that also owns NovArs - a German company in Passau developing PEM fuel cells to provide small external power supplies for products such as DVDR players and laptop computers.

NovArs is also looking at domestic appliance applications and recently announced a joint agreement with Electrolux to develop an evaluation prototype of a fuel cell powered domestic vacuum cleaner.

The NovArs approach to fuel cell design was to consider materials and scaling technology to minimise size and weight. According to founder Dr Artimus Koschany, PEM systems have an energy density of nearly 100 times that of DMFCs making them less bulky for higher power applications.

Koschany sees two main challenges to commercialising the technology for electronics. The first is price. The second is more technical. "The price can be low only if we can make them in high enough quantities and this will involve considerable investment," he says.

"Technically, we need a source of hydrogen because compressed gases are not appropriate for using with electronics. We are developing hydrogen generating chemical hydrides for this purpose and these need to be integrated into the fuel cell."

NovArs plans to have a pilot production line running in 2002 to produce quantities in the order of thousands. Full commercialisation is three to four years away reckons Koschany.
Power for the new generation

Sources of energy can have massive implications for all sectors of life, from the environment to lifestyles, but one alternative energy source is making waves. Chris Evans-Pughe looks at fuel cells

Dive into the subject of renewable energy sources and you may end up in a series of windmill-strewn, solar-panelled alternative websites populated by solar-powered folks who apparently have the patience to wait half a day to cook dinners in a box of hay. Someone should tell them about pizza delivery... I'm kidding. Alternative energy ideas are great, but not suitable for most everyday man-market needs. But sure a little further and you'll find fuel cells — probably the most commercially promising renewable energy technology and one of growing interest to the electronics industry.

At the heavy-duty end of the energy market, governments, utility companies and our firms are embracing fuel cell technology. Their zeal is mainly due to pressure to cut emissions prompted by concerns about climate change. The US Department of Energy projects that if 10 per cent of cars in the US were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and carbon dioxide by 60 million tons.

The companies developing fuel cells for portable electronics applications have different motivations. They're interested in the technical advantages of a significantly longer operating time than today's batteries. cheap fuel and a re-fuel time of seconds. According to Motorola Energy Systems, fuel cells would be able to power a mobile phone for over 30 days and keep a laptop running for 20 days. Consequentially, fuel cells may be ideal for handling the increased power needs of multifunctional mobile applications such as 3G that will support video and Internet.

A fuel cell is a cross between an engine and a battery. Like an engine, a fuel cell will run as long as fuel (Hydrogen) is supplied. Like a battery, it produces electricity by electrochemical reactions. A fuel cell comprises two electrodes and an electrolyte. Hydrogen is fed into the anode and oxygen — or air — enters through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be used before they return to the cathode, to be reunited with the hydrogen to form water.

The first fuel cell was built in 1839 by a Welsh judge called Sir William Grove, but the technology wasn't really used until the sixties, when the US space program chose fuel cells for the Gemini and Apollo spacecraft.

Nowadays there are many varieties of fuel cell around. At the high end arc industrial systems using phosphoric acid and molten carbonate. At the very alternative end are entertaining concepts such as University of South Florida's microbial fuel cell. This can be powered by food, preferably meat because of its higher energy density. Within the fuel cell are bacteria that speed the breakdown of its food-fuel, releasing electrons that charge a battery.

The systems of most interest for electronics are proton exchange membrane (PEM) — the technology being used by firms such as Ballard for cars — and direct methanol fuel cells (DMFC). Both systems can operate at relatively low temperatures — from 40 to 80°C — have high power densities and can vary their output quickly to meet shifts in power demand.

PEM systems include a fuel reformer so they can use the hydrogen from any hydrocarbon fuel. DMFCs are less efficient but have the advantages that the anode catalyst draws the hydrogen directly from methanol, eliminating the need for a reformer.

Fuel cell work going on in Los Alamos, New Mexico looks to be the most significant for portable applications. Companies including Motorola Labs and recently Mechanical Technology are working with Los Alamos National Laboratory to develop miniature DMFC devices to replace batteries in laptop computers and mobile phones.

Motorola's fuel cells are two to four years away from a market timeline that the company says its liquid methanol-powered cell will be able to last up to ten times longer than existing rechargeable batteries. Fuel cell powered cell phones could be fueled by a small methanol reservoir about the size of an ink pen cartridge.

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This image shows Energy Related Devices' methanol powered fuel cell.

From air

A PEM cell uses a catalyst to split hydrogen into H+ ions and electrons. They recombine with oxygen to form water. Diagram courtesy of Breakthrough Technologies Institute/Fuel Cells 2000.

From air

A PEM cell uses a catalyst to split hydrogen into H+ ions and electrons. They recombine with oxygen to form water. Diagram courtesy of Breakthrough Technologies Institute/Fuel Cells 2000.
The definitive biography of the century's godfather of invention—from the pre-eminent Edison scholar "Israel's meticulous research and refusal to shy away from the dodgy aspects of Edison's personality offers a fresh glimpse into the life of the inventor."

New Scientist

"Remarkable."—Nature

"An authoritative look into Edison's working methods, here leavened by enough personal detail to give the achievements shape."—Publishers Weekly

"Israel's book should go a long way toward taking Edison out of the shadows and placing him in the proper light."—Atlanta Journal-Constitution

"Exhaustively researched, with strong emphasis on Edison's methods and achievements."—Kirkus Reviews

The conventional story of Thomas Edison reads more like myth than history: With only three months of formal education, a hardworking young man overcomes the odds and becomes one of the greatest inventors in history. But the portrait that emerges from Edison: A Life of Invention reveals a man of genius and astonishing foresight whose career was actually a product of his fast-changing era. In this peerless biography, Paul Israel exposes for the first time the man behind the inventions, expertly situating his subject within a thoroughly realized portrait of a burgeoning country on the brink of massive change. Informed by Israel's unprecedented access to workshop diaries, notebooks, letters, and more than five million pages of archives, this definitive biography brings fresh insights to a singularly influential and triumphant career in science.

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2 Good Old Summertime, The American Quartet 1904
3 Marriage Bells, Bells & xylophone duet, Burchard & Daab with orchestra, 1913
4. The Volukar Organist, Peter Dawson, 1913
5. Dialogue For Three, Flute, Oboe and Clarinet, 1913
6. The Toymaker’s Dream, Footrot, vocal, B.A. Rolfe and his orchestra, 1929
7. As I Sat Upon My Dear Old Mother’s Knee, Will Oakland, 1913
8. Light As A Feather, Bells solo, Charles Daab with orchestra, 1912
9. On Her Pic-Pic-Piccolo, Billy Williams, 1913
10. Polka Des English’s, Artist unknown, 1900
11. Somebody’s Coming To My House, Walter Van Brunst, 1913
12. Benny Scotland Medley, Xylophone solo, Charles Daab with orchestra, 1914
13. Doin’ the Raccoon, Billy Murray, 1929
14. Luca Mal’ Francesco Daddi, 1913
15. The Olio Minstrel, 3rd part, 1913
16. Peg O’ My Heart, Walter Van Brunst, 1913
17. Auf Dem Mississipp, Johann Strauss orchestra, 1913
18. I’m Looking For A Sweetheart And I Think You’ll Do, Ada Jones & Billy Murray, 1913
19. Intermezzo, Violin solo, Stroud Hatchon, 1910
20. A Juanita, Abrego and Picasso, 1913
21. All Alone, Ada Jones, 1911

Total playing time 72.09

44-tap pots with four 6-bit E²PROM registers
Xicor has introduced the X9421 and X9249 64-tap, single supply, non-volatile digital potentiometer ICs. The devices are for applications in which a variable resistance value must be maintained during the system manufacturing process. They have four 6-bit E²PROM registers per potentiometer for storage of tap settings and system parameters. This lets the system designer automatically save resistance values during power down and preset values to suit system demands. The X9421 communicates via a serial port supporting the SPI interface, while the X9249 uses a new-wire interface. Both operate from a 2.7V single supply voltage and each has four non-volatile registers that can be individually programmed. Applications include fibre optic modules, RF amplifier biasing, LCD brightness control, power supply calibration, battery operated applications and vending machines. They can recover their last position after a power down cycle and suit manufacturing applications that use preset analogue system values. Standby power is 200mA typical and 5mA maximum.
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Xicor has introduced the X9421 and X9249 64-tap, single supply, non-volatile digital potentiometer ICs. The devices are for applications in which a variable resistance value must be maintained during the system manufacturing process. They have four 6-bit E²PROM registers per potentiometer for storage of tap settings and system parameters. This lets the system designer automatically save resistance values during power down and preset values to suit system demands. The X9421 communicates via a serial port supporting the SPI interface, while the X9249 uses a new-wire interface. Both operate from a 2.7V single supply voltage and each has four non-volatile registers that can be individually programmed. Applications include fibre optic modules, RF amplifier biasing, LCD brightness control, power supply calibration, battery operated applications and vending machines. They can recover their last position after a power down cycle and suit manufacturing applications that use preset analogue system values. Standby power is 200mA typical and 5mA maximum.
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RF channel emulator with modelling feature
Telecom Analysis Systems has added a dynamic channel modelling feature to its 4500 Flex3 RF channel emulator. Available from Sematron, the 3G power-delay-profile emulation mode can be programmed to provide time-varying RF channel profiles that let it meet and exceed CDMA2000 and W-CDMA test specifications. It implements a dynamic, mobile propagation environment for time-sensitive algorithms such as rake finger management and wide band channel estimation. It also implements moving-propagation and birth-death channel models in accordance with 3G specifications. These two classes of channel models emulate the temporal variations in the propagation channel by changing delay spread characteristics versus time. A diversity technique lets the receiver pick up multiple signal paths over time and select the strongest rather than the average, which may be several decibels less than the strongest. This is for testing smart antennas that are proposed for 3G networks where up to four TA5400 units can be combined. It also provides the ability to go beyond two-path dynamic models by letting all its paths be independently varied over time.
Sematron
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32-bit micros based on V850 Eisc architecture
NESC has introduced 32-bit microcontrollers based on V850 Risc architecture with programmable CAN gateway engines. The Atomic and Cargate device family have a hardware-based CAN that lets them serve as gateways for communication between networks within the vehicle. This function lets them manage multiple tasks simultaneously from up to five automotive networks, such as the power train, navigation system or comfort control system. By implementing the CAN bridge in hardware, the microcontroller leverages the CPU of routine tasks, such as data transfer from one message buffer to another. Time triggered functionality lets signals be delivered based on time slots rather than arbitrary external events. Time out monitoring lets the microcontrollers anticipate the receipt of critical messages in a defined time frame. For example, an air bag system can be programmed to communicate with the microcontroller regularly, and if the microcontroller will investigate if no message is received. The Atomic controller supports three CAN interfaces and includes 256kbit on chip ROM and peripherals such as LCD controller, 13 channel AD converter, 46 I/O pins and various 16 and 32-bit timers. The Cargate has 128kbit ROM and supports five CAN interfaces. Flash memory versions of both are also available to support secure self-programming of the memory.
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21 tracks – 72 minutes of recordings made between 1900 and 1929. These electronically derived reproductions are no worse than – and in many cases better than – reproductions of early 78rpm recordings – some are stunning...

All tracks on this CD were recorded on DAT from cylinders produced in the early 1900s. Considering the age of the cylinders and the recording techniques available at the time, these tracks are of remarkable quality, having been carefully replayed using modern electronic technology by historian Joe Pengelly.

Track
1 Washington Post March, Band, 1909
2 Good Old Summertime, The American Quartet 1904
3 Marriage Bells, Bells & xylophone duet, Burchnitt & Daab with orchestra, 1913
4. The Volauer Organist, Peter Dawson, 1913
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10 Polka Des English’s, Artist unknown, 1900
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12 Benny Scotland Medley, Xylophone solo, Charles Daab with orchestra, 1914
13 Doin’ the Raccoon, Billy Murray, 1929
14 Luca Mia! Francesco Daddi, 1913
15 The Olio Minitrel, 2nd part, 1913
16 Peg O’ My Heart, Walter Van Brunt, 1913
17 Auf Dem Mississippi, Johann Strauss orchestra, 1913
18 I’m Looking For A Sweetheart And I Think You’ll Do, Ada Jones & Billy Murray, 1913
19 Intermezzo, Violin solo, Stroud Hatcht, 1910
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www.xicor.com

RF channel emulator with modelling feature
Telecom Analysis Systems has added a dynamic channel modelling feature to its 4500 Flex3 RF channel emulator. Available from Sematron, the 3G power-delay-profile emulation mode can be programmed to provide time-varying RF channel profiles that let it meet and exceed CDMA2000 and W-CDMA test specifications. It implements a dynamic, mobile propagation environment for time-sensitive algorithms such as rake finger management and wide band channel estimation. It also implements moving propagation and birth-death channel models in accordance with 3G specifications. These two classes of channel model emulate the temporal variations in the propagation channel by changing delay spread characteristics versus time. A diversity technique lets the receiver pick up multiple signal paths over time and select the strongest rather than the average, which may be several decibels less than the strongest. This is for testing smart antennas that are proposed for 3G networks where up to four TA5400 units can be combined. It also provides the ability to go beyond two-path dynamic models by letting all its paths be independently varied over time.

Sematron
Tel: 01286 81222
www.sematron.com

32-bit micros based on v850e Risc architecture
NEC has introduced 32-bit microcontrollers based on V850E Risc architecture with programmable CAN gateway engines. The Atomic and Cargate devices have a hardware-based CAN that lets them serve as gateways for communication between networks within the vehicle. This function lets them manage multiple tasks simultaneously from up to five automotive networks, such as the power train, navigation system or comfort control system. By implementing the CAN bridge in hardware, the microcontroller relieves the CPU of routine tasks, such as data transfer from one message buffer to another. Time triggered functionality lets signals be delivered based on time slots rather than arbitrary external events. Time out monitoring lets the microcontrollers anticipate the receipt of critical messages in a defined time frame. For example, an air bag system can be programmed to communicate with the microcontroller regularly, and then the microcontroller will investigate if no message is received. The Atomic controller supports these CAN interfaces and includes 256kbit on chip ROM and peripherals such as LCD controller, 12 channel A/D converter and various 16 and 32-bit timers. The Cargate has 128kbit ROM and supports five CAN interfaces. Flash memory versions of both are also available to support secure self-programming of the memory.

