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December issue on sale 6 November
**DC Motor Speed Controller (6A/100V)**
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Assembled Order Code: AS3149 - £44.96
Wireless, wireless everywhere......

And half of it doesn’t work. I reported a few months ago about the trouble I was having with getting a simple Bluetooth connection going between my laptop and a GPRS phone. Well, I have to admit defeat – the Nokia and Belkin softwares combine to be the most hideous piece of code and I’m now using infra-red.

The point of this, as I said at the time, is that we as engineers need to make this kind of technology accessible to the average member of the public for it to be successful, so that lots of people buy it and in the long term to keep us all in a job.

I’ve just had a similar ‘radio’ experience by putting in a Wi-Fi network at home. In fact, setting up the network and even the ADSL router was extremely easy. The software and instructions from the ‘black box’ maker (D-Link) and the installation instructions from my ISP (Pipex) combined on this occasion to make the project go very smoothly.

I look forward to more ‘public’ Wi-Fi points opening up in the future – although the small bandwidth allocated thus far is getting very cluttered. It will be wonderful, though in the not too distant future to be able to hook up to a proper, high-speed network, just using the adaptor in the laptop as opposed to hooking into other (not very reliable) networks. The hugely indebted G3 franchise holders could also learn a lesson or two. Whilst they are scrabbling around looking for a ‘killer app’ – the business community needs high-speed data on the move and is willing to pay for it. Sending your mates stupid videos or watching sports highlights on the phone is not going to do repay the huge fees these networks have had to shell out to unscrupulous governments selling off bandwidth. But the plus side is that the proliferation of all this mobile networking can only help our industry back on its feet.

More housekeeping

As I reported last month, we are still experiencing problems with our admin without a new ‘Jackie’. Readers who have been waiting for our offers will be pleased to hear that they have all been dispatched (in fact, by the time you read this I will be sunning myself in Rhodes and you will have received your goods.

And of course look out for a new reader offer for those who were unlucky in our competition last month. You can buy an Observant Datastation development kit for £20 off (see page 42).

Phil Reed

New editorial and advertising address

The Highbury Business Communications office previously at Cheam, Surrey has moved to Swanley in Kent. All correspondence intended for the editorial and advertising departments should be addressed to:

Electronics World,
Highbury Business Communications,
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16MW switch is fastest yet

Researchers at the US Virginia Tech have developed a high-power semiconductor switch.

Called an emitter turn-off thyristor (ETO), it operates without snubber circuits and can be controlled fibre-optically.

"An optical pulse is applied to turn on current flow. It can conduct 10,000 amps of current and will withstand 16MW of instantaneous power," said Professor Alex Huang of Virginia’s electrical engineering department.

For continuous operation, the ETO can carry 1.5kA (at 125°C) and block 6kV. Switching time is 5ps, on or off. "This switch allows us to advance very high power converters from a line speed of 60Hz to 3kHz switching at the same power level," said Huang. "This speed allows you to chop the voltage into whatever shape you need."

Present technology is the GTO (gate turn-off thyristor). "The GTO is reliable and inexpensive, but requires a snubber capacitor to protect it in the turn-off process," said Virginia, "The snubber uses significant power itself and increases the size of the switch."

UK lags in Pb-free race

The British electronics industry has its head in the sand over the ban on lead-based solders and components, said ERA Technology.

The Surrey-based research firm has surveyed the UK electronics industry to find how ready it is to make the transition from tin/lead solders to lead-free solders, and lead-free components.

"Only three per cent of companies have developed lead-free products, only nine per cent of companies have started trials with lead-free solders and 50 per cent of companies admit they don't understand the impact of banning lead-based solders," said ERA.

The EU 'Restriction of use of certain Hazardous Substances' (RoHS) directive bans lead from many finished electronic and electrical products from July 1st 2006.

“While the deadline may seem a long way off, there are currently no lead-free solders that are direct replacements for use in all existing products,” said ERA, "All lead-free solders are different in their properties and the way they need to be used."

Over 150 small, medium and large size companies were questioned by ERA. "These were a broad cross-section of the country's electronics industry, which means the findings are truly representative," said ERA. "The good news is that 87 per cent of the sample at least knew about the RoHS directive, and half had contacted one supplier."

www.era.co.uk/product/lead-free-survey.htm to buy the report.

Casimir force measured

Physicists in the US have made a more accurate measurement of the Casimir force, that pushes together objects at close separations. The work could result in better photonic mirrors and nanomachines.

"The Casimir force is not a new discovery," said Purdue University’s Professor Ephraim Fischbach. "It's effects on machines are essentially negligible until you start building at the nanoscale. When the teeth of two tiny gears come together, for example, the Casimir force could push them together so strongly that they would stick and freeze up."

First predicted by Hendrik Casimir of Philips Research Labs in 1948, the force is due to the fact that objects close together cannot fit any photons, real or virtual, between them. Thus photons striking the outside of the objects push them together.

In experiments the forces have been measured at up to Inanoneutron, or 100µ dynes. Purdue’s work has proven the theory within one per cent of experiment, which should lead to better modelling. "It is not often you get to unify theory and practice this closely," said Fischbach.
UPDATE

Robot swarm maps and searches

US research institute SRI has made 100 Centibots to map and search unknown spaces.
"As totally self-contained, untethered entities, these robots can determine their own location and plan their own path, process images they see, make decisions based on a continually expanding knowledge base, and negotiate with other robots when teamwork is required," said SRI’s Artificial Intelligence Center.

There are two types of Centibot. Mapping robots with laser range finders enter an area first, followed by a larger second wave of tracking robots that search.

As they move, the robots create an adhoc 802.11 (WiFi) network to enable all machines to stay in touch with the control centre which directs the swarm.

The robots run the Debian distribution of Linux and use a software control system developed the Artificial Intelligence Center that was first created as an integrated architecture for robot perception and action.

Processing power comes from 1GHz mini-ITX size PC motherboards from VIA - which recently launched a Robotics Initiative "in response to the inexorable melding of mechanical robots and the PC architecture", it said.

