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ELECTRONICS WORLD

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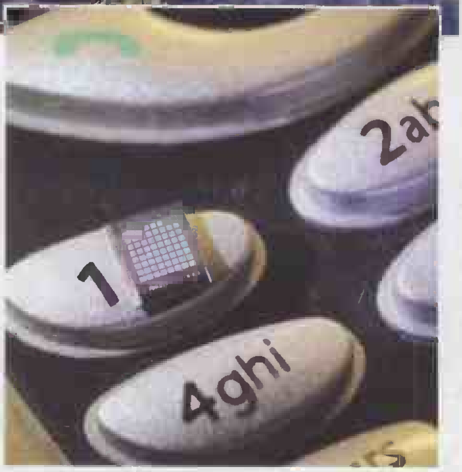

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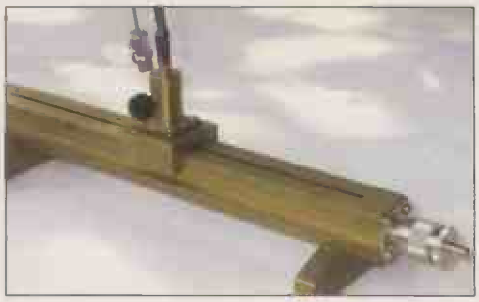

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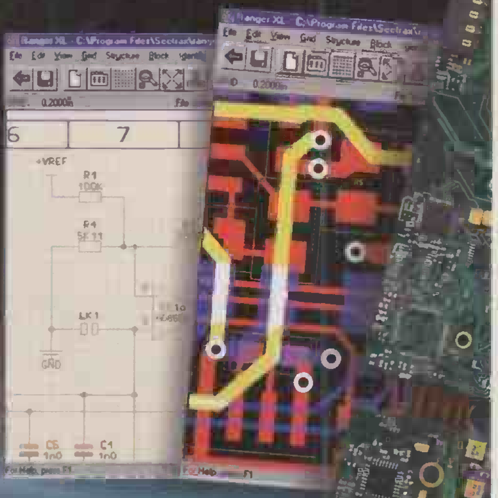

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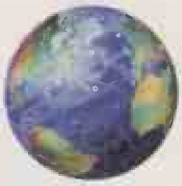

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Hard times

Hard times are here again. The statistics may say that U.K. Ltd. has fewer people out of work than for a very long time, but the picture is patchy. Fortunately, having started work in the 1950s, I am now in harbour, "and out of the swing of the sea". But some of those who still need to earn their daily crust are not so fortunate. And just at the moment, software engineers are going through a very black patch. My wife, a retired professional translator, recently received an unrequested email, from an agency that had obviously bought a circulation list. Did she have any work for fifteen software engineers, recently made redundant? A very long shot, especially as there was no mention of any of them having any linguistic qualifications.

As one who uses a computer a lot, without being an expert on its internal workings, my future son-in-law is my "help desk". He, a junior partner in an IT company, has suddenly found the company can no longer continue, due to cash flow problems. Should he hang on hoping to find a post to take advantage of his great software/systems expertise, or consider a mid-career job change?

At the same time, various practical tradesmen are in exceedingly short supply, as anyone who has tried to obtain the services of a plumber or electrician at short notice will be able to confirm. Should he become an electrician? He has the main qualification - an appreciation of just how dangerous 240V nominal (not to mention 415V three phase) can be - and given a few days study of the latest edition of the IEE Wiring Regulations, could probably make a comfortable living at the trade. The only employment my son can find locally is as "bank staff", (occasional) work as a receptionist in the local city health centre, so in the mean time fills in as a jobbing gardener. This self-employed work not only pays a higher hourly rate, but threatens to expand to a full time business, due to recommendations from customer to customer - gardeners, like plumbers, are like gold dust these days.

Why such a shortage of plumbers, electricians, welders and other tradespeople? It's because of our unbalanced education system, with politicians of all shades, blue orange and pink, wanting everyone to finish up with a degree. The result is that many young people waste time finishing up with a Mickey-Mouse degree, in media studies or the like, or even at one redbrick university which had better remain nameless, 'tribal African art studies'. You would imagine the Labour Party (Britain's current government) would be all for encouraging "the workers" in practical trades, but that party is now led by products of the public schools: Keir Hardy must be turning in his grave, at close to synchronous speed, no doubt.

Many continental countries have a much more sensible approach. For instance, in Germany, instead of trying to fit every child into an academic mould, for which some are by nature not equipped, at fourteen they are "oriented" according to their strengths and weaknesses. Those for whom it would be more appropriate are recommended to a place in a technical school, where they can learn a trade that will provide them with a livelihood. We have in this country some brilliant educationalists, who have discovered over the years that teaching children their multiplication tables *is* after all a good idea, and that the Initial Teaching Alphabet after all was *not* a good idea. Perhaps they could be encouraged to discover that a degree of some sort, *any* sort, is not the one essential thing that absolutely everybody needs. But there would still be the problem of selling the idea to the politicians.

Ian Hickman

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Microphone is micromachine

Pittsburgh-based fabless chip company Akustica has introduced what is claims is the first successful microphone made using Mems (micro-electromechanical systems) technology.

The company is calling its chips 'acoustic system-on-chip' (SoC) devices and it claims it can make both microphones and loudspeakers.

"Akustica's acoustic SoCs are based on patented technology that integrates the functionality of multiple microphones or speakers with microelectronics and software onto a single, standard CMOS semiconductor chip," said the firm. "The result is a new class of acoustic solutions that deliver unprecedented capabilities for capturing, processing and reproducing sound."

The initial chip has an array of 64 membranes combined with an on-chip analogue amplifier. It measures 0.5 x 3 x 3.65mm and "its performance is on a par with standard electret condenser microphones", said Akustica which is currently sampling key customers in North America, Europe and Asia.

"We look forward to introducing a wide-range of chips in the coming months," said James Rock, Akustica's president and CEO.

Other Mems microphones exist. "[Ours] offers distinct advantages over other MEMS microphones," said the company. "Akustica is producing its Microphone Chip with multiple membranes on each chip, enabling a number of advanced capabilities for capturing and processing sound. Other MEMS microphones on the market today offer only one membrane per chip, limiting the ability to provide new acoustic capabilities."

www.akustica.com

Akustica's chips are certainly based on a standard CMOS process, but with extensive post-manufacture micromachining.

The top metal layer in the CMOS chip has a grid pattern across part of the chip which will later be the microphone's membrane.

After CMOS processing is finished, this pattern is used to mask etching which bites deep into the substrate through the CMOS layers.

Once etching is finished, the circuitry is left on CMOS islands and a grid pattern of thin beams is left suspended above a corresponding pattern of ditches in the substrate.

Chemical vapour deposition of polymer lays down an airtight horizontal elastic membrane which connects each element of the grid with the walls of its ditch - but leaves the ditch empty to act as an air chamber.

The overall effect is to leave a micro-grid over an air chamber formed by all the ditches - which sound waves bounce up and down.

CB goes free, but channels cut

CB radio will become licence-free if the the UK's Radiocommunications Agency has its way.

The RA is proposing to deregulate CB and remove the licence fee, however it also plans to cut 40 of the available 80 channels.

According to the RA, applications for the £15 CB licence have dropped from 300,000 to just 24,000 in recent years.

This declining use does not justify keeping 80 channels, said the RA. It proposes to cut the 40 UK channels, leaving the 40 European channels.

The UK channels occupy from 27.60125MHz to 27.99125MHz, while the EU uses 26.965MHz to 27.405MHz.

To avoid disruption to users and manufacturers the UK channels would not be dropped until 2010.

Equipment would still need to conform to European Standards EN 300 135-1 and -2, said the RA.

Digital valves to cut nitrous oxide

Camcon, the UK firm developing electronic valves, has won a £45,000 Smart Award from the DTI. The money will be used for a feasibility study to assess its valves' ability to reduce greenhouse gas emissions from gas and liquid fuel turbines.

Nitrous oxide, said the firm, is emitted by turbines, but cannot be recycled, unlike CO_2. Fortunately the emissions can be reduced by running the turbine in 'lean-burn' mode, but this causes another problem, that of instability and failure of the flame chambers.

A solution proposed by the Engineering Department at the University of Cambridge is to modulate the incoming fuel stream at a high frequency. Camcon's digital valves might be the mechanism for this modulation.

The Smart Award will help us accelerate research on the application of the Camcon binary actuator in many areas of flow modulation. We believe that the elimination of the greenhouse emissions is a severe technical challenge, but if we succeed, it will lead to extremely positive environment benefits," said Christopher McDouall, commercial director at Camcon.d

UK on track for analogue TV switchoff

The Government has reiterated its plans to switch off analogue TV transmissions sometime between 2006 and 2010.

A recent report from the ITC and the BBC (Progress Towards Digital Switchover) showed the uptake of digital TV has reached 40 per cent and could double in the next five years.

Culture Secretary Tessa Jowell stressed the Government would take the necessary steps to ensure that the challenging target is met.

"I welcome this report. It underlines how well the market has done by itself in driving forward digital take-up. It is to be applauded for this," said Jowell.

"Doomsayers may suggest we won't meet the target. I would say to them that if industry can make this much progress on its own, anything is possible. The strong take-up since the launch of Freeview shows digital television is a product the public wants."

If progress by industry slows, the Government will take steps to hasten the change. These steps include announcing a firm switch off date, mandating digital decoders in all new TVs, public information campaigns, and a commitment to supporting coverage across the UK.

"I believe digital TV is the future and if we in Government have to play a more forceful role to boost its take-up, rest assured, we will do," warned Jowell.

The ITC/BBC report can be found at www.digitaltelevision.gov.uk

The big picture

A massive 380 million pixel sensor, developed by Essex-based e2v Technologies, has taken its first pictures at the Canada-France-Hawaii Telescope.

Called Megacam, the device is made up from 40 separate sensors, each with 4,608 x 2,048 pixels.

Each individual sensor measures 62 x 28mm, while pixels measure 13.5μm on each side.

The device's main spectral response is between 325nm and 825nm, where quantum efficiency exceeds 50 per cent, claimed the firm.

Sensors can be butted up next to others on three sides, allowing the large area camera to be created.

The resulting camera has an overall image view of one degree by one degree.

The image shows the Rosette nebula, a cloud of hydrogen gas and dust around 3,000 light years from Earth.

Cool bubbles are key to future computers

Researchers at Indiana's Purdue University researchers have found a way to improve liquid cooling for integrated circuits.

Chips have been getting hotter, to the point where liquid-cooling kits are already available for the hottest PC processors.

Whereas current high-performance chips generate about 75W/cm^2, chips in the near future will generate more than 300W/cm^2, said the University's Professor Issam Mudawar.

One extremely effective way to implement liquid cooling is to run the liquid through fine channels, called micro channels, directly over the silicon. This gives the liquid maximum surface area to extract heat and best thermal contact.

Unfortunately, as liquids boil, bubbles form and block the micro channels - forcing the use of a pump to keep the liquid circulating.

Mudawar tested coolants and found one, FC-72, which never blocks its channels as it produces smaller bubbles as micro channel diameter is decreased.

"We were surprised to see that the dielectric liquid forms really miniature bubbles, so they slip through really fast," Mudawar said. "The bubbles don't block the flow, as you would expect."

Using this liquid in micro channels and a passive thermal loop driven by chip heat at the bottom and a radiator at the top, he estimates 5.7 times more heat could be extracted compared with previous pump-less systems. "This is only a starting point, and much better performance might be possible," Mudawar said.

Professor Issam Mudawar with a pump-free liquid chip cooling system which removes almost six times more heat.

Robot learns to walk

Fujitsu's latest walking robot, the HOAP-2, uses a neural network in order to learn to walk and perform tricks.

HOAP-2 has a very smooth walking action, can perform handstands and pick itself up when it falls over, whether forwards or backwards.

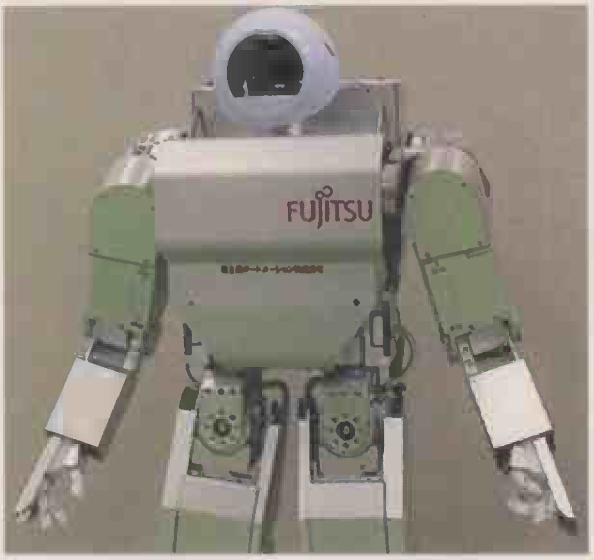
To speed up the learning process, Fujitsu Laboratories developed a dynamically reconfigurable neural network.

Neural networks are seen as a way to overcome the huge amount of processing power needed to control a walking robot. This is especially slow for HOAP-2 with its 20 degrees of freedom.

In HOAP-2, the firm used a central pattern generator (CPG) network, a mathematical simulation of the neural oscillators used for walking and running in vertebrate animals, and also found in creatures such as earthworms or lampreys. CPG's are often found in nerve ganglia in spinal cords and translate the brain's commands into muscle control.

Self-induced oscillations in the CPG activate muscles, or in this case the motors in the robot. Movements are accepted or rejected by the learning software, with the good movements changing the connection weights in the CPG.

Less than a tenth of the software code is needed compared to conventional systems, said Fujitsu, while learning time for a robot like HOAP is cut dramatically, to minutes.



Nanotube emits light

The quest to bring carbon nanotubes into the mainstream has taken a further step forward, with IBM demonstrating infra-red light emission.

Devices made using the emitter could be used in optoelectronic and comms systems.

"Nanotube light emitters have the potential to be built in arrays or integrated with carbon nanotube or silicon electronic components, opening new possibilities in electronics and optoelectronics," said Dr Phaedon Avouris, head of nanoscale science at IBM Research.

Avouris' team made the device by placing a 1.4nm diameter nanotube across the drain and source of a transistor. The gate was made underneath an oxide layer, rather than on top.

As electrons are injected into the source and holes into the drain, the nanotube emits light at around 1.5μm as they recombine.

Previous attempts to get nanotubes to emit light have relied on pumping the material with a laser, said IBM.

EMF limits to be reduced

The National Radiological Protection Board has issued a consulation document on exposure to electromagnetic fields.

It proposes that the UK adopts guidelines set by the International Commission on Non-Ionizing Radiation, which would see limits drop from 1,500μ Tesla to 100μ Tesla.

The consultation document includes a detailed summary of research into the effects of electromagnetic fields on the human body. The review considers epidemiology, experimental biology, volunteer studies and dosimetry.

The ICNIRP sets limits for electric field strength (at 50Hz) at 5kV/m^2 and for magnetic fields at 2mA/m^2, which corresponds to around 100μ Tesla.

The closing date for comments on the proposals is July 28.

www.nrpb.org

The incredible shrinking fuel cell

Researchers in the US at the Department of Energy's Pacific Northwest National Laboratory have developed a tiny catalytic fuel cell.

Aimed at hand-held equipment for soldiers in the battlefield, the unit combines a fuel reformer and fuel cell.

"This system can produce an equivalent power (20mW) to batteries, but at one-third the weight," said Evan Jones, PNNL principal investigator.

"What can be achieved on a large scale can be achieved at a microscale," he added.

The lab reckons fuels such as butane, jet fuel and even diesel could be used as well as the more conventional methanol in the cell.

Start-up swaps PMR for GPRS

A firm from Cambridge is using the public GPRS mobile communications network for taxi and courier data services, claiming it is more flexible than private mobile radio (PMR) systems. Cordic is installing its first system at a taxi firm now.

Taxis, couriers and the emergency services traditionally make use of PMR for their despatch systems, carrying voice and simple text messages to vehicles. However, PMR has fairly low data rates, is not 'always-on', and cannot be accessed by consumer devices.

By using the public GPRS network, Cordic can send voice and higher rate data to standard consumer devices such as handheld PDAs and smartphones. As these can be carried by drivers, they can access data even when away from their vehicles.

Add-ons to the system, such as GPS, would allow vehicles' locations to be monitored. This can be used for asset tracking or to provide time-of-arrival text messages to customers awaiting delivery or collections. Adding mapping software would allow directions to be sent to drivers, while the system also allows for international coverage.

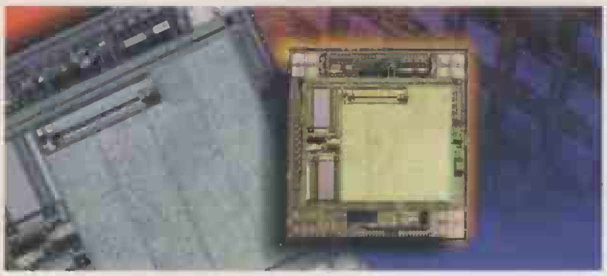
"There has been high level of interest in our products from both taxi and courier companies and we expect to deploy our products in a commercial environment during Q2 2003," said Fara Arani, director of sales and marketing and a founder of Cordic.

The firm was set up by ex-Tality engineers, freed up when the firm closed its Cambridge office. Cordic has just won its first round of funding from The Bruce Group, a firm usually associated with recycling.

"The new funding will provide Cordic with the working capital it requires to fulfill its sales and marketing activities and on-going development," said Arani.

In the future the firm hopes to develop its technology to allow real-time video surveillance for the safety of both drivers and passengers.

Motorola integrates analogue, power and logic



Motorola's latest Smartmos process integrates high-density logic and up to 90V power drivers in one process.

Aimed at automotive systems, industrial controls and consumer electronics, Smartmos8 MV (medium voltage), the process has moved to a 0.25μm feature size and includes deep trench barriers. Together these cut system size by 50 per cent compared with its previous generation, said the company.

The deep trenches separate devices on the chip, cutting inter-device leakage and isolating sensitive logic blocks from high voltage circuits which might otherwise interfere. First products are expected in 2004.

UK display is the brightest yet

Printable Field Emitters of Oxfordshire is claiming an intensity record for its latest second-generation field-emission display.

"Best previous reported data for a second generation FED was Samsung's at a show in Hiroshima last December," said PFE technical director Richard Tuck. "Theirs was around 150cd/m^2, ours gives 2,000cd/m^2."

Displays based on micromachined emissive tips, called first-generation, have achieved more than 2,000cd/m^2. "Raytheon got somewhere over 10,000cd/m2 with a very special display," said Tuck.

This would seem to make first-generation displays better candidates for outdoor applications. The trouble is, they are also extremely expensive to make and are limited to around 20cm across as they have to be made on a chip-making production line.

Currently it looks as though it will be possible to make second-generation FEDs over 1m across as the emitter is a flat surface coated with an inherently emissive material - usually some form of carbon.

"It is due to changes in the electrical structure and in processing techniques," is all Tuck would say about the source of the new-found brightness - not, he said, through turning the display up to self-destructive levels.

www.pfe-ltd.com

By the light of their own display, PFE marketing director Bill Taylor, technical director Richard Tuck and chief operating officer Ivor Thomas admire their latest creation under test in a vacuum rig.

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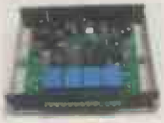

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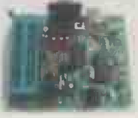

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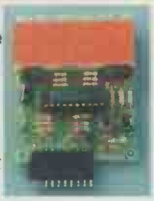

Starting count can be set. The 4-digit counter has four modes to control how the output behaves when it reaches zero. Max count rate of 30/sec or 30,000/sec. PCB: 51x64mm. 9-12VDC.
Kit Order Code: 3154KT - **£13.95**
Assembled Order Code: AS3154 - **£22.95**

4-Digit Timing Module

The firmware included with this motherboard kit is a programmable down timer of 10,000 sec. Timing accuracy: 0.04%. PCB: 51x64mm. 9-12VDC Current: 50mA. 5 other firmware chips can be used with this motherboard. Each has a different timing mode and can be purchased as a pack.
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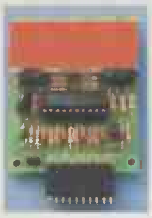

Count range is from 0000,1,2.. to 9999.It can also count down. Maximum count rate of about 30 counts per second. Two counters can be connected together to make an 8-digit counter. PCB: 51x64mm. 9-15VDC.
Kit Order Code: 3129KT - **£13.95**
Assembled Order Code: AS3141 - **£22.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

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Microphone goes digital

A digital version of the electret microphone has been developed by National Semiconductor, with a complex IC replacing the traditional single FET amplifier.

National's IC combines an analogue pre-amplifier and a second order sigma-delta converter. The third stage in a digital mic circuit, the filter, has been left out. This is because it often needs altering, which would require too many wires going to the microphone.

The firm has kept the pin count down to four in a quadrant pattern. The connections are power, ground, clock and data. Clock varies between 1.1 and 3MHz, with the oversampled output stream being MP3 and AC97 compatible.

The digital IC is housed in a 1.8x1.5x0.5mm 5-bump surface mount package, with the whole microphone fitting in a standard 2.2mm height housing.

Signal to noise ratio is claimed to be around –60dB, which is similar to standard electrets, but RF immunity and power supply rejection ratio are claimed to be better.

Computer firm NEC has added four models to its range of PCs with SoundVu screens, the UK developed technology that doubles the screen up as a speaker. Technology developer NXT is hoping for further design wins for its technology.

Smartcards are coming

The UK's banks have come together to replace credit and debit cards with secure smartcards, a two year programme costing over £1.25bn.

The move is an effort to reduce fraud associated with cards, a problem that cost the financial sector £425m last year.

"This is a turning point in the fight against plastic card crime in the UK. More than £1m worth of card fraud is committed every day - that's a fraudulent transaction every eight seconds," said Chris Pearson, chief executive of APACS, the UK's clearing house for payments.

Introduction of the Europay, MasterCard, Visa (EMV) cards will boost the smartcard, equipment and software manufacturers.

Over 120 million cards, 850,000 retailer transaction systems and 40,000 cashpoint machines will need to be replaced or updated. The whole process is due for completion by 2005, said APACS.

EMV cards contain a secure microcontroller and require the user to input a four-digit PIN for every transaction, not just at cashpoints - similar to the system used in France.

The first trial involving 1,000 retailers has already started in Northampton.

APACS says the smartcard programme is the biggest consumer project in the UK since decimalisation. All other European countries are expected to switch to EMV cards in the coming years.

Solar power ups efficiency

Research at Sheffield Hallam University has shown how the cost of photovoltaic solar cells can be reduced, while efficiency can be increased.

Solar cell efficiencies are typically measured in the range of 16 per cent for cadmium telluride cells. Using a new mathematical model, the Sheffield team managed to produce devices with 18 per cent efficiency.

"We've already applied for two patents and are preparing the final draft of the third patent in connection with our work, but there's a lot more science to be explored that could increase conversion efficiencies to over 20 per cent in the near future," said research leader Dr I M Dharmadasa.

Low cost manufacturing has also been examined, using electrodeposition, and less reliance on expensive semiconducting materials.

The team has also modelled solar cells based on copper indium gallium di-selenide.

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0-500mA	0• 12
0-1A	60m•
0-3A	20m•
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20 Way	£0.20	£10.72
26 Way	£0.26	£13.94
34 Way	£0.34	£18.22
40 Way	£0.40	£21.44
50 Way	£0.50	£26.80
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Robot home help runs Linux

Wakamaru is a 1m tall robot from Mitsubishi, claimed to be the first human-size robot that can provide companionship, or function as a caretaker and house sitter.

Inside is an embedded computer running a version of Linux from MontaVista Software. "The robust operating system plays an important role in enabling Wakamaru to service a household 24 hours a day." said Ken Onishi, Mitsubishi robotics group manager.

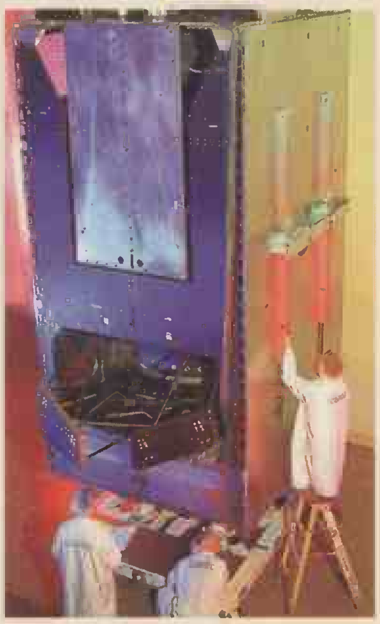
The robot has continuous Internet access and comes equipped with voice and face recognition capabilities that allow the robot to search for, and follow, voices, faces and movements.

It can, claims Mitsubishi, comprehend and interact with humans - including discussing daily news it obtains via the Internet.

If it notices a problem, it can call or e-mail a designated person, a hospital or security firm.

Mitsubishi will be marketing the robot in Japan first, at the beginning of next year. Price is somewhere near £10,000.

Largest satellite gives 8Mbyte/s Internet access



This is iPSTAR-1, at 6,775kg the world's largest commercial communications satellite.

Shown undergoing static load testing at Space Systems/Loral (SS/L), iPSTAR-1 is being built by SS/L in California for Shin Satellite of Thailand.

The spacecraft will be used to provide broadband Internet services throughout a large portion of Asia, Australia and New Zealand.

With eighty-four spot beams and a total throughput capability of around 40Gbyte/s.

This data rate will support individual user download rates of up to 8Mbyte/s and a return rate of 4Mbyte/s to as many as eight million users.

Launch is planned for early 2004 into an orbital slot at 120 degrees East longitude.

In Brief

The University of Southampton has applied for a patent covering optical amplifiers and modulators based on holey fibres - a kind of fibre the University specialises in.

Optical fibres are made of two kinds of glass: core glass surrounded by cladding glass.

Fibre amplifiers and modulators rely on non-linear effects in the glass from which they are constructed. These non-linear effects increase with increasing difference between the refractive indices of core and cladding.

"With conventional fibres, the difference is a few per cent at most," said Southampton's Professor David Richardson.

Holey fibres have a ring of closely spaced holes running along their length. The ring of holes acts as the cladding and the glass left suspended in the middle acts as the core.

"With holey fibres, the core has a refractive index of 1.45 and the cladding is mostly air with a refractive index approaching one," said Richardson.

Holey fibres are therefore more non-linear than conventional fibres.

When they are used in optical equipment "you get a shorter device, or you can pump the same device with less power. Not by a factor of two, the potential is very much greater", said Richardson.

When holey fibres are combined "with glasses of higher non-linearity, we have reported 500 times more non-linearity", said Richardson.

If commercialised, the research should spawn a significant cut in the bulk and power consumption of fibre-based amplifiers.

London-based RadioScape has demonstrated video-over-DAB to a PDA.

"DAB is perfectly suited for portable devices as it can provide a low cost means to access video and data anytime, anywhere making it a key technological advance for products being designed for tomorrow's digitally-connected mobile society," claimed RadioScape CEO John Hall.

The video, encoded in Windows Media 9 was Internet protocol (IP) encapsulated with a separate audio stream, then multiplexed using RadioScape digital radio infrastructure products.

This was up-linked via satellite from the UK and then re-broadcast via DAB for the demonstration in Las Vegas.

Using 150kbit/s, full motion streamed video was received on a personal computer using RadioScape's software-based DAB receiver card.

The demonstration also included portable applications with streaming video to a PDA sized screen using 64kbit/s.

Data over DAB on the move was demonstrated using an IPAQ PDA with an Etheractive DAB data card sleeve.

"It is a very robust technology that was specifically created to be used to receive digital content on the move you can even receive it at 300 kilometres per hour on a speeding train," said Hall, "Because DAB uses relatively little power with low processor requirements, it is ideal for mobile applications that want to access television programming - currently only available via cable or a satellite dish."

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32μF 250V A.C. CAPACITOR. Order Ref: 2P452.
4μF 440V A.C. CAPACITOR. Order Ref: 2P454.
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BATTERY CHARGER METER. 0A-3A. Order Ref: 2P366.
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DIMMER SWITCH. Standard size flush place, state colour – red, yellow, green or blue. Order Ref: 2P380.
TELEPHONE EXTENSION LEAD. 12m with plug end, socket ends. Order Ref: 2P338.
FIGURE-8 FLEX. Mains voltage, 50m. Order Ref: 2P345.
INFRA-RED UNIT. As fitted TV receiver. Order Ref: 2P304.
L.C.D. CLOCK MODULE with details of other uses. Order Ref: 2P307.
AM/FM RADIO RECEIVER with speaker but not cased. Order Ref: 2P308.
2A MAINS FILTER AND PEAK SUPPRESSOR. Order Ref: 2P315.
45A DP 250V SWITCH. on 6in. x 3in. gold plate. Order Ref: 2P316.
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20M 80 OHM TV COAX. Order Ref: 2P270.
LOCTITE METAL ADHESIVE. Tube and some accessories. Order Ref: 2P215.
6-DIGIT COUNTER. Mains operated. Order Ref: 2P235.
13A ADAPTORS. Take two 13A plugs, pack of 5, £2. Order Ref: 2P187.
3-CORE 5A PVC FLEX. 15m. Order Ref: 2P189.
MAINS TRANSFORMER. 15V, 1A. Order Ref: 2P198.
7-SEGMENT NEON DISPLAYS. Pack of 8. Order Ref: 2P126.
MODERN TELEPHONE HANDSET. Ideal office extension. Order Ref: 2P94.
13A SWITCH SOCKET on satin chrome plate. Order Ref: 2P95.
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INSULATION TESTER WITH MULTIMETER. Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges: AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50 each, yours for only £7.50 with leads, carrying case £2 extra. Order Ref: 7.5P4.
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D.C. MOTOR WITH GEARBOX. Size 60mm long, 30mm diameter. Very powerful, operates off any voltage between 6V and 24V D.C. Speed at 6V is 200 rpm, speed controller available. Special price £3 each. Order Ref: 3P108.
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We have thousands of relays of various sorts in stock, so if you need anything special give us a ring. A few new ones that have just arrived are special in that they are plug-in and come complete with a special base which enables you to check voltages of connections of it without having to go underneath. We have 6 different types with varying coil voltages and contact arrangements.

Coil Voltage	Contacts	Price	Order Ref:
12V DC	4-pole changeover	£2.00	FR10
24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13

Price includes base
MINI POWER RELAYS. For p.c.b. mounting, size 28mm x 25mm x 12 mm, all have 16A changeover contacts for up to 250V. Four versions available, they all look the same but have different coils:
6V – Order Ref: FR17
12V – Order Ref: FR18
24V – Order Ref: FR19
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Price £1 each less 10% if ordered in quantities of 10, same or mixed values.
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Weather information

Its collection, distribution and collation

This year is the 130th anniversary of the founding of the World Meteorological Organisation, the WMO. A United Nations (UN) agency, the WMO is responsible for one of the largest electronic collecting, distributing and collating systems in the world. Gregg Grant outlines its various elements

Let's start by asking a hardly original question: what IS weather? One answer is the five million billon tons of air storming around above our heads. Modelling the Earth's atmosphere therefore is - perhaps - the most demanding scientific-technological job around.