NEC Electronics
Tel: 01908 691133
www.nec.com

May 2001 ELECTRONICS WORLD
Digital backboard for Eureka DAB radios

Texas Instruments has unveiled a reference design and single-chip digital backboard for Eureka DAB radios to help make products such as integrated digital radios and Internet audio players for automotive, portable and home applications. TMS320DM3200 digital backboard includes programmable DSP technology and Radioscape software. The reference design contains components necessary to design a receiver including the DRE200 baseband, analog parts and RF circuitry. The backboard consumes less than 200mW. The software uses additional applications on top of the baseboard, such as integrating M251 audio codec with digital radio on one chip.

Power relay module is customisable

A power relay module that can be customised for automotive requirements has been introduced by Tyco Electronics. Applications include power windows, fuel pumps, power sunroofs, wiper control, vehicle lighting and cooling fans. With a footprint of 38.2 x 38.2mm and a height of 25.2mm, the F47 can be supplied with plug-in terminals positioned to ISO7558 or terminals prepared for soldering to an integrated PCB. Terminal one, two, six, seven, eight and nine are optional, while terminals three, four and five are fixed. Pin assignment is according to ISO780. Limiting continuous current is up to 70A at 23°C or 50A at 85°C. Nominal voltages are 12 and 24V; a 24V version with a contact gap more than 0.8mm can be supplied. Nominal unsuppressed power consumption is 1.6W at the nominal voltage, typical operating time 7ms and release time 2ms.

Tyco Electronics
Tel: 0790 080 200
www.tycoelectronics.co.uk

Inlet filters rated at 16 and 20A

Schaffner EMC has introduced EN9223 ECI inlets filters rated at 16A and 20A for applications from industrial machinery to vending machines. They use the IEC32222 connector and are safety rated for IEC950 applications. Other approvals include VDE, UL, CSA and Semko. The 20A version has dual 0.6mm2 input wires with Y capacitors on the load side and one X capacitor on the line side.

Schaffner
Tel: 01865 977 000
www.schaffner.com

Electrolytics come in laminated cases

The RU electrolytic capacitors from Nichicon come in laminated cases and have operating temperatures of -40 to +85°C at 6.3 to 400V and -25 to +45°C at 450V. Working voltage is 6.3 to 450V, capacitance 0.1 to 6800μF, tolerance 20 per cent and allowable ripple 190 to 930mA depending on transmission and working voltage. The radial lead measures 12.5 or 25mm diameter by 12.5mm high and are available with trimmed or formed leads.

Nichicon
Tel: 01276 685551
www.nichicon.co.uk

USB connectors take an eighth of the space

The Micro-ITM USB connectors from Molex take up about an eighth the space of standard USB connectors. They are for portable applications such as digital cameras, cell phones and PDAs and comply with USB 2.0, which enables speeds up to 480Mbit/s. The design includes five circuits, with one reserved for future use. Features of the 0.8mm pitch unit include metal shielding and grounding provisions for EMI protection and a lock for secure mating.

Molex
Tel: 01258 720751
www.molex.com

Rectifier is efficient at 86 per cent

International Rectifier has introduced topology-specific HEXFET power Mosfet for isolated and buck DC-to-DC converters. As DC-to-DC converter output voltage approaches 1V, the Mosfets increase efficiency by up to one per cent. The 100V IRFP743 in an SO-8 package is for the primary stage of two-stage isolated converters with 48V input, 1.8V output at 60A. Peak efficiency ratings in up to 90 per cent can be achieved when it is matched with the IRFP222 synchronous rectification module. The IRFP743 can also be used in a full bridge configuration. The 40V Mosfet in SO-8 packages work with a 28V bus in notebook computers. There is a choice between two converter types, the IRFP222 and IRFP747, and two synchronous Mosfets, the IRFP740 and IRFP741. Synchronous buck topologies using the IRFP740 and IRFP741 result in an efficiency of 82 per cent in 28V input, 1.3V output converters running at 300mA. Four additional Mosfets (IRF743, IRFP740, IRFP651 and IRFP681) have reduced on-resistance and gate charge and are for 48V input, active and passive reset, primary-side isolated DCDC converters below 30W. International Rectifier
Tel: 0208 645 8000

SMD capacitors extend to 100V DC rating

The VS surface mount aluminium electrolytic capacitors from Panasonic have capacitance values from 0.1 to 150μF. Rated working voltage options are 4, 6.3, 10, 16, 25, 35, 50, 63 and 100V DC. Case diameters are 10mm for the highest capacitance parts, falling to 3mm for devices with lower values. All capacitors with case diameters of 6.3mm or lower have heights of 5.4mm, while the maximum board mounting height is 10.2mm. For operation between -40 and 45°C, they have maximum DC leakage currents between 3 and 6μA and ripple currents at 120Hz and 85°C are 1mAms for 0.1μF devices and 700μAms for the 150μF parts.

Panasonic Industrial
Tel: 01244 452667
www.plai.co.uk

SBC for Pentium III or Celeron applications

The Rebo 678 single board computer from Portwell provides Intel Celeron or Pentium III processing power up to 600 or 800MHz respectively. It supports up to 512MB of SDRAM and is based on the Intel 815SB chipset. Onboard features include dual 10/100BaseT Ethernet, ISB up to 133MHz and an integrated 3D graphic controller with DirectX 8 and 64-byte display cache. It is PICMG compliant and has two SGDMA dmas 33, 66 or 100 IDE ports, one disk-on-chip socket that supports up to 288MB of flash memory and a PCI connector for expansion. An optional Ultra-160 SCSI daughter board is available. Built in system monitoring and a watchdog timer are included.

Portwell
Tel: 01323 618316
www.portwell.co.uk

Micro reset circuit is radiation-hardened

Intersil has introduced a radiation-hardened-power-up microprocessor reset circuit. The Star Power IS7530RH can monitor power supply voltage levels and interface with satellite control units to ensure proper device operation during power-up. It sends a reset pulse to the microprocessor when the supply reaches a nominal operating voltage of 4.65V. This prevents code execution errors that occur when signals are present on microprocessor inputs during power-up. Features include a watchdog circuit that verifies that a proper reset has occurred and power-fail circuit for monitoring other supply voltages. Single event latch-up immunity is to 38Kv/m/s and single event upset capability is 38MeV/kg cm².

Intersil
Tel: 01344 350250
www.intersil.com

Simulator software for high-speed networking

Ansoft has announced version 8.0 of its HFSS structure simulator software. It is a full-wave finite element electromagnetic simulator that lets engineers design three-dimensional structures such as connectors, IC packages and antennas in cellular telephones, broadband communications systems and microwave circuits. Models can be generated for the electrical analysis of metal layers, simulations of Gigabit Ethernet IC packages, boards and connectors, optoelectronic devices and optical fibers using 3-dimensional models. Ansoft will offer training on the software.
Digital baseband for Eureka DAB radios

Texas Instruments has unveiled a reference design and single-chip digital baseband for Eureka DAB radios to help make products such as integrated digital radios and Internet audio players for automotive, portable and home applications. The TMS320DRE200 digital baseband includes programmable DSP technology and Radioscape software. The reference design contains components necessary to design a receiver including the DRE200 baseband, analogue parts and RF circuitry. The baseband consumes less than 200mW. The software lets users add applications on top of the baseband, such as integrating MiC3402C digital radio on one chip.

Power relay module is customisable

A power relay module that can be customised for automotive requirements has been introduced by Tyco Electronics. Applications include power windows, fuel pumps, power sunroofs, wiper control, vehicle lighting and cooling fans. With a footprint of 36.2x36.2mm and a height of 25.2mm, the F47V can be supplied with plug-in terminals positioned to ISO7558 or terminals preprepared for soldering to an integrated PCB. Terminals one, two, six, seven, eight and nine are optional, while terminals three, four and five are fixed. Pin assignment is according to ISO7809. Limiting continuous current is up to 70A at 23°C or 50A at 85°C. Nominal voltages are 12 and 24V; a 24V version with a contact gap more than 0.8mm can be supplied. Nominal unsuppressed power consumption is 1.6W at the nominal voltage, typical operating time 7ms and release time 2ms.

USB connectors take an eighth of the space

The Mini-USB USB connectors made by Tyco take up about an eighth the space of standard USB B connectors. They are for portable applications such as digital cameras, cell phones and PDAs and comply with USB 2.0, which enables speeds up to 480Mbit/s. The design includes five circuits, with one reserved for future use. Features of the 0.8mm pitch unit include metal shuffling and grounding, and appropriate EMI protection and a lock for secure mating.

Electrolytics come in laminated cases

The RU electrolytic capacitors from Nichicon come in laminated cases and have operating temperatures of -40 to +85°C at 6.3 to 400V and -25 to +85°C at 450V. Working voltage is 6.3 to 450V, capacitance 8 to 6800µF, tolerance 20 per cent and allowable ripple 190 to 930mA depending on transmission and working voltage. The radial lead capacitors measure 12.5 or 25mm diameter by 12.5mm high and are available with trimmed or formed leads.

Nichicon
Tel: 01276 865531
www.nichicon.co.uk

SM capacitors extend to 100V DC rating

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Panasonic Industrial
Tel: 01244 452667
www.plesi.co.uk

SBC for Pentium III or Celeron applications

The Rebo 678 single board computer from Portwell provides Intel Celeron or Pentium III processing power up to 500 or 850MHz respectively. It supports up to 512MB of DRAM and is based on the Intel 815SB chipset. Onboard features include dual 10/100BaseT Ethernet, FSB up to 133MHz and an integrated 3D graphics controller with 8MB and 4-bit display cache. It is PICMG compliant and has two IDE/ATA 33, 66 or 100 IDE ports, one disk-on-chip socket that supports up to 2GB of disk capacity and a PCI connector for expansion. An optional Ultra-160 SCSI daughter board is available. Built in system monitoring and a watchdog timer are included.

Portwell
Tel: 01702 815916
www.portwell.co.uk

Micro reset circuit is radiation-hardened

Intelsat has introduced a radiation-hardened power-up microprocessor reset circuit. The Star Power 15705R/1 can monitor power supply voltage levels and interface with satellite control units to ensure proper device operation during power-up. It needs a reset pulse to the microprocessor when the supply reaches a nominal operating voltage of 4.65V. This prevents code execution errors that occur when signals are present on microprocessor inputs during power-up. Features include a watchdog circuit that verifies if proper reset has occurred and power-fail circuit for monitoring other supply voltages. Single event latch-up immunity is to 35MeV/in² and single event upset capability is 38MeV/in². It is available in an eight-lead flatpack package, either at QML class V or Q. Intelsat
Tel: 01344 850250
www.intelsat.com

A NEW simulator software for high-speed networking

Ansoft has announced version 8.0 of its high-speed simulator software. It is a full-wave finite element electromagnetic simulator that lets engineers design three-dimensional structures such as connectors, IC packages and antennas in cellular telephones, broadband communications systems and microwave circuits. Models can be generated for an optical layer translational simulations of Gigabit Ethernet IC packages, boards and connectors, optoelectronic
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devices for broadband fibre modulators, receivers and transmitters, and electronic devices for signal conversion in hybrid fibre-optical systems. With the full-wave Spice add-on model, users can generate frequency-dependent Spice models automatically from waveguide electromagnetic field simulations.

Ansoff
Tel: 0208 981 6106
www.ansoft.com

Water-scale package saves on space

The USP-6 plastic moulded package from Torex is about two-thirds the size of an SOT-25 package. Doing away with the conventional lead frame, it measures 1.8 by 2.0 by 0.65mm and has a 0.5mm pin pitch. Torex Semiconductors
Tel: 01509 211992
www.torex.co.jp

VDSL filters in a single package

APC's APCR7110 and APCR7112 are integrated hybrid filters for use with VDSL and T1a85 applications. Compatible with the Infintron PED22810, 22811 and 22812 chokes, the components combine common mode choke, hybrid and transmit and receive filters.

Samples are available to let users evaluate central office and user modem designs and for field trials. A POTS ISDN low pass filter (APC77101) is available to support designs using either product. In system tests over category five cable, the components achieved a symmetric data rate of 12Mbits/s to a distance of 15km, supporting telephony applications.

APC
Tel: 01634 290588
www.apc-pc.co.uk

Op-amp operates on supplies down to 2.5V

Linear Technology has introduced the LT1807 deal 3.5mV/μA, rail-to-rail single supply amplifier. Gain bandwidth product is 25MHz and THD-800μc at 5MHz. Input common mode range includes both rails. The output swing ranges within ±12V of each rail for supplies down to 2.5V. Maximum output voltage is less than 0.5V, CMRR is 106dB and signal voltage gain 300V/V. Applications include broad-band digital communications, data acquisition and video. slew rate is 140V/μs, supply range 2.5 to 12.6V and output current 10mA. For operations over the industrial and commercial temperature ranges, it is available in eight-pin SOIC and MSOP packages.

Linear Technology
Tel: 01276 776767
www.linear.com

CCD products have 325kHz bandwidth

Mattone is launching products based on its L2VisCCD technology, including scientific sensors, modules, digital and analogic cameras and camera subassemblies. Applications include night surveillance, infrared cameras, dynamic bio-sciences, machine vision and astronomy. The sensors use an output amplifier circuit to improve the vision at low light levels. Scientific and TV rate sensor formats, including 512 and 1024 pixels, are being developed. Drift correction can be used in two compatible formats. The HVC clock module provides all the input required for driving the sensors. A camera control module consists of a buffer and bias board with a video logic-board and interfaces directly with the HVC clock module allowing complete control of the CCD sensor. The camera subassembly is a circuit assembly where there is no case or lens mount. The incident light is converted directly into signals and read out through a port at normal video frame rates allowing control of functional modes.