The Centibots project is sponsored by the US military Defense Advanced Research Projects Agency (DARPA).

UK starts ceramic antenna research

Leatherhead technology firm ERA Technology has begun a research programme on antenna technology using ceramic structures.

"The new technology will combine the efficiency and bandwidth of conventional antennas with the compactness of current ceramic designs," said the firm.

ERA will use the low temperature co-fired ceramic (LTCC) process to create complex 3D structures.

The technique could also lead to low cost phased arrays, said the firm, by combining conductors and active circuits in the same ceramic block.

"This new technology is a real breakthrough because of its versatility, compact size and low manufacturing cost," said Dr Robert Pearson, head of ERA’s antenna business.

"In military applications, it offers favourable radar and electromagnetic compatibility characteristics and therefore can be used as a fundamental building block on a range of future military platforms. As a bonus, the construction technique also offers exceptionally high temperature performance, making it ideal for fast jets and missiles.

Operating bandwidths will be better than ten per cent, claimed ERA, while the antennas could be configured as multiband devices.

These SEM images show (a) randomly oriented and (b) aligned composites of carbon nanotubes and polypyrrole.

A Cambridge University researcher has found that coating carbon nanotubes with conducting polymers could lead to supercapacitors that rival existing technology.

Dr Mark Hughes from the department of materials science and metallurgy found that both of the two materials have desirable properties and has worked on merging them.

Carbon nanotubes have high conductivity and a large surface area, while the conducting polymers, such as polypyrrole, can be oxidised and reduced easily and quickly, allowing many charge and discharge cycles.

When combines, these two materials offer a high capacitance material of more than 2.6Fcm².

The capacitance is more than double that of either material on its own, said Hughes.
Second-generation DRM broadcast receiver

A second-generation DRM (Digital Radio Mondiale) receiver has been announced by Coding Technologies.

A joint venture with Munich-based product design house Mayah, the radio is smaller (21 x 7 x 13cm) than the 29 x 7 x 19cm #1,000 first-generation design, will be cheaper, said Coding, and also receives standard AM transmissions.

DRM is the digital transmission standard chosen by most of the world’s broadcasters to replace analogue AM broadcasts on shortwave, mediumwave and longwave. Coding is the company behind the audio compression technology which makes it possible to fit good quality audio into the limited spectrum normally allocated to an AM broadcast channel - hence its interest in popularising the format by developing receivers. "Now that many radio stations already broadcast a full DRM programme daily, these first mass-produced receivers will open the path to the end consumer for affordable access to Digital Radio Mondiale broadcasts," said Coding.

Called Spectral Band Replication (SBR), Coding's technology allows a fictitious but realistic spectrum from 7kHz upwards to be generated from an audio signal low-pass filtered to below 7kHz, plus some 'helper' information.

Part of the helper information is the shape of the discarded upper spectrum and SBR generates harmonics of the low-pass filtered signal to fit the original upper spectrum profile. Other helper information describes significant signals above 7kHz which were not harmonically related to lower frequencies.

The sub 7kHz signal is compressed using standard MPEG 4 AAC audio compression. The whole scheme is called aacPlus, where the Plus is SBR.

"aacPlus delivers streaming and downloadable 5.1 multi-channel audio at 128Kbit/s, CD-quality stereo at 48Kbit/s, excellent quality stereo at 32Kbit/s, and excellent quality for mixed content at 20Kbit/s mono and below," said Coding.

www.mayah.com
www.codingtechnologies.com

Giant detector comes online

UK scientists have started receiving data from the 6,000 ton MINOS detector located in an iron mine in northern Minnesota. Minos - the Main Injector Neutrino Oscillation Search - hopes to gain more understanding of the neutrino mass.

"The MINOS detector in Soudan, Minnesota, together with the new Fermilab neutrino beam line, will provide a detailed look at the secrets behind neutrino oscillations," said Dr Raymond Orbach, director of the US department of energy’s office of science.

MINOS is over 30m in length and took more than four years to build. Its 486 steel plates are each about 7m high and are coated with scintillating plastic.

The detector is said to be able to tell the difference between neutrino and anti-neutrino interactions. Eventually neutrinos ‘made’ in Illinois will be sent through 450 miles of the earth directly to MINOS. Out of one trillion neutrinos per year, only about 1,500 will collide with an atomic nucleus in the detector.

Scientists hope to discover more about the three known types of neutrino - electron, muon and tau - and how they switch from one to another as they move through space and matter.
UPDATE

1kW output from fibre laser

A fibre optic laser with an output power exceeding 1kW has been developed by Southampton Photonics (SPI) and Southampton University's Optoelectronics Research Centre (ORC).

While higher power fibre lasers have been reported, these are (optically) less pure multi-mode systems.

"Breaking the kW barrier with a single fibre having high beam quality is a milestone thought to be virtually unattainable just a few years ago," said David Payne, SPI's chairman and director of the ORC.

SPI uses a cladding pump technique for its fibre lasers, which allows a multi-mode source to produce single-mode output. Light from a diode stack is launched into the inner cladding of a double-clad single-mode fibre. The pump light propagating through the inner cladding excites the rare-earth elements in the core, in this case ytterbium, producing single mode light at 1090nm.

The firm has quadrupled its output power of these lasers since February. It will produce commercial versions for industrial and aerospace applications.

Book-sized PC for servers

Taiwanese PC component maker VIA has introduced a new series of motherboards in the 17 x 17cm mini-ITX format, aimed at networked systems "enabling the development of a wide variety of networking applications including servers, firewalls, and routers", said VIA.

Called the EPIA CL-Series, the boards have dual 10/100 Mbit/s LAN controllers, six USB 2.0 connectors for peripherals, four serial COM ports for older peripherals, support for LVDS embedded LCD panels and a PCI slot for expansion.

The soldered-in processor is VIA's own x86-compatible range including the fanless 677MHz Eden (CL6000), the 800MHz C3 (CL8000) and the CL1000 that uses VIA's top-end 1GHz Nehemiah chip.