Weather signals readily span 80dB of dynamic range, are random in nature and are distributed quasi-continuously over huge areas. Measurements have to be made at almost every location on Earth, and in a matter of minutes. Yet this doesn't stop the public berating the meteorological profession and, in this regard at least, nothing has changed over the years.

When the British government created a meteorology branch in the Board of Trade in 1854, its task was simply to collate statistics on wind speed and direction, as an aid to sea navigation. The Branch's first head, Admiral Robert Fitzroy, expanded its role to include weather forecasting, at that time more a compilation of old wives tales and local suspicions than a science.

Fitzroy was among the earliest advocates of the new technology of the telegraph, for the collection and distribution of weather information. When he got things wrong - which was quite frequently - he was fiercely criticised by the Press, the Public and above all the Royal Society, who had grave doubts about looking into anything so unpredictable as the weather. By April 1865, Fitzroy had enough and on the last day of the month he committed suicide. Today, matters are a lot less fraught

Radiosonde

Radiosonde, or upper atmosphere information gathering, was the earliest example of aerospace telemetry, indeed the basis for the later - far more sophisticated and extensive - telemetry of space exploration. The basic system is illustrated in **Fig. 1.**

Meteorologists produce synoptic weather maps of the upper atmosphere twice daily from radiosonde information alone. Presently - as Table 1 shows - new techniques of high atmosphere measurements have been developed.

Yet despite this, the primary synoptic clock times for producing upper air weather maps remain those originally established by radiosonde observations, namely 0000h [midnight] and 1200h [noon] Greenwich Mean Time, GMT.

Moreover, present-day, computer-based weather forecasts use radiosonde times as their baseline, from which they calculate the changes that characterise modern weather forecasts. This - in effect - is the modern variation of the synoptic approach, developed as a result of the radiosonde systems set up throughout the 1930s.

Indeed radiosonde not only comprises some 12,000 land stations and 700 radiosonde-launching sites, but also measuring equipment on ships.

Despite their ubiquity however, radiosondes have their faults, as the

WMO are aware. A comparison was carried out in the early 1980s, when five radiosonde beacons, one each from Australia, Finland, India, the United Kingdom (UK) and the US were launched from the National Aeronautical and Space Administration's (NASA's) Goddard Space Flight facility. The final report on this international comparison revealed that discrepancies had been found in temperature, pressure and humidity measurements.

This trial provided the largest, uniform, data-set ever gathered on operational radiosonde performance. It was important because, although hardly ideal, they have several advantages over other methods. A radiosonde balloon can be sent into clouds where an aircraft would not venture and it travels more slowly than an aircraft, giving longer measurement times. In fact - surprising as it may sound - a radiosonde system even has advantages over satellites.

Satellites

In 1947, meteorologists first saw a view of the Earth's clouds from space. The images had come to them courtesy of a German V2 rocket which photographed part of the planet's weather at an altitude of roughly 135 kilometres (km).

These images resulted in proposals for obtaining such information on a regular basis and by mid-1955, the Americans announced that - as part of their contribution to the International Geophysical Year (IGY) programme - they would launch a satellite to investigate weather further. On the 13th October 1958, they kept their word.

The First Earth Radiation Experiment, or FERE, was the earliest 'meteorological' satellite to be launched, it producing some useful measurements of the Earth's radiation balance. It was equally as influential as the V2 experiment, the result being a determination to harness rocket technology and exploration devices to weather studies.

On April 1st 1960, NASA launched what they termed a Television Infra-Red Observation Satellite, TIROS 1 - who's orbit is shown in **Fig. 2**, - in an almost circular orbit, some 450 miles above the Earth. Circling the planet every 99 minutes this elegant-looking hatbox, 19 inches high and 42 inches in diameter, took 22,952 cloud photographs in the course of the 77 days its cameras and communications equipment worked satisfactorily.

The vehicle's cameras were slow-scan devices, recording an image once every 10 to 30 seconds, as instructed by NASA ground controllers. When the satellite came within range of a ground station, it transmitted its pictures immediately.

Once out of range, it stored the images on magnetic tape, subsequently relaying them to control on the vehicle's next orbit over a ground station.

Although TIROS 1 gave a complete global weather picture at a moment's notice, the satellite had its limitations. The on-board transmitter's failure to switch off drained the batteries on the 17th of June, a little over two months after its launch. Nevertheless, some 60% of its photographic output was meteorologically useful. The next eight satellites in the series were also judged to have been successful, TIROS 7, 8 and 9 having had operational lifetimes of 1809, 1287 and 1238 days respectively.

On the 13th of October 1978, the TIROS-N system was launched by the American National Oceanic and Atmospheric Administration, NOAA. With an all-up weight of 1421 kg and some 3.1 metres long, each vehicle carried an Advanced Very High Resolution Radiometer, (AVHRR), as well as infra-red and microwave sounding systems and a stratospheric sounding system, all of which are high-lighted in **Fig. 3**. Each satellite covered a portion of the Earth's surface some 6,200 km in diameter, the vehicles making 14.18 and 14.07 orbits of the planet daily.

This meant that each point on Earth was sensed for about 14 minutes at a time. The TIROS vehicles were a revelation, their most important achievement being the discovery that clouds often assume a regular spiral form over areas as large as 2,000 miles in diameter. This finding helped not only to improve weather forecasting, but also led to a better understanding of world weather patterns.

By far the least complicated orbit for a satellite is the geo-synchronous - often termed the geo-stationary - orbit. First proposed by Arthur C. Clarke as long ago as 1945 - albeit for an entirely different reason - placing a satellite in an equatorial orbit means that the vehicle will

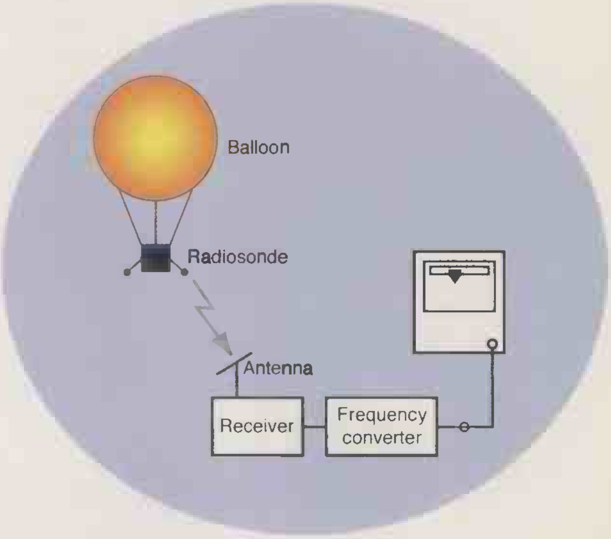


Fig. 1. Block diagram of a Radiosonde system.

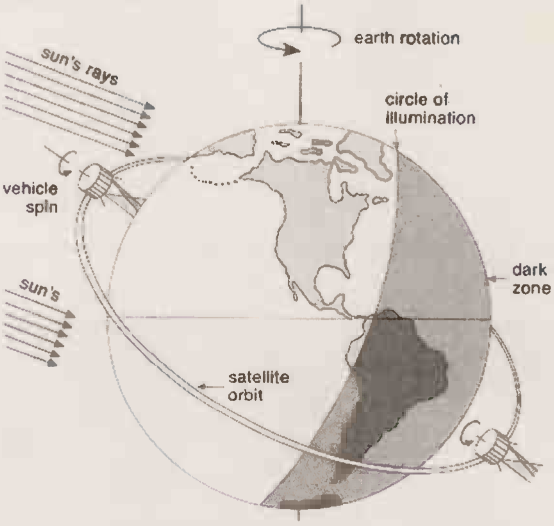


Fig. 2. The TIROS 1 satellite's inclined orbit

Table 1. Data Sources for Met Office Forecasts Circa 1986

Source Platform	Mean No. of Sets of Observations Daily
Land weather stations	14,471
Satellites	12,208
Aircraft	3,265
Shipping	2,857
Upper atmosphere (Radiosonde)	2,362
Drift buoys	1,785

circle the Earth above the equator.

Depending on the orbit's radius will depend its period. If - for example - the radius is such that the vehicle's period is 24 hours, then the Earth will rotate at exactly the same angular velocity and the vehicle will stay at precisely the same location above the equator. This situation occurs when a satellite is some 35,900 kilometres (kms) above the equator.

Following this track means that the satellite can observe Earth between 55EN and 55ES in latitude and to some 55E of longitude on either side of its location. The vehicle scans the planet sequentially, the measurements of each scanned element being radioed to a ground station, where an image is gradually built up. The earliest geo-stationary weather satellite was NASA's Advanced Technology Satellite 1, or ATS 1, which was blasted into orbit in 1966. This too was another 'proof of concept' vehicle, to determine the usefulness of the measurements such a satellite could make.

Since then geo-stationary vehicle design has remained largely unchanged, they being cylindrical and stabilised, so that they spin about an axis parallel to the Earth's, at 100 rpm.

The on-board instrumentation scans Spaceship Earth - in sequence - every half an hour which, as a result of the vehicle's spin, gives a West to East scan. Each revolution lasts some 0.6 seconds, during which the Earth is in view for a mere 0.03 seconds.

Yet in this brief glimpse, the infrared monitors make no less than 2500 consecutive measurements of the planet's radiation from an area 5 to 10 kms wide.

Ships And Buoys

In 1946, the recently-formed International Civil Aviation Organisation, ICAO, held a conference the outcome of which was the creation of an oceanic weather monitoring capability. This entailed the stationing of weather ships at specific points in the North Atlantic, and was an international effort, as **Fig. 4,** illustrates.

The British vessels were ex-Royal Navy corvettes, which had served throughout the war as convoy escorts in the very waters in which they were now observing the weather. By the late 1950s, these corvettes were replaced by former navy frigates, which were some 10 metres longer, enabling them to carry more up-to-date electronics, including wind-finding radar. These vessels served on the Atlantic weather stations until the early 1980s and were replaced - if that's an adequate description - by a single trawler!

In fact, seaborne weather monitoring was changing fundamentally. The Americans had already terminated their western Atlantic weather fleet and the WMO was in the process of taking responsibility for a modified scheme, to cover the western Atlantic.

Besides, the reports of these specialised vessels were being supplemented by those of merchant vessels, oil exploration rigs, drilling barges and production platforms, as oil exploration advanced from the continental shelves to deeper waters. And there was another factor involved in the study of oceanic weather: drift buoys, similar to the example shown in **Fig. 5.**

The latest development in this field is *Argo,* an international effort which has created an Ocean-Area Net, or OAN, of some 3000 free-drifting buoys.

An element in the Global Climate

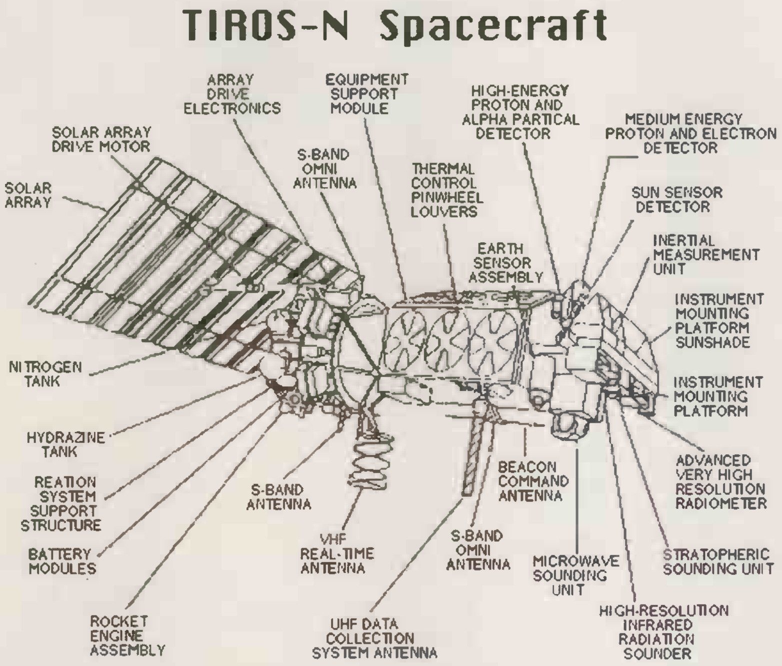


Fig. 3. The on-board equipment of the TIROS-N weather satellite. The most important instruments are highlighted.

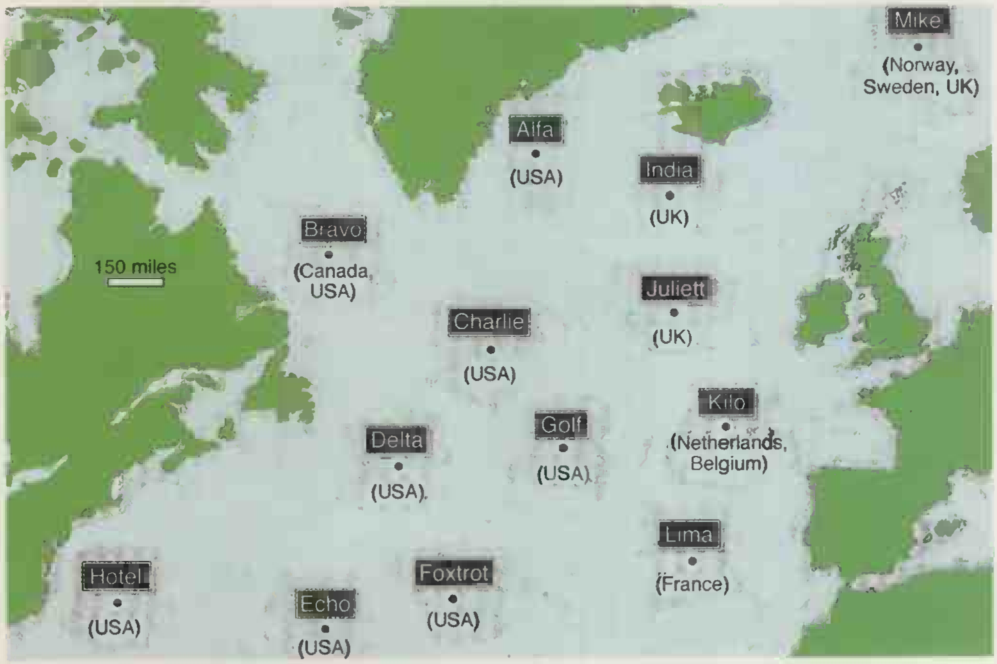


Fig. 4. North Atlantic weather ship positions.

Observing System, whose aim is to observe the oceans in real time, the *Argo* system measures the salinity and temperature of the upper 2000 metres of the oceans. The information gathered is relayed by satellite and in the public domain within hours of its collection.

In keeping with the internationalism that is meteorology, the planet's major nations - the US, Australia, Canada, Japan and the UK - are participating in this attempt at global ocean forecasting.

Radar

Generally, establishing the date of birth of a particular technological discipline is well nigh impossible. Where radar meteorology is concerned however it can be said to have been born precisely on February 20th 1941.

On this date, a shower was tracked to a distance of 7 miles by a 10-centimetre radar located on the English coast. Before long, radar operators and engineers realised that radar provided workable returns from wavelengths in the 5-10 centimetre band.

To meteorologists, this meant that they could now track and observe the birth, growth and decay of rain and snow showers and also, note the precipitation structure of much larger storms.

If a radar beam is fired vertically into a rain cloud, each raindrop returns an echo. The frequency of each of these drops differ by a minute amount, depending on the velocity of the raindrop relative to that of the radar beam. This Doppler Shift, named after the Austrian physicist Christian Johann Doppler, results in fluctuations in the intensity of the echo arising from large numbers of drops in motion, relative to one another. Measuring these fluctuations gives information on the drop size distribution.

Another form of radar is the radar altimeter, which generates pulses of nanoseconds duration which, as shown in **Fig 6,** are transmitted directly downwards towards the Earth. The time between transmission and reception of a pulse - generally about 0.005 seconds - can be used to calculate the height of the satellite to within centimetres.

Since the satellite's orbit is known, the radar reflections can be used to give details of the planet's deviation from the geoid. When the satellite passes over the oceans, the reflected pulses can be used to - for example - reckon the strength of currents. Nor is this all. Turbulent seas will blur the reflected signal and the degree of blurring can be used to calculate the wave height and, by inference, the wind speed over the ocean.

If those techniques are impressive, then Synthetic Aperture radar, or SAR, is even more so. The technique employs a method of standard radar techniques and the frequency shift resulting from the satellite's motion to create images of the Earth's surface. The result is that the scattering properties of each facet within the area scanned can be uniquely determined, giving a spatial resolution of about 25 metres.

However, in the along-track, or azimuth, direction the resolution is proportional to antenna beamwidth and so, by utilising the satellite's motion, it's possible to mimic a very long. antenna and therefore a very narrow beamwidth. This results in along-track resolution of between four and six metres. Furthermore, SAR image spectra appear to broadly agree with buoy measurements when calculating directional wave height.

Facsimile

Many people imagine that facsimile is a recent communications development. In fact the idea was born 33 years before the telephone, and a year before Samuel Morse's first successful transmission of his signalling code. The first facsimile machine was developed by the Highland Scot Alexander Bain.

Bain's equipment enjoyed some limited success, and throughout the 19th century his original idea was improved upon and redeveloped. By 1902, a satisfactory facsimile system was developed in Germany by Professor Arthur Korn, and by the early 1920s, the new technology of radio was developing apace. The leading companies in the field - both in Europe and America - began to consider combining facsimile and radio into a communicative whole.

The first American radio transmission of a weather map - shown in **Fig 7**, - took place on the 18th of August 1926. It was sent from the naval radio station at Arlington, Virginia and received at the Washington office of the US Weather Bureau. The transmitter operated on a frequency of 36kHz, its power output being around 30 kW. This short range test culminated in the Radio Corporation of America, the (RCA), pioneering the transmission of weather maps to ships, by radio-facsimile.

In Germany too, radio-facsimile was in use. The Munich Broadcasting Company began transmitting meteorological charts every weekday morning at 9 am, as well as on Sundays and holidays at 12.15 pm. The station used Dieckmann telephotographic equipment.

In 1929, the Marconi company introduced the Marconi-Wright facsimile equipment, which had been designed by one of the company's leading research engineers, G.M. Wright. On the 3rd of November a demonstration before a large gathering of Fleet Street's finest

Fig. 5. An example of a driftbouy (Photo courtesy NOAA)

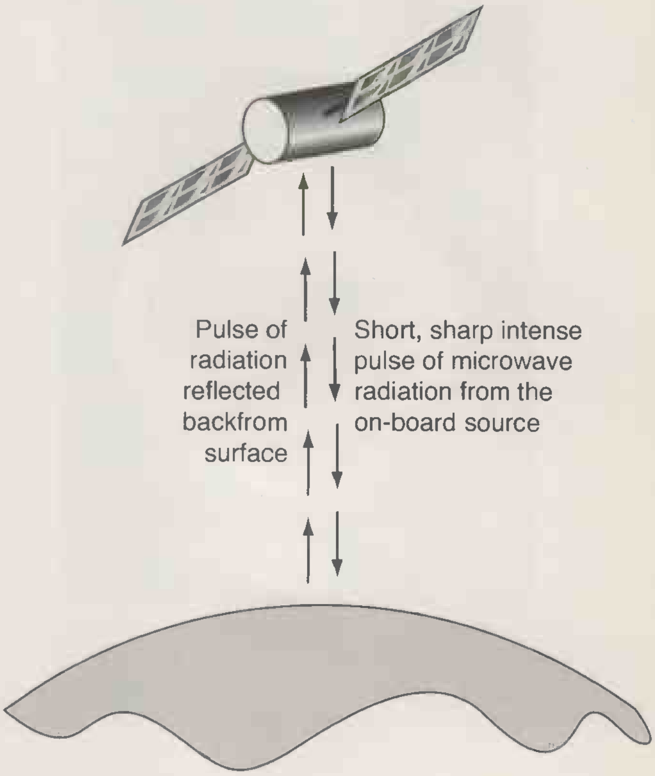


Fig. 6. Radar altimeter schematic.

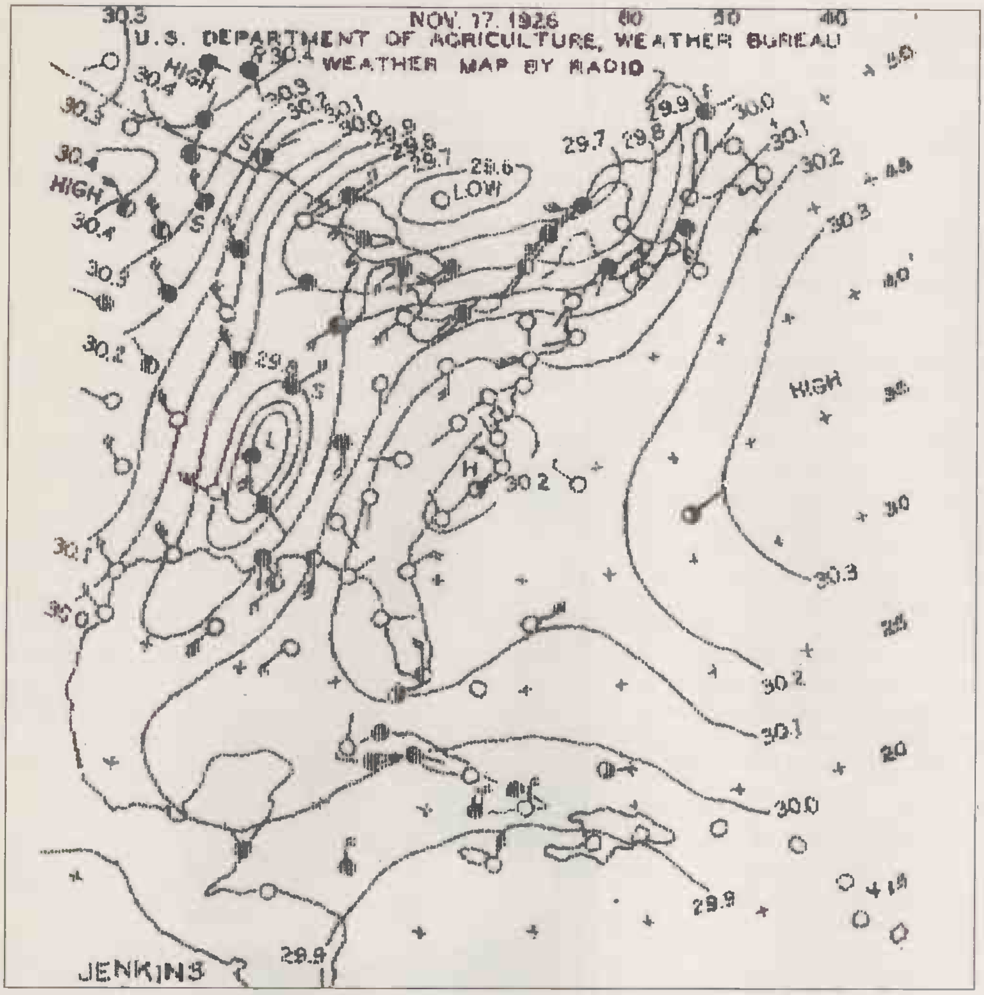


Fig. 7. The first US radio weather map, 1926.

resulted in the reception of a transmission from Rocky Point, in the United States, via the beam station at Somerton, Somerset.

Five years later, Cable and Wireless began a facsimile service between the UK and Australia, using the Marconi-Wright equipment and prominent among its traffic was weather maps.

In 1935, the American Associated Press inaugurated a wirephoto service - as facsimile was known in the US - providing the initial 39 subscribers with two weather maps, one for the morning papers and one for the afternoon editions.

Today, national facsimile networks are supplemented by the WMO's Regional Centre for Tropical Meteorology in Miami via its tropical Regional Analysis, or TROPRAN, facsimile circuit.

This network transmits tropical weather information to forecast offices in the southern US, the Carribean and South America. For a number of years, weather radio facsimile operated in the HF band, utilising the Frequency Shift Keying (FSK) method of two-level transmission, ie 2.3 kHz representing white and 1.5kHz black.

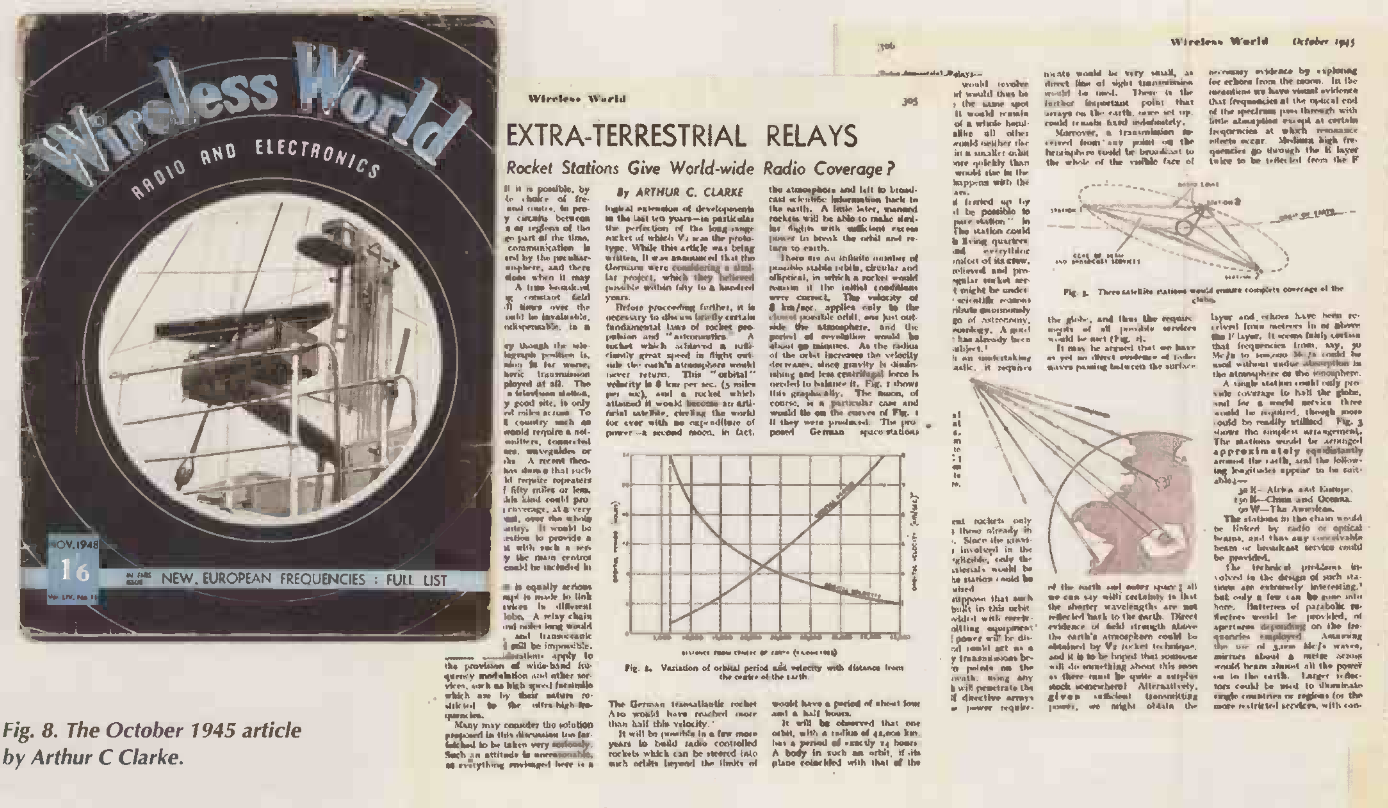


Fig. 8. The October 1945 article by Arthur C Clarke.

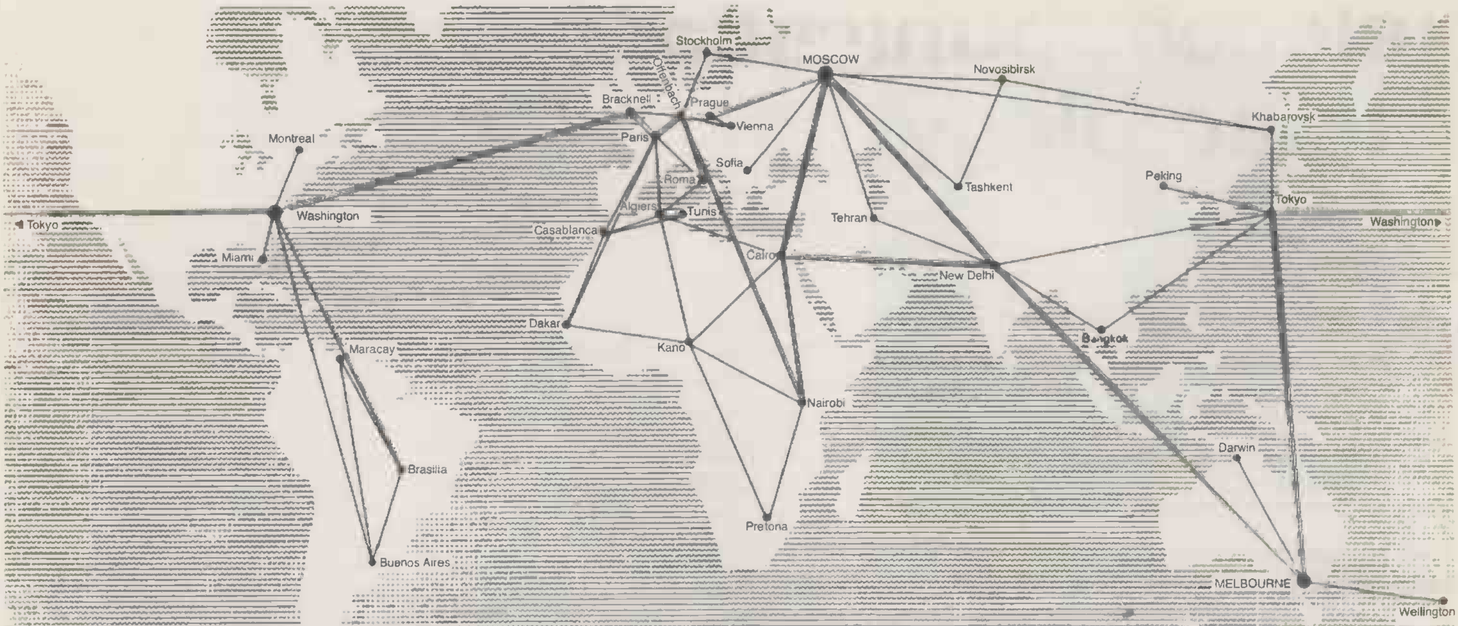


Fig. 9. The major hubs of the WMO's communications network.