Mattone
Tel: 01246 434383
www.mattone.com

Multiplex IC with three DS3 framers

Vitesse Semiconductor has introduced the Timestream VSC9675 IC with three integrated DS3 framers, M13 multiplexers and 84 T1 and 112 framing. Applications in the access and switching infrastructure include access concentrators, routers, and switches. It supports a combination of channelised and unchannelised DS3 signals. Supported channelised formats include M3 and C-bit mode and supported T1 and J1 formats include SF and ESF. Features include performance monitoring and diagnostics such as network and local loopback. It is packaged in a 304-pin HBGA with power dissipations of 1.0, 1.5 or 2.0W.

Vitesse
Tel: 0171 805 39700
www.vitesse.com

Accelerometer cuts monitoring costs

Endevco has introduced the Piezoptik 56 accelerometer for commercial and industrial ODM engineering. The device is

PC/104 board with Elan-400 CPU

The PC/104 Microsensor MSM486SV module from Digital-Logic is said to support embedded board based on an AMD 66MHz Elan-400 486SX CPU. Standard interfaces include a PS/2 keyboard, mouse, printer, floppy disk drive, IDE hard disc and four com ports. A clock-controlled S to 3V DC-to-DC converter has more than 90% efficiency. Power saving functions make it possible to control power consumption in the 50 to 710mA range. It operates within a temperature range of 25 to 70°C and does not require active cooling. A version for -40 to +85°C is also available. Draw can be extended from 4 to 3.25mV. Two flash memories are available - program memory with capacities of 0.3 to 32MBytes with a flash file system or an IDE hard disk compatible flash drive that can be directly attached to the module. Features include an eight by 16 key matrix decoder, watchdog and EPROM for saving the setup settings. Graphics support is provided by a Chips & Technologies 65548 and 65550 SYGA controller with 16MByte of video memory.

Digital Logic
Tel: 04 41 32 681 850
www.digitallogic.co.uk

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SURREY ELECTRONICS LTD
The Forge, Lucches Green, Cranleigh GU6 7BG
Telephone: 01483 276997 Fax: 01483 276477

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Digital Logic
Tel: 04 41 32 681 850
www.digitallogic.co.uk

The aerial consists of an outdoor head unit with a control and power units and offers exceptional intermodulation performance: SOPP 480MHz, TOIP 55dBm. For the first time this permits full use of an activity system across the UK and fm broadcast bands where products found are only those radiated from transmitter sites

- 100% gain, strength field in volts/metre to 50 Ohms.
- Preselector and attenuators allowing full dynamic range to be realised on practical receivers and spectrum analysers.
- Noise - 150dBm in Hz. Clipping 16 volts/metre. Also 50volts/metre version.
- Broadcast Monitor Receiver 150MHz-200MHz. Frequency Shifters for Hotw Railway, Stereo and TV, Emphasis Limited with PPMP-Invision PPM and chart recorder, Twin PPM Rack and Box Units, PPMP hybrid, PPMP microprocessor and PPMP 16000E/DIN
- 50-500dB drives and meter movements

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Tel: 0208 891 6106
www.ansoft.com

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Tel: 01509 211992
www.torex.co.uk

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APC
Tel: 01634 200588
www.apc-pc.co.uk

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Linear Technology
Tel: 01276 776767
www.ansoft.com

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Marconi
Tel: 01246 483483
www.marconitechnology.com

Multiplexer IC with three DS3 framers

Vitesse Semiconductor has introduced the TimeStream VSC9675 IC with three integrated DS3 framers, M13 multiplexers and 13 and 11 framers. Applications in the access and switching infrastructure include access concentrators, routers, and switches. It supports a combination of channelised and unchannelised DS3 signals. Supported channelised formats include M13 and C-bit mode and supported T1 and J1 formats include SF and ESF. Features include performance monitoring and diagnostics such as network and local loopback. It is packaged in a 304-pin HBG with power dissipations of 1.0, 1.5 and 2.0W.

Vitesse
Tel: 0118 805 39700
www.vitesse.com

Accelerometer cuts monitoring costs

Endevco has introduced the Pneumap 56 accelerometer for commercial and industrial O&M engineering. The device is

PC104 board with Elan-400 CPU

The PC104 Microchip MCM-486SV module from Digital-Logic is supported motherboard based on an AMD 604MHz Elan-400 486SX CPU. Standard interfaces include a P/S keyboard, mouse, printer, floppy disk drive, EIDE hard disc and four com ports. A clock-controlled 5 to 3.3V DC-to-DC converter has more than 90% efficiency. Power saving functions make it possible to control power consumption in the 30 to 710mA range. It operates within a temperature range of -25 to 70°C and does not require active cooling. A version for -40 to 85°C is also available. Draw can be extended from 4 to 32MByte. Two flash memories are available - program memory with capacities of 0.5 to 8MByte with a flash file system or an IDE hard disk compatible flash drive that can be directly attached to the module. Features include an eight by 16 key matrix decoder, watchdog and EPROM for saving the entire boot sequence. Graphics support is provided by a Chips & Technologies 65548 and 65550 VGA controller with 1MByte of video memory.

Digital Logic
Tel: 04 32 661 8600
www.digitallogic.com

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• Purpose: professional reception for 4kHz-30kHz.
• -10dB gain, field strength in volts/metre to 50 Ohms.
• Preselector and attenuators allow full dynamic range to be realised on practical receivers and spectrum analyzers.
• Noise ~ 150mV/m in Hz. Clipping 16 volt/metre. Also 50volt/metre version.
• Broadcast Monitor Receiver 150kHz-30MHz.
• Frequency Shifters for HDTV Reduction +-Starke Emphasis Limiter + PPM/AM In-Line VSM and chart recorder + Twin PPM Rack and Box Units. + PPM hybrid, PPM microprocessor and PPM IEQ/DIN
• Switching and meter movements.

SURREY ELECTRONICS LTD
The Forge, Lucks Green, Cranleigh GU6 7BG
Telephone: 01483 276897 Fax: 01483 276477

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Firewire controller with debug indicators

From IV-M is the PAB-FW2 three-port PAB Firewire controller module. Using the Texas Instruments TSB12LV36 IEEE1394 OHCI compliant host controller and the TSB41AB3 three-port transceiver and arbiter, the module complies with IEEE1394a-2000. LED indicators for cable connected, transmit and receive, and throughput speed are on the back of the module. The module supplies cable power from an on-board converter powered from the host power supply, and generates 5VDC, sufficient to power up the remote PHY ICs on powered-off modules. It enables a hotswap plug-in plug-out capability for the Firewire connector.

Also new is the i2C110-LV36 IC in the 30pin SOIC package. The i2C110-LV36 IC is a small, low-power, low-voltage 1394 transceiver suitable for link distances up to 15m. The IC consists of an equaliser circuit and a transceiver section. The equaliser circuit provides the equalisation required for the 1394 standard where propagation delay varies with distance.

New to the CIRCLE MINIIPC range is the CIRCLE MINIIPC5-M. The CIRCLE MINIIPC5-M is an all-in-one solution for small business computing. In particular, its small form-factor allows it to be used in environments where space is at a premium. With an Intel Celeron processor, a 140MHz hard disk, and a 32MB memory, the CIRCLE MINIIPC5-M is ideal for small business applications such as POS systems and small home offices.

Pocket processing engine for camcorders

Blue Wave Systems has extended its family of Construct communications processing building blocks with a platform processing hardware platform. The IPC/ICU5441 provides OEMS and ISVs with 132 channels, each of which can provide compressed video or voice. It is designed to be used in a CompactPCI slot. It provides telephony applications processors with a platform for applications such as softswitches and VoIP. The platform also includes a media processor with 600MHz of main memory and 512MB of DRAM.

Ceramic capacitors have no polarity

Phil's Mega Cap ceramic capacitors in the TDK CK series have no polarity, so they can be mounted in either direction. There are two case sizes - model 5TD measures 5.5 x 5.5 x 7.0mm and model 4SD 5.5 x 5.5 x 6.6mm. They can absorb shocks from thermal and mechanical shocks even on metal substrates such as aluminium. Applications include smoothing circuits, temperature variable systems, maintenance free power supplies, vehicles and DC to DC converters.

High-speed matched impedance interfaces

Sencor can supply surface mount, micro pitch interfaces for matched impedance applications. Options include chip mount designs and integrated designs with 16, 19 and 22mm board spacing. These interfaces in the QTE series measure 0.4mm pitch and have an integral ground plane. From 40 to 200 I/Os are available and they are tested for 50 and 75ohm systems for impedances, VSWR, intermodulation, cross-talk, propagation delay and rise time frequencies at temperatures from 0°C to 85°C.

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Firewire controller with debug indicators

From IV M is the PAMC-FW2 three-port PAMC Firewire controller module. Using the Texas Instruments TSB12L26 IEEE1394 OHCI compliant bus controller and the TSB14A13 bus transceiver and arbiter, the module complies with IEEE1394-2000. LED indicators for cable connected, transmit and receive, and throughput speed are on the back of the module. The module supplies cable power from an on-board converter powered from the host process's 12V line, sufficient to power the remote PHY ICs on powered-off modules. It enables a hot swap plug-and-play capability for systems dependent upon power down the host system. Each front panel mounted independent port supports transfer speeds of 100, 200 or 400Mb/s, providing an interface from industrial workstations or servers to mass storage devices.

Tel: 01438 730144
www.bwmd.co.uk

Packet processing engine for 10BaseT

Blue Wave Systems has extended its family of Construct communications packet processing building blocks with a platform for applications. The CPCIUS441 provides three 10BaseT interfaces, each of which can provide compressed voice or fax over IP or ATM in a CompactPCI slot. It provides telephone equipment makers with a platform for applications such as softswitches and IP. The CPCIUS441 provides an embedded 10BaseT Ethernet interface for 10BaseT. It includes a built-in 10BaseT Ethernet transceiver for 10BaseT.

Ceramic capacitors have no polarity

Phil's Mega Cap ceramic capacitors in the TDK CGX series have no polarity, so can be mounted in either direction. There are two case sizes - model SDT measures 5.5 x 5.5 mm and is mounted using a 0.8 mm pitch and have an integral ground plane. From 40 to 200 ICs are available, they are tested for 50 and 700V systems for in- chass call distribution and to support external line termination, such as OC3/1.

Features include RA drivers, an IPMI interface, SNMP management interface and hot swap capability. A redundant hotswap Ethernet interface gives the board a multipath redundant architecture. The interface will initially run under the Solaris 2.6-64-bit operating system and Linux.

A VME64x open system architecture

A VME64x compatible 16-slot backplane is being introduced by Schofield. The unit has built in EMI shielding and an integrated chassis monitoring module to control system parameters. Applications include industrial automation, measurement and control. Integrated modules provide power, thermal management and system monitoring. The 16W DC power supply tray is designed to be removable from the rear panel and can be installed and removed using EET handles. Two fan trays that are accessed from the front of the backplane each give 500W/hr airflow. Thermal management includes speed control and failure supervision. The 6U high backplane is designed to fit the front of the enclosure plug into a 7U high backplane that uses SMP technology to provide 21 slots.
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They operate from a 3.3V (±0.3V) supply and have a programming time of 200μs per page. Access times are 30ns serial and erasing time is 2ms per block. The packages measure 12.5 by 20.0 by 1.2mm.
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Valve Radio and Audio Repair Handbook

A practical manual for collectors, owners, dealers and service engineers * Essential Information for all radio and audio enthusiasts * Valve technology is a hot topic

This book is not only an essential read for every professional working with unique radio and gramophone equipment, but also dealers, collectors and valve technology afficionados the world over. The emphasis is firmly on the practicalities of repairing and restoring, so technical content is kept to a minimum, and always explained in a way that can be followed by readers with no background in electronics. Those who have a good grounding in electronics, but wish to learn more about the practical aspects, will benefit from the emphasis given to hands-on repair work, covering mechanical as well as electrical aspects of servicing. Repair techniques are also illustrated throughout.

This book is an expanded and updated version of Chas Miller's classic Practical Handbook of Valve Radio Repair. Full coverage of valve amplifiers will also be of appeal to audio enthusiasts who appreciate the sound quality of valve equipment.

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and current analysis can be measured visually via an external PC letting diagnostics be interpreted in relation to the operating conditions. The integrated amplifier can handle 1.6A per phase 230V or 115V at 60Hz. It measures 48 by 10cm and weighs 24kg.

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Protocol analyser for Tetra radio tests

IFR Systems has added the Tetralog protocol analyser to its 2968 Tetra radio test set. The PC-based application enables capture and detailed analysis of mobile protocol transactions. As well as Tetra radios, it can also be used as a verification and evaluation tool for mobile radio developers who are not developing software in-house, but purchase protocol stacks from third parties. The application acquires data, analysing and displaying it graphically in the form of message sequence charts. The acquired messages are decoded to produce test files of the information elements contained in the messages for display, storage or printing. It can help evaluate and verify operation of a given radio type to be used on a system. Data capture is performed by connecting the mobile to the test set via its RF connection.

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QMS Systems has announced multi-port PC and PDU serial cards for downloading software to mobile phones. Using the card, a PC can program and control over 16 phones at once at up to 12.5Mbaud per phone. Programmable output levels and optional TTL or open drain output provides the flexibility to control and program different phone types. Available in four, eight, 16 and 16 port versions, each port provides outputs levels programmable between 0.5 and 10V. The units incorporates RS332, RS422 and RS485 and the option of adding digital I/O for interfacing to input signal lines and output indicators and actuators.

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Smartcard reader software goes public

Applied Card Technologies has developed software for an intelligent dual-sided smartcard reader with Talko Electronics and Oki. The technology will work with most public access devices such as vending machines, printers, PCs, photocopiers and vending boxes. It will let large organisations, libraries and universities offer a cashless service. The reader is also suitable for secure entry systems and employee verification across multiple locations. The software less the circuit and الساب system with mainstream smartcards. The reader hardware includes a dual-sided smartcard connector, which lets a card be read either way up. A separate satellite reader connects to the main PCB containing the ACT coded Oki chip and extra peripheral ports, so operations can replace just the satellite reader unit in the event of vandalism or breakage.