All boards have a hardware MPEG-2 decoder and integrated graphics core.

www.via.com.tw

Physics turns schoolkids off

A-level entries for physics and other science subjects have fallen again, according to figures from the Institute of Physics.

The number of students taking A-level physics dropped by three per cent this year.

On the positive side, said the IoP, the ten year trend which has seen entries dropping from 60,000 to 30,000 is slowing.

The IoP blamed subjects such as law and media studies for the declining fortunes of science subjects. In its promotion of the hard sciences it points to evidence that science graduates "have higher salaries than arts and humanities graduates in later life".

A shortage of physics teachers is being addressed by a £750,000 investment from the IoP in supporting development of teachers of 11 to 14-year olds.
PCB Production - Development

A 5" Copper Stripboard

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One step closer to SkyNet

US computer scientists are to test a prototype of Cyberinfrastructure, the technology which will eventually support its inter-supercomputer data grid.

The prototype, NPACI Grid, is from the US National Partnership for Advanced Computational Infrastructure and will connect its main resource sites: at the San Diego Supercomputer Center (SDSC), the Texas Advanced Computing Center (TACC) in Austin, TX, and the University of Michigan, Ann Arbor. It will then be extended to the California Institute of Technology, Pasadena.

"NPACI Grid is a production, heterogeneous national Grid consisting of interoperable software, scientific applications, and hardware resources," said the organisation. "It unifies mature software infrastructure efforts through the development of the interoperable, tested and hardened 'NPACKage' deployed at all resource sites."

Other parts of Cyberinfrastructure development are US National Science Foundation's NSF Middleware Initiative (NMI) and TeraGrid/ETF project.

The hardware resources in the NPACI Grid are a 1.7Tflop AIX cluster, Blue Horizon at SDSC, a 435Gflop AMD based Linux cluster at the University of Michigan and three large shared-memory server nodes at TACC delivering 1.16Tflop.

Smart sand is more than silica

Grains of sand might be worth a second glance if research at five of Scotland’s leading universities comes to fruition.

A team from the universities of Edinburgh, Glasgow, Napier, St Andrews and Strathclyde has just won a £1.3m grant to develop networked computers as small as sand grains.

The project, called Speckled Computing, aims to integrate modest amounts of digital signal processing, an RF transceiver, power source and sensors.

Professor DK Arvind, director of Edinburgh's Institute for Computing Systems Architecture, said the project will proceed in two stages: "The aim is to produce these specks in a millimetre cubed of semiconductor."

There is an intermediate stage of 5mm² in two years, with the final mm³ in four years.

Although each device will not have large amounts of processing power, because they are networked they will form a distributed system.

Arvind said the power source will be a photovoltaic cell, made using a gallium arsenide process. The radio will also use GaAs, while digital sections will use CMOS. The two sections will be bonded together.

Qinetiq wins windfarm funding

Defence technology research firm Qinetiq has won funding from the DTI to develop ‘stealthy’ wind turbine blades.

Qinetiq hopes that by modifying their glass fibre reinforced polymer construction, it can reduce the unwanted radar reflections from the blades.

Air traffic control, marine navigation, weather monitoring and Ministry of Defence systems are all affected, it said.

NOI Scotland with work with Qinetiq on the blades. The firm, originating from Germany, has technology for building 50m, resin-infused blades suited to offshore turbines producing 2MW more.

"This is an excellent example of how the results of military research can be exploited for civil gain," said Steve Appleton, the QinetiQ technical leader of the DTI project.

The UK Government has set ambitious targets for clean energy production, with ten per cent of the countries energy to come from sustainable sources by 2010, and 20 per cent by 2020.

Despite our constant complaints about wind, the UK has only the eighth largest amount on installed wind generating power in the world at 570MW. Germany tops the list with 12,000MW, while the US has 4,700MW and Spain 5,000MW.

According to the British Wind Energy Association, last year over a quarter of all proposals for windfarm developments were the subject of objections from radar operators.

Chip de-thumps headphones

Maxim has revealed a novel chip which removes switch-on clicks and thumps from headphones.

The MAX9890, as it is called, is placed between amplifier and headphone socket and open-circuits both left and right paths until transients are under control.

The device requires only one additional 0.1µF capacitor and deals with switch-off transients as well.

Applications in portable equipment such as notebook, phones, DVD players and PDAs are foreseen, particularly where an existing model has a click problem, or the thump-prone audio amplifier is part of a larger chip which cannot be designed out.

There are two versions. The MAX9890A for use with DC-blocking capacitors of up to 100µF and the 9890B for capacitors up to 220µF.

Supply is 2.7V to 5.5V, 23dB of click-and-pop suppression is provided, supply current is 20µA and added THD+N is under 0.006% into a 32Ω load. Package is either 3 x 1.5 x 0.6mm (9-pin) or an 8-pin.
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RTTY Decoder

Radio Teletype (RTTY) is a direct machine-to-machine communications mode and has been in existence since the 1930's. The commercial use of RTTY on short wave has declined having been replaced with more robust transmission modes, however radio amateurs still use RTTY. Roger Thomas has designed an ingenious decoder

To encode and transmit text characters two different audio frequencies are transmitted. These two audio frequencies are commonly referred to ‘mark’ and ‘space’, where mark is usually the higher frequency. The most common audio frequencies used within Europe are 1275Hz (space) and 1445Hz (mark) and the difference between the two audio frequencies is called the ‘shift’. Most amateur radio transmissions use 170Hz audio shift, but shifts of 425Hz or 850Hz are used on other bands. It is possible for the transmission to be 'up side down' with the space frequency higher than the mark frequency, changing the receiver's side band settings and re-tuning will correct this. American amateur stations use a different set of audio frequencies (2125Hz and 2295Hz) but as the shift is still 170Hz this does not pose any problems with tuning or decoding.

Transmission speed is specified in baud, where baud is defined as the number of signal changes per second. Amateur RTTY transmissions in Europe are normally 45 or 50 baud but other speeds including 75 and 110 baud are used on other commercial bands. Although 45/50 baud transmission may seem very slow in comparison to computer modems, it is fast enough for a typed conversation. A 45/50 baud RTTY transmission equates to approximately 66 words per minute.