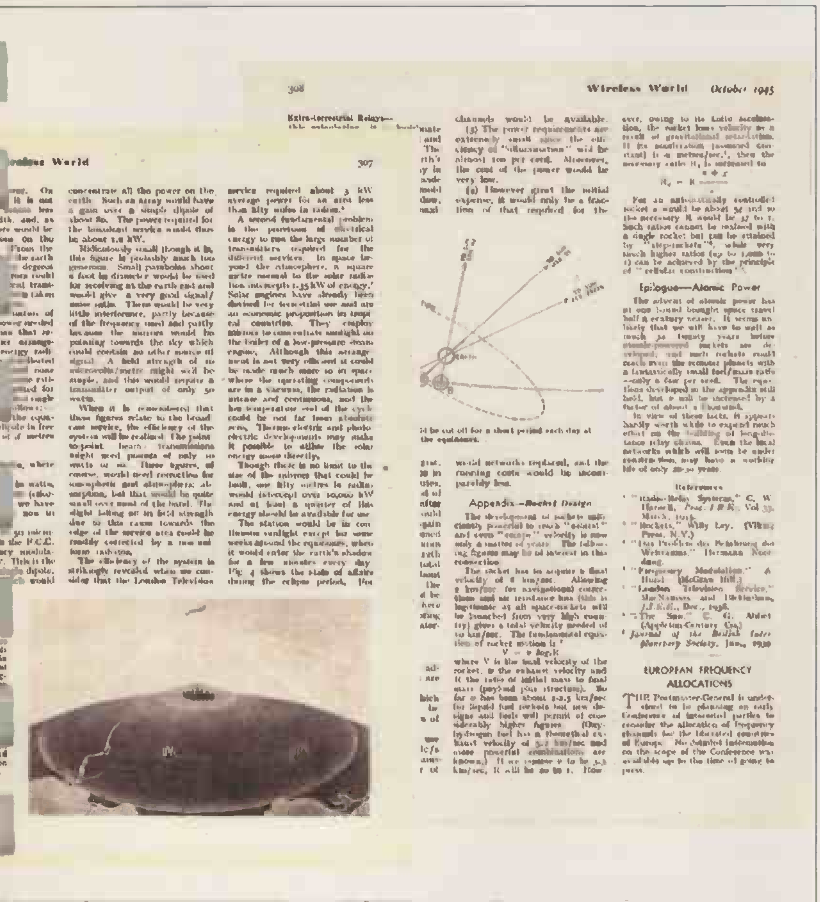
More recently Automatic Picture Transmission, or APT, has been used. In this technique, television camera views of the Earth's cloud cover are sent to the surface periodically from orbiting satellites, and then reconstructed at facsimile ground stations, world-wide.

Communications

The WMO's communication system links world weather centres in Moscow, Washington and Melbourne as well as eleven regional meteorological centres. No less astonishing is the fact that some 157 nations, states and sundry territories co-operate in this huge endeavour through the auspices of the WMO.

Fig. 9, gives some idea of just how extensive this network is. From Aruba to Vacoas, by way of Bracknell and Seoul, the system also includes such pariah states as Iraq (Baghdad) and North Korea (Pyongyang) as well as virtually every remote island on Earth!

A more realistic picture is presented in the WMO's publication *Forty Years of Progress and Achievement,* in which an A3 pull-out, throw-clear page is required to - literally - shoehorn all the remote outposts of the network on to the page. The WMO's network is extensive in another way also: the variety of equipment and techniques used to collate and distribute the vast amount of information coming in from sensors above, below and on the surface of the Earth.



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Epilogue—Atomic Power

Appendix—Rocket Design

EUROPEAN FREQUENCY ALLOCATIONS

Models

When meteorological scientists talk of a 'model' of the atmosphere, they're talking about a collection of equations which describe the behaviour of the Earth's atmosphere as accurately as can be determined by collating the mass of data available to them.

The first man to attempt to put weather forecasting on a mathematical footing was the British mathematician Lewis Fry Richardson. His method was based on the motion of the atmosphere and the physical processes taking place within this movement all of which - he thought - could be represented by mathematical equations.

As early as 1922, he published a far-sighted research paper *Weather Prediction by Numerical Process,* in which he outlined the first equations to predict air mass movement. It also introduced the Richardson Number, an important parameter in atmospheric turbulence.

Over many months, this eccentric genius carried out the calculations needed to produce a weather forecast for 24 hours ahead. Although his

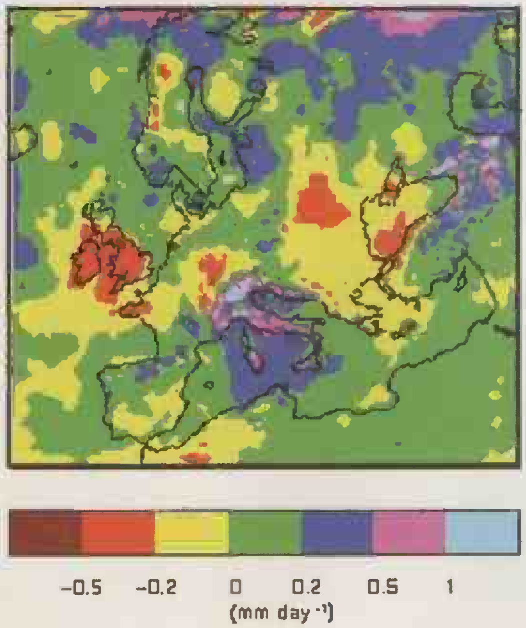


Fig. 10. A supercomputer simulation predicting summer rainfall over Europe from the present till 2020. (Courtesy UK Met office)

pressure change predictions - for example - were anything from 10 to 100 times larger than they should have been, Richardson laid the foundations of accurate, numerical weather forecasting.

In the process of this work, he flagged up the major hurdle to be overcome if forecasting was ever going to approach accuracy: the massive amount of calculations had to be carried out very rapidly indeed. In fact, he thought that such rapidity and accuracy would have to be on an industrial scale, envisaging that a 'maths factory' of some 64,000 mathematicians would be required, each with his - or her - own calculator!

Fig. 11. MSG-1 Meteosat second generation. (Photo courtesy ESA)

Enter The Computer

In the UK in the late 1940s, the most powerful computer available was Lyons Electronic Office, or LEO, which was used to calculate the number of pies, buns and other products required in the Lyon's teashops. LEO though had an 'evening' job also: number crunching for the Met Office.

In America too ENIAC, originally designed to calculate artillery firing tables, was turned to the weather. The Hungarian-American mathematician John von Neumann and his team at Princeton's Institute for Advanced Studies used the machine to produce the earliest, tolerably accurate, numerical weather forecast.

Five years later the Americans were making computer forecasts with increasing regularity. To begin with, these predictions were only marginally better than the techniques already in use. However, as computers became faster and capable of storing much more information, so more accurate models of the atmosphere were developed.

Super Computers

Nowadays of course, meteorological number crunching is done by supercomputers and indeed it was the demands of meteorological scientists that led to the development of these machines. The amount of data available to the forecasters is simply staggering. As we have seen, satellites have been investigating the planet's weather since the mid-1960s, and they not only handle their own observational data but also that from buoys, aircraft, some 7,000 ships and a further 4,000 land-based automatic weather stations. Modern weather instruments such as radiometers have both a rapid scan rate and high resolution, which means that the period of each measurement is some tens of microseconds. This results in an observation rate approaching 1Mbit/second in some multi-channel devices.

Geostationary vehicles are different again. In the case of Meteosat for example, the two data transmission radio channels are supplemented by a further 66 channels for handling data from automatic weather stations, and another eight for the exchange of processed data between meteorological centres.

Furthermore, the current GOES vehicles handle data from no less than 12,000 other meteorological platforms per hour, including seismometers and tidal and river gauges. All of these can be programmed to release their data at specific times or, in the manner of an aircraft's transponder, be interrogated by the satellite. All of which indicates the immense amount of data that needs to be processed and why a supercomputer is the only way to go about it.

The man behind the first supercomputer was Seymour Cray. The UK Met Office bought its first Cray machine in 1990. Nine years later it bought a second Cray, the T3E model, which it uses for accurate, real-time weather forecasting as well as the study of future climate change, an example of which is shown at **Fig. 10.**

Supercomputer performance of course is reckoned in floating point operations per second or *flops/s*. Some supercomputers recently developed in the US are capable of Teraflop performances, or 10^{12} floating point operations per second. Since a human being is capable of less than one flop/second, it would take the same person some 32,000 years to complete a Teraflop! Since supercomputer performance has increased by a factor of 500 throughout the 1990s, it's easy to see why the Met Office uses not one, but two such machines.

The future

Currently, a local thunderstorm is not easy to predict. The British Met Office for example - one of the world's foremost climatic research organisations- can only forecast for areas of 144 square kilometres or, in geographical terms, inner London. The problem here was the computer model of the atmosphere. This was updated last year, and so small scale forecasting will become more accurate.

Another problem is the world's oceans, since little is known of their interiors. Monitoring this vast area would give scientists models of the oceans akin to those of the atmosphere. This is vital, for both clearly interact with each other over vast areas of the planet.

As has happened over the last 30-odd years technology - and in particular electronic technology - will continue to play an important part in forecasting improvements. The Met Office for example is due to take delivery of a new computer this year, which will be 10 times faster than the current machines. Next year sees the launch of NASA's GIFTS satellite, designed to provide higher quality atmospheric measurements, thus making the modelling of atmospheric interactions that bit easier. Thanks to electronics, forecasting is gradually becoming that bit more accurate. ■

Metal detection: permittivity or permeability?

Frank Thompson presents his investigation into metal detection circuits, which includes a working circuit that is simple yet effective

More than two decades ago an article, entitled "Discriminative metal detector", was presented by Macario[1]. It described a metal detecting circuit that was claimed to have the ability to distinguish between ferrous and non-ferrous samples. Such a detector would therefore be useful in searching for buried treasure since 'bits of old iron' would not give rise to false hopes of having discovered a valuable hoard of coins.

This circuit was constructed at the time as a student project but the results were not totally convincing and the article was filed away in a 'to be looked at later' file box and has there remained, undisturbed, for a considerable time.

More recently[2], a circuit similar to Macario's has been described and this has provided yet another project. Again, it has not been possible to discriminate between ferrous and non-ferrous samples and it was therefore felt worthwhile to carry out some basic experimentation to shed a little light on the matter.

Theoretical aspects

A full description of the theory relating to the interaction of electromagnetic fields with materials has been given by Carl Moreland[3] (Web search via Google – beat-frequency oscillator theory).

There is a fundamental mistake in equation 5, page 6, of Moreland's work but otherwise the article covers all salient details.

An ideal *LC* oscillator has a resonant frequency given by:

$$\frac{1}{2\pi\sqrt{L.C}} \tag{1}$$

A change in frequency occurs if a change occurs in either the inductance or capacitance (or both) and this can be determined from the derivative of Equation 1.

$$\frac{\Delta f}{f_0} = -0.5\frac{\Delta L}{L} - 0.5\frac{\Delta C}{C} \tag{2}$$

Equation 2 replaces Moreland's Equation 5 in which a product,

$$\frac{\Delta L}{L}.\frac{\Delta C}{C}$$

is used incorrectly to calculate frequency shifts.

The value of L may be changed by changes in the *permeability* of the medium in which the inductance is situated (ferrous materials result in a frequency decrease).

Note that permeability values can be less than unity as are present in diamagnetic materials and this will result in a frequency increase. However, the effect is so small as to be beyond the limits of detection[4].

Capacitance changes occur if there are changes in the *permittivity* of the medium within the capacitor. This, again, increases the capacitance value and so reduces the resonant frequency. In addition to the above there are induced currents resulting from Lenz' Law. These so-called Eddy currents cause an increase in the frequency of oscillation in all metals and can often override the permeability effect, thus the discrimination between ferrous and non-ferrous metals may well not occur.

At high frequencies even more problems arise – inductances have associated capacitance[5] and they become self-resonant. This, however, is a topic beyond the scope of the present article.

Initial experiments

A simple inductance meter has been given by Miguel-Lopez[6] and a test inductor similar to that used in the article was used in these initial experiments. This test loop is shown in **Fig. 1**.

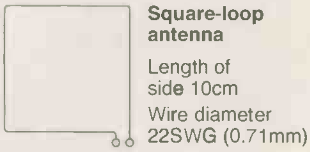


Fig. 1. A single-turn square-loop antenna as test inductor.

The inductance for the above loop is given by:

$$L = \left(\frac{2\mu_o\mu_r l}{\pi}\right).\ln\left(\frac{2l}{d}\right) \tag{3}$$

For the case of this inductor in air, the inductance is calculated to be $0.45\mu H$ as the relative permeability, μ_r, has a value of unity.

Inductance measurement at 10kHz (Wayne-Kerr meter B905) gave a value of $0.48 \pm 0.01\mu H$ in air which was considered to be in reasonable agreement with the theoretical value. Further measurements were carried out with the loop placed on sheets of material:

- Inductance equal 0.37 ± 0.01μH when placed on an aluminium sheet.
- Inductance equal 0.45 ± 0.01μH when placed on a steel sheet.

Thus inductance is lowered for both materials indicating eddy current effects are predominant in both materials. There is, however, a smaller difference in the case of steel and this may be due to a combination of the permeability of iron and a conductivity lower than aluminium.

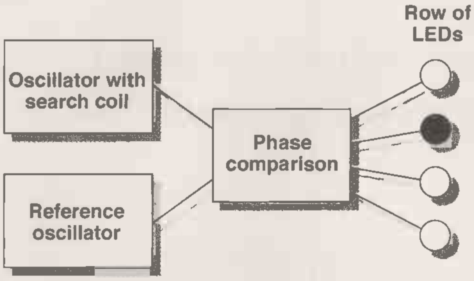


Fig. 2. Basic detector arrangement.

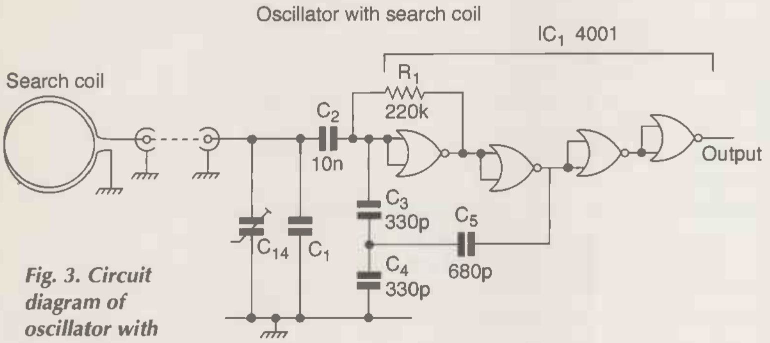


Fig. 3. Circuit diagram of oscillator with search coil.

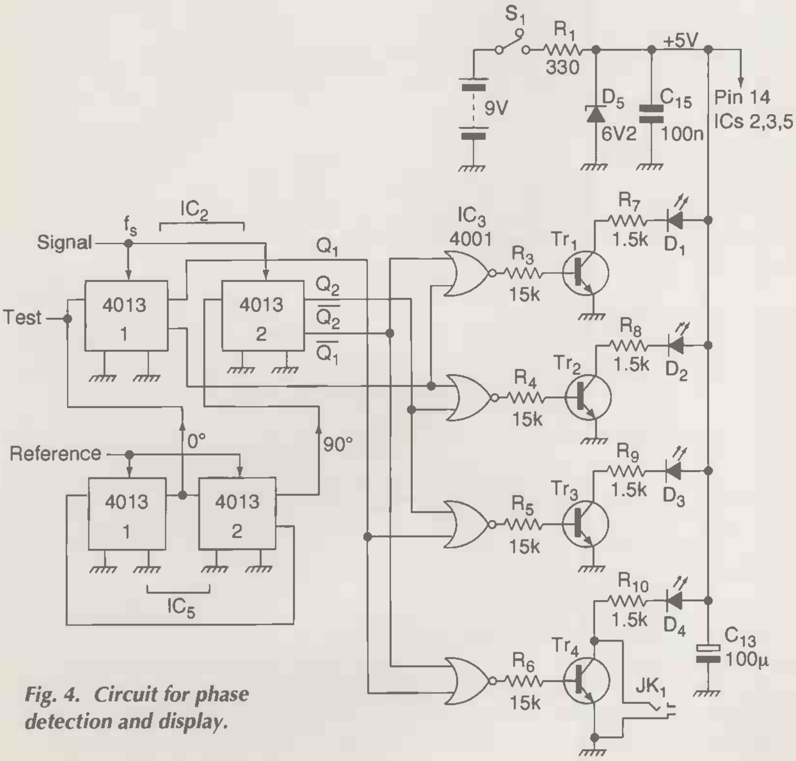


Fig. 4. Circuit for phase detection and display.

One additional measurement was made with the loop. Since ferrites have a large permeability and low conductivity, a slab of ferrite, 10cm square and 4mm thick, was made by casting some Ecosorb (supplied from Hyteck Ltd.) in a tray.

The measured inductance was found to be significantly higher, 0.51 ± 0.01μH, than that measured in air, thus showing that the inductance had been increased according to equation 3. For this material it is expected that the eddy current effects will be very low.

These initial experiments, though checking both effects due to permeability and eddy currents, are somewhat limited in sensitivity and it was therefore decided to reconstruct a circuit similar to that given by Macario[1] and to check, again, whether discrimination does occur between ferrous and non-ferrous materials.

Circuit details from Macario[1]

The basic detector arrangement is shown in **Fig. 2**.

Two signals from oscillators are fed into a circuit for phase comparison and a frequency difference causes the light to run up or down the display corresponding to the sign of the difference. It was claimed that when the search coil was passed over a ferrous material a frequency decrease occurred whereas a non-ferrous sample gave rise to an increase in frequency.

Oscillator circuits are readily constructed from quad NOR or NAND integrated circuits and the circuit for the oscillator with the search coil is illustrated in **Fig. 3**. A frequency of 120kHz was used in the previous work.

In the present work, the value of capacitance C_{14} was variable between 5pF and 60pF and the search coil (30 turns of 26 SWG on a 6cm diameter former) had an inductance of 125μH. To achieve relatively good stability at the oscillator output a silvered mica capacitor (RS 495-868) was selected for C_1, the value being 1000pF. The output frequency was close to 460kHz which was significantly higher than that used by Macario. It was hoped that a move to higher frequency would give greater sensitivity and may, indeed, yield a circuit capable of discriminating between ferrous and non-ferrous metals.

The phase detection circuit is given in **Fig. 4**.

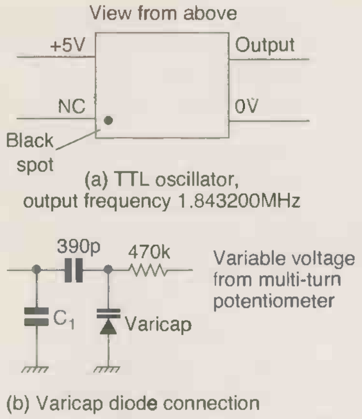
As described in the original article, the phase detection requires zero and quadrature reference signals which are derived from a dual D-type flip-flop, IC type 4013, IC_5 a second 4013, IC_2, being used to derive the phase information.

It should be noted that this mode of operation requires a reference frequency to be FOUR TIMES the value of the signal frequency. An output is finally provided for the LED display via a quad NOR gate IC_3 (component numbering follows that used in the article where a full circuit is given in Fig. 7 on page 45; some confusion does appear to have occurred in the labelling of ICs – 4001 is a NOR not a NAND as listed in the article).

Circuit modifications

Only minor modifications have been made to the circuit and these are shown in **Fig. 5**.

Only one modification was deemed necessary for the search coil oscillator. A varactor diode (varicap type



(a) TTL oscillator, output frequency 1.843200MHz

(b) Varicap diode connection

Fig. 5. Diagram showing: (a) connections for the TTL reference oscillator and (b), inclusion of varicap diode across capacitor C_1.

MV2108 or BB809) was connected in parallel with capacitor C_1. The search coil oscillator is housed in a die-cast metal box with a glass-fibre lid, the coil being glued to this lid with epoxy glue.

It is advantageous to have the capability of tuning the oscillator at some point remote from the die-cast box and electronic tuning is the most convenient method of achieving this. Thus, power is supped from an upper control box together with a variable voltage that is connected to the 470kΩ resistor.

The 390pF capacitor acted as a block to prevent a direct current passing through the coil and the high value of the series resistor, 470kΩ, prevents signal leakage from the tuned circuit.

A crystal module (RS 316-6692) has been used to replace the reference oscillator and a regulator IC 7805 (RS 810-295) maintained a 5 volt supply for this module. The visual display from the LEDs was not satisfactory for large frequency differences and, as the article suggests, a speaker may be attached to the jack socket JK_1 to make a qualitative assessment of frequency shifts.

Two other alternatives were used with the present unit: (a) a counter was connected to JK_1. (b) a frequency to voltage converter type LM2917 (Maplin WQ38R plus PCB YQ68) was constructed so that frequency shift could be visualised on an analogue voltmeter.

All the above items, together with a battery supply, were placed in the upper control box.

Results

Metal detection. With the present system it has been impossible to differentiate between ferrous and non-ferrous objects. *All metals gave a frequency shift to higher levels.* As expected, larger pieces of metal gave larger frequency shifts. In addition, the proximity of the sample had an influence on the frequency shift and both effects are illustrated in **Fig. 6**.

With the above figure it is likely to be fortuitous that there is a logarithmic relationship between frequency difference and sample to coil separation but, as expected, it

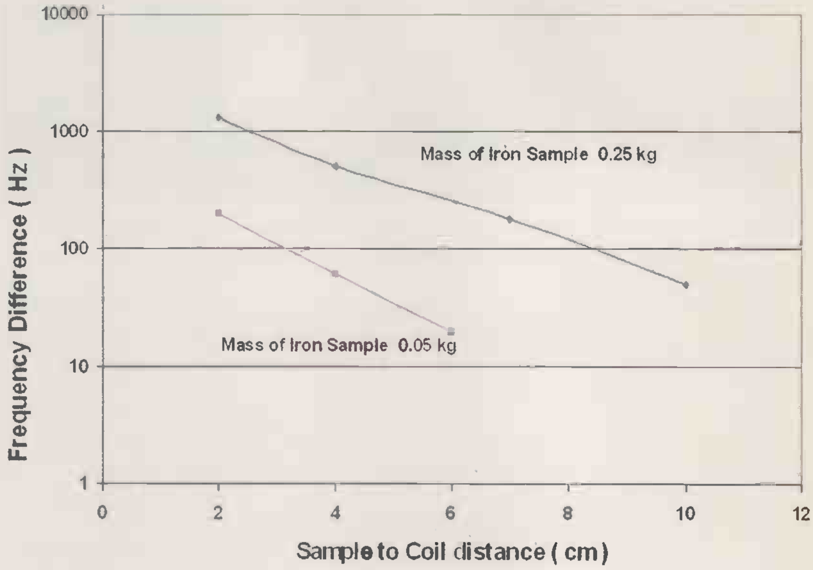


Fig. 6. Frequency difference resulting from proximity of iron object.

Fig. 7. Frequency difference correlated with permittivity.

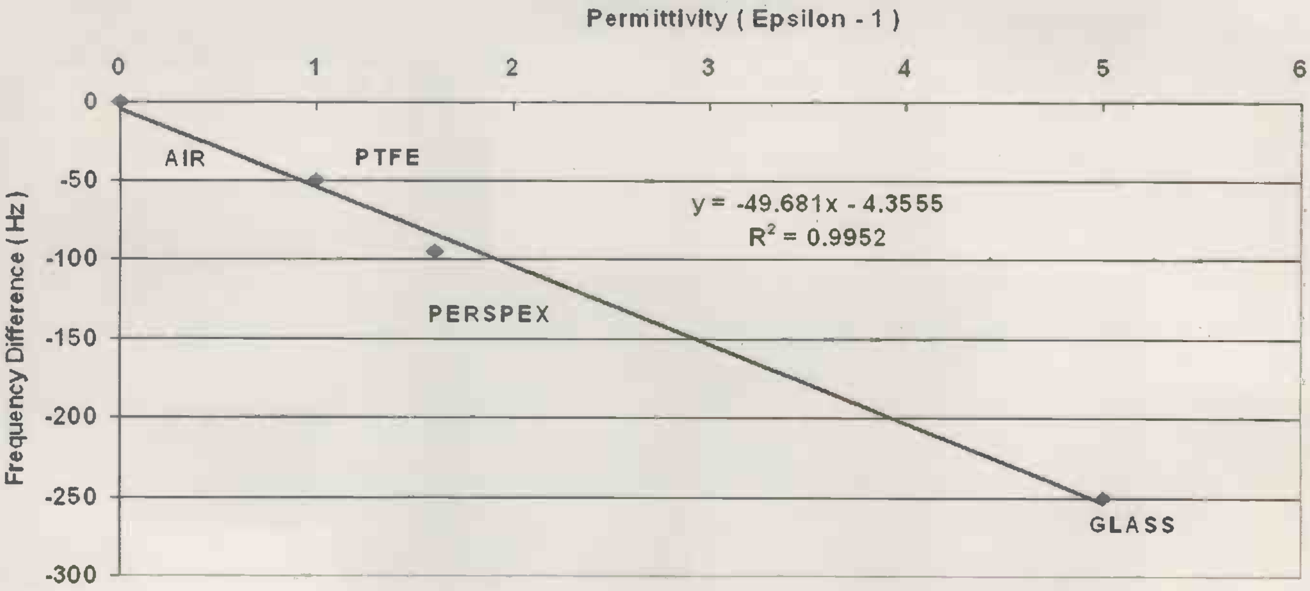


Fig. 8. Photograph of metal detector.

shows that large objects will obviously be detected at greater distances than small objects.

Negative frequency shifts. Firstly, the slab of ferrite gave a large frequency shift, 25kHz, when the coil was placed on the sample. Clearly, an increase in inductance had reduced the resonant frequency according to Equation 2.

Secondly, a smaller effect was observed. With the instrument 'zeroed' on a block of expanded polystyrene (approx. dimensions 300mm square and thickness 100mm), the frequency reduced by about 50Hz when placed at floor level on a carpeted concrete floor.

Further investigations revealed that for slabs of material placed under the probe, there was a very good correlation with permittivity as shown in **Fig. 7**. Thus, parasitic capacitance was being changed and, according to Equation 2, a frequency reduction was occurring.

Although the original intention of this work was to examine metal detection, the circuit has demonstrated the ability to act as a permittivity meter. Now, since water has a much greater value of permittivity than most other substances, the instrument can also act as a moisture meter.

The probe head is particularly convenient since it can be placed next to a wall, for instance, and any dampness can be recorded. Of course, in the presence of a metal inclusion one would inadvertently record a negative value of moisture!

In summary

A metal detector has been constructed from relatively simple circuit units at a minimal cost. The present system has not been able to distinguish between ferrous and non-ferrous metals as claimed by Macario or Algalandis but the inductive coil in the present instrument is rather different tothat used by the previous authors. Clearly, the inductance coil and its attachment to an upper control box are crucially important to the operation of the detector.

A permittivity meter has been made by default although one should hasten to add that the use of parasitic components in a design procedure is very bad practice indeed. Work is now being undertaken to design a concentric ring capacitor that may be included in a resonant circuit (and be under design control) to act as a sensor for a moisture meter. ■

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Fig. 9. Close-up view of control box.

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Low profile 40A POI converter

Artesyn Technologies has introduced the first DC-DC converters in its Typhoon family which comprises a single-output eighth-brick converter capable of delivering up to 40A at 1.8V, and two dual-output quarter-bricks offering 20A per channel. Based on an open-frame single board package, designed for operation without a heatsink, the converters use synchronous rectification and advanced control techniques to maximise efficiency and transient response, and employ surface-mount components and planar, in-the-board transformer structures which limits their height to 7.7mm (0.3in). The first product is a 1.8V output model designed for through-hole mounting, capable of delivering up to 40A. It has an efficiency of 89 per cent at full load, giving a power density figure in excess of 180W/in^3. The dual output devices offer 3.3V/1.2V or 3.3V/1.8V output configurations, and have independently regulated outputs, with each channel capable of delivering up to 20A, and have an efficiency of 90 per cent at full load. All the converters feature 48V inputs and isolated outputs, making them suitable for telecom systems employing distributed power architectures. According to the supplier, the converters are specifically designed for use in applications such as mobile switching, wireline A/D Mux's/optical switches, high-end servers and network multi-gigabit routers.

Artesyn
www.artesyn.com
Tel: +44(0) 0353 2425 388

Complex 3D board design is verified

Zuken has an updated version of its 3D verification module that allows complex board outlines to be directly imported and exported from mechanical CAD tools and transferred to its Cadstar 6.0 PCB design tool suite. Called Cadstar 3D, it is a verification tool that links the 2D PCB design world with the 3D mechanical design-engineering environment. According to the supplier, it removes the need for an IDF file as the design information is directly compatible between the two design environments. Design rule checks within the tool identify potential collisions between any and all objects on the PCB, and between the PCB and enclosure. This can eliminate the need for physical prototypes by delivering accurate verification of the PCB within its enclosure, said the firm. Other features that have been added include the ability to re-load the component geometries, the capability to import/export a solid board outline showing the component pin holes, and a design browser dialog. The new version also allows engineers to change the design units to use different clearance values for keep-out areas.

Zuken
www.zuken.com
Tel: +44(0) 1454 207800

RF connector for 6GHz signals

The QMA connector from Huber+Suhner is designed for RF applications up to 6GHz. Suitable applications include radio basestations and other radio equipment, especially where high density connector population is required, said the supplier. The interface is based on the SMA dimension and features a snap-lock mechanism which requires a low mating force. The interface retention force is greater than 60N. Instead of a threaded coupling mechanism, the new snap-lock mechanism also offers reduced pitch between connectors as no torque wrench clearance is required. The QMA connector can be rotated 360° in mated position and also features self alignment capability during interface mating.

Huber+Suhner
www.hubersuhner.com
Tel: +44(0) 1869 364229

Battery manager has 7X drop out regulators

Atmel's latest battery management device for mobile handsets and wireless systems, running from a lithium polymer or lithium-ion battery. The AT73C202 features a low-voltage 1.8V/300mA DC-to-DC converter, a set of 7X low drop out voltage regulators, a battery charger and a 2.8V/1.8V SIM level shifter interface.

Atmel
www.atmel.com

Protection rated at 240V AC

Raychem Circuit Protection is offering the LVR series of PolySwitch resettable devices which are designed for use in line voltage applications and are rated at 240V AC, permitting maximum voltages of up to 265V AC. The devices are available in hold currents from 50 to 400mA. The thermally active devices can help protect against both overcurrent and overtemperature faults on the primary side of power supplies and transformers. The LVR device was developed to help prevent damage to control boards and components by limiting current in the event of a load-side short-circuit or overdraw, or improper incoming voltage. According to the supplier, unlike a single-shot current fuse, this resettable device can help protect against conditionswhere faults may cause a rise in temperature with ony a slight increase in current draw.