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* A practical manual for collectors, owners, dealers and service engineers * Essential Information for all radio and audio enthusiasts * Valve technology is a hot topic

This book is not only an essential read for every professional working with unique radio and gramophone equipment, but also dealers, collectors and valve technology afficionados the world over. The emphasis is firmly on the practicalities of repairing and restoring, so technical content is kept to a minimum, and always explained in a way that can be followed by readers with no background in electronics. Those who have a good grounding in electronics, but wish to learn more about the practical aspects, will benefit from the emphasis given to hands-on repair work, covering mechanical as well as electrical aspects of servicing. Repair techniques are also illustrated throughout.

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Doug Self has been writing for Electronics World and Wireless World over the past 20 years, offering cutting-edge insights into scientific methods of electronics design.

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Current- conveyors III

In this third and final article on low-voltage current conveyors and their applications, Giuseppe Ferri et al describe how easy it is to implement capacitance multipliers using conveyors, and how such multipliers can benefit filter designs.

In the following, we describe how capacitance can be multiplied using current conveyors. Figure 1 outlines such a multiplier. It comprises a current conveyor followed by a current amplifier. Ideal input equivalent capacitance is

\[ C_\text{eq} = A C_x \]

This shows that an equivalent capacitance is obtained that is \( A \) times greater than \( C_x \). Deviations from this ideal behaviour are mainly due to:

- Voltage and current-transfer inaccuracy in the conveyor and the conveyor's finite output resistance at terminal \( X \).
- Bandwidth limitation of the current amplifier and its finite output resistance.

Equivalent input impedance is

\[ Z_\text{eq} = \frac{1}{A} \left( r_x + \frac{1}{C_x} \right) \]

Here, \( r_x \) is resistance at \( X \) and \( r_x \) is resistance at the amplifier output. Voltage and current transfer errors of the conveyor and current multiplier are

\[ \frac{V_2}{V_1} = A \]

\[ \frac{I_2}{I_1} = B \]

respectively. Figure 2 is the equivalent circuit.

It is obtained from this expression that \( Z_\text{eq} \) is the parallel of two terms. The first term is due to capacitance \( C_x \). This is multiplied by a factor equal to \( 1/A \) and a series resistance equal to

\[ \frac{1}{C_x} \]

times the output resistance at \( X \) terminal. Therefore, this contribution decreases for high values of the current gain \( A \).

The second term is due to the output resistance of the current amplifier. This contribution can be dominated at low frequencies. It turns out that, in order to have an ideal capacitance, as multiplied by \( A \), \( r_x \) must be low and \( r_x \) high. This last condition is more important because \( r_x \) is divided by the gain \( A \).

Now we will describe some configurations implementing both the CCII and the current amplifier.

Conveyor and current-amp solution

Figure 3 shows a capacitor multiplier made up using a second-generation 'inverting' conveyor, commonly called a CCII+, and a current-based operational amplifier, or COA. Figure 4 is a simplified schematic of the COA used in simulations, while Table 1 outlines its performance.

Capacitance \( C_x \) is the grounded capacitance that has to be multiplied. Resistances \( R_1 \) and \( R_2 \) are selected to set the closed-loop current gain of the amplifier as given by

\[ A = \frac{r_x}{r_x + \frac{1}{C_x}} \]

With this solution, high capacitance gain factors can be readily achieved by simply setting the ratio \( R_1/R_2 \).

In addition, the gain can be further increased by exploiting the current-gain capabilities of the CCII. For example, if you choose a COA current gain, \( A \), of 100 and set the current gain of the CCII, \( A_1 \), to 10, an overall multiplication factor of \( 10^3 \) is achieved with a limited increase in power dissipation.

Usually, the current gain of a CCII is determined either by controlling the aspect ratio of the output current mirror, or by using techniques that allow electronic control of the current gain. With these solutions, the quiescent current is proportional to the multiplication factor. This means that there is a trade-off between power dissipation and gain.

Steady current at the conveyor's terminal limits the amount of capacitance gain that can be obtained. This current, associated with \( R_1 \), produces a offset voltage that can saturate the op-amp's output. For this reason, the CCII needs an accurate offset control.

Multiplier using two conveyors

In order to obtain high and controlled capacitance gain factors, the second topology shown in Fig. 5 has been developed. It is made up of two CCII and two resistors. These resistors determine the multiplication factor.

For ideal CCII, the following expression gives the input equivalent capacitance:

\[ C_\text{eq} = \frac{r_x}{r_x} \]

This equation shows that an equivalent capacitance \( R_2/R_1 \) times greater than \( C_x \) can be obtained.

For real CCII, the following expression for the input equivalent voltage can be deduced:

\[ Z_\text{eq} = \frac{r_x}{r_x} \]

\[ \frac{1}{A} \left( r_x + \frac{1}{C_x} \right) \]

Here, \( \gamma \) is \( \alpha, \beta, \gamma, r_\text{g}, \) and \( r_\text{g} \) are the voltage and current gain for the CCII, respectively. All gains are nominally equal to 1.

This solution allows high gain factors. However, some limits on the values of \( R_1 \) and \( R_2 \) have to be considered.

The lower limit of \( R_1 \) is related to the output resistance at \( X \)-terminal, while the upper limit for \( R_2 \) is related to the output resistance at \( Z_2 \)-terminal.

Multiplier using a single conveyor

This final multiplier is simple because it does not make use of a current amplifier. It uses only a current conveyor with a current gain of greater than 1, as in Fig. 6.
Current-conveyors III

In this third and final article on low-voltage current conveyors and their applications, Giuseppe Ferri et al. describe how easy it is to implement capacitance multipliers using conveyors, and how such multipliers can benefit filter designs.

I n the following, we describe how capacitance can be multiplied using current conveyors. Figure 1 outlines such a multiplier. It comprises a current conveyor followed by a current amplifier A. Ideal input equivalent capacitance is,

\[ C_{eq} = A C_i \]

(1)

This shows that an equivalent capacitance is obtained that is \( A \) times greater than \( C_i \). Deviations from this ideal behaviour are mainly due to:

- Voltage and current-transfer inaccuracy in the conveyor and the conveyor’s finite output resistance at terminal X.
- Bandwidth limitation of the current amplifier and its finite output resistance.

Equivalent input impedance is,

\[ Z_{eq} = \frac{1}{A} F \left( \frac{1}{R_z X} \right) \]

(2)

Here, \( R_z \) is resistance at \( X \) and \( r_z \) is resistance at the amplifier output. Voltage and current transfer errors of the conveyor are:

\[ V_{X-} = \alpha \frac{1}{A} F \left( \frac{1}{R_z X} \right) \]

(3)

Conveyor and current-amp solution

Figure 3 shows a conveyor multiplier made up using a second-generation 'inverting' current conveyor, commonly called a CCII+, and a current-based operational amplifier, or COA. Figure 4 is a simplified schematic of the COA used in simulations, while Table 1 outlines its performance.

Capacitance \( C_i \) is the grounded capacitance that has to be multiplied. Resistances \( R_1 \) and \( R_2 \) accurately set the closed-loop current gain of the amplifier as given by,

\[ A = \frac{R_1}{r_f} + \frac{R_2}{r_f} \]

(4)

With this solution, high capacitance gain factors can be readily achieved by simply setting the resistance ratio \( R_1/R_2 \). In addition, the gain factor can be further increased by exploiting the current-gain capabilities of the CCII. For example, if you choose a COA current gain, \( A_o \), of 10² and set the current gain of the CCII, \( A_i \), to 10, an overall multiplication factor of 10³ is achieved with a limited increase in power dissipation.

Usually, the current gain of a CCII is determined either by controlling the aspect ratio of the output current mirror, or by using techniques that allow electronic control of the current gain. With these solutions, the quiescent current is proportional to the multiplication factor. This means that there’s a trade-off between power dissipation and gain.

Standby current at the conveyor’s Z terminal limits the amount of capacitance gain that can be obtained. This current, associated with \( R_z \), produces an offset voltage that can saturate the op-amp’s output. For this reason, the CCII needs an accurate offset control.\(^{1-3,7}\)

Multiplier using two conveyors

In order to obtain high and controlled capacitance gain factors, the second topology shown in Fig. 5 has been developed. It is made up of two CCII+ and two resistors. These resistors determine the multiplication factor.

For ideal CCII+, the following expressions give the input equivalent capacitance:

\[ C_{eq} = R_i C_i \]

This equation shows that an equivalent capacitance \( R_i C_i \) times greater than \( C_i \) can be obtained.

For real CCII+, the following expression for the input equivalent voltage can be deduced:

\[ V_{X-} = \frac{1}{A} F \left( \frac{1}{R_z X} \right) \]

(5)

Here, \( \gamma = \alpha \beta \) for \( \gamma \) and \( \beta \) are the voltage and current gains for the ith CCII, respectively. All gains are nominally equal to 1.

This solution allows high gain factors. However, some limits on the values of \( R_1 \) and \( R_2 \) have to be considered. The lower limit of \( R_1 \) is related to the output resistance at \( X \) terminal, while the upper limit for \( R_2 \) is related to the output resistance at \( Z \) terminal.

Multiplier using a single conveyor

This final multiplier is simple because it does not make use of a current amplifier. It uses only a current conveyor with a current gain of greater than 1, as in Fig. 6.

Table 1. Main features of the single op-amp, dc-CCII, of Fig. 3

Parameter & Value

| Loop gain | 68dBi |
| GBW | 100MHz |
| PM | 64° |

Fig. 3. Capacitance multiplier using a current conveyor followed by a current-based op-amp.

Fig. 4. Simplified schematic of the low-voltage COA used to simulate the performance of the circuit in Fig. 3.

Fig. 5. Enhanced capacitance multiplier using two conveyors. Two passive resistors determine the capacitance gain.

Fig. 6. The third multiplier topology uses a single current conveyor.
resistance equal to \(1/\beta \) times the output resistance at \( X \) terminal. This term is predominant at high frequencies and decreases as the high value of the current gain \( \beta \).

The second term is due to the resistance at the \( Z \) terminal. This term is important at low frequencies. Its contribution can be made negligible by choosing CCC implementation with high values of \( \beta \).

Non ideal situations due to \( X \) and \( Z \) node resistances limit the circuit's capacitance multiplication range, as shown in Fig. 7.

**Using CCCs for low cut-off filters**

Here we present a low-pass filter design based on a capacitive multiplier using current conveyors. This is a first-order low-pass filter with a low cut-off frequency, of below 10Hz, Fig. 8.7-11

This filter uses a CCC with current gain, \( I = \beta > 1 \).

In Fig. 8, \( C \) is the capacitance to be multiplied. Resistance \( R \) was set to 100\( \Omega \) in order to achieve a cut-off frequency of 1Hz. Figure 9 shows the magnitude response of the filter. The cut-off frequency is 0.96Hz, which is in good agreement with what you would expect. The DC gain of the active filter is \(-1 \)dB instead of \(-6 \)dB. This is due to the parasitics effect caused by the finite value of \( \beta \).

**In summary**

Current conveyors are versatile building blocks suitable for many applications. Many complex analogue functions are easily implemented using current conveyors. The current conveyors can give better performance than traditional operational amplifiers. This is particularly so in terms of speed and bandwidth, due to the local feedback of the follower-based structure of the device.

Commercial current conveyors are easily realised in CMOS technology, and at low cost. In the first two articles of this review, we proposed some novel low supply voltage current conveyors for use in portable instrumentation application. In this final article, we have also shown how capacitance multipliers are used to implement using current conveyors. Such multipliers make it possible to produce fully integrated filters that can work at very low frequencies.

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**Fig. 9. Magnitude responses for an ideal RC filter and the one proposed in Fig. 8.**

---

**Fig. 8. Schematic of a low cut-off frequency low-pass filter implemented using current-conveyor technology.**

---

**Fig. 7. Input admittance of the circuit of Fig. 6 for \( C = 1 \)pF and a capacitive gain of \( 10^2 \).**

---

**Fig. 6. A 1.5V current-source capacitance multiplier - IEEE Proc. IEECS '98, London, Sept. 1998.**

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**References**

resistance equal to 1/sα times the output resistance at Z terminal. This term is predominant at high frequencies and decreases for high values of the current gain β.

The second term is due to the resistance at the Z terminal. This term is important at low frequencies. Its contribution can be made negligible by choosing CCI implementations with high values of α.

Non ideal situations due to X and Z node resistance limit the circuit's capacitance multiplication range, as shown in Fig. 7.

Using CCIs for low cut-off filters
Here we present a low-pass filter design based on a capacitance multiplier using current conveyors. This is a first-order low-pass filter with a low cut-off frequency, of below 10kHz, Fig. 8.11

This filter uses a CCI-3 with current gain, $I_c = \beta > 1$

In Fig. 8, C3 is in the capacitance to be multiplied. Resistance R was set to 1MΩ in order to achieve a cut-off frequency of 1Hz. Figure 9 shows the magnitude response of the filter. The cut-off frequency is 0.96kHz, which is in good agreement with what you would expect.

The DC gain of the active filter is 1-1db instead of 0dB. This is due to the parasitic effect caused by the finite value of C3.

in summary
Current conveyors are versatile building blocks suitable for many applications. Many complex analogue functions are easily implemented using current conveyors. The current conveyors can give better performance than traditional operational amplifiers. This is particularly so in terms of speed and bandwidth, due to the local feedback of the follower-based structure of the device.

Commercial current conveyors are easily realised in CMOS technology, and at low cost. In the first two articles of this review, we proposed some novel low supply voltage current conveyors for use in portable instrumentation application. In this final article, we have also shown how capacitance multipliers are easy to implement using current conveyors. Such multipliers make it possible to produce fully integrated filters that can work at very low frequencies.

References

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ELECTRONICS WORLD May 2001

May 2001 ELECTRONICS WORLD
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Battery pack short-circuit protector

This circuit provides short-circuit protection to a removable battery pack of up to 11V. It could be fitted in the battery pack as a standard feature. Or it could be included as part of the electronics in gas powered or Sinnex charging control circuit is embedded.