RTTY text characters are encoded using ITA2 (International Telegraph Alphabet Number 2) code, which uses five bits for each character. With only five bits per character, the maximum number of unique patterns is only 32. To enable RTTY to transmit the full alphabet two different character tables are used, one for letters (all letters are in upper case) and one for figures (which includes punctuation). A letters or figures control character determines which table to use when printing the received character. Control and space characters are represented in both tables to reduce the number of times the letters or figure control character needs to be transmitted. RTTY signals do not have any error detection capabilities.

RTTY is relatively simple to decode in software, but the different combinations of transmission speed and shift means that it is impossible to decode every combination. The PIC program as given is designed to decode both 45 and 50 baud RTTY using 170Hz shift as this is the most common amateur radio signal, but both speed and shift parameters can be changed within the program.

RTTY is an asynchronous mode, which means that there is no common time frame between the station transmitting text and station receiving. In front of every 5 bit character is a single start bit (at space frequency) that makes the receiving printer ready for the incoming transmission. The five character data bits are transmitted, followed by a 'stop bit' which may be of a longer duration (one or one and a half units) and is transmitted at mark frequency. A useful feature to overcome the problem of noise or corrupt characters incorrectly signifying use of the figure table is to automatically revert to the letters table on receiving a space character.

Using start/stop bits means that after the receiving printer had printed out a character it was then waiting for the start bit of the next character. Thus synchronisation is not needed between sender and receiver.

RTTY uses the ITA2 (International Telegraph Alphabet 2) character set, sometimes called Baudot code (named after Emile Baudot), and is listed in Fig. 2. Where there is no designated character assigned (figure shift F, G, H) I have used characters from the teleprinter set.

Fig. 2. RTTY text characters.

<table>
<thead>
<tr>
<th>letter</th>
<th>figure</th>
<th>RTTY</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9</td>
<td>00001</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>?</td>
<td>11000</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>00100</td>
<td>9</td>
</tr>
<tr>
<td>D</td>
<td>5</td>
<td>00000</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>00001</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>01101</td>
<td>13</td>
</tr>
<tr>
<td>G</td>
<td>&amp;</td>
<td>11100</td>
<td>26</td>
</tr>
<tr>
<td>H</td>
<td>#</td>
<td>10100</td>
<td>20</td>
</tr>
<tr>
<td>I</td>
<td>8</td>
<td>00110</td>
<td>6</td>
</tr>
<tr>
<td>J</td>
<td>*</td>
<td>01011</td>
<td>11</td>
</tr>
<tr>
<td>K</td>
<td>(</td>
<td>01110</td>
<td>15</td>
</tr>
<tr>
<td>L</td>
<td>)</td>
<td>10010</td>
<td>18</td>
</tr>
<tr>
<td>M</td>
<td>:</td>
<td>11000</td>
<td>28</td>
</tr>
<tr>
<td>N</td>
<td>.</td>
<td>01100</td>
<td>12</td>
</tr>
<tr>
<td>O</td>
<td>9</td>
<td>11000</td>
<td>24</td>
</tr>
<tr>
<td>P</td>
<td>0</td>
<td>10110</td>
<td>22</td>
</tr>
<tr>
<td>Q</td>
<td>1</td>
<td>10111</td>
<td>23</td>
</tr>
<tr>
<td>R</td>
<td>4</td>
<td>01010</td>
<td>10</td>
</tr>
<tr>
<td>S</td>
<td>.</td>
<td>00101</td>
<td>5</td>
</tr>
<tr>
<td>T</td>
<td>5</td>
<td>10000</td>
<td>16</td>
</tr>
<tr>
<td>U</td>
<td>7</td>
<td>00111</td>
<td>7</td>
</tr>
<tr>
<td>V</td>
<td></td>
<td>11110</td>
<td>30</td>
</tr>
<tr>
<td>W</td>
<td>2</td>
<td>10011</td>
<td>19</td>
</tr>
<tr>
<td>X</td>
<td>?</td>
<td>11101</td>
<td>29</td>
</tr>
<tr>
<td>Y</td>
<td>6</td>
<td>10101</td>
<td>21</td>
</tr>
<tr>
<td>Z</td>
<td>+</td>
<td>10001</td>
<td>17</td>
</tr>
</tbody>
</table>

RTTY signals are asynchronous, and there is no common time frame between the station transmitting text and station receiving. In front of every 5 bit character is a single start bit (at space frequency) that makes the receiving printer ready for the incoming transmission. The five character data bits are transmitted, followed by a 'stop bit' which may be of a longer duration (one or one and a half units) and is transmitted at mark frequency. A useful feature to overcome the problem of noise or corrupt characters incorrectly signifying use of the figure table is to automatically revert to the letters table on receiving a space character.

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Mark (1)

Space (0)

Fig. 1. RTTY Character 'Y' or '6'.

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RTTY experimentation with different RTTY decode algorithms or variable values.

The advantage of using a Microchip PIC 16F84 18-pin microcontroller is that it is electrically erasable and therefore reprogrammable using a low cost PIC programmer. This allows experimentation with different RTTY decode algorithms or variable values.

RTTY assembler code is ready for the Microchip MPLAB assembler, part of the MPLAB development software. This software is freely available from the Microchip web site (www.microchip.com). Type in the assembler code in the same sequence as it is presented and you should end up with a working RTTY decoder program to burn into a 16F84 microcontroller. The assembler code is in upper case and to help understand the assembler code appropriate extracts from the source program are included. Feel free to alter and improve the assembler code.

Define variables routine
The first part of the decoder program defines the PIC registers, the names of the variables used and where the variable value is to be stored in memory. The STATUS register contains various flags including C (carry), Z (zero), RPO (register banks select). The C flag is set (logic 1) if the result of an arithmetic operation produces a carry-out condition (i.e. most significant bit set). The Z flag is set if the operation result is zero.