Raychem
www.circuitprotection.com
Tel: +44(0) 1793 572244

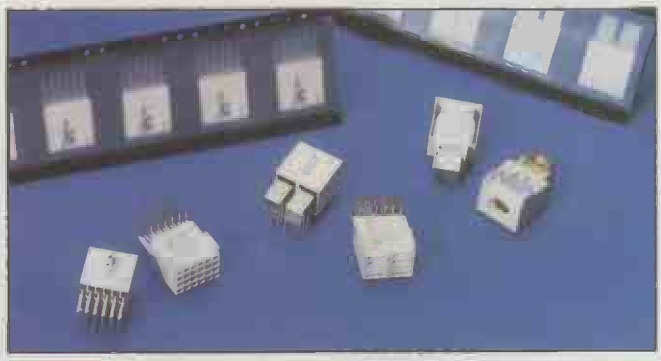
Development kit for FireWire 800 and USB 2.0

The DS-OXUF922-1394B-800 development kit from Oxford Semiconductor provides all the tools needed to creat FireWire 800(IEEE 1394b) and USB 2.0 compliant storge products. The kit's development board with a OXUF922 programmable bridge chip offers 800Mbit/s FireWire 800, 480Mbit/s USB 2.0 and 133MHz, 80Mbit/s IDE connections. It includes GNU C++ compiler and development software, source code and manuals, enabling users to write custom software on the OXUF922's embedded ARM7 microcontroller. In non-storage applications, the OXUF922's IDE controller can be configured as a high performance DMA interface, and an integrated 12Mbit/s UART provides an additional direct data communication interface.

Oxford Semiconductor
www.oxsemi.com
Tel: +44(0) 1235 821141

2mm back panels are pasted

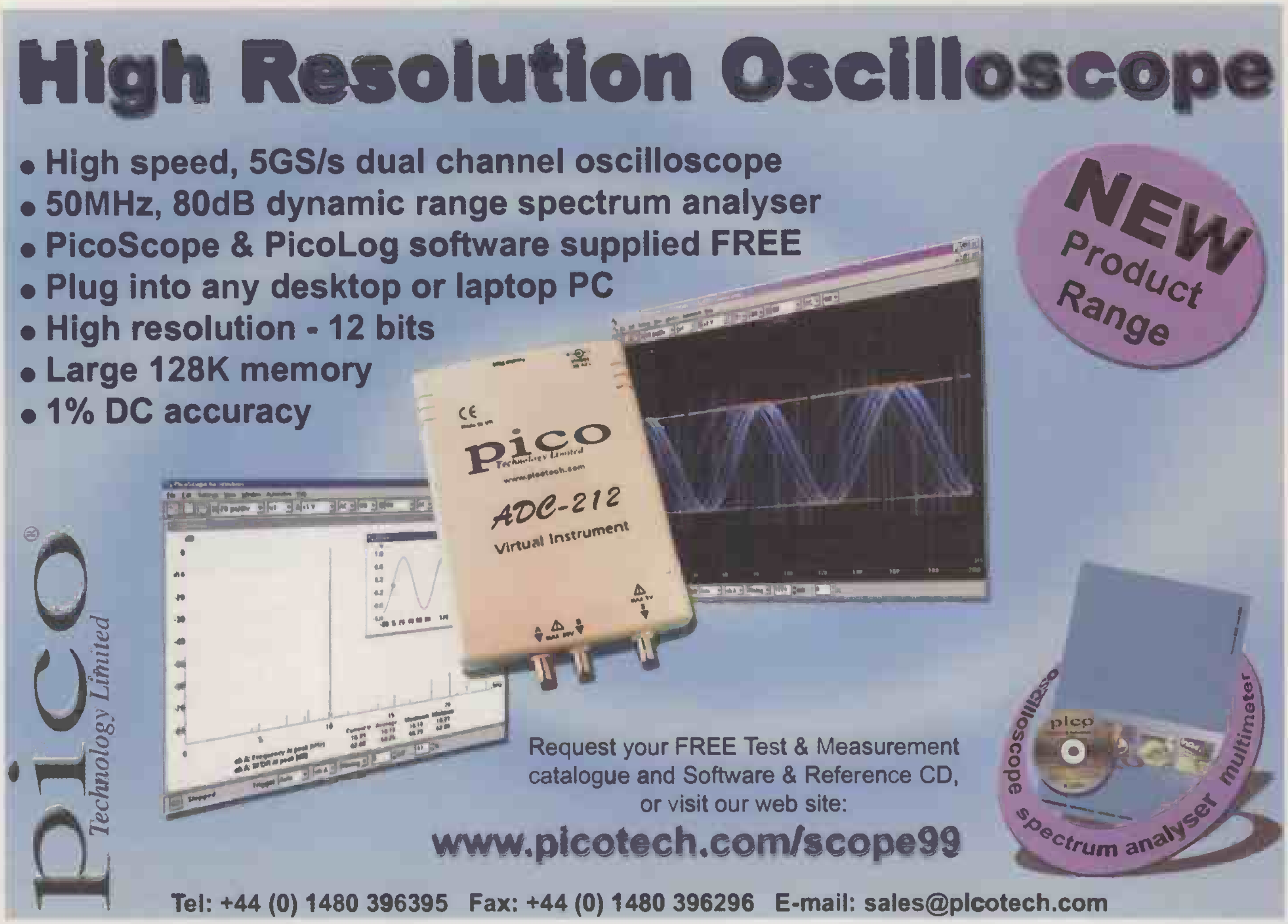
Designed to be compatible with standard pin-in-paste surface mount production processes, the Metral TINT back panel receptacles from FCI are designed to remove the need for secondary assembly operations including heat stacking, wave soldering or press fitting. Available in 4-row (24 position) and 5-row (30 position) sizes, the receptacles are based on the firm's standard connector range conforming to the 2mm pitch IEC 61076-4-104 specification. According to the supplier, pin-in-paste process compatible, the receptacles can be reflow soldered in the same operation as smaller active and passive surface mount components. The sharp and symmetrical nature of the receptacle's rigid tail tips and integral location and force retention pegs are designed to simplify mounting. They also feature a one-piece rigid plastic housing that offers a large usable target area to a vacuum nozzle, but which also presents a front and rear surface for the use of mechanical grippers. The location and retention pegs have been designed to cope with a mounting force of 20N.



FCI
www.fciconnect.com
Tel: (+)33 139 492 222

CompactPCI digitiser with 14-bit resolution at 100Msamples

The GaGe CompuScope 14100C, available from TTi (Thurlby Thandar Instruments), is a 6U form factor CompactPCI digitiser card that can sample analogue signals at speeds of up to 100Msample/s with 14-bit resolution and store the data in the on-board memory. It uses two monolithic subranging A/D converters, each running at 50Msample/s to provide a dual-channel simultaneous sampling rate of 50 Msample/s. In the single-channel mode the two ADCs are clocked in a 'ping-pong' mode to achieve up to 100Msample/s sampling. An on-board crystal-controlled timing circuit ensures time-based accuracy and long-term thermal stability. The on-board auto-calibration circuitry allows the two channels to be matched in order to reduce the image signal. In order to isolate the high-frequency analogue circuitry from CompactPCI bus-related digital electronics, a two-board 'piggyback' configuration is used. This scheme allows maximum separation of analogue and digital grounds, thereby providing high immunity to digital noise. It is available with a memory depth of one megasample (14-bit samples). This memory can be used as a circular buffer for storage of pre- and post- trigger data. The CompuScope 14100C is fully capable of becoming a CompactPCI bus master in order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Self-calibrating gear-tooth sensor with 9-bit capture

Allegro MicroSystems has introduced a self-calibrating gear-tooth sensor with 9-bit signal capture. The ATS672LSB features tight timing accuracy over temperature, true zero-speed operation, true power-on sensing and airgap-independent switch points, said the supplier. It will operate down to 3.3V, and its vibration immunity and temperature capability make it suitable for automotive applications. The sensor assembly is based on an optimised Hall-effect integrated-circuit/magnet configuration in a single inline package (SIP). The SIP module consists of an overmoulded package which holds together a samarium-cobalt magnet, a pole piece and a true zero-speed Hall IC that has been optimised to the magnetic circuit. This small package can be assembled and used in conjunction with gears of various shapes and sizes. 9-bit peak-detecting digital/analogue converters are used to set the adaptive switching thresholds of the device. Hysteresis in the thresholds reduces the negative effects of any anomalies in the magnetic signal (such as magnetic over-shoot). The device is for operation at a supply voltage of +28V and reverse supply voltage of –18V.
Allegro
www.allegromicro.com
Tel: +0033 4505 12359

EMI shielding from a foam gasket

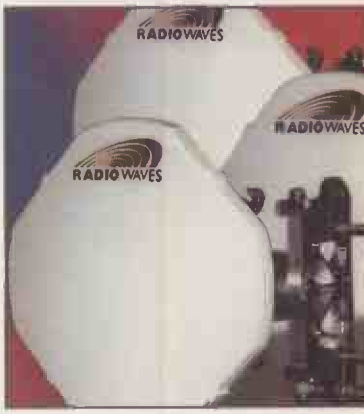
Soft-Shield 4500 from Chomerics is a conductive z-axis EMI shielding foam gasket. The material is considered ideal for applications such as I/O panels, back planes, connectors and access panels where some degree of compartmental shielding is needed. The material comprises a perforated low compression set (less than 10 per cent) micro-cellular urethane foam coated with a silver-copper filled conductive coating creating short ground paths, giving through conductivity and low resistance. Shielding effectiveness averages 90dB between 100MHz and 10GHz. Soft-sheild 4500 is suitable for use at temperatures of between –40°C and +70°C. It is available in thicknessesof 1.6mm, 2.4mm or 3.2mm.
Chomerics
www.chomerics.com
Tel: +44(0) 1628 404000

Resistor dissipates 5W

Welwyn Components is offering its first surface mount power resistor capable of 5W continuous dissipation. The cement-coated wirewound resistor designated the WA85Z, uses a lead forming technique to convert axial power resistors into an surface mount device format. The 5W component is an addition to the WA80Z series of resistors which are already available in 2W and 3W (at 25°C) ratings, with values from 10mΩ to 6.8kΩ and tolerances to 1 per cent. Meeting the automotive temperature range of –55 to +155°C, the series can be customised for specific fusing or pulse handling characteristics, said the supplier. The resistors are supplied in blister tape and are compatible with vacuum pick and place systems. They have the ability to fuse safely under fault conditions and have an inherently non-flammable construction which does not utilise toxic flame retardants. They do not rely on the PCB tracks to provide a heat sink.
Welwyn Components
www.welwyn-tt.com
Tel: +44(0) 1670 822 181

Antenna reduces interference

The latest antenna series from Smiths Interconnect - Radio Waves is available for the 10, 26, 28, 31, 32, 38, and 60GHz bands. This one foot (31.2cm) diameter antenna features first side lobes 23dB down from the main beam. This performance specification is designed to reduce interference from other microwave transmitters when co-location is required, said the supplier. The design of the Discriminator series uses a shaped reflector to optimise patterns and ensures enhanced system performance. The antennas come complete with an adjustable antenna mount.
Radio Waves
www.radiowavesinc.com
Tel: +1 978 459 8800



Power corrected supplies share current

Taiyo Yuden has added to its range of power factor-corrected switch-mode power supplies. The PFC700-S is a 700W switcher designed to provide a

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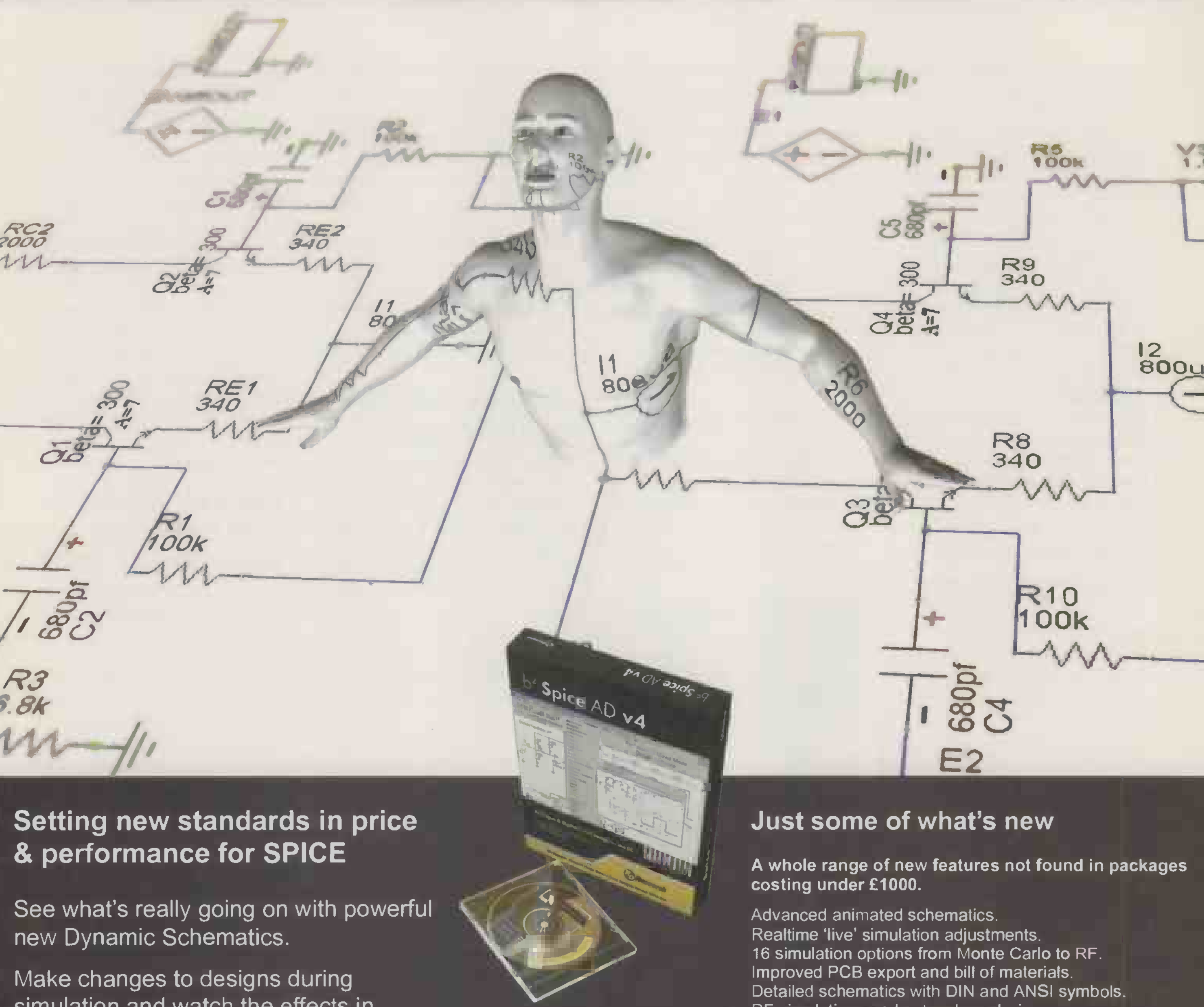

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single isolated (floating) output of 600-700W continuous output power. The PFC700-S corrects the input current wave-form to better than 0.99 power factor at the supply's full rated load of 120VAC. The user may select any of several factory-set output voltages, including 2, 3.3, 5, 12, 15, 24, 28, 36 and 48V. All models feature current sharing as a standard feature, with hot swap capability an available option. According to the supplier, the power supply is HALT tested (highly accelerated life testing) to verify design parameters.
Taiyo Yuden
www.t-yuden.com
Tel: +1 760 471 4021

Capacitors for high voltage applications

Two series of large can aluminium electrolytic capacitors have been introduced by NIC Eurotech. The NSTE and NSTEW ranges of screw terminal devices have been developed specifically for use in high capacitance, high voltage applications such as energy storage, power inverters, uninterruptible power supplies and hybrid vehicles. A selection of standard parts with capacitance values of between 150µF and 1.0F are available, the capacitance tolerance on all parts is ±20 per cent. Standard voltage ratings offered are between 16 and 500V DC. The NSTE series is designed for general purpose use and has an operating temperature range of –40 to +85°C. The temperature range of the NSTEW series is –40 to +105°C making it better suited to applications in harsher environments. Both have a rated life of 3000 hours. Ripple current ratings of up to 37.5A rms (at 120Hz and +85°C) and ESR values as low as 0.0024Ω are available.
NIC Eurotech
www.niccomp.com
Tel: +44(0) 1280 813737

Regulators operate in 10V to 100V range

National Semiconductor has two switching regulators that operate from 10V to more than 100V. LM5000, a switching regulator with integrated 80V, 2A FET, is a current-mode, pulse-width modulation (PWM) DC-DC regulator that operates with a range of input voltage between 3.1 and 40V. A built-in 80V power DMOS transistor is rated up to 2A peak with a channel resistance of 200milliohm. The regulator operates at user-selectable frequencies up to 1.25MHz. LMS030, a100V push-pull PWM controller, integrates an internal 100V start-up regulator in a thermally enhanced chip-scale package. The LM5000 is available in a TSSOP-16 or LLP-14 package.
National Semiconductor
www.national.com
Tel: +44(0) 870 242171

Boundary-scan test in volume production

Corelis is offering a boundary-scan test and in-circuit programming system designed for volume production board test. Called ScanExpress, the system is designed to enable concurrent (gang) testing and in-system programming of flash devices and CPLDs for up to 1,024 boards using a single PC and a single operator. The system concurrently applies test and programming vectors to each of its TAPs while simultaneously verifying results in hardware, at each individual TAP with sustained test clock (TCK) frequencies of 80MHz.
Corelis
Tel: +44(0) 1280 700262

Op amps have 500MHz gain bandwidth

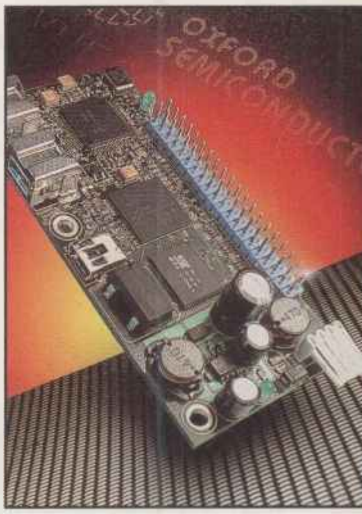
Intersil's latest family of rail-to-rail operational amplifiers includes devices which offer up to 500MHz of gain band-width with slew rates up to 600V/µs. Differential gain characteristics are 0.005° and 0.005 per cent, respectively. They all operate from a single 5V power supply and are available with or without a fast-acting disable/power down circuit. The EL8102 and EL8103 devices combine a 3dB bandwidth of 500MHz and slew rates of 600v/µs, and operate from a 5.6mA supply current. They also feature inputs that go to 0.1V below the power supply rail. With 13ns disable and 200ns enable features, the EL8100 and EL8102 are suitable for high-speed multiplexing applications. The EL8100 and EL8101 feature a 3dB band-width of 200MHz.
Intersil
www.intersil.com
Tel: +44(0) 1276 686886

Lamp driver for handheld devices

Durel's latest lamp driver combines the functionality of an electroluminescent (EL) lamp driver for backlighting monochrome displays and keypads with a high-brightness light emitting diode (HBLED) driver to backlight colour displays. With EL lamps becoming more commonly used for backlighting keypads and sub-displays on handheld communication devices, the migration towards higher resolution colour displays to accommodate new handset functions has advanced the use of high-brightness white LEDs. The D368EL/HBLED driver means that instead of using separate drivers to provide the inductive boost for the white LEDs and the high-voltage charge pump for powering the EL lamp, a single device with one inductor and minimum number of additional external components will suffice. The D3681C driver operates with a wide DC input voltage range, allowing direct conversion from alkaline/NiCad/NiMH batteries.
Durel
www.durel.com

Board for Firewire /USB bridge chip evaluation

The latest IDE bridge board from Oxford Semiconductor provides 'plug and go' evaluation of the OXUF922 bridge chip in Firewire 800 (IEEE1394b) and USB 2.0 compliant hard disk drive applications. By connecting the EV-OXUF922-1394B-800 evaluation board into an ATA/ATAPI drive via a standard IDE cable applying power, users can create a Firewire 800 or USB 2.0 drive. The reference design uses a BGA packaged version of the ARM7 based chip which is capable of handling 800Mbit/s Firewire 800, 480Mbit/s USB 2.0 and 133MHz, 80Mbit/s IDE connections. Device firmware is



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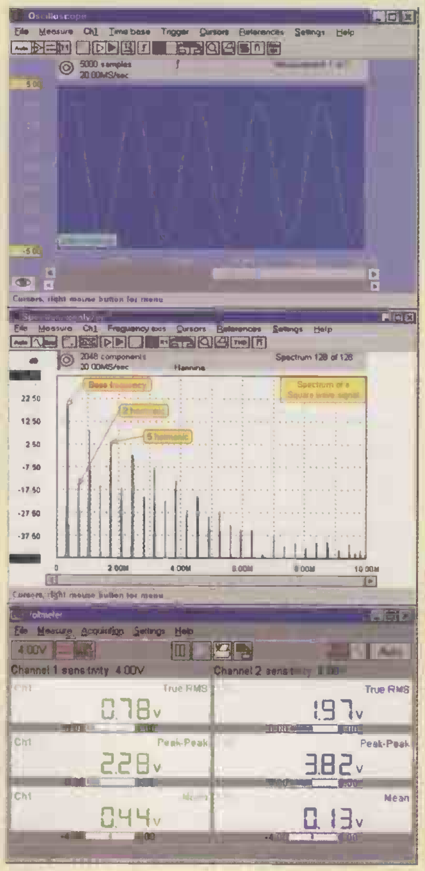
- very extensive function generator (AWG) 0-2 MHz , 0-12 Volt



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Cambridgeshire, PE17 3WJ, UK
Tel: 01480-460028
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a second generation version of that used in the firm's OFW911 bridge chip. In non-storage applications, the device's IDE controller can also be configured as a DMA interface, while an integrated 12 Mbit/s UART provides an additional direct data communication interface.
Oxford Semiconductor
www.oxsemi.com
Tel: +44(0) 1235 824900

RS-232 cards are Windows approved

Brainboxes' top four RS-232 cards have received WHQL (Windows Hardware Quality Labs) approval from Microsoft. The four cards range from one to four RS-232 ports from a single PCI slot. Interrupt pins and addressing are automatically configured by the BIOS or operating system to ensure there is no resource conflict. The supplied software CD supports all Windows operating system options from 3.x up to XP, plus DOS and OS/2. The CD also includes manuals and sample programs complete with full source code. The serial cards are host processor controlled and based on 16.550 UARTs with a buffer size of 16 bytes and capable of handling a maximum baud rate of 115.200bit/s simultaneously on each port.
Brainboxes
www.brainboxes.com
Tel: +44(0) 151 2202500

75Ω BNC good for high frequency TV work

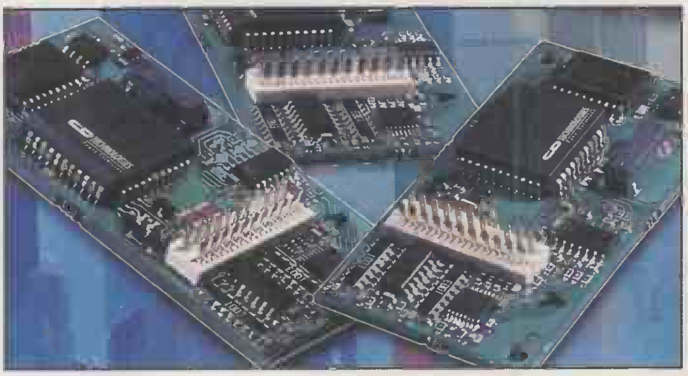
Vitelec Electronics has introduced a range of 75Ω BNC connectors designed for higher frequency design, such as digital TV systems. Including plugs for the most commonly used adapters and precision crimp tooling, the range features a controlled 75Ω impedance for high-speed signals, captivated contacts, crimp/crimp assembly and supports mating with existing standard 50Ω BNCs already present in a system. With an insulation resistance of 5000MΩ (minimum), the range delivers a centre contact resistance of 4mΩ (maximum) and an outer contact resistance of 3.55mΩ (maximum), in operating temperatures of between –55 and +85°C
Vitelec
Tel: +44(0) 1420 488661

PC/104 Processor has 700MHz performance

DSP design claims to have the highest performance PC/104-Plus processor module on the market. Its Pentium 111 architecture and AGP graphics engine makes the TTP3 processor board suitable for computer-intensive and graphics-intensive embedded applications. There are two processor options - the Intel Mobile Pentium 111 running at 700MHz and the Mobile Celeron running at 300MHz. The processor is supported by a chipset with in-built 4xAGP engine, supporting graphics performance for video, kiosk, gaming and scientific graphics. Two displays can be driven with different pictures. Display options include CRT, TFT LCD, TV and a PanelLink interface for driving displays 10m distant. Peripherals include Ethernet, serial and parallel ports, USB, keyboard and mouse, disk interfaces, a Sound-Blaster compatible sound system, game and MIDI ports. It also includes a four-channel 12-bit analogue-to-digital converter. There is also 2Mbyte of flash memory which operates a flash file system and is preloaded with ROM.DOS. Also available are the launchPad PC/104 integrated hardware/software development kits which now support the Windows CE.net real-time operating system.
DSP Design
www.dspdesign.com
Tel: +44(0) 1246 545910

Power supplies with optional platform management

C&D Technologies is offering a family of CompactPCI power supplies with an optional 12C intelligent platform management interface (IPMI) module that allows designers to implement remote power supply monitoring and management functionality. Available with a number of the company's CompactPCI power supplies, the optional factory-fitted IPMI module allows remote monitoring of key status functions via the system management bus. These functions include the voltage and current levels of all four CompactPCI outputs and the status of 'fault' and 'inhibit' signals. Intended for rack mount Internet servers or high-end industrial systems, the IPMI module conforms fully to version 1.5 of the Intel IPMI software protocol specification. To further support high system availability, the software in the IPMI processor can be upgraded remotely via the board's 12C interface without removal of the power supply from the system.
C&D Technologies
www.cdpoweronline.com
Tel: +44(0) 1908 615232



Fact: most circuit ideas sent to *Electronics World* get published

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Don't forget to say why you think your idea is worthy.

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly. Where software or files are available from us, please email Jackie Lowe with the circuit idea name as the subject.

Send your ideas to: Jackie Lowe, Highbury Business Communications, Anne Boleyn House,
9-13 Ewell Road, Cheam, Surrey SM3 8BZ *email j.lowe@highburybiz.com*

A linear voltage amplifier

The base current and the collector current of bipolar transistors are not directly proportional to the base-emitter voltage. That results in a certain amount of non-linear distortion when bipolar transistors are used as voltage amplifiers.

The non-linearity of a bipolar transistor can be compensated by means of application of a non-linear load. An example circuit is shown in **Fig. 1.** The collector current of the bipolar transistor is proportional to the exponent of the base-emitter voltage. The voltage across the diodes is proportional to the natural logarithm of their current. Therefore the non-linearity of the diodes neutralizes the non-linearity of the bipolar transistor and the voltage across the diodes becomes directly proportional to the base-emitter voltage of the bipolar transistor. The voltage gain coefficient of the circuit is equal to the number of the applied diodes, i.e. it is equal to four in this case.

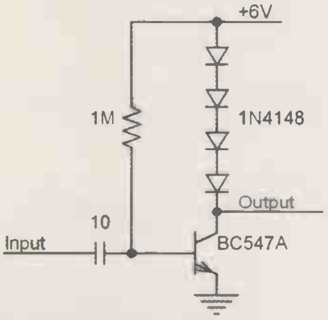


Fig. 1. Linear voltage amplifier applying diodes.

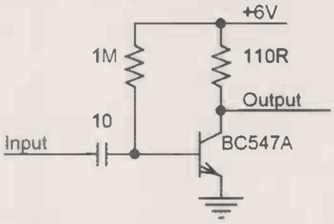


Fig. 2. Voltage amplifier with resistive load.

The circuit shown in Fig. 1 was compared with the common circuit shown in **Fig. 2,** by means of PSPICE simulation at a frequency of 1kHz. The load resistor of 110Ω (Fig. 2) ensures the same incremental resistance and therefore the same voltage gain of the amplifier as four diodes of the previous circuit. The results of the simulation are given in the table. It is easy to see that the circuit shown in Fig. 1, ensures approximately 150 times smaller non-linear distortion than the common circuit shown in Fig. 2.

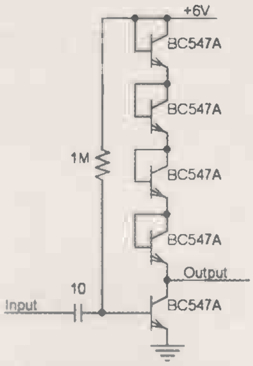


Fig. 3. Linear voltage amplifier applying transistors.

The application of the same bipolar transistors instead of the diodes ensures much better compensation. The results of simulation of the circuit shown in **Fig. 3,** are given in the table. The non-linear distortion of that circuit is approximately 1500 times smaller in comparison with the non-linear distortion of the common circuit.

Therefore the non-linear load can be sometimes used in voltage amplifiers instead of large amounts of negative feedback. This is especially convenient for high frequency arrangements.

Another advantage of the circuits shown in Fig. 1 and Fig. 3 lies in the fact that they are not sensitive to variations of supply voltage and temperature. Let us assume that the collector current is increased N times due to the change of the supply voltage or temperature. In that case the transconductance of the transistor becomes N times larger, but the incremental resistance of the diodes becomes N times smaller. The resulting voltage gain remains the same.

S.Chekcheyev
Tiraspol
Moldova

Amplitude of input signal (mV)	Non-linear distortion factor (percent)		
	Fig. 1	Fig. 2	Fig. 3
1	0.0057	0.9	0.00062
10	0.058	0.96	0.0056

Stepper motor drivers for wave, 2 phase and half-step operation

Stepper motors have an advantage over small DC motors because they are easy to run at a slow speed and still have control. This means that no high-ratio gearbox, which is usually hard to find (and fit) is needed. As long as the torque required is not too high, a simple direct drive is possible. A toothed belt drive is also relatively easy to set up. In addition they are easily obtained, many as surplus. The difficulty is that information is usually fairly sparse. This promoted the development of a simple test circuit. The 4017 and 4019 are readily available.

The NE555 provides a variable pulse signal between 1Hz and about 1kHz for easy testing. The 4017 continuously steps through Q0, Q1, Q2, and Q3. The very slight difference in time due to the additional propagation delay (when reset) will be of no consequence in most applications. The 4019 is switched between the A inputs (order A1, A2, A3, A4) and to the B inputs (order B4, B3, B2, B1) for reversing. The driver transistors can be chosen to suit the motor. The ZTX689B proved to be eminently suitable for most small motors. With the addition of eight diodes the stepper can be driven in 2-phase mode. Making the 4017 step to eight and using 12 diodes, the stepper can be tested in half-step mode.