The circuit can be used with a working battery terminal voltage range between 2.5V and 11V. It is suitable for NIMH or NiCd batteries from 3 cells (where the lowest working voltage limit of 0.9V per cell gives 2.7V) to 6 or 7 cells, depending on the worst case fast charge terminal voltage. It is also suitable for one or two Lithium ion cells.

As drawn, the circuit trips at 2.7A current, but this limit can be easily changed by adjusting the value of R_{sense}. Quiescent current consumption on a 3.6V battery is 3pA maximum for the MAX382EX, plus 0.4uA to 2.8mA — roughly proportional to current load for current sense q_{2}. The core element is the tiny 5 pin SOT-23 MAX382EX latch output voltage monitor. It has a 3.6V to rail output at pin 5, which is normally high, turning on the N-channel MOSFET Q_{2} and allowing load current to pass from the battery to the external load. Transistor Q_{3} is a Temic "TS80" packaged transistor, shown because it has a very small power dissipation (0.4W) with a V_{CE} of 2.7V. When the input signal to pin 4 drops below the internal reference voltage of 1.2V, an internal latch is set which takes the output low. This turns off Q_{2}, thereby disconnecting the battery from its load. The latch can only be closed by a pulse taking the CLR input (pin 1) above 2V for at least 1ms. The reset pulse is provided by a push switch — typically, membrane type — which is AC coupled into the CLR input. The AC coupling prevents the user from disabling the protection by keeping the switch permanently pressed.

The value of R_{sense} (100kΩ) is deliberately quite low to give high noise immunity to the switch input. Resistor R_{X} (1MΩ) can be high resistance because its purpose is just to discharge C_{1} after the switch is released, and noise pickup at this point current resets the latch.

The intrinsic body diode of Q_{2} (cathode to drain, anode to source) is used for this purpose. If the battery is totally flat, then Q_{2} cannot be turned on. However the pack can still be charged because the body diode allows reverse (charging) current to flow.

When the pack is charged sufficiently, the protection latch can be cleared and the battery pack used in the normal way.

Dual transistor Q_{3} and Siemens RCV01, ensure that the very small current sense voltages of 50mV up to IC's trip threshold of 1.2V. A transistor pair was selected because it is low cost and small, in a SOT-143 package. The transistors are monostable, so thermal coupling and V_{CE} matching is intrinsically good.

To understand the current sense amplifier's operation, first consider the case where no current is flowing through R_{sense}. The V_{CE} voltages of the two transistors are the same in this condition. New Q_{2} (diode connected) has 10MΩ R_{sense} in its collector, whereas Q_{X} has a 1MΩ R_{sense} load.

Transistor Q_{3}'s emitter current is lower than that of Q_{4} by virtue of this collector load disparity, and so its working V_{CE} is lower than the working V_{CE} of Q_{4}. Hence Q_{3} is essentially turned off when no battery load current is flowing.

Now consider an increasing load current through R_{sense}. This resister will incur an increasing voltage drop, which has the effect of taking Q_{3}'s emitter negative with respect to Q_{X}'s emitter. This in turn increases the V_{CE} of Q_{X}, and at some point of increasing load current through R_{sense}, Q_{X} will be large enough for the collector voltages of Q_{X} and Q_{3} to equate. Voltage across R_{sense} at which this occurs is 0.026V/log_{10}(R_{sense})=60mV at room temperature. The IC will actually switch when the collector of Q_{3} drops to 1.2V, so there is a small inaccuracy in the switch point calculation — the circuit will actually switch at a slightly lower current than calculated.

The higher the supply voltage, the smaller the error is because the difference between V_{CE} and 1.2V as a fraction of the supply voltage reduces. The table shows the latching currents for several supply voltages:

<table>
<thead>
<tr>
<th>Supply voltage</th>
<th>Switching current</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0V</td>
<td>2.5mA</td>
</tr>
<tr>
<td>3.6V</td>
<td>2.75mA</td>
</tr>
<tr>
<td>3.3V</td>
<td>2.68mA</td>
</tr>
<tr>
<td>2.7V</td>
<td>2.56mA</td>
</tr>
</tbody>
</table>

Also, the switch point varies with temperature because absolute temperature, T, is in the equation. This isn't as bad as it first appears. The working temperature range of a pack may be from as low as −30°C up to +40°C, which is a variation of ±30K around a mean of +10°C or 383K. So the variations in trip point is about ±10% with temperature.

Tim Hesketh and Dave Watson
MAXIM Integrated Products UK Ltd

Ten year index: new update

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<td>5</td>
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<tr>
<td>6</td>
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</tbody>
</table>

The ten year index is published every year in Electronics World. It covers the years 1990 to 2000, and is available free of charge. It contains about 1000 references to articles, circuits and applications — including a synopsis for each.

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CIRCUIT IDEAS

CIRCUIT IDEAS

Electronics World May 2001

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Electronics World May 2001

383
### Battery pack short-circuit protector

This circuit provides short circuit protection to a removable battery pack of up to 11V. It could be fitted in the battery pack as a stand-alone protection. Or it could be included as part of the electronics if gas gauging or SMBus charging control circuit is embedded.

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As drawn, the circuit trips at 2.7A current, but this limit can be easily changed by adjusting the value of \(R_{short}\). Quiescent current consumption on a 3.6V battery is 3μA maximum for the MAX835EUK, plus 0.4μA to 2.8μA – roughly proportional to current load – for current sense \(Q_2\).

The core element is the tiny 5-pin SOT-23 MAX835EUK latching voltage monitor. It has a rail-to-rail output at pin 5, which is normally high, turning on the N-channel MOSFET \(Q_2\) and so allowing load current to pass from the battery to the external load. Transistor \(Q_2\) in a Because **TSSOP** packaged transistor, chosen because it has a maximum \(I_{ch} \times 400mA\) with a \(V_{ce} \leq 2.7V\). When the input signal to pin 4 drops below the internal reference voltage of 1.2V, an internal latch is set which takes the output low. This turns off \(Q_2\), thereby disconnecting the battery from its load. The latch can only be cleared by a pulse taking the CLR input (pin 1) above 2V for at least 1μs. The reset pulse is provided by a push switch – typically, membrane type – which is AC coupled into the CLR input. The AC coupling prevents the user from disabling the protection by keeping the switch permanently pressed.

The value of \(R_{short}\) (10kΩ) is deliberately quite low to give high noise immunity to the switch input. Resistor \(R_3\) (1MΩ) can be high resistance because its purpose is just to discharge \(C_1\) after the switch is released, and noise pickup at this point current reset the latch.

The intrinsic body diode of \(Q_2\) (cathode to drain, anode to source) is useful as a back-emf clamp. If the battery is totally flat, then \(Q_2\) cannot be turned on. However the pack can still be charged because the body diode allows reverse (charging) current to flow.

When the pack is charged sufficiently, the protection latch can be cleared and the battery pack used in the normal way.

Dual transistor \(Q_2\) is a Siemens BAV50L, aiming for the very small current sense voltage of 50μV up to IC's trip threshold of 1.2V. A transistor was selected because it is low cost and small, in a SOT-143 package. The transistors are monolithic, so thermal coupling and \(V_{be}\) matching is intrinsically good.

To understand the current sense amplifier’s operation, first consider the case where no current is flowing through \(R_{short}\). The \(V_{be}\) voltages of the two transistors are the same in this condition. New \(Q_2\) (diode connected) has 10MΩ \(R_e\) in its collector, whereas \(Q_1\) has a 1MΩ \(R_e\) load.

Transistor \(Q_2\) emitter current is lower than that of \(Q_1\) by virtue of this collector load disparity, and so its working \(V_{be}\) is lower than the working \(V_{be}\) of \(Q_1\). Hence \(Q_2\) is essentially turned off when no battery load current is flowing. Now consider an increasing load current through \(R_{short}\). This resistor will incur an increasing voltage drop, which has the effect of taking \(Q_2\)‘s emitter negative with respect to \(Q_1\)‘s emitter. This in turn increases the \(V_{be}\) of \(Q_2\), and at some point of increasing load current through \(R_{short}\), \(Q_2\) will be large enough for the collector voltages of \(Q_2\) and \(Q_1\) to equate. Voltage across \(R_{short}\) at which this occurs is 0.025V/log \((I_{be}+R_3)/R_3\) = 60μV at room temperature. The IC will automatically switch when the collector of \(Q_2\) drops to 1.2V, so there is a small inaccuracy in the switch point calculation – the circuit will actually switch at a slightly lower current than calculated.

The higher the supply voltage, the smaller the error is because the difference between \(V_{be}\) and 1.2V as a fraction of the supply voltage reduces. The table shows the latching currents for several supply voltages:

<table>
<thead>
<tr>
<th>Supply voltage</th>
<th>Switching current</th>
<th>Current range</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0V</td>
<td>2.5μA</td>
<td>0.025V/log ((I_{be}+R_3)/R_3) = 60μV</td>
</tr>
<tr>
<td>3.6V</td>
<td>2.75A</td>
<td>0.025V/log ((I_{be}+R_3)/R_3) = 60μV</td>
</tr>
<tr>
<td>3.3V</td>
<td>2.69A</td>
<td>0.025V/log ((I_{be}+R_3)/R_3) = 60μV</td>
</tr>
<tr>
<td>2.7V</td>
<td>2.66A</td>
<td>0.025V/log ((I_{be}+R_3)/R_3) = 60μV</td>
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Tim Herklotz and Dave Watson, MAXIM Integrated Products UK Ltd (2002)

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A microcontroller-based signal generator with voltage-controlled frequency and duty cycle

The circuit of Fig. 1 uses a Microchip 8-pin PIC12C671 as a voltage-controlled audio-frequency oscillator. Since the 12C671 has an internal 4MHz oscillator, 4-channel 8-bit a-to-d converters and a built-in power-reset circuitry, no extra components are required to form the signal generator.

The PIC12C671 reads two analogue inputs through AN0 and AN1. The conversion reference voltage is the controller's power supply Vcc. Voltage Vcc controls the output frequency while Vcc determines the duty cycle of the output signal. Frequency and duty cycle are independent: changing the frequency will not affect the duty cycle and vice versa.

Output frequency can be further controlled by 3-bit input A-C. These 3 bits set a pre-scaler between the controller's clock and timer 0. When A=B=C='0', the measured frequency is from 114Hz to 1.4kHz. When A=B=C='1', output frequency range is between 0.9Hz and 11Hz. See Tables 1 and 2 below.

- Fig. 1.

- Table 1 (A=B=C=0)

<table>
<thead>
<tr>
<th>Vcc (V)</th>
<th>0.0V</th>
<th>0V</th>
<th>1.45V</th>
<th>4.7V</th>
<th>5V</th>
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<tbody>
<tr>
<td>0V</td>
<td>114Hz</td>
<td>114Hz</td>
<td>114Hz</td>
<td>114Hz</td>
<td>114Hz</td>
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<tr>
<td>0.3V</td>
<td>3.7%</td>
<td>41%</td>
<td>62%</td>
<td>92%</td>
<td>96%</td>
</tr>
<tr>
<td>0.5V</td>
<td>1.23KHz</td>
<td>123Hz</td>
<td>139Hz</td>
<td>139Hz</td>
<td>139Hz</td>
</tr>
<tr>
<td>1V</td>
<td>3.8%</td>
<td>43%</td>
<td>63%</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>1.41KHz</td>
<td>1.41KHz</td>
<td>1.41KHz</td>
<td>1.41KHz</td>
<td>1.41KHz</td>
<td></td>
</tr>
<tr>
<td>3V</td>
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<td>25.9Hz</td>
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<td>25.9Hz</td>
<td>25.9Hz</td>
</tr>
<tr>
<td>4V</td>
<td>4%</td>
<td>41%</td>
<td>63%</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>5V</td>
<td>4.13Hz</td>
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<tr>
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<td>4.13Hz</td>
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- Table 2 (A=B=C=1)

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</tr>
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</tr>
<tr>
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<td>4.13Hz</td>
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<td>4.13Hz</td>
<td>4.13Hz</td>
<td></td>
</tr>
</tbody>
</table>

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Yongping Xia
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\[
\text{Table 1 (A=B=C=0)}
\]

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<tr>
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<th>V8</th>
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<td>3.7%</td>
</tr>
<tr>
<td>4V</td>
<td>123Hz</td>
</tr>
<tr>
<td>3.3V</td>
<td>3.3%</td>
</tr>
<tr>
<td>2V</td>
<td>3V</td>
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<tr>
<td>2V</td>
<td>4%</td>
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<tr>
<td>2V</td>
<td>256Hz</td>
</tr>
<tr>
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<td>4%</td>
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<tr>
<td>1.8V</td>
<td>413Hz</td>
</tr>
<tr>
<td>1V</td>
<td>9.5%</td>
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<tr>
<td>1V</td>
<td>95%</td>
</tr>
<tr>
<td>0.6V</td>
<td>%</td>
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\[
\text{Table 2 (A=B=C=1)}
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<table>
<thead>
<tr>
<th>Vt</th>
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<tr>
<td>0.6V</td>
<td>%</td>
</tr>
</tbody>
</table>
Antennas and propagation for wireless communication systems

This will be a vital source of information on the basic concepts and specific applications of antennas and propagation to wireless systems, covering terrestrial and satellite radio systems in both mobile and fixed contexts. Antennas and propagation are the key factors influencing the robustness and quality of the wireless communication channel and this book includes:

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- Overview of the fundamental electromagnetic principles underlying propagation and antennas
- Basic concepts of antennas and their application to specific wireless systems
- Propagation measurement, modelling and prediction for fixed links, microcells, microcells, picocells and megacells

Narrowband and wideband channel modelling and the effect of the channel on communication system performance
- Methods that overcome and transform channel impairments to enhance performance using diversity, adaptive antennas and equalisers

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Distinctive features of this book are:

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- End of chapter questions
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The Quadrant, Sutton, Surrey, SM2 5AS

12V battery voltage level detector

This circuit was designed for a Perkins-effect cold box on a sailing boat but could have other applications, for example, in a caravan. Load current of the cold box is about 4A and this is a large burden when sailing, but it can easily be met from the engine's alternator when under power.