Likewise the FLAGS byte contains Boolean flags for LTRS, BUSYFLAG, CONVFLAG, TOPLINE. BINCHAR is the binary representation of the received RTTY character. The config command instructs the assembler on the internal PIC fuse settings (power-up representation of the received RTTY character set. An asterisk character is used where there is a non-print control character defined for that

Start routine
When power is applied to the PIC microcontroller it immediately starts program execution at address zero, this location has a jump instruction to the START routine. ORG assembler command instructs the assembler to generate code from the address given.

Interrupt routine
The rising edge of the received audio waveform on PIC port pin RB0 causes an interrupt. When an interrupt occurs the PIC automatically runs interrupt service code located at address 4. This block of code saves the current PIC status and then calls routine INTERRUPT. After returning from executing the INTERRUPT code the registers are restored to their previous values and the RETFIE (return from interrupt) instruction allows the PIC to resume execution as if the interrupt had not occurred.

Conversion tables
The character data to convert received RTTY characters into the equivalent ASCII characters for display is stored in look up tables. How this table is derived is quite simple, for example the RTTY 'E' character has a value of 1 (binary 00001), therefore 'E' is located in the 1st position of the table called letters. RTTY character 'A' has a value of 3 (binary 000011) so is located in the 3rd position in the table, and so on for the rest of the RTTY character set. An asterisk character is used where there is a non-print control character defined for that

Fig. 3. RTTY control characters.

<table>
<thead>
<tr>
<th>RTTY</th>
<th>function</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111</td>
<td>letters shift</td>
<td>31</td>
</tr>
<tr>
<td>1101</td>
<td>figures shift</td>
<td>27</td>
</tr>
<tr>
<td>0100</td>
<td>carriage return</td>
<td>8</td>
</tr>
<tr>
<td>0010</td>
<td>space</td>
<td>4</td>
</tr>
<tr>
<td>0000</td>
<td>line feed</td>
<td>2</td>
</tr>
<tr>
<td>0000</td>
<td>blank</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 4. Defining the PIC variables used in the RTTY decode program.

; Radio Teletype (RTTY) program.
; Written by Roger Thomas.

list p=16F84
_config H'3FF9'

; PIC register definitions
RTCC EQU D'1' ; timer
STATUS EQU D'3' ; status flags
C EQU D'0' ; carry
Z EQU D'2' ; zero
RPO EQU D'5' ; page select
PORTA EQU D'5' ; lcd port
RA0 EQU D'0' ; lcd_RS line
RA1 EQU D'3' ; lcd_WR line
RA2 EQU D'2' ; lcd_RD line
PORTB EQU D'6' ; ldd data port
RB0 EQU D'0' ; audio input
RB4 EQU D'4' ; ldd DB4
RB5 EQU D'5' ; ldd DB5
RB6 EQU D'6' ; ldd DB6
RB7 EQU D'7' ; ldd DB7
INTCON EQU D'11' ; register
IRQ_RB0 EQU D'1' ; interrupt flag
IRQ_TIMER EQU D'2' ; interrupt timer
OPT EQU D'1' ; option register

; program definitions
STACK0 EQU D'12' ; temp use
STACK1 EQU D'13' ; temp use
STACK2 EQU D'14' ; temp use
STACK3 EQU D'15' ; temp use
STACK4 EQU D'16' ; temp use
IRQW EQU D'17' ; interrupt
irq EQU D'18' ; interrupt
IRQSTK EQU D'19' ; interrupt
RTCCVAL EQU D'20' ; timer value
VALRTCC EQU D'21' ; timer value
CHAR EQU D'22' ; output character
SAVECHAR EQU D'23' ; temp save CHAR
TEMP EQU D'24' ; store temp value
LCDCPOS EQU D'25' ; ldd cursor position
MARKCOUNT EQU D'31' ; mark frequency count
SPACECOUNT EQU D'32' ; space frequency count
BITCOUNT EQU D'33' ; which bit of bincat
BINCAT EQU D'26' ; binary RTTY char
CHAR1 EQU D'0' ; bit 1 RTTY character
CHAR2 EQU D'1' ; bit 2 RTTY character
CHAR3 EQU D'2' ; bit 3 RTTY character
CHAR4 EQU D'3' ; bit 4 RTTY character
CHAR5 EQU D'4' ; bit 5 RTTY character
FLAGS EQU D'27' ; Boolean byte
LTRS EQU D'0' ; letter/figure shift
BUSYFLAG EQU D'1' ; ldd busy flag
CONVFLAG EQU D'2' ; data convert flag
TOPLINE EQU D'3' ; top or bottom line
particular position. For example, RTTY character 2 (binary 00010) is a line feed control character. There is a similar table for numbers and punctuation.

These look up tables (including the RTTY LCD message) are stored sequentially in memory in ascending order located after the interrupt handler routine.

Audio conversion
To calculate the specific mark and space audio frequencies that the RTTY program has to respond to, the following formula is used, assuming a 4MHz clock crystal. The actual timer frequency used is the 4MHz clock divided internally in the microcontroller by four.

$$\text{Audio conversion}$$

These numbers cannot be represented by the RTCC (Real Time Clock Counter) timer which is 8 bit (0 to 255 range), thus the clock used by the RTCC has to be divided by 4 using the internal prescaler.

The START routine is always called whenever the PIC is reset. The START routine calls INITVAR, INITPORT, INITLCD, and DISPLAY. After this the prescaler ratio is set (using bits PSx defined in the option register). The PSA bit is set to 0, which assigns the prescaler to the timer rather than the watchdog timer. RB0 interrupt is selected and enabled in the INTCON register.

Loop routine
After initialising various options within the PIC microcontroller the program sits in the loop checking the CONVFLAG Boolean flag. This flag is set (true) in the INTERRUPT routine to indicate whenever new data is available and this flag is tested using the BTFSS instruction (Bit Test File, Skip if Set). If CONVFLAG is false then the next instruction GOTO LOOP is executed. If the result of the BTFSS is true the GOTO LOOP instruction is ignored and the CALL CONVERT is executed. File is Microchip terminology for what everyone else calls a register.

Initialise routine
INITVAR (initialise variables) routine sets various variables to zero using CLRF (Clear Register File) single instruction.