Neville Frewin
Fontainbleau
South Africa

WAVE DRIVE SEQUENCE

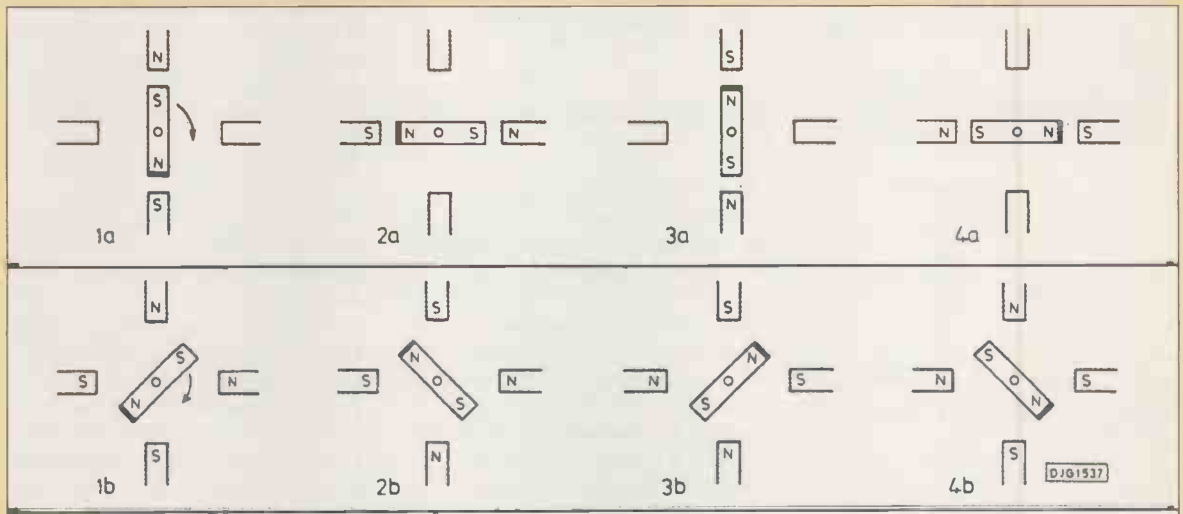
Step	A	B	C	D
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
3	OFF	OFF	ON	OFF
4	OFF	OFF	OFF	ON

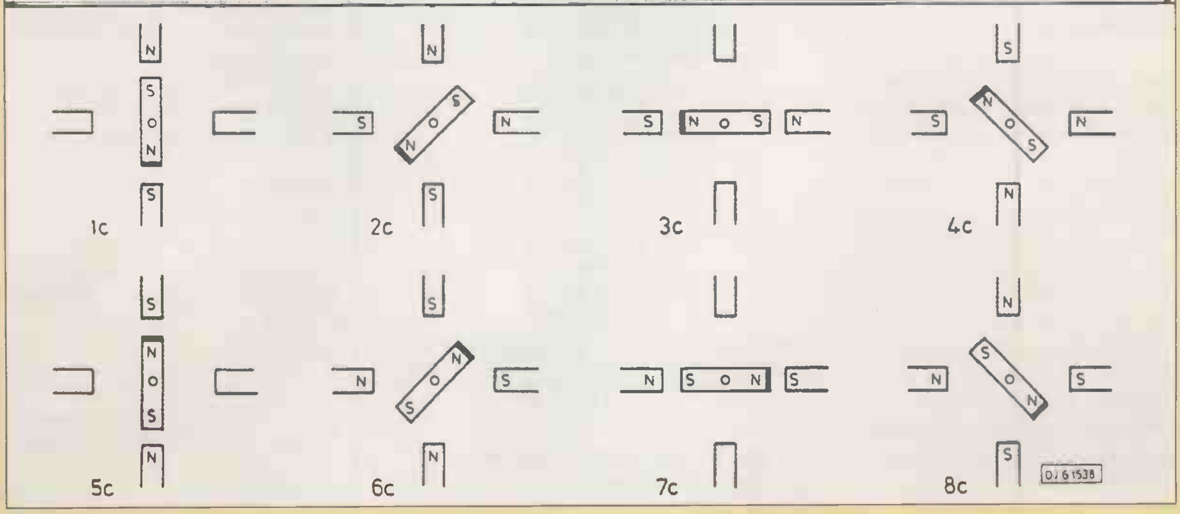
TWO PHASE SEQUENCE

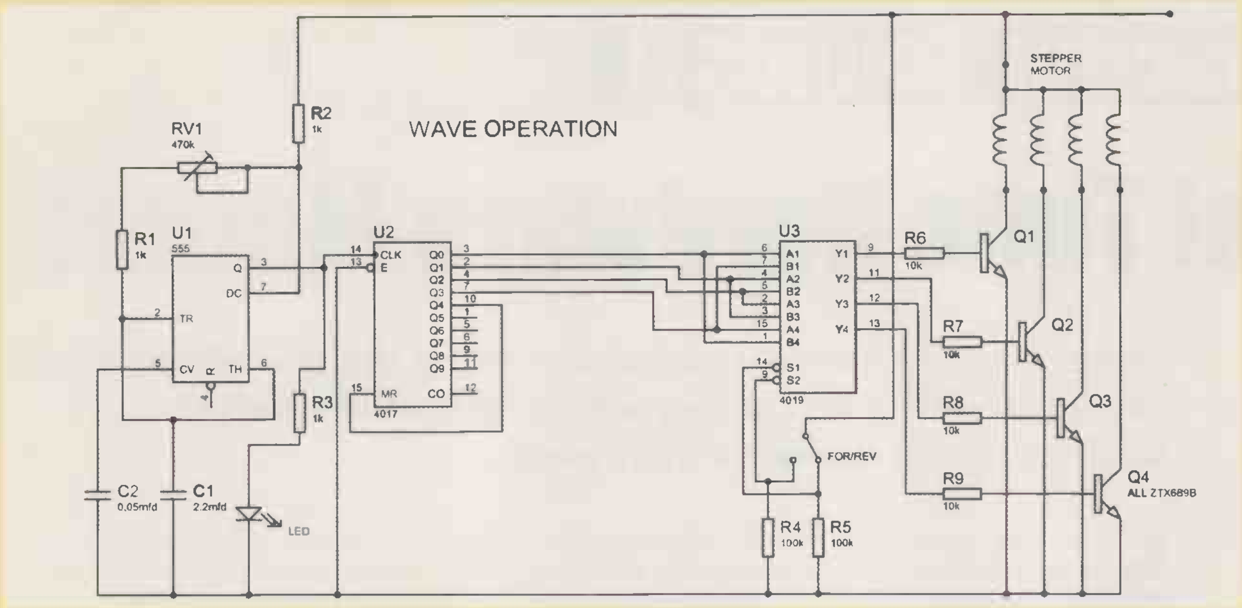
Step	A	B	C	D
1	ON	OFF	OFF	ON
2	ON	ON	OFF	OFF
3	OFF	ON	ON	OFF
4	OFF	OFF	ON	ON

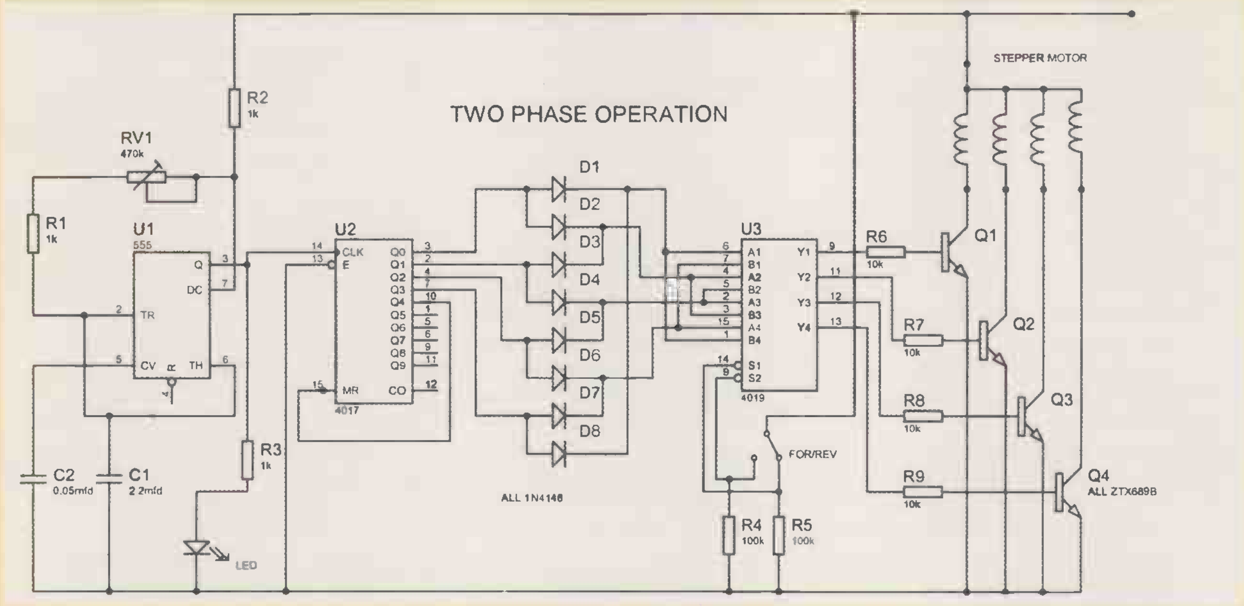
HALF-STEP DRIVE SEQUENCE

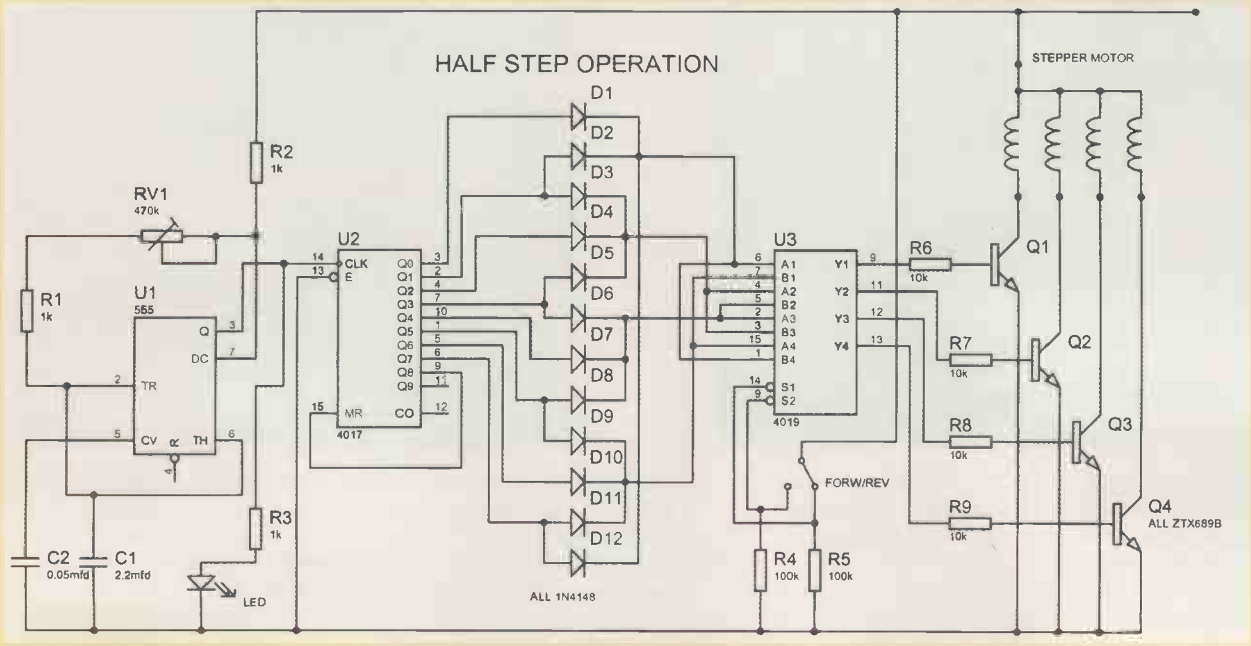
Step	A	B	C	D
1	ON	OFF	OFF	OFF
2	ON	ON	OFF	OFF
3	OFF	ON	OFF	OFF
4	OFF	ON	ON	OFF
5	OFF	OFF	ON	OFF
6	OFF	OFF	ON	ON
7	OFF	OFF	OFF	ON
8	ON	OFF	OFF	ON






WAVE OPERATION
RV1 470k
R1 1k
R2 1k
R3 1k
U1 555
Q DC TR CV TH
C2 0.05mfd
C1 2.2mfd
LED
U2 4017
CLK E MR CO
Q0 Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9
U3 4019
A1 B1 A2 B2 A3 B3 A4 B4 S1 S2
Y1 Y2 Y3 Y4
FOR/REV
R4 100k
R5 100k
R6 10k
R7 10k
R8 10k
R9 10k
Q1 Q2 Q3 Q4
ALL ZTX689B
STEPPER MOTOR


TWO PHASE OPERATION
RV1 470k
R1 1k
R2 1k
R3 1k
U1 555
C2 0.05mfd
C1 2.2mfd
LED
U2 4017
D1 D2 D3 D4 D5 D6 D7 D8
ALL 1N4148
U3 4019
FOR/REV
R4 100k
R5 100k
R6 10k
R7 10k
R8 10k
R9 10k
Q1 Q2 Q3 Q4
ALL ZTX689B
STEPPER MOTOR


HALF STEP OPERATION
RV1 470k
R1 1k
R2 1k
R3 1k
U1 555
C2 0.05mfd
C1 2.2mfd
LED
U2 4017
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12
ALL 1N4148
U3 4019
FORW/REV
R4 100k
R5 100k
R6 10k
R7 10k
R8 10k
R9 10k
Q1 Q2 Q3 Q4
ALL ZTX689B
STEPPER MOTOR

Capacitor Sounds II

Real Time Hardware Method

Some readers have asked about using the low distortion set-up from the last series with a spectrum analyser. Cyril Bateman answers their pleas

Some modern equipment now includes an audio spectrum analyser comprising vertical chains of LEDs which illuminate to indicate the level of the various frequencies being monitored. Frequently these analysers sample at third octave intervals and use a third octave bandwidth filter and rectifier for each LED column, to provide a low cost, real time spectral analysis.

A number of readers asked whether my existing 1ppm low distortion test oscillator/buffer amplifier and twin 'T' notch filter/preamplifier could be used together with a similar display arrangement, replacing the computer soundcard/FFT software approach used for my *Capacitor Sounds* series, to provide a self contained, freestanding portable test station. I felt such an arrangement would also benefit my own test workshop, enabling quicker and easier distortion measurements, both of capacitors and amplifier systems[1].

To reliably measure distortions produced by the better quality capacitors requires a measurement system producing less than 1ppm distortion, together with a noise floor better than 120dB below a 1 volt test signal. Such equipment, although optimised for measurements of capacitor distortions, is ideally suited to measuring and identifying pre-amplifier and power amplifier distortion components.

Equipment Design

This article describes the design and construction of a 'Real Time' hardware method able to measure second and third harmonic distortions from 60dB to 120dB below the test signal. Monitoring the rectified outputs from the second and third harmonic band-pass filters shows that with some capacitors distortion levels do change with time as well as with test voltage.

Comparison of measurement results using this prototype with those from the computer/soundcard software method has shown excellent correlation measuring good, low distortion capacitors. Measurements comparing poorer capacitors, especially when using DC bias, have since highlighted capacitor distortion anomalies while the capacitor charges or discharges, which were masked using the soundcard/software methods. As will be seen in later articles, investigations into these anomalies revealed significant additional insights into how dielectric absorption really does affect capacitor sound distortion. **Figs. 1 & 2.**

Two alternative display methods have been provided, a string of LEDs showing 3dB level changes for the second and third harmonics over a –60dB to –120dB range together with two DMM displays that indicate 0.1dB level changes over the same range. The LED display reacts almost instantaneously to any change in

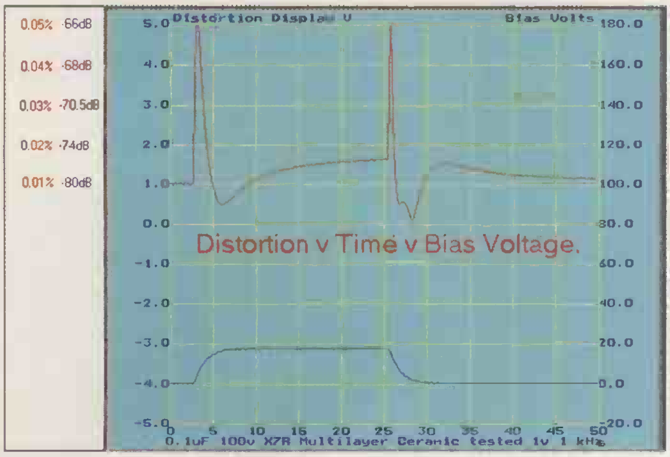


Fig. 1. The top plot, left scale, of a 0.1µF X7R multilayer ceramic, illustrates how second harmonic distortion can both increase and reduce prior to a prolonged settling period, in a capacitor having significant dielectric absorption (1.76%). This anomalous behaviour was hidden using the soundcard/software method. Bottom trace, right scale, shows DC bias voltage as measured across the capacitor.

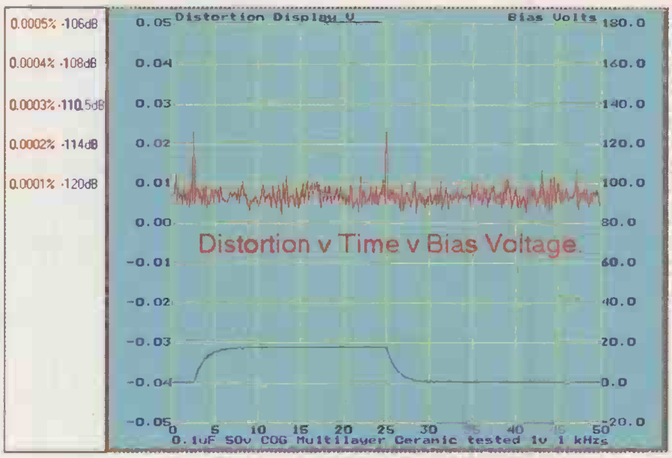


Fig. 2. This distortion plot of a 0.1µF COG multilayer ceramic, scaled 100 times more sensitive than Figure 1, was made a few seconds later. This 'normal' behaviour shows a near ideal capacitor having little dielectric absorption (0.06%). Two brief switching transients can be seen, caused when operating the bias charge discharge switch.

distortion levels and is significantly quicker than the DMM displays which take some 1 or 2 seconds to settle. The soundcard/software method takes even longer to complete the averages needed to reduce noise. Both the LED and the DMM display methods can be used, as in my prototype, or to save cost, just select the display method of your choice and omit the unwanted components. **Fig. 3.**

The design task

Following a few simulations it became clear that third octave band pass filters would not suffice and much better, narrower bandwidth, very deep sideband rejection filters would be needed. Unlike the simple audio 'real time' analysers, we need the capability to measure very small second harmonic distortions in the presence of a much larger test fundamental. To provide similar performance to the soundcard method, we should be able to measure to at least 120dB below a 1 volt test signal.

The twin T notch in my notch filter/preamp attenuates the test fundamental by some 65-70dB[2]. This reduced fundamental together with harmonic components is then amplified by 40dB and bandwidth limited in the preamplifier. Our task, then, is to accurately measure distortion components having an amplitude of 100µV in the presence of a much larger 50mV fundamental one octave away. We must use low noise, low distortion, band-pass filters having a relatively high 'Q' and sufficient gain to amplify distortion components to a measurable level. Requirements more easily met when using continuous time MFB style, RC active filters[3]. Naturally it is essential the capacitors used in these filters are easily available in 1% tolerances and are low distortion types. These requirements are most easily assured by choosing low cost extended foil and Polystyrene or extended foil and Polypropylene capacitors in the vertical mounting 'tombstone' case, together with 1% metal film resistors.

The largest amplitude harmonic components that could be measured without overloading the soundcard software approach of my last series were around –60dB, the smallest some 120dB below the test fundamental, so I targeted to provide a similar 60dB dynamic range.

I decided to raise these -60dB distortion signals to some 6 volts RMS, the -120dB distortion harmonics would then be just 6mV. From experience gained designing my RF millivoltmeter, I knew these two extremes would be measurable with good accuracy and without range switching, provided the rectifier stage used well-matched Schottky diodes and ±15 volt supplies. At these low frequencies this should be well within the capability of the inexpensive NE5532, TLE2072 or similar ICs, without sacrificing too much accuracy at the lowest harmonic distortion voltages[4].

Using an AD536 true RMS IC would allow this 60dB dynamic range to be displayed using a 200mV DMM or a test meter for a display having 0.1dB resolution. An alternative, much faster settling and less costly display using two of the National LM3915 log display LED drivers in series would also just suffice, driving

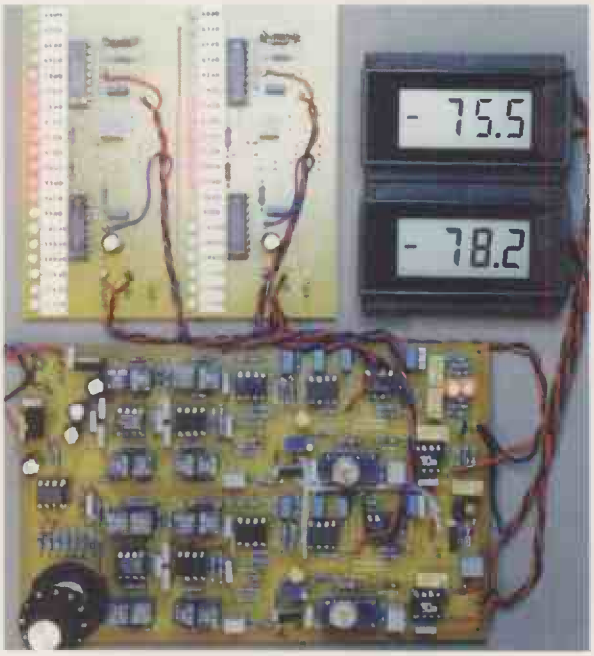


Fig. 4. The real time hardware on initial tests shows good agreement between the two LED tree displays and the two DMM displays. The LEDs respond instantly at each 3dB step in distortion and the DMM displays take time to settle but provide improved resolution. Only the LEDs reveal the anomalous responses of Figure 1.

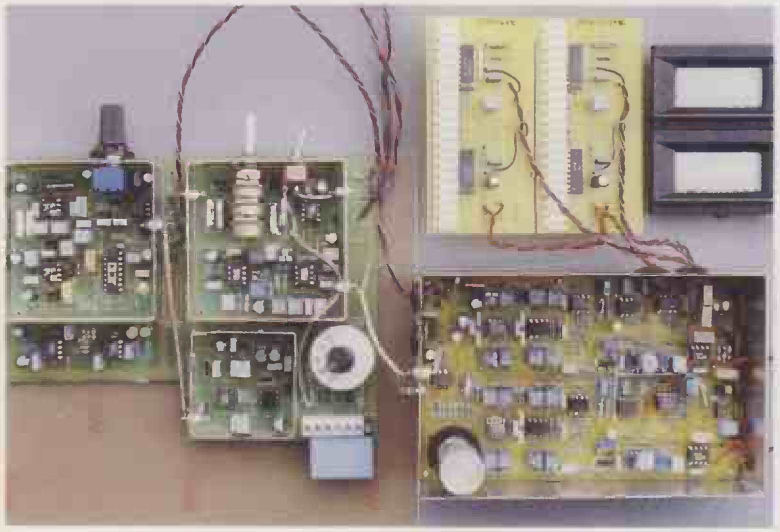


Fig. 3. The complete measurement set-up less screening lids, as used for Figures 1 & 2, shows this new real time hardware connected to my notch filter/preamp described in the Capacitor Sounds series. The DC bias network simply fits in place of the calibration capacitor in the Figure.

Diode Matching

Select two close pairs of BAT86 diodes by chaining together 5 to 10 diodes in series together with a 15kΩ current limiting resistor, and apply 15V DC. Adjust voltage to pass 1mA through the diode resistor chain, easily monitored by measuring the voltage drop across the 15kΩ resistor. Allow to stabilise for a few minutes, then using a DMM measure and note the voltage drop across each diode.

Reduce the current to 100µA and allow to stabilise and re-measure voltages. Reduce the current to 10µA and repeat. Select two closely matched pairs, having particular reference to best matching at the lowest current. Insert and solder matched pairs in place.

a string of 20 LEDs, each LED then indicating a 3dB change in distortion. **Fig. 4.**

Harmonic Bandpass Filters

Following a number of simulations using *Microcap6*, I designed a multistage 2kHz band-pass filter based on 10nF 1% extended foil/Polystyrene capacitors, able to suppress both the 1kHz fundamental and the 3kHz harmonic by considerably more than 60dB, while providing some 35dB of gain at 2kHz. This filter is low noise and has a reasonably flat topped response able to accommodate a few Hz variation in the 1kHz fundamental test frequency, without needing to use variable frequency filtering.

Replacing the 10nF capacitors with

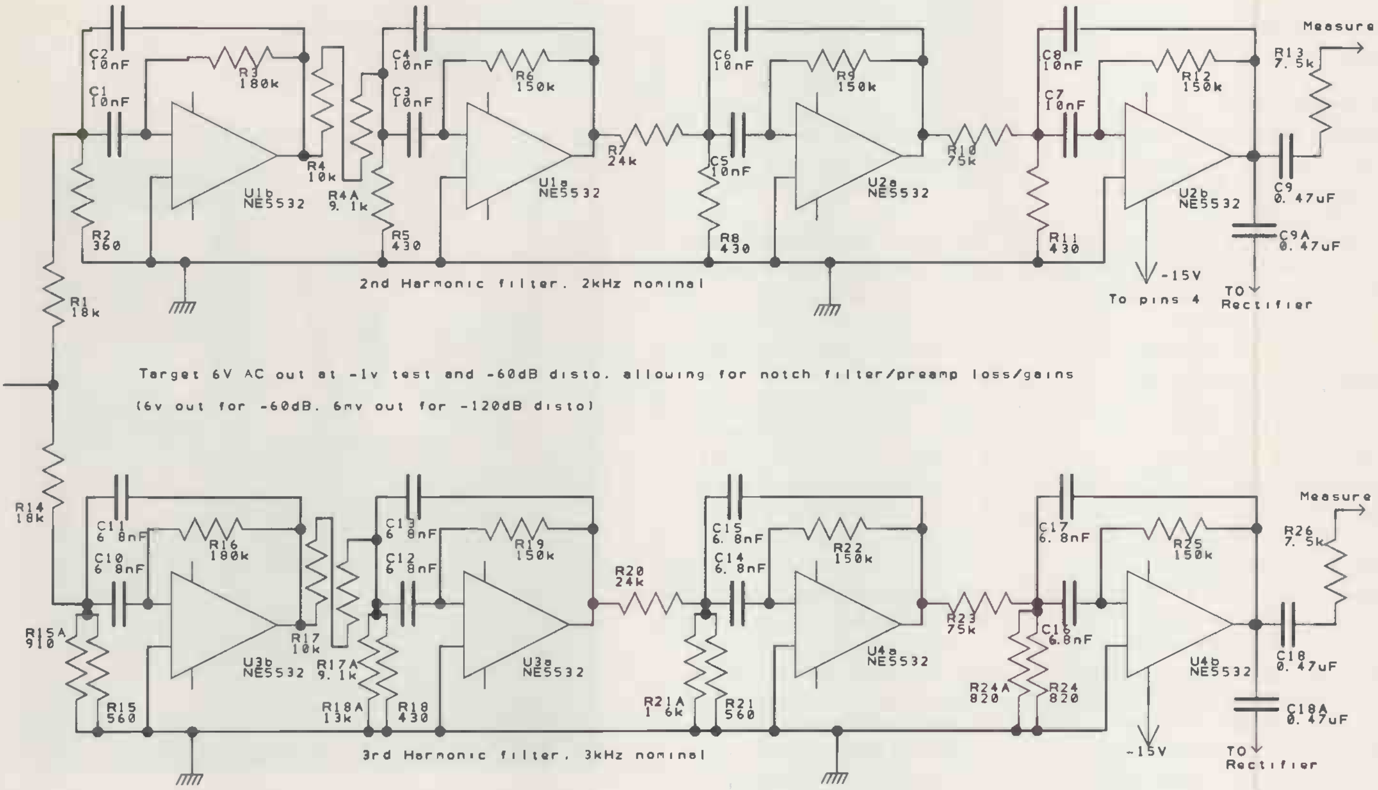


Fig. 5. These second and third harmonic MFB filters have low noise, low distortion and high rejection of unwanted frequencies, responding accurately to distortions down to -120dB, in the presence of the much larger fundamental test frequency.

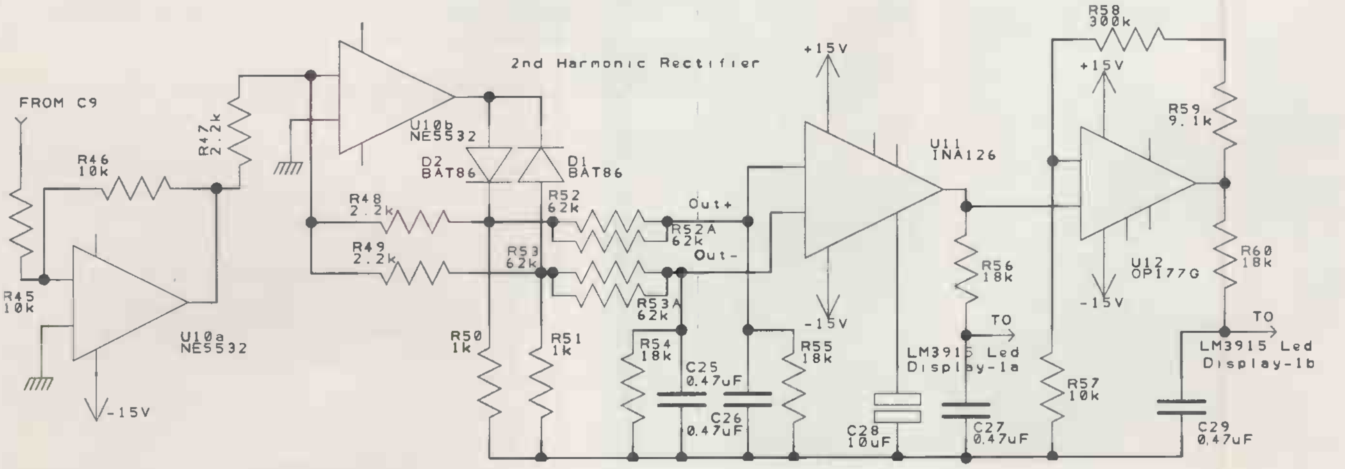


Fig. 6. The full wave rectifier used to drive 10 volts DC to an LM3915 for -60dB full-scale distortion is driven from a low source impedance, unity gain inverting buffer. The right most IC is the +30dB gain stage for the second LM3915 IC for -90dB to -120dB distortion components. The Figs 1 & 2 top trace voltages were taken from C27, the output of U11.

similar style 6n8F values, allowed an almost identical series of gains and 'Q's' to be used for the third harmonic 3kHz filter, assuring matching performance for both harmonic distortion frequencies. These band-pass filters were breadboarded and careful testing confirmed the design was easily able to provide more than the needed rejection of the much larger fundamental test signal as well as rejecting the adjacent harmonic distortion signals. **Fig. 5.**

To accommodate differing levels of capacitor test voltages, from 0.5 volt to 5 volt, I assembled a switched gain preamplifier to maintain consistent input signal levels into both the 2kHz and 3kHz band-pass filters, when switched to correspond with the test signal used.