The circuit detects the rise in the 12V supply when the battery is being charged. When this is about 14.2V (set by VR1) R12 closes and connects the load. When the supply falls to about 12.7V on stopping the engine, R12 opens and the load is removed.

The threshold between the two voltages prevents 'hunting' and can be changed by adjusting R7 (see graph).

The normally closed contact on R12 connects an external 12V supply.

This is for use in harbour when a mains connection is available. The external 12V supply also opens R12 and inhibits the detector. As the mains supply also feeds a separate battery charger, without R12 the detector will operate whenever the battery charger brings the battery voltage up to the threshold level and thus switch away from the external supply. The need for this relay was discovered in practice!

The detector should be installed as near to the battery as possible, to avoid the voltage drop in the cables to the cold box causing malfunction.

Tony Meacock
Norwich
Norfolk

LDR-stabilised Wien-bridge oscillator

This sine wave oscillator uses feedback via an LDR to stabilise the output amplitude. The circuit arrangement of IC2 should be familiar: if R1=K, R2=K and C1=C, then f=1/(2KR2C1).

With values shown, the frequency will be 1.99kHz.

Op-amp IC3 provides current to the LEDs according to output amplitude thus modifying the resistance of the LDR. Resistor R5 should be just greater than twice the value of R3. Adjust amplitude by modifying the value of R5. The circuit will work from 0Hz to 10kHz with 550 op-amps and values shown. Using rail-to-rail output amps and low voltage red LDRs, the circuit will work from a 5V supply.

The LEDs and LDR should be put in a light proof box such as a black pill cap. No claims are made for a perfect sine wave but it is adequate for exciting a transistor etc.

Some LDRs have a very slow response, which helps with distortion, especially at low frequencies.

Andy Little
Pencarrow
Cornwall

May 2001 ELECTRONICS WORLD
Antennas and propagation for wireless communication systems

This will be a vital source of information on the basic concepts and specific applications of antennas and propagation to wireless systems, covering terrestrial and satellite radio systems in both mobile and fixed contexts. Antennas and propagation are the key factors influencing the robustness and quality of the wireless communication channel and this book includes:

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- Overview of the fundamental electromagnetic principles underlyng propagation and antennas
- Basic concepts of antennas and their application to specific wireless systems
- Propagation measurement, modelling and prediction for fixed links, macrocells, microcells, picocells and megacells

- Narrowband and wideband channel modelling and the effect of the channel on communication system performance
- Methods that overcome and transform channel impairments to enhance performance using diversity, adaptive antennas and equalisers
- It will be essential reading for wireless communication engineers as well as for students at postgraduate or senior undergraduate levels.

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12V battery voltage level detector

This circuit was designed for a Pelican-effect cold box on a sailing boat but could have other applications, for example, in a caravan. Load current of the cold box is about 4A and this is a large burden when sailing, but it can easily be met from the engine's alternator when under power.

The circuit detects the rise in the 12V supply when the battery is being charged. When this is about 14.2V (set by VR) R1L closes and connects the load. When the supply falls (to about 12.7V) on stopping the engine, RL2 opens and the load is removed.

The threshold between the two voltages prevents 'hunting' and can be altered by adjusting R4 (see graph).

The normally closed contact on RL2 connects an external 12V supply. This is for use in harbour when a mains connection is available. The external 12V supply also opens RL2 and inhibits the detector. As the mains supply also feeds a separate battery charger, without RL2 the detector will operate whenever the battery charger brings the battery voltage up to the threshold level and thus switch away from the external supply. The need for this relay was discovered in practice.

The detector should be installed as near to the battery as possible, to avoid the voltage drop in the cables to the cold box causing malfunction.

Tony Measock
Norwich
Norfolk

LDR-stabilised Wien-bridge oscillator

This sine wave oscillator uses feedback via an LDR to stabilise the output amplitude. The circuit arrangement of IC1 should be familiar if $R_1 = R_2$ and $C_1 = C_2$, then $f = (1.2f_0)/(R_1C_1)$. With values shown, the frequency will be 1.59kHz.

Op-amp IC3 provides current to the LEDs according to output amplitude thus modifying the resistance of the LDR. Resistor R5 should be just greater than twice the value of R4. Adjust amplitude by modifying the value of R5. The circuit will work from 3V to 12V with 358 op-amps and values shown. Using rail-to-rail output amps and low voltage red LDRs, the circuit will work from a 5V supply.

The LDRs and LDR should be put in a light proof box such as a black pill box cap. No claims are made for a perfect sine wave but it is adequate for existing a transistor etc.

Some LDRs have a very slow response, which helps with distortion, especially at low frequencies.

Andy Little
Pencarrow
Cornwall
Precise single-supply baseline clamp and baseline measurement circuit

The circuit shown, right, accurately clamps the baseline incoming waveform to within a couple of millivolts of zero volts. Subtraction of the clipped signal from the original measures the low point of the incoming waveform. Using two series analogue switches reduces baseline ripple to almost zero...
Precise single-supply baseline clamp and baseline measurement circuit

The circuit shown, right, accurately clamps the baseline incoming waveform to within a couple of millivolts of zero volts. Subtraction of the clamped signal from the original measures the low point of the incoming waveform. Using two series analogue switches reduces baseline ripple to almost zero. Busking the switches with the output signal reduces the switches' off-state leakage and keeps the IC component stored on R4 from drooping between cycles. Capacitor C4 was chosen to allow processing of signals from 1kHz down to 0kHz. For higher frequency signals, a lower capacitance value can be chosen.

Linear pot gives logarithmic gain control

The volume control of an amplifier is generally logarithmic and sets the output to about 12% in its position. Apart from expensive models though, the tracking of the potentiometers is far from ideal. There are good linear potentiometers with 1% or better accuracy, but in general they are not suitable as volume controls. However the circuit of Fig. 1 will give you a calibrated output signal with a gain depending on the value of the resistors used.

The input has a voltage divider R1 and R2. If R2/R1 the 0dB signal of a CD player will give 1V ac to the input of Q1. With 10kΩ potentiometers, a null position and resistors R3 and R4 of 1kΩ, the gain of Q4 is (1+1.1)1.1. But there is an equal立法real attenuation of 1.1 between Q2 and Q3, hence the output signal will be 1V ac or 0dB also.

With R8 fully clockwise, gain of Q6 is x5 but attenuation to Q8 is now 1.1-[(10x+1)1-20xΩ]. This potentiometer scale will be almost linear in decibels, covering -20dB to 0dB. This is accurate enough for audio applications. Increasing R8 to 4.7kΩ will give a range of -10 to 0dB. In fact you can set the zero dB point anywhere, e.g. at 3 o'clock to give a range of -15 to 0dB.

Use LED as photo-diode

Light emitting diodes are cheap and readily available. They can also act as photo-diodes, an example being in the circuit shown. Some sixty LEDs, of various colours, were tested in the photo voltaic mode, and all acted as photo-diodes. Testing was done using a 2.5V 0.5A lamp over-run on 3V. Yelloworange LEDs worked best, producing about 50mV into 1MΩ. It is reasonable to suppose that LEDs would also operate on the current mode, which provides a wide dynamic range with response linearly related to intensity of illumination.

CIRCUIT

Letters to the editor

Letters to "Electronics World" Quartz House, The Quadrant, Sutton, Surrey, SM2 5AS
e-mail jackie.low@ri.co.uk using subject heading 'Letters'.

High-voltage power amp

I am writing in response to a letter from Ged Landen in the March issue on high-voltage amplifiers for electronic leak detectors. Back in 1985, I designed and built a push-pull transistor amplifier with a 31V HT supply as my final year thesis while I was at Chalmers University of Technology in Gothenburg. I did not use CRT deflection transistors, as a typical low power specification of the devices available at the time was >3V.

I used two transistors instead, with a voltage rating of 350V and a beta of greater than 40. Some 18 Darlington connected pairs were used for each leg.

Ann Ingesson
Linkoping
Sweden

On skill and training

I was very interested to read Malcolm Lisle's letter in the March issue - "An Unskilled Generation" - on the back training in the electronics industry. I'm under the impression that all the graduates go in the software sector or in electronics design.

I work in the field of automated functional test of populated circuit cards and I'm keen to employ some intelligent, motivated trainees - not necessarily graduates.

How do I find them?

I've tried Job Agencies, Job Centres and the local TUC with no results.

I believe me that some readers of Electronics World probably fit the bill, having a good knowledge of electronic circuitry, experience of software writing - possibly as a hobby - and who are addicted to electronics.

Allan Gee
Wrexham

More choice on FM

As the audio broadcast FM band is so much bigger than the AM MW and LW bands, it seems a pity that it has so few stations – especially as Radio 1 decided to have a narrower audience.

Digital radio doesn't seem very much, presumably this is because it takes a lot of processor power to decode and hence digital processors tend to be more expensive batteries than is required. An FM/AM/FM personal radio.

I read that 20kHz AM was considered for the FM band before 20kHz wideband with a FM signal chosen. I wonder if narrow-band FM could be used to square in extra channels - and could it be backward compatible? Could narrowband FM be combined with a digital helper signal? Even if it's Fm, extra stations would be good. John Bradley
Via e-mail

EMC and the individual

In the April 2001 issue, Leslie Green commented on EMC standards and spread spectra. While I agree with most of his comments, his statement that an individual can make a PC with CE certification is incorrect.

All equipment built and put "into service" must comply with the EMC directive. The maker is responsible, and there's no distinction between individuals or companies.

In theory, all equipment should be tested or have a Technical Construction File – even one card that is used in-house and not sold. With Trading Standards enforcing the regulations, it is difficult to see how anyone could be caught unless they actually caused interference and a complaint resulted. The only exception to this rule is that radio amateurs - and if anyone has licence ones – may construct equipment as long as it is not sold commercially.

Every time I have taken a system for EMC testing that included a ready built CE-approved PC, the PC has required work before it would pass on its own.

Lower cost monitors also fail emissions tests. Ensures or complaints to the PC suppliers just get responses such as "well all the parts are CE marked" and a copy of a certificate (2 years old) for the mini from an unknown Korean company.

Robert Atkinson, GERPI
Via e-mail

Phono preamp

Norman Thagard is not the first person to use a two stage preamplifier in order to avoid calculating the full RIAA network. This seems an extraordinary approach to circuit design.

He does not draw attention to the massive loss of headroom caused by this amplifier's design. This loses at 1kHz at 1kHz, and rises at 20kHz at 20kHz.

In general greater, R3 produced by the single circuit, because the gain cannot drop below unity, is easily cancelled out by placing a passive HP filter after the amplifier, so I have pointed out many times.

It did indeed come as a surprise to learn that most of the noise comes from the resistive part of the capacitor impedance - because it is not true. RIAA caps can be made of JFET op-amps, bipolar op-amps, discrete PNP or discrete bipolars, but in every case the major noise contribution is either the amplifier or the 470k input resistor.

Mr Thagard overlooks that the most resistive component of a typical moving magnet cartridge is completely dominated by its huge inductance. To this he adds a 100k resistor in series with the input, this adds little extra high value for EMC purposes.

For a 20MHz THD, the relevant values are

£75 winner

The answer: The circuit of the single-supply baseline clamp and baseline measurement circuit is shown. The circuit is designed to accurately clamp the baseline incoming waveform to within a couple of millivolts of zero volts. The subtraction of the clamped signal from the original measures the low point of the incoming waveform. Using two series analogue switches reduces baseline ripple to almost zero. Busking the switches with the output signal reduces the switches' off-state leakage and keeps the IC component stored on R4 from drooping between cycles. Capacitor C4 was chosen to allow processing of signals from 1kHz down to 0Hz. For higher frequency signals, a lower capacitance value can be chosen.

Electronic World May 2001

389
IT'S a great pity that so much information was given on noise and distortion performance.

Douglas Self
Huntingdon
Cambs

Dr Thagard replies...

I made no claim for originality of the two-stage concept. To the contrary, I wrote that I used a National Semiconductor abstract as the basis of the design. The only new feature was the single-stage op amp, but this was also based on a text book example.

The 15EF choke was per "The Art of Electronics" recommendations. I went so far as to explain the effect of adding the choke. Reduce the choke to 2.5 or 2mV or eliminate it entirely, if it offends your sensibilities. I prefer to keep it because the reception of radio stations through a phono preamp is less desirable than the negligible alteration in frequency response.

Anyway, the original articles for all three of these references were appropriately cited in the footnotes.

I see the article circuit on 2SK389 along with 2SK3894 as the vector that places the 47kΩ resistor in series with the input rather than in shunt. I did not overlook the "huge inductance" (of the cartridge). I went so far as to mention that balanced phone preamps, but could never get rid of input leakage noise, as the 2.5mΩ high source resistance; 10kΩ to 20kΩ is about right.

As the last half-century, the subject of electromagnetism, or EMC for short, has become increasingly complex and confusing. It now presents an enormous burden to the system designer. EMC is just another functional requirement on a system, and can be treated as such. All that is needed is an understanding of the coupling mechanisms. Given such an understanding, a few simple guidelines can be formulated. Many books and learned articles have been published. None of them adopts the approach outlined herein.

Circuit modelling

It is unreasonable to suggest that any EMC problem can be analysed in terms of circuit modelling. A wealth of analytical tools is available to anybody who has completed a course in basic circuit design. Just as circuit diagrams can be used to describe how the signals in a system are processed, so they can be used to define the interference coupling mechanisms. A circuit diagram gives the whole picture.

There is no point in trying to understand how a multivibrator works by focusing attention on the properties of resistors, capacitors, or transistors. Analysing the electrical and magnetic fields at different locations is just as futile, when assessing the EMC of a system.

The ground plane

A widespread belief exists in the engineering profession that the construction of an equipotential ground plane is to show some feature of any good EMC design. This is less likely to be successful than the search for the Holy Grail, because there is no such thing as the equipotential ground plane.