INITPORT ( initialise port) routine configures the various port pins
that are attached to the LCD display as outputs using the BCF (Bit Clear File). Port pin RBO is set as an input using BSF (Bit Set File) instruction; this is the PIC pin that the RTTY audio is connected to.

```
INITVAR

; topline = true
BSF FLAG, TOPLINE
; ltrs = true
BSF FLAG, LTRS
RETURN

READ_TIMER_INTERRUPT_ROUTINE

In the following interrupt routine, the 8-bit RTCC counter value is assigned to RTCCVAL variable. The timer overflow flag is set if the counter has reached 255 (maximum byte value) and has started counting again. The status of this flag is checked and if the timer overflow flag is true then the program will ignore the timer value as it is invalid.

The RTCC count is then cleared and starts to automatically count up from zero and the flags indicating an interrupt condition are cleared. After this call the PIC re-loads the previously saved information and resumes processing from where it was before the interrupt had occurred.

```
if irq_Timer = false then
begin
    RTCCVAL = rtcc ; read 8-bit timer value
    convFlag = true ; set data ready flag
end
clr(rtcc) ; zero 8-bit timer
irq_RBO = false ; clear interrupt flag
irq_Timer = false ; clear interrupt flag
RETURN

CONVERT RTTY mark audio

Within the routine, CONVERT the MarkCount and SpaceCount variables translates a sequence of mark or space frequency into either a 1 or 0 by counting the number of consecutive pulses received.

With reference to the line if (valRTCC >= 161) and (valRTCC <= 185), the two numbers set the mark frequency (1445Hz) capture range as 1553Hz to 1352Hz. Any number received within this range will be treated as a mark frequency and will increment the MarkCount variable accordingly. Variable bit count is used to keep track of which bit within the BINCHAR variable is to be used. After receiving a predetermined number of mark frequencies (26) a '1' is added to the BINCHAR variable by making the relevant charX bit within BINCHAR to '1'. BINCHAR (binary character) becomes the binary representation of the received RTTY character.

The start bit of a RTTY character is always a space frequency, so if a mark frequency is detected as the first bit received this will be ignored and the bitcount is set back to zero. This helps prevent random noise generating random text. A RTTY station will send a continuous mark tone if there is no text ready to transmit.

```
if (valRTCC >= 161) and (valRTCC <= 185) then
begin
    inc(MarkCount) ; MarkCount = MarkCount + 1
    if MarkCount >= 26 then
        clr(SpaceCount) ; SpaceCount = 0
        inc(bitcount) ; bitcount = bitcount + 1
end select
```

```
Convert RTTY space audio

Using valRTCC numbers of 181 to 212 gives a frequency capture range of 1381Hz to 1179Hz and any number received within this range will increment the SpaceCount variable. The relevant BINCHAR bit variable is already '0' so the space routine does not need to change BINCHAR but still needs to increment variable bitcount to the point of the next bit.

Text output routine

After receiving five bits (BITCOUNT = 6) the Text routine is called (stop bits are ignored). Within the Text routine the value of BINCHAR (binary char) is checked for a control character such as carriage return, line feed or letter/figure shift.

If a space character is received (BINCHAR value equals 4), this forces the program to use the letters table then the space character is sent to the display. As the display is only two lines, any carriage returns or line feeds received result in the display cursor being moved to the beginning of the top line but the existing text is not erased.

If the received character (char) is not a control character then it is converted into an ASCII character based on a look up table and sent to the display. For example, if the binary sequence of the BINCHAR variable is 01010 then the decimal equivalent is (msb first) 0+8+0+2+0 = 10. The look up (read) routine is used to access the appropriate table (letters or numbers) is selected by the fifth item in the letters table and returns the character 'R' in the char variable. The appropriate table (letters or numbers) is selected by the Boolean value of the LTRS variable.

Char variable is used in the TEXTLCD routine that handles sending this value to the display. The TEXTLCD routine also keeps track of where the cursor is (LCDPOS) and will move from the end of the top line to the first position on the bottom line when appropriate (TOPLINE flag).

If the value of char is 255 then we have received a non-print character and the second half of the routine is not called.

Text:

```
clr(bitcount)
char = b'10000000'
topline = true
clr(lcdpos)
case b'000100' : ltrs = true ;space forces letter shift
case b'010000' : clr(lcdpos) ;carriage return
case b'001000' : char = b'10000000' ; cursor to top line
CommandLCD
topline = true ; lcd top line
case b'100001' : char = 255
case b'000101' : clr(lcdpos) ; line feed
case b'10000000' ; cursor to top line
```

Text:

```
if (valRTCC >= 181) and (valRTCC <= 212) then
begin
inc(SpaceCount) ; SpaceCount = SpaceCount +1
if SpaceCount >= 24 then
begin
clr(MarkCount) ; MarkCount = 0
clr(SpaceCount) ; SpaceCount = 0
inc(bitcount) ; bitcount = bitcount +1
if bitcount >= 6 then
begin
Text
end
end
end
```

```
BEGIN
BIT1 MOVF BITCOUNT,W
SUBLW D'1'
BTFSS STATUS,Z
GOTO BIT2
CLR BITCOUNT
GOTO ALLDONE

BIT2 MOVF BITCOUNT,W
SUBLW D'2'
BTFSS STATUS,Z
GOTO BIT3

BIT3 MOVF BITCOUNT,W
SUBLW D'3'
BTFSS STATUS,Z
GOTO BIT4
BSF BINCHAR,CHAR1 ; set bit

BIT4 MOVF BITCOUNT,W
SUBLW D'4'
BTFSS STATUS,Z
GOTO BIT5
BSF BINCHAR,CHAR2 ; set bit

BIT5 MOVF BITCOUNT,W
SUBLW D'5'
BTFSS STATUS,Z
GOTO BIT6
BSF BINCHAR,CHAR3 ; set bit

BIT6 MOVF BITCOUNT,W
SUBLW D'6'
BTFSS STATUS,Z
GOTO ALLDONE
BSF BINCHAR,CHAR5 ; set bit
CALL TEXT
```

```
; Space = 1275Hz
if (valRTCC >= 181) and (valRTCC <= 212) then
begin
inc(SpaceCount) ; SpaceCount = SpaceCount +1
if SpaceCount >= 24 then
begin
clr(MarkCount) ; MarkCount = 0
clr(SpaceCount) ; SpaceCount = 0
inc(bitcount) ; bitcount = bitcount +1
if bitcount = 6 then
begin
Text
end
end
end
```