LED Display Rectifiers

To accommodate the peak voltages without incurring excessive diode and op-amp currents, three matched 2k2 resistors and matched pairs of BAT86 Schottky diodes are used with a low cost NE5532, TLE2072 or similar IC. The design being loosely based on the full wave design used for my RF millivoltmeter published in the April 2000 issue of *EW* that produces a balanced rectified output. A low cost INA126 in-amp is used to convert this balanced output to unbalanced and scale the rectified level to the 10 volt DC full scale output needed to represent -60dB distortions and drive

Calibration initial tests

Insert ICs U1 through U5. Apply ±18 volts, set switch SW1 to the 1 volt position. Allow some minutes warm up then check all ICs' output offset voltages. They should be near 0 volts.

Apply 0.1 volt 2kHz test signal to R43 input Vero pin, and ensure the filter output at junction R45/C9A does peak very close to 2kHz. Reset frequency to 2kHz and measure voltage at junction R45/C9A, it should approximate 6 volts AC. The exact value will vary according to the actual gain of your chosen ICs and can be corrected later. At this stage just check for correct function.

Repeat above using 3kHz, measuring at R67/C18A junction.

LED display drivers

Insert U10, U13. Insert both INA126 ICs and allow the assembly to fully warm up.

With no input signal, adjust VR5 to zero DC at the Vero pin OutA 2kHz. Repeat using VR6 for the 3kHz channel. If unable to attain zero, try replacing U10/U13, which should be low offset types. If this is not successful, diode matching should be improved.

Reapply 0.1 volt 2kHz signal. Voltage at OutA 2kHz should read 10 volt ±0.1 volt DC, if less add a shunt resistor across R45 to compensate. Repeat using 3kHz and OutA 3kHz adjusting R67.

Install U12, U15. These must be very small offset types. OP177G worked well in my prototype. Reapply 0.1 volt 2kHz. Voltage at OutA 2kHz should be as above, voltage at OutB 2kHz should be clipping around 13-14 volts. Reduce the signal by 20dB to 0.01 volt. OutA should now read 1 volt, OutB still clipping. Reduce another 20dB to 0.001 volt. OutA should read 0.1 volt, OutB should read approx. 3.1 volt. Repeat using 3kHz and OutA and B for 3kHz

DMM dB displays

Insert both AD536s and U6/U9 and allow to fully warm up. Set switches SW5 and 6 to measure (slider towards AD536). With no input signal, the DC voltage at both Vero pins adjacent to pins 8 of both AD536s should be close to 0 volt.

Apply 0.1 volt input at 2kHz to R43 with SW1 set for 1 volt, voltage at Vero pin at IC1 should be close to 3 volts. Input 0.1 volt at 3kHz, voltage at Vero pin at IC2 should be close to 3 volts.

Set slider of SW7 away from U7 (sets calibrate voltage to 3 volt). Check the DC output from U7 is 3.0 volt ±1% measured at the junction of R86/C22. Voltage at the opposite end of R86 should be ten times less and close to 0.3 volt. These two calibration DC voltages are used to set the accuracy of the dB measurements.

Set both switches SW5 and SW6 to calibrate (Slider away from AD536) and set SW7 to 3 volt cal. (Slider away from U7).

Monitor Out 2nd dB voltage and slowly adjust VR2 to attain 0 volt. Monitor Out 3rd dB voltage and slowly adjust VR3 to attain 0 volt.

This adjustment is quite coarse, so to minimise TC effects VR2/3 are the minimum usable values needed for adjustment. Unfortunately the current output from pin 6 of AD536 is not tightly specified for value only for change of value. Consequently you may need to amend the values of R36 or R40 to compensate for your particular IC.

The datasheet shows a much larger value variable used with a smaller value fixed resistor. In practice due to the very much larger TCR of Cermet pots compared to that of 1% metal film resistors, the datasheet values that should work with all ICs could degrade the dB accuracy over temperature.

Set SW7 to 0.3 volt cal. (slider towards U7), both outputs should now read -2 volt. If not adjust VR2 and VR3 the 5kΩ presets that adjust the gains of U6 and U9. Both these gain and offset adjustments interact. If either of the above trimmers needed adjustment, reset SW7 to 3 volt position and repeat above VR2/VR3 0 volt settings. Repeat as needed.

Set -60dB offset reference

Using VR7, adjust the output from LM317, U16, to 6 volts as measured at the Out +6 volt dB Vero pin.

Connect the positive lead of the DMM to Out 2nd dB, negative lead to Out +6 volt dB and without changing the above switches the DMM should now read -8 volt for -80dB. Reset SW7 to 3 volt cal. (slider away from U7). The DMM should now read –6 volt for –60dB. Repeat using Out 3rd dB, for above readings.

Set SW5 and SW6 to measure, (slider towards AD536).

We now only need to compensate for gain errors in the band-pass filters.

Connect DMM negative to ground. Apply 0.1 volt input to R43 at 2kHz with SW1 set for 1 volt, voltage at Out 2nd dB voltage with respect to earth should now read 0 volt (for –60dB). If low, shunt R13 to compensate. If high, shunt R35. Using the 3kHz signal repeat above measurement for IC2, adjusting R26/R44 if needed.

Reduce input signals by 20dB and repeat above. Voltage at Out 2nd dB voltage should be -2 volt (for -80dB). Reduce input signals by another 20dB and repeat above. Voltage at Out 2nd dB voltage should be -4 volt (for –100dB).

The unit is ready for use with dB DMM displays.

LED display PCB

Apply +15 volt power and allow to stabilise. Apply 10 volt DC input to In 0 dB Vero pin. Check that the –60dB LED connected to LM3915 pin 10 (LED22 also 42) is just illuminated. If needed add shunt resistors across the 15kΩ so as to display with 10 volt drive. The prototype needed 68kΩ shunt for one board, 75kΩ for the second board.

Both displays should now illuminate their -60dB LED with 10 volt input to In 0 dB Vero pins.

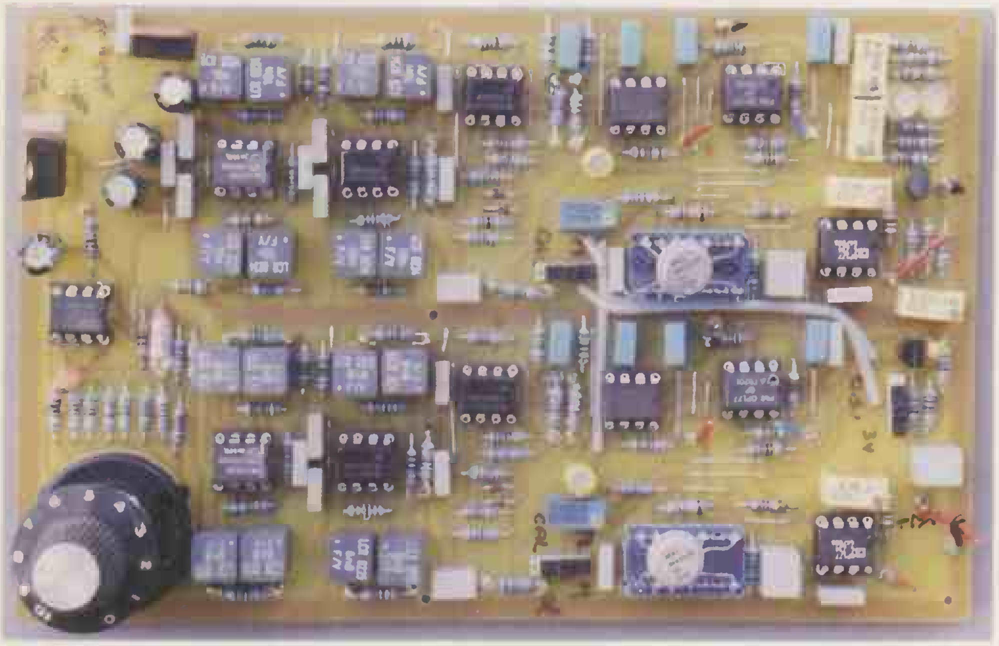


Fig. 7. The completed prototype shows how the lower cost Maxim AD536 IC's leadwires can be pre-formed to fit the socket designed for the more expensive DIL package. The three insulated wire links should be fitted last, after other components have been soldered.

Technical Support

Full details of this new hardware test method and my original Capacitor Sounds 1ppm low distortion oscillator, buffer amplifier, notch filter/preamplifier and DC bias assemblies, together with parts lists, assembly manuals and full size printed circuit board drawings, all as .PDF files arranged for easy viewing on screen or hardcopy, are provided in my new 'Capacitor Sounds' CD ROM.

This CD also includes updated and expanded re-writes with very many more figures, of my 'Capacitor Sounds' articles, supported now by some ninety capacitor distortion measurement plots. Also on the CD are PDF re-writes of my earlier 'Understand Capacitors' series together with articles how to diagnose failed capacitors while still mounted on printed circuit boards and essential low cost capacitor measurement methods, more than twenty popular articles.

This CD is now available, cost £15 Sterling including postage and packing. Send cheques or postal/money orders in Pounds Sterling only to:-

C.Bateman. 'Nimrod' New Road. ACLE.
Norfolk. NR13 3BD. U.K.

the LM3915 LED driver to full range. **Fig. 6.**

This 0 to 10 volt DC output was used to record changes in distortion levels with time and DC bias voltage, for figures 1 and 2, using two Coline M12SW oscilloscope probes feeding into my Pico ADC100. One probe is displaying second harmonic distortion by monitoring the voltage across C27 and the second probe was used to monitor the actual DC bias voltage across the test capacitor. To separate the DC bias from the AC test voltage, this probe was isolated via a 100kΩ series resistor and decoupled using a 10nF Polystyrene capacitor to ground.

A single LM3915 IC with 10 LEDs provides a 30dB display range, each LED indicating a 3dB change. To cover our 60dB range, two LM3915 ICs are chained in series driving 20 LEDs. Each LM3915 was set for full-scale with a 10 volt maximum input drive. The first LM3915 display was driven directly from C27, the output of the INA126, for the –60dB to –90dB range display.

Smaller voltages are amplified by 30dB to drive the second LM3915 for the -90dB to -120dB signals. Combined, these two drivers provide our target 60dB dynamic range. The LEDs draw significant current and so can introduce switching transients on the display board ground and supply rails. For accuracy it is essential this 30dB gain pre-amp has a very small, stable DC offset. An OP177G is mounted on the main printed board, rather than on the display sub boards with the LM3915s. To adjust for any residual INA126 offset also any rectifier unbalance, a small adjustable voltage, derived from two LED stabilisers, is provided.

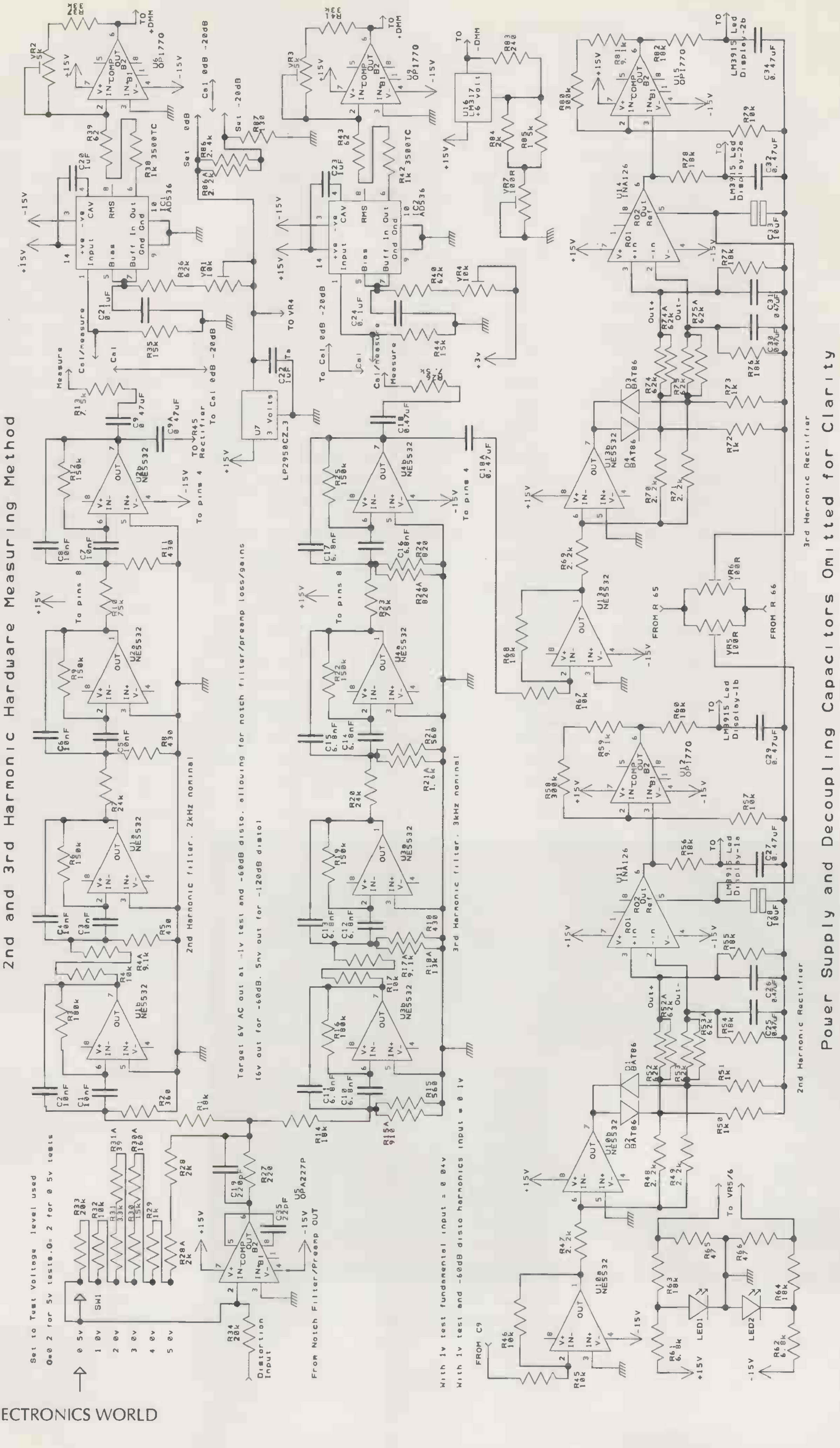
As can be seen from the schematic, all distortion voltages are passed into the +30dB OP177G pre-amplifier, which clips at around +14 volts output when overdriven. The two LM3915 ICs are connected so that the –90dB to –120dB display LEDs are turned off while this IC is overdriven, ensuring a contiguous display. By linking pins on the LM3915s, either a dot or bar display graph can be arranged.

DMM Display Rectifiers

The AD536 IC is a true RMS to DC converter and so provides its own internal rectifying stages to produce two outputs. A DC voltage output at DIL pin 8 corresponds to the AC input voltage and a dB related current output from DIL pin 6. This dB output is temperature sensitive so must be compensated using positive coefficient temperature sensing resistors R38/R42.

The DIL package version of the AD536 integrated circuit plugs directly into the printed board. The less expensive Maxim TO-100 package seen in the photograph can be used, but having different pin numbers and pin assignments, its lead wires must be pre-distorted before inserting to the board. While not essential, I found this alignment was facilitated by pre-forming the leads and soldering onto a low cost DIL header. This header then plugs into the PCB DIL socket. Note that other

Fig. 8. The schematic of the prototype assembly, less supply and decoupling capacitors omitted for clarity. Six Rubycon 100μF 25 volt YXF electrolytics with twenty three BC Components 0.1μF 63 volt type 470 metallised PET decoupling capacitors and two 15v stabilisers were used.



2nd and 3rd Harmonic Hardware Measuring Method

Power Supply and Decoupling Capacitors Omitted for Clarity numbered versions of the RMS DC converter chips should not be used as the AD536 version either in the DIL or TO-100 packages, is essential for this design. **Fig. 7.**

Ideally the temperature sensing resistors R38/R42 should exhibit a positive 3500ppm characteristic, not easily sourced in UK. Farnell stocks a near alternative, having a positive 3000ppm characteristic[5]. This reduction in TC is partially compensated by using the minimum practical value for VR1 and also VR4. Cermet pre-set resistors have a relatively high TC, so are used with much larger value low TC 1% metal film resistors. With the circuitry mounted in a case to shield it from room drafts and allowing a 15 minute warm up, this compensation worked well producing stable, repeatable and consistent readings.

The dB related current output from pin 6 of the AD536, is then converted, amplified and scaled to 100mV/dB, using another OP177G amplifier. Unlike the RMS DC function which is factory pre-calibrated, this dB scaled output is not and so must be calibrated using known DC voltages. An LP2950CZ-3 IC provides a 1% precision and stable 3 volts to input a balancing current into the AD536 pins 5 and 7. Adjusted using VR1 and VR4 to produce a 0 volt output from U6/U9 when this 3 volt calibration voltage is also input to pin 1 of the AD536.

To calibrate the desired 20dB scaling factor, an accurate 0.3 volt DC is needed. A 10:1 potential divider, R86/R87 provides this second calibration voltage from our stable 3 volt supply. With this 0.3 volt input to pins 1 of both AD536s, VR2 and VR3 are adjusted to set the outputs from the OP177G ICs U6/U9, to exactly –2 volt, displaying a –20dB change in reading on a panel meter, set for 20 volt full-scale but with decimal point set for a 2 volt range. Three PCB c/o switches are provided, two switch the AD536 inputs between calibrate and measure and the third selects between the 3 volt and 0.3 volt calibration voltages.

To offset the DMM readings to display the desired –60dB to –120dB range, a stable 6 volt supply is provided by U16, an LM317L adjustable voltage stabiliser. Both DMM 'low' inputs are connected to the positive of this 6 volt supply. With the DMM set to read 20 volts full scale but with decimal points set as for 2v, each DMM then displays a range of -60 to -120dB. **Fig. 8**

To simplify assembling this design, standard 1% metal film resistor values are used and two resistors either in series or parallel provide non-standard values. When two parallel resistors are needed, to save PCB space, mounting pads accepting a pair of Vero pins are provided. A number of wire links are needed and all but three can be uninsulated. These three insulated linkwires must be installed last; after all other components have been soldered. All ICs were mounted in low profile Harwin turned pin sockets. **Fig. 9.**

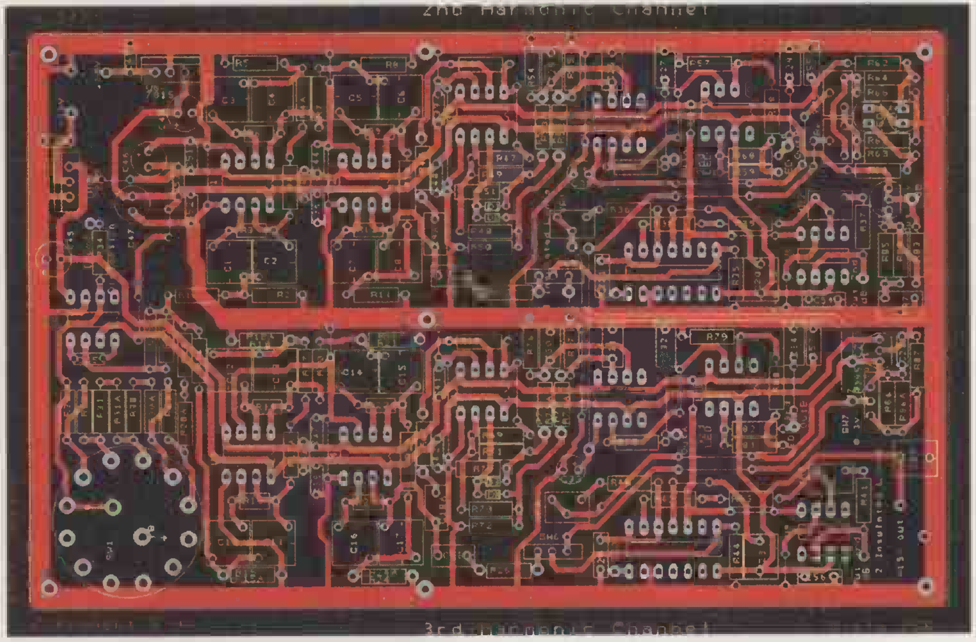


Fig.9. The main PCB used for the prototype assembly shown. This board houses the complete real time distortion measurement system but the forty display LEDs and their LM3915 logarithmic display drivers were located on two small, low density, panel mounting PCBs.

Prototype Performance

With no signal input, all displays are off scale, below -130dB. With a distortion free, 10 times normal, 1kHz input all displays still show less than –120dB. With a distortion free, normal full scale input signal at 2kHz the 3rd harmonic display reads –130dB, input with 3kHz the 2nd harmonic display also reads -130dB, confirming more than adequate isolation between measuring the harmonics and the fundamental test frequency.

The 2kHz band-pass filter measured -1dB at 1960Hz and 2015Hz, the corresponding 3kHz filter frequencies being 2950Hz and 3025Hz. Both band-pass filters are able to accommodate several Hz of frequency error in the 1kHz fundamental test signal.

My next article explores in detail the affects test capacitor voltage coefficient and the much more significant dielectric absorption, have on capacitor sound distortions, by measuring distortions of test capacitors over time, with and without a DC bias voltage, using test capacitors carefully measured and pre-selected for voltage coefficient and dielectric absorption, using a range of DC bias voltages. ■

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In circuit RF measurement

There are two basic measurements in any electronics workbench, that of voltage and frequency. If more than one signal is present, there is also the added complication of relative phases, but this will not be of concern to us here in this article. Tuck Choy PhD (M0TCC/VK3CCA) has a practical solution.

Present technology has made available at very reasonable prices digital frequency counters to fulfill the needs of frequency measurements. The other test instrument most work benches require is an oscilloscope, but the prices for these are still quite high and for the frequency range we are talking about they can cost tens of thousands of pounds. The standard oscilloscope with bandwidths in the 60MHz region would cost around £750. Interestingly, even for those who can afford the expensive scopes such as the 400MHz Tektronix 2465B, the accurate measurement of voltages still presents a delicate problem in some cases, where spurious oscillations are present[1]. While the oscilloscope is still the equipment of choice for making RF voltage measurements, its use cannot be made without careful consideration of the appropriate oscilloscope probes and accessories which strongly influence the accuracy of measurements as we shall see.

Affordable measurement

This article is devoted to discussing some of these issues. For those less fortunate mortals who do not own one of the more expensive scopes, the use of an RF voltage probe represents the only available means for making voltage measurements above about 100MHz. Traditionally, the home constructor, average radio amateur and even some more experienced engineers would, some time or other, have made up a simple diode voltage detector probe. We shall examine some of these detectors later and some of the issues involved, but they are generally not suitable for accurate measurements, rather functioning more as relative detectors of RF voltage energy. Commercially available RF voltage probes for connecting to a digital multimeter meter (DMM) are scarce and they generally cost £150 or more although some new vendors are now appearing on the market[2]. My aim here is to give the reader some further insight into RF voltage measurements in general and more importantly alerting them to the issues involved and the equipment currently available to enable the task. The frequency range we are mostly concerned with will be from about 100kHz to around 1.5GHz, a very broad range indeed that covers most of the present day radio communication spectrum. For frequencies less than the lower limit the techniques for AC voltage measurements are quite standard. Although there are problems to be concerned with[3], such as true RMS detection, peak versus average detectors, slew rates of the input circuitry, etc., many common problems can be answered by having a high input impedance, currently about 10MΩ for most DMMs. Nowadays the more expensive DMMs like the Fluke 79 and 87 series and others, already incorporate such an AC true RMS measurement facility. For frequencies above the upper limit of 1.5GHz, the techniques of RF probing change considerably. In particular non-contact measurements become essential since any form of direct contact will undoubtedly overload the circuit under test (CUT). Microwave losses are also a serious problem so that the design of test probes will have to overcome the considerable attenuation of the test signal.

Table 1. Various commercial scope probes made by Agilent

Probe No.	Impedance	Division	Model
1	10MΩ/10pF	1:10	HP10004B
2	100kΩ/3pF	1:1	HP1120A
3	1MΩ/1pF	1:10	HP1120A with its 10:1 divider tip
4	500Ω/0.7pF	1:10	HP10020A with its 10:1 divider tip
5	5kΩ/0.7pF	1:100	HP10020A with its 100:1 divider tip

Oscilloscopes and test probes

The most common measurement of RF voltages is via the use of an oscilloscope with appropriate test probes and leads. These are generally supplied by the manufacturer and have a detachable ground lead (which must be connected to a proper ground for any RF voltage measurements) and a switch providing a 1:1 and a 1:10 attenuated range. The former is not straight through as one might expect since there is an important compensation capacitor at the BNC plug to the scope that must be adjusted for proper operation. Note that the probe and the oscilloscope form an integral instrument, if you lose your probes you must contact the manufacturer and buy a set appropriate to your scope's model number. For the lower frequency scopes however, there appear to be some standard probes that are suitable from several manufacturers but there is no guarantee. Typical scopes have an input impedance of 1MΩ shunted by a capacitance of about 20 to 45pF, which is frequency dependent. On the 1:1 range the probe on my Korean Goldstar 40MHz scope, for example, has an input impedance of 1MΩ shunted by a capacitance of about 180pF. It is compensated for a flat frequency response that goes from DC to 3MHz (±1dB) or DC to 6MHz (±3dB) only and is thus quite unsuitable for higher frequency measurements without a considerable loss of accuracy. On the 1:10 range my probe has input impedance of

10MΩ and a shunted capacitance of 22pF. This is compensated for a flat response from DC to 40MHz (±1dB) or DC to 50MHz (±3dB). Proper operation requires that the compensation capacitors be adjusted using the calibrator source provided on the scope, which is normally a square waveform. These adjustments must be done for each probe and each channel and in particular for each range 1:1 or 1:10 separately, if accurate measurements are required. In view of the higher impedance of the 1:10 range, which is most often used, the price to pay is of course reduced sensitivity. Trying to observe a 1mV signal is particularly difficult and no doubt measurement errors become greater than the 2% or so specification of your scope for such a signal. One might be led to think that all is well, because the test signal as displayed on the screen of the scope is an almost perfect sinusoidal wave since one has used a properly adjusted compensated 1:10 high impedance probe. Unfortunately life is not that simple for RF measurements, if it were this article would not need to be written. There are two gremlins that tend to foil our efforts in spite of having the best equipment, which we shall discuss next.

Resistive loading

Accurate measurements require some good knowledge of the circuit loading. In particular the source impedance versus the probe/scope combination cannot be ignored. In **Fig. 1**, we have drawn the equivalent circuit of the signal source impedance R_g and the impedance R_{in} which is our probe/scope combination. The error to be expected is the amplitude error caused by the resistive loading. This is given by the formula:

$$\%Error = \frac{R_g}{R_g + R_{in}} \times 100$$

Therefore in situations where the source and probe/scope impedance are comparable, for example, FET input circuits, the loading errors can be quite high. To keep this error to about 1% would require R_{in} to be of the order of 100 times greater than R_g, not an easy task for FET input circuits already in the MΩ ranges. Apart from CW amplitude or pulse amplitude attenuation that can result from excessive resistive loading, the additional current drawn from the signal source can drive a circuit into saturation or into a nonlinear region of operation. In severe instances of resistive loading, the CUT might stop operating all together as often happens in the case of oscillator circuits in particular. Direct voltage measurements may not be feasible in these cases and the use of a loosely coupled RF sniffer coil might be a better alternative, although accurate measurement of amplitudes is hard to achieve with these arrangements.

Capacitive loading

Capacitances are as common as daylight in RF circuitry and their presence leads to errors that vary with frequency. Therefore careful attention to the input capacitance of any probe is important to minimise errors due to capacitive loading. In effect the oscilloscope probe forms a low pass filter (see **Fig. 2**) that shunts high frequencies to ground, thereby reducing the probe's input impedance. For example my Korean Goldstar 22pF 1:10 scope probe would have an impedance of about 240Ω at 30MHz, while at 100MHz it is only about 72Ω. Hence the high 10MΩ input impedance of my probe becomes ineffective beyond 100MHz. In order to minimize capacitive loading the probe's input capacitance must be kept low, unfortunately this requires also keeping the input resistance low due to the bridge balancing compensation requirements for scope probes[3]. In **Table 1,** we have examples of various commercial probes made by Agilent (formerly Hewlett-Packard).

For a probe impedance of 500Ω and 0.7pF such as Probe No. 4, we can find nearly constant impedance characteristics that begin to fall off beyond 200MHz, whereas the higher impedance probes such as the HP10004B (1) are quite useless except for low frequency measurements (see **Fig. 3**). The combined effects of resistive and capacitive loading leads to signal losses that can be modelled by an equivalent circuit as shown in **Fig. 4,** from which the percentage loss as discussed above can be calculated using the formula:

$$\%Error = \frac{Z_{in}}{Z_{in} + Z_g} \times 100$$

Where the input impedance is a combination due to the R and C:

$$Z_{in} = \frac{R_{in}X_{in}}{\sqrt{R_{in}^2 + X_{in}^2}}$$

and the reactance:

$$X_{in} = \frac{1}{2\pi f C_{in}}$$

Note that these formulas are for ideal conditions only and no doubt the assumption of a constant value for the input R and C for all frequencies will be problematic as the frequency increases. Moreover the great unknown in most cases is Z_g and we would be naive to assume that it corresponds to R_g in general. To achieve high frequency measurements beyond 100MHz, a compromising sacrifice of 50% of the signal has to be made in order to achieve the required frequency response. For source impedance as high as 5kΩ, the 1kΩ/ 0.7pF probe (HP 10020A with 20:1 divider tip) combination appears to be the best choice from the point of view of response, but only less than 20% of the signal is present even before division. The following example, taken from the HP application note[4] highlights the considerations necessary for making a typical RF voltage measurement. Example: Signal source: 35MHz, Source impedance: 500Ω, Signal amplitude: 1V p-p. The consideration is (neglecting vertical amplifier roll-off), which of the probes in table 1 is best suited for making the measurement. Naively probe (1) appears to be the best selection, but a simple calculation shows that probe (5) has the minimum error:

However, the low signal level after division leads to a poor resolution on the scope and the better compromise would be probe (2). The reader should by now appreciate that measuring RF voltages is by no means straightforward even when expensive oscilloscopes are at one's disposal. It appears that for high frequency measurements beyond the 100MHz region really expensive oscilloscopes are involved such as the Tektronix 2465B mentioned in the beginning of this article. In most

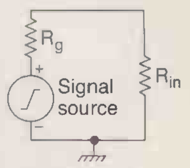

Fig. 1. Resistive loading due to the scope's input impedance R_{in} typically about 1MΩ.

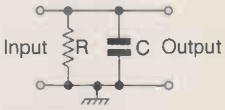

Fig. 2. Typical scope input seen as a low pass filter.