Figure 1 illustrates the concept of the conducting plane and the image conductor. The plane lies on the x-z axis and the conductor based above it, parallel to the x-z axis. When an alternating voltage source is connected to the circuit, a short circuit placed over the other, a current flows. It is true that, along any line on the surface parallel to the x-z axis, the voltage is the same. But it is not true that the entire plane is an equipotential surface. Along any line parallel to the x-z axis, the voltage varies continuously.

As far as the electromagnetic field is concerned, replacing the conducting plane with the image conductor makes absolutely no difference. Figure 2 is a circuit model of the upper conductor and its image. The plane is a half space, and its physical properties, it must also have identical electrical properties. The
610Q and 0.47H. Over most of the audio spectrum, the total cartridge impedance is much higher than the resistive part. So the noise generated by the 47kΩ input resistor is not swatted away, but goes into the amplifier input. For the best noise performance it is necessary to design for a much higher impedance than the cartridge resistance; 10kΩ to 20kΩ is about right.

It is a great pity that no information was given on noise and distortion performance.

Douglas Self
Huntingdon
Cambis

Dr Thagard replies...

I made no claim for originality of the two-stage concept. To the contrary, I wrote that I used a National Semiconductor abstract as the basis of the design. The only new feature was the single-stage op amp, but this was also based on a text book example.

The 10kΩ choke was per "The Art of Electronics" recommendation. I went so far as to explain the effect of adding the choke. Reduce the choke to 2.5 or 3MΩ or eliminate it entirely, if it forefends our sensitivities. I prefer to keep it because the reception of radio stations through a phonograph is less desirable than the negligible alteration in frequency response.

Anyhow, the original articles for all three of these references were appropriately cited in the footnotes.

I see the article circuit on PSpice along with various techniques such as the resistor that places the 47kΩ resistor in series with the input rather than in shunt. I did not overlook the "huge inductance" (of the cartridge). I went so far as to say balanced phone preamps, but could never get rid of the input resistor noise, as the 3.25kΩ resistor is in series with the input.

The Shure V15XH EMI and dc resistance were modelled as well. I also had and used the PSpice models for the input PTFEs, types 25KMR and 25109. The only devices in the model that differed from the prototype devices were the current mirror BJTs. Even then, I entered their models to make them more clearly compatible with the dual JFET transistors of the prototype.

Unless PSpice is wrong, the cartridge resistance is the greatest source of noise throughout the audio band. The preamp, as I stated in the article, constituted little additional noise. I wrote the disclaimer in the article that, "If the model is correct, the preamp, itself, adds little to the total noise output." Obviously, I acknowledged the basis of my claims for good noise performance.

I don't believe that I am even the first author to cite the cartridge as the key source of noise. I am confident of that. Given the wide range of early phonograph noise generators, we have known for years that the cartridge noise is the major noise source in the system.

New thoughts of EMC

Ian Darney

Dr Darney presents a new approach to EMC with a view to demystifying the subject.

Due to the last half-century, the subject of electromagnetic compatibility, or EMC for short, has become increasingly complex and confusing. It now presents an enormous burden to the system designer.

EMC is just another functional requirement on a system, and can be treated as such. All that is needed is an understanding of the coupling mechanisms. Given such an understanding, a few simple guidelines can be formulated. Many books and learned articles have been published. None of them adopts the approach outlined here.

Circuit modelling

Circuit models are invaluable as you can have someone to clarify the schematic diagrams. In particular, circuit diagrams can be used to describe how the signals in a system are propagated, so they can be used to define the influence of the electromagnetic environment. A circuit diagram gives the whole picture.

There is no point in trying to understand how a multivibrator works by focusing attention on the properties of resistors, or capacitors, or transistors. Analysing the electromagnetic and magnetic fields at different locations is just as futile, when assessing the EMC of a system.

The ground plane

A widespread belief exists in the engineering profession that the construction of an equipotential ground plane is to show some feature of any good EMC design. This is less likely to be successful than the search for the Holy Grail, because there is no such thing as the equipotential ground plane.

Figure 1 illustrates the concept of the conducting plane and the image conductor. The plane lies on the x-z axis and the conductor is placed above it, parallel to the x-z axis. When an alternating voltage source is connected to the circuit, a short circuit is placed between the object and the circuit plane at the origin.

The ground plane is true, that along any line on the surface parallel to the x-z axis, the voltage is always the same. But it is not true that the entire plane is an equipotential surface. Along any line parallel to the x-z axis, the voltage is always equal.
The ground plane can be represented by an inductance, and the value of that inductance is the same as the signal conductor.

Since the return current is the same magnitude as the signal current, it follows that the voltage drop along the ground plane is also equal to that in the signal conductor. Most definitely, the voltage is zero.

However, this does not mean that the ground plane has no practical value. When implemented as one layer of a multi-layer printed circuit board, it acts as a dedicated return conductor for every signal track on the adjacent surface. The return current is concentrated in that region of the plane immediately adjacent to the relevant signal track. Crosstalk between signals is minimized. Intra-system design

Figure 3 illustrates an intra-system problem. During normal operation, signal 1 is carried from A to B, and signal 2 is carried from C to D. Both use the structure as the return conductor.

Coupling between the two signals can be analysed using the model of Fig. 4, where it is assumed that signal 1 is the threat, and signal 2 is the victim. If it is initially assumed that signal 2 is zero, then any voltages in the victim loop must be due to interference.

Component values for the circuit model can be derived from the physical construction of the test assembly, or from electrical measurements made with general-purpose test equipment. When values have been assigned to all components of the model, then circuit analysis can be used to determine the level of interference created by the threat current, or the layout of the cables could be altered.

Circuit loops

Circuit diagrams normally show a section of a system, with the various inputs and outputs displayed as open-circuit terminals. The interconnections between circuit sections are seldom depicted either. Few people are interested in drawings of parallel lines. When electromagnetic coupling is being analysed, the focus of attention is reversed. The function of circuit sections is largely irrelevant.

The purpose of Fig. 4 is to analyse the effects of the magnetic field surrounding the three conductors. Values must be calculated for the loop currents \( I_{loop} \) and \( I_{loop} \) before spurious voltages at the terminals can be determined. Such a calculation is only possible if all components of Fig. 4 are defined. If any detail is omitted, analysis is impossible.

So, every loop of the circuit under review must be completely defined.

Inter-system problems

When the source of interference is outside the control of the designer, it is still possible to predict the response of the circuit under review. Figure 5 illustrates a problem. Equipment units A and B are mounted on a framework which is subject to lightning strikes. A single wire is used to carry a signal from A to B, with the structure used as the return path. What level of protection is needed at the interface circuitry to ensure that the system survives a strike?

Figure 6 shows the circuit model. Component values are determined as before. A waveform is assumed for the lightning pulse, and a current generator is created to simulate that current. Carrying out a circuit analysis of the system, and then comparing the results with voltages at Z₁ and Z₂, is needed to predict the effect.

Predicting EMC test results

Figure 7 illustrates the set-up for a typical conducted susceptibility test. A single circuit loop is used to induce a predefined voltage into the loop formed by cable and structure. The circuit model is shown in Fig. 8. Here, \( V_{loop} \) simulates the voltage applied by the test equipment.

A general frequency response analysis, or transient analysis, can be used to predict how the system will respond to an externally induced signal. If the prediction is favourable, the system can be confidently submitted for formal EMC testing. If unfavourable, modifications can be carried out, and the cost of failure will be avoided.

Correlating results

A linear network that contains one or more voltage or current sources can be replaced by a single voltage source and a series impedance. (Thévenin's theorem). Hence, the set-up of Fig. 7 can be correlated with conditions during a lightning strike (Fig. 5) or with interference from another circuit in the equipment under review (Fig. 3).
Circuit design

In fact, any number of interference sources can be treated as a single voltage source in series with the structure.

The structure as a shield

The first line of defense of any system from external electromagnetic fields is the outer conducting shield. This could be the metal of an equipment box, an aircraft fuselage, or the framework of a building. Extensive electromagnetic energy is converted to transient currents in the shield, rather than in the functional circuitry. Transient voltages will be developed along the paths that the currents take, due to the shield's inductance. From this point of view of circuitry inside the shield, the source of interference is a voltage generator in series with the inductance and resistance of the shield. In this context, the terms "shield", "ground", "earth", "structure", and "framework" are synonymous.

Return conductors

Up to this point, it has been assumed that all signals use the structure as the return path. It has been shown that any such configuration is subject to the full threat voltage. If this "single-wire" configuration is adopted, then every interface must be designed to withstand that level of threat. A significant degree of protection can be provided, by routing a return conductor alongside every signal conductor, as illustrated in Fig. 9. The circuit model for this configuration is shown in Fig. 10, where it is assumed that the return conductor is grounded at both ends. The inducers of loop and field are act as a potential divider to reduce the voltage induced in the inner loop. As a result, the differential currents, Levo, are significantly less than the common-mode current Im. The effect of interference on the system is reduced.

If the wires are close together, Llev and Im are less that Im, improving common-mode rejection. If in Fig. 10, the voltage source were in series with Zg, and Vlev was zero, then Im would be less than Levo. Emissions from power supply wiring would be reduced.

Ground loops

It does not take long to deduce that the inclusion of return conductors will create inescapable ground loops in a normal system. This is not a bad thing. Fear of ground loops is akin to being scared by bogeymen. Every ground loop provides a measure of common-mode rejection.

Current balance

If the two conductors of Fig. 10 were identical, the resistance and inductance values would also be equal. If the common-mode current were the shared equally, then Vme of the source would be equal to Vme of the common source. There would be no interference. Figure 11 illustrates this concept.

In Fig. 12, this circuit is viewed from the point of view of its normal function. Currents in the signal conductor is balanced precisely by current in the return conductor, and the common-mode current becomes zero. There is minimal emission. So, if the circuit design ensures that there is current balance in the signal and return conductors, then maximum common-mode rejection and minimum emission can be achieved.

Screened cable

Another way to improve common-mode rejection is to use a screened cable, as illustrated in Fig. 13. The circuit model for this configuration is shown in Fig. 14. Here, the transfer impedance between the common-mode loop and the differential loop is just the resistance of the screen. At low frequencies, common-mode rejection is minimal.

In Fig. 15, the circuit configuration from Fig. 14 is depicted. This is the general situation that we have been considering. The difference in levels of the two signals is small, and the screen is grounded at both ends. The shielding of the screen and the differential loop acts as a potential divider to reduce the interference voltage. This provides a measure of common-mode rejection.
but as the frequency increases, the impedance of $L_{cm}$ decreases, $L_{cm}$ rises and so does $R_{cm}$. Interference level rises at 20dB per decade. Then the situation worsens. Inductance $L_{cm}$ comes into play, and the slope of the curve increases, and continues to increase until the response reaches a resonant peak. It would be wise to expect much more than 10dB of common mode rejection at this frequency. A

Transmission-line considerations
When the loop formed by cable screen and structure is treated as a transmission line, an explanation for the performance of the floating and grounded configurations emerges. When the floating configuration is used, and the frequency of the interference reaches a quarter-wavelength of the line, voltage reflections occur at the open-circuit termination, with current reflection at the short-circuited termination. The amplitude of the current at the grounded termination builds up to a peak and a higher level of interference is observed in the differential loop. When both ends are grounded, and the frequency of the interference corresponds to the quarter-wavelength of the line, current reflections occur at both ends of the line. Again, the level of interference in the inner loop reaches a peak value. The inevitable conclusion is that neither the grounded configuration nor the floating configuration can give a consistent and predictable performance across the entire spectrum. Even so, they offer a vastly improved performance on the 'single-wire' configuration. If both ends of the line are defined, the frequency of resonance can be predicted.

Damping resistors
As well as providing an explanation of the problem, the transmission line theory offers a solution. Terminate each line with a damping resistor, ideally, with the characteristic impedance. Fig. 18 shows how voltage reflections can be avoided at a floating termination, by adding damping resistors. Since there are two loops involved, there are two transmission lines to be terminated. Values for $R_{cm}$ and $R_{cm}$ can range from less than 50Ω to 150Ω, depending on the configuration. Fig. 19 shows one way of terminating a wire pair, where the return conductor is grounded at both ends. A common-mode transformer is used to insert a resistor in series with the cable. As far as differential signals are concerned, the transformer is transparent; any voltage across the signal winding is cancelled precisely by a voltage across the return winding.

The performance of the configuration is better than that of the common-mode choke, which looks relatively poor at high frequencies. As with the floating configuration, an open-circuit causes resonant peaks. A common-mode resistance can be inserted into a screened cable without compromising the integrity of the screen. Just wind a few turns of copper onto a ferrite core and add a resistive loop.

Conclusion
A method of analysing various types of interference problems has been introduced. I have demonstrated that circuit modelling can be used to provide a clear understanding of the coupling mechanisms. A number of simple guidelines have been formulated. Designing circuits to minimise interference is not particularly difficult.

The biosensor: electronics meets biology
Advances in materials and sensors have made sensors smaller and more sensitive than ever. Despite this, sensors still rely on the same principles of physics and chemistry that were used to make the measurements of physical parameters in the early days. Now, there is a new class of device coming into wide-scale use. It is based on biology and biochemistry - fields of science until now largely unexploited in instrumentation and control.

These sensors will determine the concentration of many substances found in industry, the environment and living organisms - at speeds and resolutions previously unattainable with electronic devices. A device for measuring specific concentrations of chemicals in living organisms or molecules, especially enzymes or antibodies, to detect the presence of chemicals.

Early days
Perhaps the first sensor ever manufactured was Galileo's thermometer Fig. 1, made around 1592 AD. This was followed half a century later by Torricelli's baryometer, both instruments for measuring temperature and pressure parameters of various types.

It took until the nineteenth century, however, before the rise of the science of biochemistry. The interest in knowledge in this field was primarily due to the work of Michael Faraday. It eventually led to the development of sensors capable of measuring the presence and concentrations of atoms and ions in solutions. Perhaps the best known of these is the pH electrode, used for measuring the concentrations of hydrogen ions in solution, a measure of the solution's acidity. An important class of these sensors is the ion-selective electrode, which can be made sensitive to a particular ion through the use of a membrane that is only permeable to ions of a certain size. These membranes are often made of glass, Fig. 2.