```
; Space = 1275Hz
if valRTCC >= 181 and <= 212 then
SPACE MOVF valRTCC,W
MOVWF STACK0
MOVWF D'181'
SUBLW D'212'
CLRW
BTFSC STATUS,Z
ADDF W'0'
MOVWF STACK4
BTFSC STATUS,C
ADDF W'0'
MOVW STACK4,W
SUBLW D'2'
CLRW
BTFSC STATUS,C
ADDF W'0'
MOVW STACK4,W
GOTO ALLDONE

; SpaceCount = SpaceCount +1
INCF SPACECOUNT,F
if SpaceCount >= 24 then
MOVW SPACECOUNT,W
MOVWF STACK0
MOVW D'24'
SUBWF STACK0,W
BTFSS STATUS,C
GOTO ALLDONE
CLR MARKCOUNT ; = 0
CLR SPACECOUNT ; = 0

; bitcount = bitcount+1
INCF BITCOUNT,F
if bitcount = 6 then
MOVW BITCOUNT,W
SUBLW D'6'
BTFSS STATUS,Z
GOTO ALLDONE
CALL TEXT
```

```
return
```

Text:

```
select bicnchar
```

```
case b'00100' : ltrs = true ;space forces letter shift
case b'010000' : clr(lcdpos) ;carriage return
case b'10000000' ; cursor to top line
CommandLCD
topline = true ; lcd top line
case b'10000000' ; cursor to top line
```
CommandLCD
topline = true ; lcd top line
char = 255
case b'11011' : ltrs = false ; figure shift
char = 255
case b'11111' : ltrs = true ; letters shift
char = 255
end select
if char <> 255 then ; 255 = non-print character
begin
if ltrs = true then
begin
read(letters,binchar,char)
TextLCD
end
else
begin
read(numbers,binchar,char)
BTFSC STATUS,C
TextLCD
end
end
clr(binchar) ; = b'00000'

TEXT CLRF BITCOUNT ; = 0
MOVW D'63'
MOVW CHAR ; char = '?'
MOVW BINCAR
SUBL D'4' ; space ?
BTFS STATUS,Z
GOTO CR
BSF FLAGS,LTRS
GOTO TEXT1
; carriage return ? (4)
CR MOVW BINCAR,W
SUBL D'8'
BTFS STATUS,Z
GOTO LF
CLRF LCDPOS
; char = b'10000000'
; cursor to top line
MOVW D'128'
MOVW CHAR
CALL COMMANDLCD ; topline = true
BSF FLAGS,TOPLINE
MOVW D'255'
MOVW CHAR
GOTO TEXT1
; line feed ? (2)
LF MOVW BINCAR,W
SUBL D'2'
BTFS STATUS,Z
GOTO FS
CLRF LCDPOS
; char = b'10000000'
; cursor to top line
MOVW D'128'
MOVW CHAR
CALL COMMANDLCD ; topline = true lcd top line
BSF FLAGS,TOPLINE
MOVW D'255'
MOVW CHAR
GOTO TEXT1
; figure shift ? (27)
FS MOVW BINCAR,W
SUBL D'27'
BTFS STATUS,Z
GOTO LS

RTTY element timing
For 45 baud RTTY each element (bit) of the character is 22ms long,
for 50 baud each element is 20ms long.

Fig. 7. Integer values for MarkCount and SpaceCount.
45 baud
1445 * 22ms = 31 (mark)
1275 * 22ms = 28 (space)
50 baud
1445 * 20ms = 28 (mark)
1275 * 20ms = 25 (space)
75 baud
1445 * 13ms = 18 (mark)
1275 * 13ms = 16 (space)

A compromise has to be reached between the theoretical and actual
number chosen for the mark and space comparison count. Too small a
number and one bit may be interpreted as two consecutive bits or two
consecutive bits misread as three bits. Too large and a poor quality
RTTY signal may never reach the required number. If the parameters
are too exact then the PIC program will only accept RTTY that is
'perfect'. Ideally we want the software to respond to both 45 and 50
baud. With all these numbers there will be small variations due to
interrupt latency.

November 2003 ELECTRONICS WORLD
The vast majority of these are based around the Hitachi A low cost 16 character, two-line LCD is used to display the received transmissions. Numbers 4 and 6 will appear if the figure table is being used. This distinctive pattern helps receiving stations to tune to the letter Y alternates between mark and space (10101) these two characters are sometimes used alternately (RYRY) when calling CQ. As the letter R is alternating between space and mark (01010) and the interference could introduce errors.

To change the frequency range the valRTCC values need to be altered within the assembler program. Selecting too narrow a frequency range may make tuning difficult and not all amateur transmissions have exactly the right shift. Frequency drift within the receiver itself may need to be taken into consideration. Making the receiver itself may need to be altered within the assembler program. Selecting too narrow a frequency range wider makes tuning easier and increases the chance of receiving less than perfect RTTY, however noise and co-channel interference could introduce errors.

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<tr>
<td>line 1</td>
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</tr>
</thead>
<tbody>
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<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>74</td>
<td>75</td>
<td>76</td>
<td>77</td>
<td>78</td>
<td>79</td>
</tr>
</tbody>
</table>
; send routine to output 4 bits
CALL SEND
; swap over lower 4 bits
SWAPF CHAR,F
CALL SEND
RETURN

INITLCD CALL WAIT
BCF PORTA,RA2
BCF PORTA,RA0
CALL SEND
RETURN

Displaying RTTY text

The text and data is transferred to the display four bits at a time (routine send). The variable LCDPOS (LCD cursor position) is to make sure that we have not passed the end of the display line. If you are using a LCD that can display more than 16 characters then change this number. If the cursor is at the end of the line then the output character is stored and the Boolean flag is checked to see if the display is using the top or bottom display line. The appropriate command is then sent to the LCD to use the other display line and the cursor set to the first position before restoring the character and sending that to the LCD.

The higher four bits are sent first then the four lower bits. The swap command is used to exchange the lower and upper 4 bits of the byte, hence the output routine (SEND) is called twice.

Fig. 11. LCD text output routines.

Text LCD:
if lcdpos > 15 then ; end of lcd line ?
begin
clr(lcdpos) ; position 0
savechar = char ; temp save char
if topline = false then
begin
char = b'10000000'; cursor to top line
CommandLCD
topline = true
end
else
begin
char = b'10000000'+64; cursor to bottom line
CommandLCD
topline = false
end
char = savechar ; restore original value
end
call wait ; is lcd busy ?
RA2 = 0 ; 0 - writing to lcd
RA0 = 1 ; 1 - data register
call send ; output upper 4 bits
swap(char) ; swap lower/upper 4 bits
call send ; output upper 4 bits
inc(lcdpos) ; next lcd position

TEXTLCD MOVF LCDPOS,W
SUBLW '15'; LCD
BTFSC STATUS,C
GOTO LINE
;if lcdpos > 15 then
CLRF LCDPOS; position 0
; savechar = char
MOVF CHAR,W
MOVWF SAVECHAR
;if topline = false then
BTFSC FLAGS,TOPLINE
GOTO BOTTOM
;if char = b'10000000'; cursor to top line
MOVW D'128'
MOVWF CHAR
CALL COMMANDLCD
BCF FLAGS,TOPLINE
GOTO REST
;if char = b'100000000'+64 ; cursor to bottom line
BOTTOM MOVW D'192'
MOVWF CHAR
CALL COMMANDLCD
BCF FLAGS,TOPLINE
;if char = savechar ; restore original value
REST MOVF SAVECHAR,W
MOVWF CHAR
;if is lcd busy ?
LINE CALL WAIT
BCF PORTA,RA2
BCF PORTA,RA0
; send output upper 4 bits
CALL SEND
; swap lower/upper 4 bits
SWAPF CHAR,F
CALL SEND
; next lcd position
INC LCDPOS,F
RETURN

Port A (bits 0 to 2) is used to provide the LCD control lines and port B (bits 4 to 7) is used as the four bit data bus. The Enable control line (RA1) is used to inform the display that data is available by taking the line high then low.

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Fig. 12. Summary of LCD control lines.

<table>
<thead>
<tr>
<th>PIC name</th>
<th>function</th>
<th>RA2</th>
<th>RA1</th>
<th>RA0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>read/write</td>
<td>lcd_rw</td>
<td>enable</td>
<td>register select</td>
</tr>
<tr>
<td></td>
<td>0 - write, 1 - read</td>
<td>0</td>
<td>1</td>
<td>0 display register</td>
</tr>
</tbody>
</table>

These LCD displays are slow in comparison to the operation of a PIC microcontroller and require time to complete commands. These range from 40ms to 60ms when sending data and up to 2ms for clearing the display. Worst case delays have to be assumed to ensure that the PIC's internal busy flag is read in routine wait. This requires the port delays. To enable the PIC to send text to the display as fast as possible the PIC program can send data to the display without using software time delays. If a command has been completed, which may make the program wait for 40ms to 60ms when sending data and up to 2ms for clearing the display. The PIC and require time to complete commands. These range from 40ms to 60ms when sending data and up to 2ms for clearing the display. Worst case delays have to be assumed to ensure that the PIC's internal busy flag is read in routine wait. This requires the port to switch from output to input. Busy flag is contained in the status byte as the most significant bit (the rest of the status information is ignored).

**Circuit description**

The circuit can be built using strip board with the majority of connections between the display and the PIC. LCD displays either have a single line of 14 pin holes or a double row of seven pins holes. If the display has a back lighting option then there will be 16 holes.

The LCD display may need a potentiometer (20-50 kΩ) to set the contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. This potentiometer should be connected between the positive supply rail and ground, connect the wiper to the LCD contrast voltage. 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considerably if display back lighting is used. The amount of current depends on the type of back lighting, the display that I have (manufactured by Anders) has two side type LEDs and consumes over 50mA when using the back lighting option.

Display routine
When power is first applied to the circuit, the PIC program should display 'RTTY DECODER' message, demonstrating that the program and display has been initialised correctly. The READ routine gets the appropriate character from the look up table.