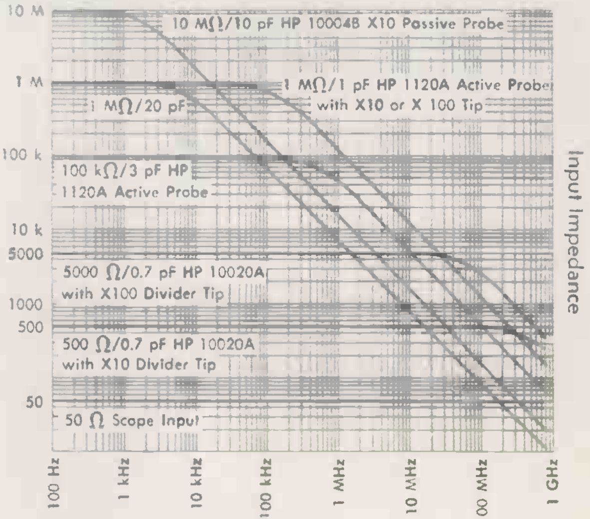

Fig. 3. Probe + Scope input impedance characteristics for various HP scope probes, from ref. 4.

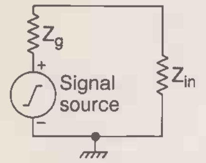

Fig. 4. Equivalent circuit to model input impedance.

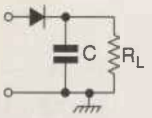

Fig. 5. Peak envelope diode detector.

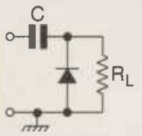

Fig. 6. The correct diode detector circuit, see ref. 6.

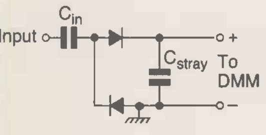

Fig. 7. Full wave RF diode detector, relying on stray capacitance C_{stray} for its function.

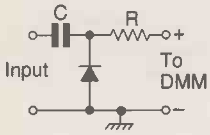

Fig. 8. Standard home made RF probe based on the ref. 3.

cases the only equipment at our disposal appears to be the old faithful diode probe. The rest of this article is devoted to examine this naively simple, but really highly sophisticated measurement tool.

Diode detectors

The simple diode detector is as old as the discovery of wireless itself. Yet the proper operation of a diode detector and the appropriate circuit configuration can vary a great deal, with some explanation needed. The simplest circuit configuration is that of a peak envelope detector as shown in **Fig. 5.**

This circuit functions as a peak voltage rectifier and requires a sufficiently large signal voltage (0.7V) to operate. Small signal detection usually functions from the square law detector mode. As explained in most textbooks, such as ref. 5, the fundamental diode characteristic equation is:

$$I = I_0 \; exp \; (\frac{qV}{kT})$$

Where I is the current flowing through the diode, I_0 is a constant, q the electronic charge, V the voltage across the diode, k the Boltzmann's constant and T the absolute temperature in Kelvin. The small signal analysis, assumes an expansion of this equation about some bias V_b such that $V = V_b + V_s$ with $V_s << V_b$:

$$I \approx I_b + g_m V_s + \frac{1}{2} g_m^2 V_s^2 + \ldots$$

Indeed a small signal AM voltage of the form:

$$V_s = A[1 + m_s(t)] \; cos(2\pi f_c t)$$

with f_c the frequency of the carrier and $m_s(t)$ the modulating signal, becomes demodulated into its components. Here for our purpose where we assume an ideal pure sine wave (i.e. $m_s(t) = 0$), the demodulated DC component is proportional to the square of the amplitude:

$$I_{dc} \approx I_b + \frac{1}{2} g_m^2 A^2 + \ldots$$

This well-known circuit of Fig. 5 unfortunately will not work as a RF detector for in-circuit testing. The difference between a peak diode detector and a RF detector is a subtle one and the proper circuit operation of a RF detector has been expounded by Gruchalla[6].

The correct circuit functions essentially as a diode clamp and a proper DC measurement voltage corresponding to the peak voltage A in equation 7 requires that the diode and capacitor be switched in the circuit, see **Fig. 6**. In all of the above circuits, proper operation requires a DC return path for the diode. RF grounding is also essential in order that proper RF voltages are developed across the detector circuit and in Fig. 6, these two grounds are identical. A well-known diode probe configuration removes the ground by using a full-wave two-diode circuit, see **Fig. 7.** This circuit is suitable for VHF and above and relies in general on stray capacitance to couple the RF to ground from one end of the output capacitor. While suitable for relative signal detection, its operation can be quite erratic in view of the coupling to outside components. For many years, the ARRL handbook published a RF detector probe based on the circuit of **Fig. 8,** with a high input impedance DMM, typically 10MΩ and the resistor of 4.7MΩ provided a voltage divider circuit that approximately converts the peak voltage to RMS. The circuit relies on the coaxial cable capacitance for RF bypass and can be improved by adding a 50pF capacitor directly across the output. Needless to say, the choice of the diode determines the characteristics of the probe and there is generally a trade off between high frequency, i.e. low diode capacitance, versus safe reverse voltage limitations. Generations of amateurs must have made up diode detectors based on this circuit design, (see **Fig. 9**). The use of a germanium diode 1N34A will provide operation up to UHF.

Recently Cyril Bateman also discussed the construction of various RF probes[8,9,10] for home construction. Their low cost is based around the AD8351, MAX4005 and other instrumentation amps such as MAX4144 and MAX 4107.

Table 2. Relative probe accuracy

Probe	Percent of signal remaining	Scope input voltage after the effects of loading after probe division
1	48%	48mV
2	76%	760mV
3	78%	78mV
4	50%	50mV
5	89%	8.9mV

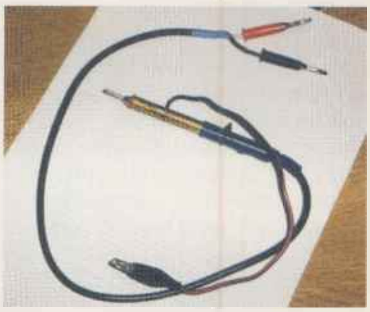

Fig. 9: The author's RF probe

Considerable care and effort in designing input compensating networks went into the circuit development to achieve a flat response from 0.1MHz to 100MHz with ±0.2db errors. The AD8351 is a true marvel of modern technology being able to provide true RMS measurements from audio to 2.5GHz with up to 30dB dynamic range, but this performance cannot easily be achieved without proper front end design and an appropriate low capacitance test prod in order to make use of adaptors from a commercial 250MHz Coline M12SW scope probe[8]. In this respect the Australian company RF Probes Pty Ltd.'s product RFP5401A is well worth its cost considering the probe's response which stretches to 750MHz at 10mV sensitivity with useable outputs to 4GHz[2]. ■

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Measuring 2.4 GHz Helix Antenna using Slotted Lines

The helical-beam antenna (or axial-mode helix) was invented by John D. Kraus in 1946[1]. Commencing with Kraus's correct hypothesis that travelling wave structures then used in electro devices would make efficient antennas, the helix has proven to be the radiator of choice for many radio astronomy and space science applications. Paolo Antoniazzi and Marco Arecco explain.

The helical antenna has been carried to the Moon and Mars and the Navstar GPS satellites use arrays of axial-mode helices. At the end of 90's a new interest was born for helix antennas thanks to the Amsat[2,3] Phase 3D program (the well known AO40 satellite with an easy to use S-band down link).

It's not very difficult to design and make a specific helix for different working frequencies and gain. More difficult for the serious experimenter is the way of making precise measurements. The network analysers, today standard in all the telecom labs, are not accessible to experimenters because of budget limits. We have analysed the possible use of directional couplers, but they are not suited because of the wide-band, very high directivity needed for precise measurements. Directivity is the measure of how well the coupler isolates two opposite-travelling (forward and reverse) signals. In the case of measuring the reflection coefficient (return loss) of a device under test, directivity is a crucial parameter[4,5] in the uncertainty of the results. For example, with a coupler directivity of 35dB and a measured return loss of 30dB (SWR = 1.07), the measurement error can be between – 4 and +7dB!

Using directional couplers we need also some form of RF vector voltmeters (both magnitude and phase angle of the reflection coefficient) to transfer the measured value on a Smith chart for impedance analysis. At this point we took the decision to start with the design and realisation of a 2003 version of a famous instrument, leading part of the first measurements in the history of the microwave: the Slotted Line.

Slotted line project

Some types of slotted lines are still available on the surplus market, for example the HP805A and General Radio type 874-B, but they are expensive. Hewlett Packard also built, in the seventies, the 805C, a professional 'slotted line' employing two parallel plates (slab line) instead of the normal coaxial line. The equipment with a 40cm probe travel length, has been made to work in the 0.5 to 4.0GHz frequency range.

Fig. 1. The Complete Home-made Slotted Line.

The slotted line is essentially a precision 50Ω, low-attenuation, low-SWR coaxial line intended for precise measurement of standing wave ratio and related impedances. For those interested in the complete project including mechanical realization, the notes in the box (The Slotted Line) are intended as a short tutorial. Our version of slotted line (**Fig. 1**) was constructed by starting from a 30cm long brass square bar, drilled with a precision 14.00mm hole. Two high quality Amphenol N-type female connectors are fixed at both ends of the bar. The inner pin of two panel connectors supports the internal precision rod (diameter = 6.08mm for an exact 50Ω line) made in golden copper. One side of the rod is soldered and the other side is connected via a homemade spring contact. This point is very critical in order to obtain the targeted very low SWR. See **Table.1** and **Fig. 3** for the maximum permissible mechanical errors. A probe, mounted on a carriage (**Fig. 2a**) and movable in a narrow slot (3mm) cut longitudinally along the outer conductor, extends into the line to sample the RF field.

In the past the probe used was a diode. Today the best solution is a very small loop connected via a short cable and a 6dB attenuator to a wide-band 20dB preamplifier. The input attenuator is needed to reduce the risk of the amplifier oscillating. For some tests we also used the Drake 2880 converter followed by a Boonton RF Millivoltmeter model 92B.

Error sources

The primary function of a slotted line is to provide a method of detecting a standing wave pattern along a transmission line. Thus, to faithfully reproduce this pattern, the critical parameters are the residual SWR and the irregularities. The commercial slotted lines, manufactured to work at these frequencies, had a guaranteed SWR =~ 1.04 (>32dB) and 0.2dB of irregularities. A line with a perfect 50Ω characteristic impedance is associated with the fact that both SWR and impedance measurements' accuracy are strictly linked to this value.

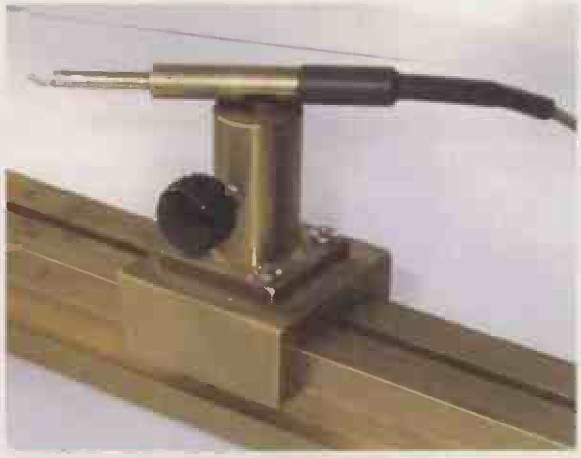


Fig. 2a. Carriage and probe (particular).

Fig. 2b. Slotted line output connector with High Quality N to SMA Adapter.

For this reason, during the manufacturing phase it is necessary to pay attention to all the possible errors caused by the dimensional tolerances. They have been analysed in a singular way even if, in the end, we have to overlap the total analysed effects. The first one is related to the ratio between the inner diameter of outer conductor 'D' and the outer diameter of the inner conductor 'd' that must be exactly 2.30 to have a perfect 50Ω characteristic impedance as described by the following expression[6]:

$$Z_0 = 60 \ln (D/d)$$

In Table 1 the 'slotted line' SWR changes versus mechanical data (tolerances) are shown. For instance if we consider D = 14.00mm and a SWR = 1.02 the 'd' tolerance will be about +/– 0.10mm. Remember that a value of SWR = 1.02 is equivalent to a resistive characteristic impedance change of +/-1Ω or +/–0.5%.

Another error that does not allow you to obtain a perfect 50Ω characteristic impedance line is linked to the placement of the inner conductor at exactly the centre of the outer one: in the ideal case the two symmetry axes must coincide. The following equation shows the relationship between the eccentricity 'c' and the characteristic impedance of the line[6]:

$$Z_0 = 60 \operatorname{acosh} \{[D / d + d / D - (4 c^2) / (d D)] / 2\}$$

Table 1 shows the change of characteristic impedance

Table.1 Max Permissible Mechanical Errors

Standing Wave Ratio	SWR	1.00	1.01	1.02	1.05	1.10
	SWR (dB)	•	46.1	40.1	32.3	26.4
Reflection Coefficient	Γ	0	0.005	0.010	0.024	0.048
Diameters tolerance	D/d ratio	2.30	2.28 2.32	2.26 2.34	2.21 2.40	2.13 2.50
	D (mm)	14.00	-	-	-	-
	d (mm)	6.08	–0.05 +0.06	–0.10 +0.11	–0.24 +0.25	–0.48 +0.51
	D (mm)	14.00	–0.13 +0.11	–0.25 +0.24	–0.55 +0.60	–1.04 +1.21
	d (mm)	6.08	-	-	-	-
Eccentricity	c (mm)	0	0.57	0.80	1.24	1.69

versus the eccentricity 'c' that is the distance between the centres of the inner and the outer conductors. The reported values are relative to our case (D = 14mm and d = 6.08mm). If we consider a SWR = 1.02, the maximum eccentricity allowed is 0.80mm.

A third source of error can be the discontinuity created by the longitudinal slot on the outer conductor (to detect the field within the 'slotted line' via a loop probe). Nevertheless its impact is negligible as can be seen looking at the following equation[6]:

$\Delta Z = 0.03\,\theta^2$

where: ΔZ = characteristic impedance increase compared with a 50Ω coaxial line

θ = angular opening of the slot (radian)

Coaxial cables and adapters: a critical point

One of the critical points in the low-SWR measurements with the slotted line is done by the use of extremely high quality coaxial cables and adapters[7]. The time and money spent on high-quality cables can be wasted if there are large impedance mismatches within the connectors at the connector-cable interface and with the adapters (typically N to SMA, for the device on test, see **Fig. 2b**). David Slack of Times Microwave Systems writes "a microwave cable assembly is not 'just a wire'. It is a passive, TEM mode, microwave component and an integral part of a system." Assuming a high-quality cable is used, the predominant contributor to the SWR of a cable assembly (on a 10-50 cm short assembly) is the connector. Improperly compensated geometry changes in the connector interface will exhibit very poor SWR characteristics. In previous eras, this design was considered a 'black art' and trial and error was a key component of high performance design. Today the computer simulation of discontinuities in connectors is a fine art and the practical results are visible in **Fig. 4.** where the SWR Performances of a very good 30 inch cable assembly (N-male connectors) of the Times Microwave Systems are shown. The only types of connectors used in our tests are N and SMA.

Another cause that can impact the characteristic impedance of the slotted line is SWR induced by the incorrect characteristic impedance of parts of the line, particularly the transition between the inner conductor and the 'N' type panel connector lead that have different dimensions.

The following equation give the standing wave 'ρ' of the whole line when a little part of it ($L<0.1\lambda$) does not meet the characteristic impedance of the line under test[8]:

$$\rho = 1 + 2\pi(\rho_1 - 1/\rho_1)\,L/\lambda$$

where: ρ_1 = standing wave ratio of the mismatched part of the line: Z_1/Z_0 or Z_0/Z_1 according the values:

Z_1 = characteristic impedance of the mismatched part of the line (Ω)

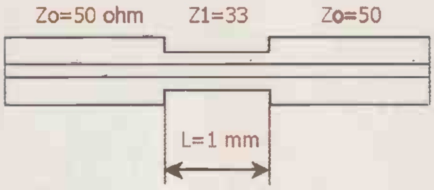
L = length of the mismatched part of the line (mm)

Z_0 = characteristic impedance of the main part of the line (Ω)

λ = wavelength of the line (mm)

To better clarify the use of the above equation here's a practical example: if $Z_0 = 50\Omega$, $Z1 = 35\Omega$, $L = 1$mm, λ = 125mm, the total SWR increases to 1.04 with a discontinuity of the characteristic impedance of only 1mm.

Analysing the possible errors during the slotted line-manufacturing phase, a low SWR value was considered because its worst case can increase rapidly as shown



$$SWR = 1 + 2\pi(S - 1/S)\,L/\lambda$$

where : $S = Z0/Z1 = 1.515$

L = 1 mm

$\lambda = 125$ mm

$$SWR = 1 + 6.28(\,0.855 \times 0.008)$$

$$\mathbf{SWR} = 1 + 0.043 = \mathbf{1.043}$$

Fig. 3 Effect of a Short Length of mismatch on the Slotted Line.

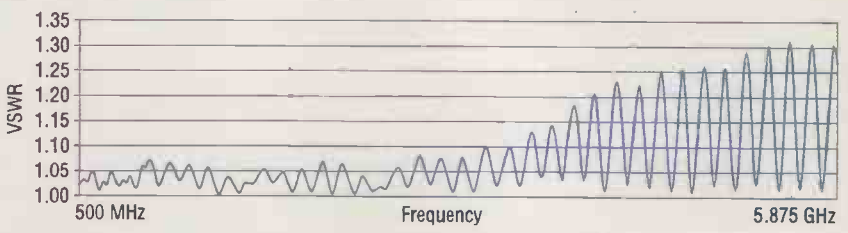


Fig. 4 SWR Performances of a Very Good 30 inch Cable Assembly (N-male connectors).

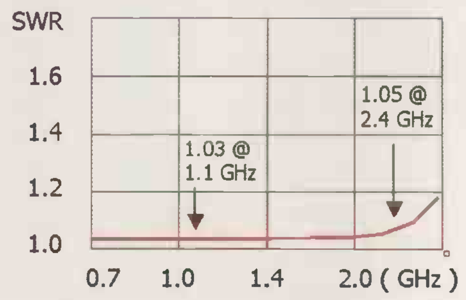


Fig. 5. A very good Slotted Line Measured SWR from 500 to 2500MHz.

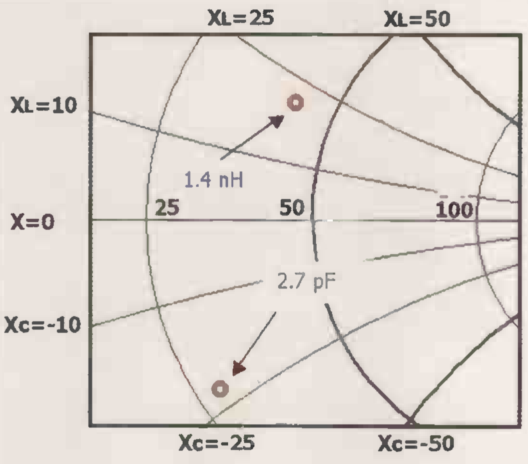


Fig. 6. Examples of Measured Impedances @ 2.4GHz.

below. To connect the slotted line to the load, several components are used: adapters, connectors and cables. These components can introduce very important impedance mismatches and the worst case of the standing wave ratio can increase rapidly as can be seen by applying the following simple expression considering four mismatches.

$$\rho_{total} = \rho_1 \rho_2 \rho_3 \rho_4$$

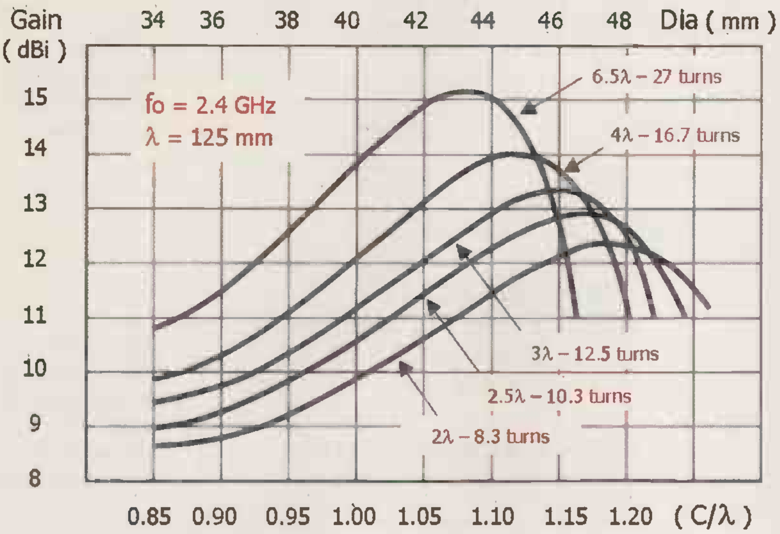


Fig. 7. Simulated Gain vs Helix Diameter and C/λ @ 2.4GHz.

Fig. 8. Five Turns and 16.7 Turns Helices in Test.

The slotted line

The 'slotted line' is an air low-loss coaxial transmission line (<0.3dB) having a precise 50Ω characteristic impedance. It is 30-50cm long, depending on the minimum working frequency and at the ends it presents two connectors, generally 'N' type, to connect them to a RF generator and a load or a line to be measured. Along the outer conductor of the coaxial line there is a narrow longitudinal slot in which is placed a small probe. The penetration of the probe into the line is a tradeoff between the voltage levels to be detected and the need to minimise the perturbation of the line field in which it is immersed. To detect the field existing in the slotted line an RF millivoltmeter is used which is connected to the probe via a shielded cable. The probe is placed on a sliding carriage that can move along the line and its positing can be read with a resolution of about 0.5mm, by a pointer moving on a suitable ruler fixed to the slotted line body. The low frequency limit is a function of the maximum length on which the carriage probe can travel. When a generator is connected at one end of the slotted line and a load to the other, we get two possibilities: the load has impedance equal to the characteristic impedance (Z_0) or not. In the first case we have no reflection from the load and the voltage detected by the probe along the line is flat. If the load impedance differs from Z_0 - a standing wave pattern occurs and moving the probe along the line we will find one or more maximums (loops) and minimums (nodes). In this case the distances between two contiguous maximums (see **Fig.14**) or minimums is one half a wavelength and so we are able to estimate the frequency of the RF source used to feed the load. We are also able to calculate the standing wave ratio (SWR or r) using the following equation:

$\rho = (e_{MAX} / e_{min})$ or in decibels $= 20 \log_{10} [(e_{MAX} + e_{min}) / (e_{MAX} - e_{min})]$

where:

e_{MAX} = maximum voltage, measured with the probe, along the 'slotted line' (mV).
e_{min} = minimum voltage, contiguous to the previous maximum, measured with the probe (mV).

Moreover, the slotted line gives us the possibility to calculate the impedance, both the real and imaginary parts, measuring the node displacement when the line is connected to the load and the load is replaced by a short circuit. The computation of the complex impedance can be performed using the expression of the loss-less line:

$$Z = Z_0 [Z_L + j Z_0 \tan(\beta l)] / [Z_0 + j Z_L \tan(\beta l)]$$

Where:
β = phase constant: $2\pi/\lambda$ (cm^{-1})
l = nodes displacement (cm):
λ = Wavelength (cm)

The same kind of calculation can be performed easier with the aid of the Smith Chart.

The 'slotted line' can be used also to establish the cable attenuation repeating the standing wave ratio measurement both at the beginning and at the end of the line to be tested. The computation of the attenuation A (in dB) can be performed using the following equation achieved from the one lossy line:

$$A = [\operatorname{atanh}(1/\rho_1) - \operatorname{atanh}(1/\rho_2)]\ 8.69$$

Where:
ρ_1 = SWR at the beginning of the line
ρ_2 = SWR at the end of the line

A numerical example will clarify this quick SWR increase. For instance a SWR = 1.02, that is very small, can become 1.08 when you consider four similar mismatched sources.

SWR and impedance measurements

Using a slotted line is becoming a lost art, but the basic ideas are quite simple. The first suggested measurement with a newly made slotted line is the SWR of the system terminated on a very good commercial termination. Our first results with an old HP termination model 909A (N-male connector) are not the best, as the 909A is guaranteed no better than SWR=1.04. The results are better using the famous Minicircuits[9] type Anne-50 with an SMA male connector (SWR = 1.03 @ 3GHz) and a good Amphenol N-male/SMA-female adapter. The measured values on our slotted line are shown in **Fig. 5**. For almost all of the tests we used a 2.2 to 2.6GHz generator constructed with a JTOS-3000 VCO followed by the new amplifier MNA-6 (3x3mm package).

Another interesting measurement is the impedance test using the short-circuit technique. We measured two components (a thin wire terminating a microstrip line and a bad surface mount capacitor). The results are in **Fig. 6**. (Smith Chart). We checked two contiguous maximum and minimum voltages from the probe in order to calculate the relevant SWR = e_{MAX}/e_{min} = 2.4. After we found one minimum near the load, and we recorded the relevant mechanical position of the carriage pointer on the ruler. It is better to use a minimum instead of a maximum because the reading is easier due to the rapid variation of the voltage near the node instead of the soft slope near the loop. The best thing to improve the measurement accuracy is to perform two readings at the same level before and after the node and calculate the average position.

Having just defined the carriage position for the minimum, we replaced the load with a perfect short circuit and we then try to find the new position at which the previous node disappears. Also in this case it is better to perform two measurements around the node taking care that the maximum displacement between the two measurements can be +/– 0.25λ or, if you prefer, +/– λ/4.

Fig. 9. TriHelix Antenna on the Support for AO40 Satellite Reception.

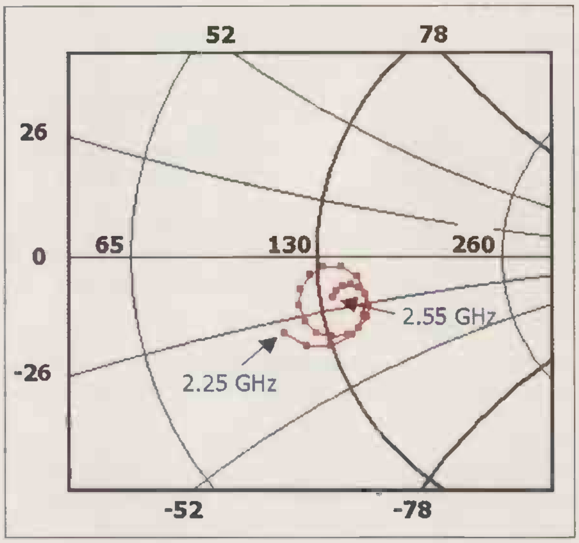


Fig. 10. Simulated Input Impedance of the 16.7 Turns Helix.

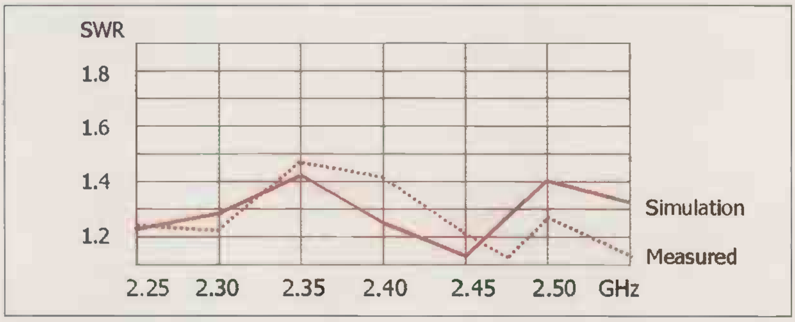


Fig. 11. First Approch to the SWR vs Frequency of a 16.7 Turns Helix.

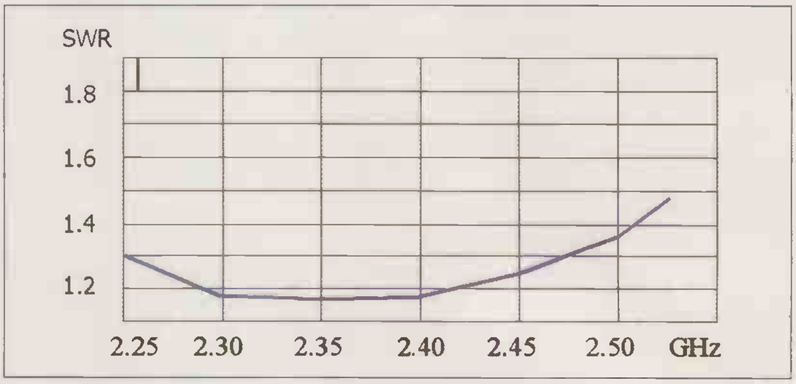
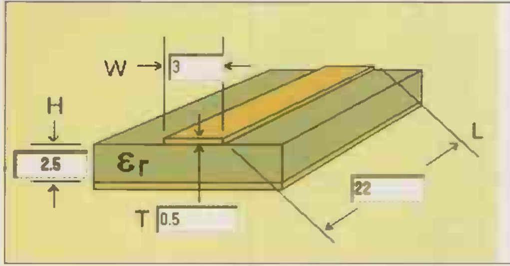


Fig. 12. Finally Tuned 16.7 Turns Helix : Measured SWR vs Frequency.

If the displacement is greater than 0.25λ it is necessary to concentrate on the fact that we are measuring the next minimum or the previous one according the carriage movement. It is very important to know if we are shifting the carriage through the load instead of the generator because it changes the sign of the imaginary part of the impedance (inductive instead of capacitive or vice versa). In our case we measured a displacement of 11.0mm corresponding to 0.09λ through the load at the frequency of 2.4GHz. At this point we use a Smith Chart to simplify the computations (Fig.6). With a compass we can trace a circle with its centre in the centre of the Smith Chart (point signed with 1 or 50Ω) and a radius corresponding to the SWR = 2.4 (the circle will pass through the points 0.42 and 2.4 of the horizontal axis, in other words, the axis of the normalised resistance). Next we trace a line segment that connects the central point of the previously mentioned



$\lambda/4$ transformation from 130 to 50 ohm. The transformer is realized using a Teflon plate (22 x 30 mm) and a copper stripe with W=3 mm, Th=0.5 mm, at the beginning of the Helix.

Fig. 13. Layout of the Teflon $\lambda/4$ Transformer Optimized Using HP-AppCAD.

Smith Chart with the point 0.09λ, through the load, found at the periphery of the Smith Chart. The intersection point between the circle and the line gives us the normalised impedance that we wanted - 0.54–j0.48. Now, to calculate the impedance in ohms, it is enough just to multiply the normalised value by the characteristic impedance of the line ($Z_0 = 50\Omega$): 27–j24Ω. The reactive part of the impedance has the sign '–' and so means that the impedance is capacitive. Now we are also able to calculate the capacitance at 2.4GHz with the simple equation:

$C = 1/2\pi\ f\ X = \sim 2.7$pF. Naturally the resistance in series with the capacitance is 27Ω.