The biosensor
A biosensor consists of three main components: a biologically active agent, a transducer for generating a non-electrical output that can be connected to some form of instrumentation and a fixing material. This fixes the agent into a device set to flourish in the twenty-first century - the biosensor.

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The biosensor article takes a look at how biological materials can be connected into the electronic world, the interface that makes all these applications possible.

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but as the frequency increases, the impedance of $L_{cm}$ decreases, $V_{cm}$ decreases, the voltage across $R_{cm}$ decreases, $I_{cm}$ decreases, and so does the level of interference at the interface circuitry.

**Capacitive effect**

Taking capacitance into account, the circuit model changes to that shown on Fig. 15. Carrying out an analysis of the frequency response reveals that the common-mode current will drop to a minimum, then rise again to a peak. At this peak, common-mode rejection is minimal. Even so, performance of a screened wire is better than the single wire or wire-pair configurations.

**Floating configuration**

By removing the link between unit B and structure, that interface can be made to float, giving rise to the configuration of Fig. 16. The circuit model now becomes as shown in Fig. 17. It is obvious that for the floating configuration, common-mode rejection is excellent at low frequencies. There is virtually no common-mode current.

However, as the frequency increases, the impedance of $C_{cm}$ decreases, $V_{cm}$ rises and so does $Y_{cm}$. Interference level rises at 20dB per decade. Then the situation worsens. Inductance $L_{cm}$ comes into play, and the slope of the curve increases, and continues to rise until the response reaches a resonant peak. It would be wise to expect much more than 10dB of common mode rejection at this frequency.

**Transmission line considerations**

When the loop formed by cable screen and structure is treated as a transmission line, an explanation for the performance of the floating and grounded configurations emerges.

When the floating configuration is used, and the frequency of the interference reaches corresponding to the quarter-wavelength of the line, voltage reflection occurs at the open-circuit termination, with current reflection at the short-circuited termination. The amplitude and frequency at the grounded termination builds up to a peak and a higher level of interference is observed in the differential loop.

When both ends are grounded, and the frequency of the interference corresponds to the half wavelength of the line, current reflections occur at both ends of the line. Again, the level of interference in the inner loop reaches a peak value.

The inevitable conclusion is that neither the grounded configuration nor the floating configuration can give a consistently good performance across the entire spectrum. Even so, they offer a vastly improved performance on the 'single-wire' configuration.

If both ends of the line is defined, the frequency of resonance can be predicted.

**Damping resistors**

As well as providing an explanation for the problem, the resonant transmission line theory offers a solution. Terminate each line with a damping resistor, ideally, with the characteristic impedance.

Fig. 18 shows how voltage reflections can be eliminated in a floating termination, by adding damping resistors. Since there are two loops involved, there are two transmission lines to be terminated. Values for $R_{cm}$ and $R_{cm}$ can range from less than 50Ω to 370Ω, depending on the configuration.

Fig. 19 shows one way of terminating a wire-pair where the return conductor is grounded at both ends. A common-mode transformer is used to insert a resistance in series with the cable. As far as differential signals are concerned, the transformer is transparent; any voltage across the signal winding is multiplied precisely by a voltage across the return winding.

The performance of the configuration is no better than that of the common-mode choke, which looks like a second dip at high frequencies. As with the floating configuration, an open-circuit causes resonant peaks. A common-mode resistance can be inserted into a screened cable without compromising the integrity of the screen. Just wind a few turns of wire onto a ferrite core and add a resistive loop.

**Conclusion**

A method of analysing various types of interference problems has been introduced. I have demonstrated that circuit modelling can be used to provide a clear understanding of the coupling mechanisms. A number of simple guidelines have been formulated.

Designing circuits to minimise interference is not particularly difficult.

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**The biosensor: electronics meets biology**

Advances in materials and sensors have made sensors smaller and more sensitive ever since. Despite this, sensors still rely on the same principles of physics and chemistry that were used to make the measurements. As the technology continues to evolve, the field of physics and chemistry will continue to improve.

The biosensor is a device that uses a living organism or biological molecules, especially enzymes or antibodies, to detect the presence of chemicals.

**Early days**

Perhaps the first ever sensor was the Galilean thermometer. Fig. 1, made around 1592 AD. This was followed half a century later by Torricelli's barometer, both were instruments for measuring physical parameters of the environment.

It took until the nineteenth century, however, before the rise of the science of electrochemistry. The increase in knowledge in this field was primarily due to the work of Michael Faraday. He is credited with the development of sensors capable of measuring the presence and concentrations of atoms and ions in solutions.

Perhaps the best known of these is the pH electrode, used for measuring the concentrations of hydrogen ions in solution, a measure of the solution's acidity. An important class of these sensors is the selective electrode, which can be made sensitive to a particular ion through the use of a membrane that is only permeable to ions of a certain size. These membranes are often made of glass, Fig. 2.

The new generation of sensors now coming into widespread use takes this development a stage further. These sensors combine 'traditional' physical or chemical principles with those of biotechnology and biochemistry.

Interestingly, this has come about because of a better understanding of how biological materials work on a chemical and physical level. This has enabled the construction of devices that are directed to electrochemical and physical sensing devices. To date, the main use of these devices has been in the health-care area, where measurements of levels of blood gases, ions and metabolites in the blood are often the best indicators of a patient's state of health. Using these devices in conjunction with other electronic indicators can make a much quicker and accurate diagnosis of the current situation.

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**Biological materials combined with traditional transducers allow substances to be analysed much more rapidly than is possible using conventional laboratory techniques. David Clark looks at a device set to flourish in the twenty-first century the biosensor.**

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**Inverted glass bottle with open-mouthed neck**

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**Fig. 1. Galilei's thermometer.** The liquid level rises and falls as the temperature of the air inside the bottle changes.
The transducer. With perhaps one notable and fascinating exception - surface plasmon resonance, described later - the transducer part of a biosensor operates on the same principles as the traditional physical and electrochemical sensors. The transducer must of course respond to the output of the biological agent. Depending on the agent, this output can be electrical, physical or optical. Electrical transducers can be amperometric, i.e. current measuring, potentiometric, i.e. voltage measuring, or even field-effect transistor (FET) linked. Here the gate of an FET is in intimate contact with the biological material. Changes in charge distribution within a biological material occur as a result of chemical reactions. These changes in charge directly control the FET. It is relatively easy to make the FET part of the signal-processing electronics associated with the sensor. Output that can be categorised as physical include the microscopic charge of mass, conductivity, dielectric strength and temperature that can occur when reactions take place. These effects can be monitored directly or converted to electrical measurements using fairly straightforward techniques.

Optical outputs might involve monitoring via fibre optics. Changes in transparency, i.e. change in light transmission properties, can be monitored optically. Many organic compounds absorb very specific wavelengths of visible and ultraviolet light. Fluorescence - the direct conversion of chemical energy to light energy by biochemical means - can also be monitored optically. Optical output using surface plasmon resonance can also be considered an optical technique. The fixer. One of the main problems in using biological material as part of a sensor is in fixing it in position as part of the sensor. As well as holding the material in position, the method chosen must also maintain it in an environment in which it remains active. Of course the fixer must also ensure that the material is accessible to the substance which it is measuring.

There are four ways of achieving this. The material can be fixed by:
- being adsorbed onto a surface, held behind a membrane, held within a matrix or chemically bonded, Fig. 4. The most dramatic advances that have come about in this sensor technology, however, have occurred due to the recent developments in knowledge of how biomaterials work at molecular level.

The biological agents. Currently there are four main classes of biomaterial used in biosensors. These are:
- enzymes, antibodies, receptors, proteins, and whole cells and tissues. In the future, it is possible that even whole organisms could be used as biological detectors.

The most useful aspect of biological materials is that many only react with specific materials. Enzymes are perhaps the best-known example. They are the catalysts of the biological world; without them life as we know it would not exist.

Enzymes function by reducing the energy necessary for a reaction to begin, the activation energy, and achieve this at biological molecular level by having a structural shape that "fits" - like a lock and key - with the molecules taking part in the reaction, Fig. 5. As a consequence, enzyme action is very specific, each catalyst catalysing only one reaction. As a result, it can be used to detect single substances in an environment where many may be present.

A good example of this class is the glucose oxidase enzyme, which can be used in biosensors for measuring glucose levels in blood. The shape of the glucose molecule is such that it fits into binding sites on the enzyme molecule.

The interaction affects the energy levels associated with the bonds between the atoms, and glucose and hydrogen peroxide are produced as the glucose reacts with oxygen. This means that the concentration of glucose can be determined by measuring one of three changes - the reduction in oxygen concentration, the increase in acid concentration or the increase in hydrogen peroxide concentration.

There is a simple electrochemical transducer for detecting each of these three substances - the pH electrode for example will measure the acid concentration very simply.

Antibodies. The second class of biomaterial is the antibody, or immunoglobulin protein; this is also the second most frequently encountered biomaterial used in biosensors.

The antibody is a fundamental part of the body's immune system. There is a different type of antibody for every type of particle the body recognises as foreign, an example of which is an infective agent like a bacterium. These foreign particles are known as antigens. The antibody binds tightly to the antigen for which it is specific, just as an enzyme binds to a reacting molecule. Figure 6 gives an indication of the actions of antibodies.

In the immune system, this triggers a further process that attacks the foreign particle; in the biosensor, however the property change that occurs as the antigen binds to the antibody is measured with an associated transducer. The activity of enzyme-based sensors means they are primarily useful in a medical context.

Receptor proteins. The receptor protein is a very flexible class of biomaterial for biosensor use. There are receptor proteins for many different types of biological active materials including hormones and neurotransmitters, the chemicals that mediate the activity of the nervous system.

Drugs also usually act via receptor proteins. In biological cells the binding of the appropriate molecule to the receptor protein triggers the selective, active transport of another substance across the cell membrane, a normal vital part of cell function. Figure 7 shows how the receptor protein works.

For a biosensor this action means that a receptor protein can be chosen to give a detector that only responds to the hormone, drug, etc., of interest. The use of whole cells and tissue in biosensors is more complex, primarily since living tissue needs a supply of nutrients and oxygen. Nevertheless the principle is the same, in the sense for example, that particular tissues respond to the particular molecules that "have" a particular smell. So a biosensor with some of this tissue as the detector could respond to the presence of these molecules.

Another, non-technical, complexity in this area is of course an ethical one concerning the source of this living material, whether animal or perhaps "cloned" human.
in position, provides a medium for keeping the agent stable, allows the reagent access to the agent, and links the agent's output to the transducer, Fig. 3.

The next sections look in more detail at each of these three components.

The transducer. With perhaps one notable and fascinating exception—surface plasmon resonance, described later—the transducer part of a biosensor operates on the same principles as the traditional physical and electrochemical sensors. The transducer must of course respond to the output of the biological agent. Depending on the agent, this output can be electrical, physical, or optical. Electrical transducers can be amperometric, i.e. current measuring, potentiometric, i.e. voltage measuring, or even field-effect transistor (FET) linked. Here the gate of an FET is in intimate contact with the biological material. Changes in charge distribution within a biological material occur as a result of chemical reactions. These changes in charge directly control the FET. It is relatively easy to make the FET part of the signal-processing electronics associated with the sensor. Those that can be categorised as physical include the microscopic changes of mass, conductivity, dielectric strength and temperature that can occur when reactions take place. These effects can be monitored directly or converted to electrical measurements using fairly straightforward techniques.

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Surface-plasmon resonance

The use of this sensor technology is still relatively new, but the potential is such that it is already in use.
molecules. This gives biosensors their sensitivity advantage over conventional sensors as well as the advantage of their selectivity. It does however mean that the associated transducer array must be sensitive enough to convert the biological effect to one that can be processed and displayed. Techniques can be used to detect the small changes in voltage, current, temperature etc. that are used in conventional transducers. However an existing new technique has been developed that enables the monitoring of the activity of biological molecules directly, one that operates at sub-atomic level. This technique is called surface plasmon resonance, Fig. 8. The atomic and molecular structures, and hence properties of materials, are determined primarily by the electronic forces between the charges on the atoms and electrons that compose that material. Quantum theory explains that the distribution of these charges is not fixed, as in the classical description of electron orbits. Rather, it is subject to random fluctuations, the electron orbitals for example being the "places" where the electrons are most likely to be found at any instant. A "packet", or quantum, of energy associated with this change fluctuation can be considered to act like an electron particle, and this type of "quasi"-particle is known as a plasmon. Just as atomic particles fixed in a lattice can vibrate and have a resonant frequency associated with them due to the energy of the bonds holding them, plasmons too can vibrate and have a resonant frequency associated with them.

At the surface of a material, for example a thin film of gold, these plasmons can be excited by a source of energy, for example photons of light. These energy interactions affect the reflection of that light.

If a thin layer of biological material is attached to the gold surface, the energy interactions between the biological and gold material will give a particular resonant frequency and angle of reflection for light directed at the surface. If the energy interactions are then modified, for example by the biological material binding to something else on its "outer" surface, the resonant frequency and the angle of reflection will change.

So, by simply directing a beam of polarized light at the gold film biologist-material interface and measuring the change in the angle of reflections, a highly sensitive method of detecting a substance that specifically binds to the biological material is obtained.

Prevention better than cure. Medical treatments are beginning to become increasingly based on prevention through routine clinical testing, followed by early intervention when potential problems are recognised. Similarly, better environmental protection is based on preventing contaminants reaching the environment in preference to cleaning up after it has occurred. The need for increasingly specific and sensitive detectors for the relevant substances is therefore becoming greater.

Scientists are rapidly developing the ability to "engineer" biological materials to specific requirements. Technological advances are enabling in many cases the agent and fixing medium to be screen-printed onto an electrode. This will allow the mass production of inexpensive biosensors, and it means that these devices are likely to be making greater and greater inroads into everyday life in the coming years, making a significant contribution to an increasingly healthy and "green" environment.
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