Using a similar procedure we can measure the inductance. In this new case the SWR is 1.7, but the displacement between the nodes with the load and the short circuit is different - 14.0mm through the generator instead of the load. It corresponds to a movement of 0.104λ at the frequency of 2.4GHz. Drawing the relevant circle, corresponding to the SWR, and the line segment, relative to the displacement, on the Smith Chart we are able to calculate the impedance that is: 39+j21Ω. The reactive part of the impedance has the sign '+' and so means that the impedance is inductive. Now, through this simple formula, we can calculate the inductance: $L = X/2\pi f = \sim 1.4$nH. In this case the resistance in series with the inductance is about 39Ω.

Helices measurements

After a short, but necessary didactical phase, we will go quickly to the Helix antennae. Using the powerful NEC WinPro[10] as a simulation tool and starting from the important results obtained by the great simulation work of Emerson[11] **(Fig. 7)** we have analysed three different antennae: one simple five turn, one 16.7 turn with 14dBi Gain **(Fig. 8)** and a more complex antenna named TriHelix (an 18dB array of three 16.7 turns fed via flat 130Ω air lines, see **Fig .9**). The simulated values for the input impedance (referred to 130Ω) of the 16.7 turns helix are shown in **Fig. 10.** The simulation of SWR values and the first measured values from 2.25 to 2.55GHz are visible in **Fig. 11.** In **Fig. 12.** the measured values for the finally tuned Helix are shown. The matching between the 130Ω nominal input impedance of the single Helix and 50Ω is obtained via a $\lambda/4$ transformer (Teflon support with h=2.5mm and line with W=3mm, Z=~81 ohm). The transformer layout is shown in **Fig. 13.** (calculated using an excellent HP tool, the AppCad)[12].

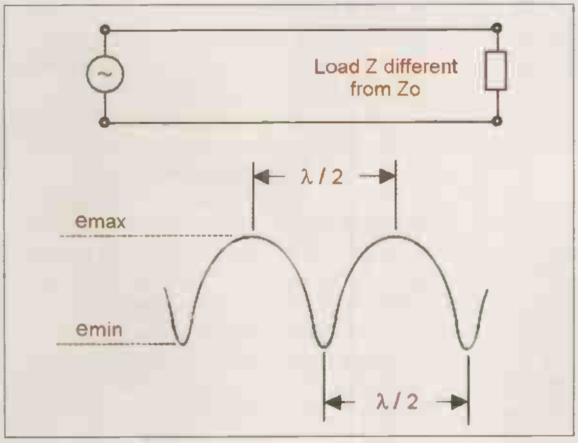


Fig. 14. Standing Wave On a Transmission Line Terminated by a Load Impedance different from 50Ω.

The first measurements on the TriHelix antenna give a SWR=1.3-1.4 at 2.4GHz +/–100MHz. With the multiple-helix arrays, the mutual impedance of adjacent helices has to be considered, but at spaces of a wavelength or more, as is typical in helix arrays, the mutual impedance is only a few percent or less than the helix self impedance (130-140Ω). Thus in designing the feed corrections for a helix array, the effect of the mutual impedance can often be neglected[1] without significant consequences.

Another important parameter is the correct RF signal levels during the measurements. The input level from the oscillator is very high (+10dBm), but some attenuation must be included for stability (the wide-band amplifiers oscillate very easily with loads not exactly 50Ω). Using the Boonton RF Millivoltmeter (model 92B) as a detector, we have also a sensitivity attenuation of about 10dB @ 2.4GHz (referred to the maximum suggested operating frequency of about 1.2GHz) and consequently the level sampled by the probe is very low (typically 0.3 to 3mV). In future measurements we will use a 2.2 to 2.6GHz heterodyne system composed of a harmonic mixer and a 1.05GHz fixed frequency local oscillator. The IF frequency will be in the range 100-500MHz, limited by a 550MHz low-pass filter. This solution is free from oscillation risks and the gain is obtained with a simple wide-band amplifier followed by the RF Millivoltmeter. In effect it's very important to minimise the coupling of the probe to the line to obtain reliable results. ■

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LETTERS to the editor

Letters to "Electronics World" Highbury Business Communications,
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e-mail j.lowe@highburybiz.com using subject heading 'Letters'.

Power-line data distribution

In his recent *EW* article, J. LeJeune describes various ways of 'communication' along power lines (i.e. the energy grid). Although he gives some examples of exotic ways of transporting data, it is obvious that his main interest is on what we know as PLC (Power Line Communication). LeJeune forgets to mention the fact that PLC uses RF (300kHz....30MHz) with immense implications for the users of the MF and HF spectrum.

ADSL technology is based on the fact that a twisted pair of wires has transmission line characteristics. Mains power lines on the other hand, have antenna characteristics, as they are not shielded, nor twisted. Look around in your house, and you'll see 'open' wires (plugs), or 'short circuited' wires (due to mains line filters), etc. Due to this, a mains network will very effectively *radiate* (PLC) energy, instead of shielding it, as coax or properly twisted wires do!

In his paragraph about noise, he *never* mentions the fact that PLC itself might be the cause of excessive noise contribution to various legitimate users of the spectrum.

EW has in the past addressed new technologies like DRM. If PLC is introduced, DRM may be thrown in the wastebasket, as only in a narrow circle around a transmitter will a sufficient Signal-to-Interference Ratio be available.

PLC is not a state-of-the-art technology; it is a low cost technology in order to make some revenue from internet customers. Today there are plenty of technologies available, that do not, or hardly, interfere with present users of MF, HF or VHF (ADSL, Cable, WLAN, WLL, Fibre, etc), and that will give data rates in excess of what can be achieved with PLC.

In his article LeJeune mentioned that ASCOM (Switzerland) is a manufacturer of PLC equipment. I can tell you that they pulled out, not on technical, but due to commercial reasons. If you don't believe the horror of PLC to the (HF) spectrum, pay a visit to:
http://www.muenster.de/~dl5qe/

On DL5QE's site you will find several audio and video samples that demonstrate the implication of PLC.

P.C. Hoefsloot
The Netherlands

Agent provocateur

How refreshing to find an article by Ivor Catt. He still retains his deep technical understanding and provocative view of the establishment that made him so popular the first time round.

Since there seems to be a mood in support of previous value adding provocateurs, I was reminded of a series of eight articles published in *Wireless World* 1982/3 by W.A. Scott-Murray entitled "A Heretic's Guide to Modern Physics", the first of which was headed "Theories and Miracles", a very Catt like opening. Physics at the time seemed to be moving down a road of increasing incredulity, where the amount of faith required made it more of a religion than a science. To me, the articles represented a huge challenge to the archbishops of physics, and the superb storm of correspondence that followed clearly demonstrated the fragility of the subject in hand.

I still find the Scott-Murray articles both challenging and inspiring as are the Ivor Catt writings of similar period. In the search for editorial content, you may like to consider reprinting some of your most ground-breaking articles from earlier times.

Well done to the *Wireless World* then and to *Electronics World* now.

Roger Wilkins
Newbury
Berks
UK

Digital replacement

The Editor threw out a suggestion for an article describing a hard-disk based VCR replacement. *(Did I? I don't think so - Ed)*

I would certainly be interested in such an article. I would just love to develop such a gadget myself - I can now buy 200Gb hard drives for around £200. Pop four of them on an IDE bus and that's quite a few hours of storage! Or one could start 'small' (e.g. 60Gb is about the smallest disk currently made and is around £55 in the trade).

The big dilemma would be whether or not to use a PC as the basis for such a system. This would give a number of benefits:

Little effort on hardware design - TV tuner cards and TV output cards are available.

It would be very repeatable.

Basics such as file management, user interface are already done.

But it has a number of disadvantages:

If it were based on MS Windows, it would probably not be very reliable. The TV tuner and video cards would probably be PCI, thus implying a PC chassis.

This in turn means the gadget will be large, and probably emanate fan noise, even when not in use and would have relatively high standby power consumption.

My view, therefore, is that a 'proper job' would involve more basic components and a bespoke design. I would keep the recording/playback hardware and software very basic - using a microcontroller to manage the thing and perhaps a second one (e.g. the excellent RISC AVR devices from ATMEL) to shovel the bytes about. I would use something like an iPaq to run the man/machine interface, with two-way infrared (or Bluetooth) communication. The hard drives would be switched off when not in use to minimise noise. I would use the FAT32 standard on the hard drives to avoid re-inventing the wheel. Or possibly find an embedded Linux kernel to do the whole O/S for me. Implementing the Program Delivery Control feature would be essential, and I'd have the device pull its clock time from the Teletext signals thereby completely eliminating the 'flashing 8s' problem most domestic videos suffer!

My very full time job means that I'm very unlikely to find the time to realise this design.

But it's nice to dream!

Chris Miller
By email

Watch this space – Ed.

EMC & Theremin

I am so glad that Ivor Catt is alive and well, his contribution to all things electronic has in past times provided many pages of great debate. I like his independent points of view, his in depth knowledge and, his ability to shrug his shoulders when confronted by the lesser brains of people who should know better.

I read the article on EMC and agreed with every word, having also worked for the great GEC empire and in particular for Marconi Instruments, I have seen at first hand what goes on in the empire that was GEC. More Catt please.

On another tack, I have noted the letter from Robin Clark page 21. He asks about a design for a Theremin and a two part article was published in *EPE* late 1996 and early 1997. Their online shop www.epemag.wimborne.co.uk should help.

From valves to ICs from A to D and all between, every design is a compromise, between power out versus power used, or distortion versus cost. Every circuit could be better made if only the laws of physics would be more flexible. Valves have some advantages but consume far too much power, or produce too much heat. Transistors are better, but still fail in many ways due to their own problems, shot noise, sensitivity to voltage and, heat. Capacitors have so many faults, it would be nice not have to use them at all. Resistors have Johnson noise and other thermal defects, also they tend to age rather unpredictably. Transformers buzz or get hot, they are heavy, bulky and inefficient.

Even wire is less than perfect, ref: speaker leads. I think that the real reason that they appear to differ is really a reflection on the design of the amplifier's output stage and its output impedance characteristics. Also the speakers' own impedance characteristics. What do they look like at realistic power levels given a piece of music? How much does the voice coil heat up? Does it create its own noise - it is after all a resistance and inductance!

I have repaired many hundreds of amplifiers of all types and, have yet to find the nearly perfect one. I still like my QUAD 33, 303. They are bomb proof, if now rather dated. I still like the sound of the triple output stage. I have completely updated both to include better components where possible. Metal film high quality holco resisters, some better electrolytics etc.

I have also had to grapple with EMC regulations that contradict themselves. Oh what a mess is our imperfect world. The Holy Grail of a better new world is still too far into the future for any of us to ever see it.

Computers are still just stupid boxes that stress even the most knowledgeable of us to breaking point. I wonder if we have over reached ourselves?

Food for thought ....

Ian Johnson
Kidderminster
Worcestershire
UK

I don't mind giving the opposition a plug – even after their editor, Mike Kenwood, had a pop at EW in his March editorial. Here at EW, we're above all that!

Gibbs disillusionment

Liking maths as I do, I felt quite disillusioned by Leslie Green's account of the Gibbs Phenomenon (*EW* March 03, p48). Evidently the 9% overshoot on synthesised square waves with undershoot preceding the edge, only disappears by summing this without limit as harmonics provided go on towards infinity.

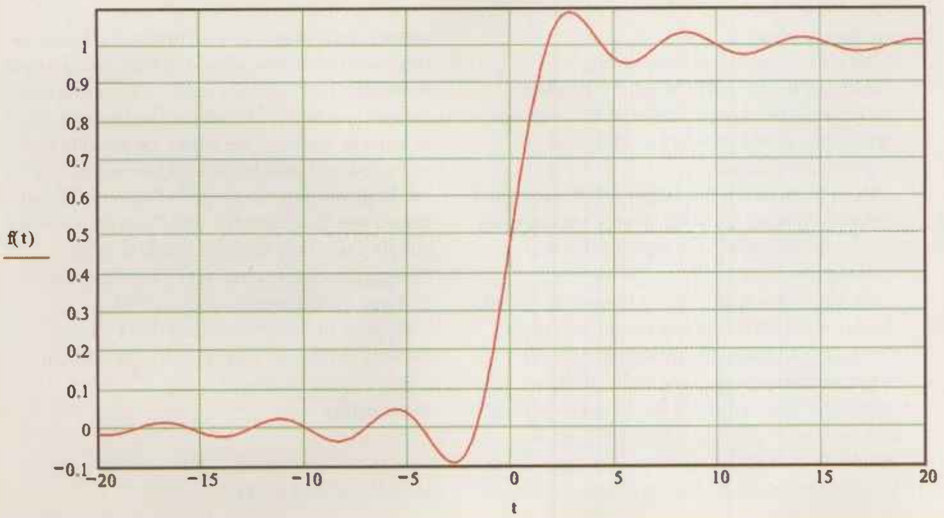
This is downright weird when we consider that if we set out to synthesise the result of passing a perfect square wave through an RC low pass half-section, while many of the highest harmonics are both attenuated and phase shifted (rather a mess one would think) these somehow kill off the Gibbs phenomenon.

Another point which surprised me was this: at the centre of Green's square wave in say Fig2, at amplitude 0.5 – at that one exact point, the fundamental has in Fig 2 a gradient of $^2/_\pi$. But so has every harmonic since while its amplitude is $^1/_n$, cycles have been crowded into 360 deg. They each boost the gradient.

However, the uppermost harmonics do not help the overall rise time: Fig 2 shows that the rise time from 0.05 to 0.95 takes as long as over four cycles of the top (111th) harmonic. As I haven't charted the sum of say the 83rd to 111th harmonics I shall refrain from asking "What use is it then?"

Bernard Jones
London
UK

Fig.2 from Leslie Green's article



No anomaly?

I wanted to agree with the tenets of your March edition's feature, EMC - A fatally flawed discipline? I really did! But as someone who has worked with academia, I am always a little worried by eccentric authors with controversial views. Can they be trusted any more than the bureaucrats?

I looked up Mr Catt on the net as other correspondents had suggested, and what I found there by way of extracts to read, perplexed me rather. Particularly the subject of the so-called Catt Anomaly, a poorly written non sequitur betraying a fundamental lack of understanding of electricity and circuitry. In short, there is no anomaly.

This begs the question as to how much other subjects written about by this author be relied upon?

Orde Solomons
London
UK

Catt's tongue

Ivor Catt's exposé of Defence Electronics in the March issue was both informative and witty. It is unfortunate that this article was marred by a number of seriously flawed statements, which need to be corrected. I should like to point out from the outset that I am on the 'victim' end of the regulations and standards, not the creation end. Also I have spent many years making equipment conform to these onerous requirements, having even had a test chamber built for the purpose[1].

In Mr Catt's article it is stated that the EMC community is "totally indifferent" to a starter motor on a car causing the brakes on another passing vehicle to lock; this statement is incorrect. The first thing to be understood about the EMC legislation is that it is worded at a "high level". The regulation is worded along the lines that equipment shall not interfere, or be interfered with, by other equipment within its normal operating environment. Regardless of anything else, if equipment fails to be electro-magnetically compatible in its intended environment, then it clearly does not meet the regulation. Some people think that meeting a harmonised standard, suitable for the product in question, fulfils the requirements of the regulation; it does not.

If you go to a certified test house they will often suggest appropriate standards for your equipment, test to these standards, and give you a pass or fail as appropriate. If you pass the standards you have a 'presumption of conformity' which means that you can legally sell your equipment. If it is later found that there is a problem, regardless of the fact that your equipment meets all the appropriate standards, you can be fined and the equipment banned; this has happened. One could therefore argue that the test house takes no responsibility for your equipment in this wider sense, and in that way they may be somewhat 'indifferent', but to declare that the whole community is indifferent is not correct. One may regard this situation of being fined and banned after 'complying with all the rules' as somewhat unfair, but if there is an oversight in the standards the consumer is still protected. After all, it would be equally unfair on passengers travelling on Crashalot Airlines if Granny's new Thrudgealot food mixer somehow managed to produce microwave radiation that made the planes crash!

It is stated in the article that EMC engineers ignore the internals of the equipment and just work on the enclosure. This statement may apply to certain individuals that Mr Catt has met, but is an unnecessary and incorrect over-generalisation. Good EMC textbooks always give guidance on the causes of emissions, and correct design procedures to minimise both emission and immunity problems. Good "internal design" at the beginning of a project is always stated as being a cheap way of attaining compliance.

There seems to be some confusion about the separation of "conducted emissions" and "radiated emissions" in the article. There is no slightest possibility of a "conducted emission" signal that is emitted from the mains lead (power cord) of a piece of equipment getting into another piece of equipment through its mains lead. Now note the wording carefully: "conducted emissions" do not interfere by conduction! This point needs more explanation. Radiated emissions primarily occur by changing currents in wires or other conductors. The length of the conductor in relationship to the wavelength of the signal frequency is the key to the amount of radiated emission produced. If the conductor is a quarter wavelength long then it will radiate very effectively. If the conductor is 10,000 times shorter it will not radiate effectively. If the equipment being considered is smaller than 1 metre on each side, it is likely that wires will be limited to this same order of magnitude. Thus high frequency signals can be launched (radiated) easily, but low frequency emission is difficult.

Typically switched mode power supplies operate in the region of 10kHz to 1MHz. At these frequencies the signal currents cannot easily get launched into space (radiated) from within the equipment. However, the mains lead and the wiring in the building are very long and give an excellent opportunity for these low frequency signals to be radiated.

Now just so there is no misunderstanding, let me be very clear that there are other disturbing signals that get "pumped out" of equipment; these signals are not classified as "conducted emissions" but do however constitute EMC non-compliance, and can adversely affect other equipment. Excessive harmonic power current, for example, can cause EMC failure, but the only people who worry about this are the mains power distribution providers. In fact any equipment designer would much prefer the mains to be a "flat topped" sine wave, since the conduction angle in the power supply diodes is improved, the peak current drawn is lessened, the efficiency is improved ....

The article suggests that equipment cases are earthed to prevent radiated emissions. This statement is untrue. Earthing a metal enclosure around electronic equipment will prevent near field "capacitive coupling" from the equipment to other systems, but the primary purpose is for safety reasons. I should point out that I have also been responsible for new equipment safety checklists and testing for many years.

The two types of electrical equipment that you will frequently encounter are designated as Class I and Class II. Class II equipment does not have an earth wire (protective conductor). Because Class II equipment is not protected by use of an earth wire, it needs a higher standard of insulation in order to protect the user against electric shock. Consumers will be familiar with power tools having the square inside square symbol meaning 'double insulated'.

Class I equipment uses the earth wire to protect the user against electric shock. Any fault current gets shunted to earth rather than through the user, thereby protecting the user. Typical fault situations include the insulation breaking down in the mains transformer and the 'live' wire falling off of its mountings and

Digital misimformation

I want to replace my TV (17 years old)/VCR (11 years old) with the digital equivalents - TV with digital tuner and DVD-Recorder. However, it seems that neither of the recording devices that are highly regarded and which I might be interested in - Panasonic DMR-HS2, Phillips DVDR880 - has a digital tuner. Even the TiVo does not have a digital tuner. Can that be correct? We are almost counting down to the end of analogue TV transmissions, and yet new equipment is obsolescent. Am I correct in the above?

Graeme Gemmill
Wallingford
Oxfordshire
UK

Funny you should say that. Despite the fact that the UK government is hell bent on switching off analogue and auctioning off the resulting free spectrum, the industry does not seem to be very interested in digital and in particular DVB. The range of TVs with DVB tuners is pretty small, especially in the smaller (second set) sizes. There are no VHS decks with DVB tuners and the DVD and HD replacement for a VHS also seems not to embrace digital. I personally think that the industry bodies and in particular the DTG (Digital TV Group) want their collective backsides kicking for a complete lack of proper information dissemination to the buying public and advice to government. If you don't believe me, just visit your local high street TV shop and listen to the salesmen. It will make your hair stand on end. Look out also for an EW project which will go some way to solving some of the shortcomings in current commercially available equipment. Ed.

touching the case. Now there has been no law passed that all electrical installations have to be retrofitted with earth leakage circuit breakers (residual current breakers) so this earth wire protection requirement is still important.

Suppose the live lead falls off and touches the equipment case just as you happen to be touching the case. Assuming there is no earth leakage trip in the circuit, protection will be provided by the mains fuse. Mains fuses are notoriously slow to blow, but until the fuse blows, you, the user, could be touching the case whilst conveniently earthing yourself to a nearby metal pipe. OK, this story is a bit concocted, but you get the point. In order to minimise the electric shock hazard you want the absolute minimum impedance in the earth path. You may have noticed earth wires being thicker than line/neutral wires to help this situation and to ensure that under fault conditions the earth outlives the line conductors. My point is this, anyone adding half an ohm of resistance to the earth path is producing a criminally dangerous system. Typical instrumentation safety standards require less than 0.1 ohms in the earth path at 25 amps; I usually aim for less than 50 milliohms.

From the article it is clear where Ivor Catt's great cynicism comes from and one can only feel sympathy for his situation. I regard it as a great pity that the true things which he has to say get mixed in with such a quantity of untrue things, forcefully asserted, that it adversely affects his credibility and the message tends to get lost.

Leslie Green CEng MIEE
Ilford
Essex

Rererence

1. Leslie Green, "Homemade Setup Tests RF emissions", *Test & Measurement World*, June 2002.

D. Lucas and Huw Jones letters

There are tons of texts like the letter from D. Lucas (February issue) on the net: they relate boring experiences and are usually full of comments like "it sounds better with..." I think such a letter is not in its place in *EW*.

The few criticisms I remember John Linsley Hood received were perfectly justified. He never replied. I always like to see John's projects, however, I built quite a lot of them and was often disappointed. There is a cult about his Class A amplifier. Devotion does not hide that its performances are very poor and if I may introduce some subjective comments here, I never found something special about it.

The *Hi-Fi News* 1980 project was quite different to my ears: really magic... But - and that's the interesting thing - when I got a distortion meter, I found more than 0.5% and this fact puzzled me a lot. I concluded that the main reason why people usually prefer some configurations and tube amps is only because the generated distortion is more appealing than (nearly) no distortion at all.

Contrarily to Huw Jones (letter, March issue), I buy EW mainly for audio, and I am certainly not the only one : it is the only serious remaining magazine I know, most articles and technical approaches are rigorous. So please keep the balance as it is.

Sébastien Veyrin-Forrer
Saint Chartres
France

Big Reductions

Mr Attwood's letter referred to a 1kW mobile phone TX (*EW* April) but the 'Political Show' (BBC1 East) showed a man walking around a mobile mast, with a radiation meter, claiming that power levels are about 50W, or less – in one case 28W – because companies are concerned about health risks. A spokesperson was quoted as saying that "this was because power levels are now being measured accurately", although invitations to appear on the show were declined. A local MP appeared, however, saying that "it wasn't about theory now – it's about people's perceptions".

Epidemiological analysis and research into the causes of spongiform encephalopathies has increased significantly during the period of rapid growth in the use of mobile phones due, to a large extent, to BSE/n.v. CJD, and this will have a bearing on claims of RF induced pathologies. Early work by Glass *et al* on bifurcation processes in brains has been advanced by Kitai and Plenz's finding of 1.8655Hz in phase locking brain synchronies. Nick Beard mentioned 'sensitive' dependence on initial conditions (butterfly Effect) in his article in *EW+WW* (June 1991) whilst Jim Lesurf's applied this to 'Chaos in Electronics' (ibid. pp 467-472) but the idea doesn't seem to have occurred to those whose job it is to investigate allegations of mobile phone risks to brains. Frequency counters can be used in this research because they appear to be triggered by the strongest ambient 'signal'. If a counter displaying 1.8655Hz, like di Mario's, were to be brought closer to a mobile phone TX, a point (Lagrange) would be reached where the counter would display the phone frequency, or a chopping frequency for multiplex (?), which is ELF. Some people have already made a connection between chopping frequencies (ELF) and brain pathologies. That's why the suggestion was made (*EW*, January, 2003 page 42) to carry out Kitai and Plenz's experiment in the presence of 1.86551Hz; or 7.46204Hz (Schumann Resonance), which also equals the θ to δ (delta) brain-wave (EEG) range transition region for different levels of awareness (consciousness).

It's interesting to note that 7.46 is the root phoneme, using gematria, for Oduseus, a monosandalic whose defect was somewhat higher – bored by a bore (sic) – than Cinderella's (Latin, cinnis = hot ashes or sparks). In Sanskrit and Hebrew the root, 'bhra', 'BaHir', means bright (vide. Job 37:21, KJ version, only!), which correlates with F2 = 2.502. Hence, we have not only an accurate value for the ultimate particle ($\lambda = 1.375 \times 10^{-50}$kg), or cold-dark matter, energy, whatever?, supported by Hu at MIT, but a means for extracting other data from old scripts, e.g.:- Bhra/ma ≡ F_2/F_1 (Feigenbaum) ≡ q/p (Malament).

This research, however, is exacerbated by transcription errors like you made (actually my wife - Ed) with A.C. Bloomfield's letter (*EW*, February, 'Shot in the foot'). Fortunately, the 'Torah' is remarkably free from this type of pollution. 'Polloi' is derived from pre-Homeric Greek 'PolFa' by assimilation of digamma (gg=F) in consonant-doubling. (F was also modified to v as, for example, in video). Some scholars believed that the sound of F was like the dipthiong 'oi', which might explain how we get polloi; that is, by confusion!

Other monosandalics are Oedipus, Achilles (1.87??) and, possibly Odin? Mr Bloomfield's interest in science and languages would be of value in fleshing out some of these mytho-poeic-religious symbolisms. Od, the root phoneme, means/t 'odour', but by allusion, came to signify 'self loathing', or 'causing trouble for oneself' ("Shot in the foot"). Athene asked Zeus why he treated him so badly but she didn't get an answer – just an inscrutable grin. She noted, however, that "..he was very fond of him, you know", perhaps signifying her part on the rightful inheritance (cf. Oduseus, Oedipus, Cinderella, Prospero iner alia).

A G Callegari Bsc.
G3OMD
Much Hadham
Hertfordshire
UK

Here we have a classic case of data corruption due to the media and data type used. In this instance – hand written letters! We are only human and errors will always creep in when characters can be read in many ways – especially when the subject matter is complex and barely understandable by a mere mortal like myself. Much better to word process and email communications to us for accuracy.

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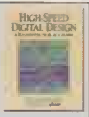

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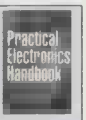

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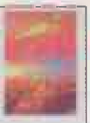

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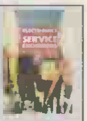

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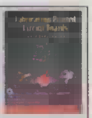

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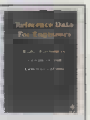

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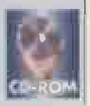

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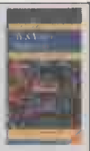

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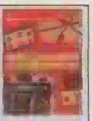

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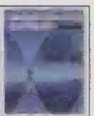

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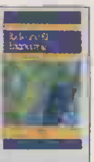

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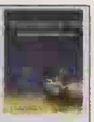

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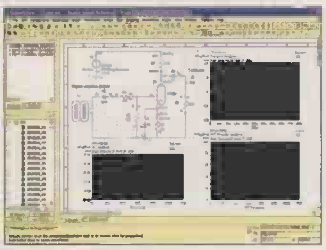

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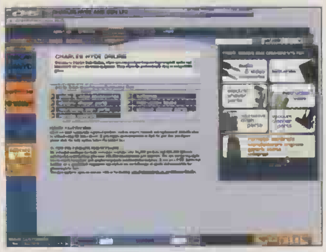

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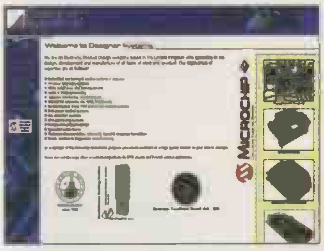

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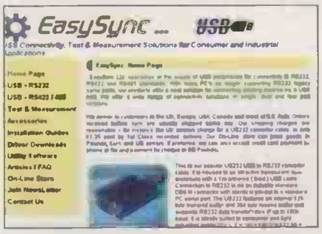

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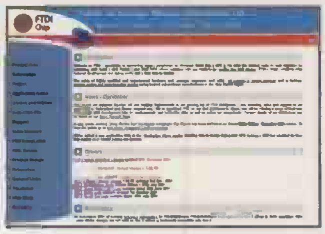

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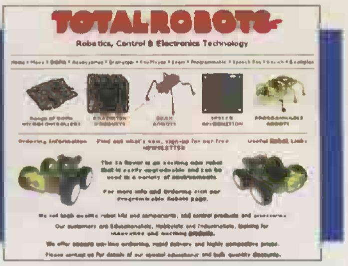
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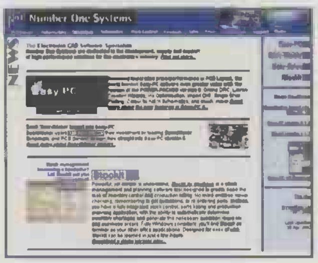
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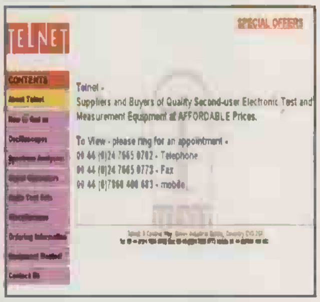
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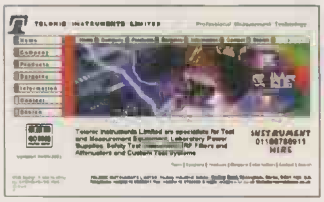
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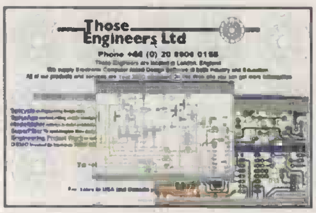
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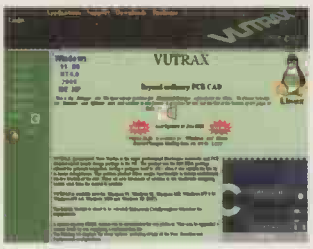

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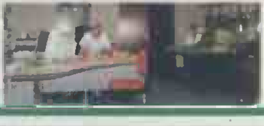

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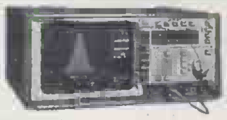

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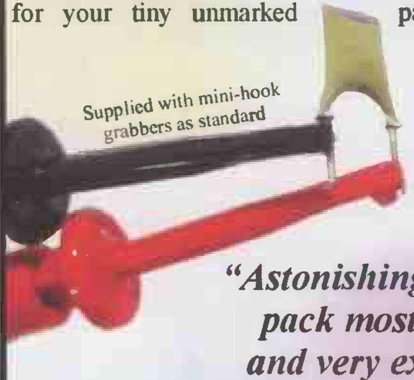

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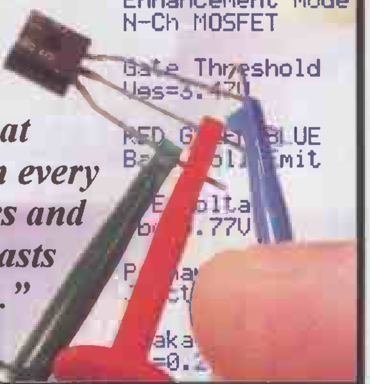

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