```
display:
temp = 0
while temp <= 11 ; 11 characters in text
    read[ready,temp,char]
    TextLCD ; char = ready[temp]
    inc(temp) ; next character
loop
```

Interface circuit
The transistor interface circuit is designed to be connected to the loudspeaker or headphones output of the receiver. Connection to the receiver is by screened audio cable, soldered either side of VR1 potentiometer. Set the potentiometer and volume control as appropriate when the radio is receiving RTTY for correct reception and comfortable listening level.

The transistor circuit changes the shape of the audio sine wave into a square wave. Using the 74LS14 buffer guarantees a constant amplitude TTL signal so that the audio edge properly triggers the PIC interrupt. The 74LS14 buffer has a Schmitt trigger type input which ensures a clean output signal and makes the interface less sensitive to noise. I used a BC549 npn transistor (plastic version of BC109) in the prototype but any general purpose npn transistor will do. Ideally, the interface circuit should be housed in a metal box to prevent any radio signals generated by the PIC from being picked up by the receiver. Take care with the input level to prevent excessive signal input. Although some clipping of the audio signal does not affect the operation of the PIC as it is triggered on the waveform edge.

To check the operation of the circuit in the absence of a RTTY signal, find a clear steady tone and tune very slowly until a row of % characters appear on the display (BINCHAR value of 0 being received). Under normal operations this display would signify that the tuning is close but incorrect. The frequency is being processed as a space frequency but a steady tone being transmitted by a RTTY station will be a mark frequency. The stronger and clearer the radio signal is the more RTTY will be correctly decoded.

Despite more ‘modern’ forms of data communications, there are still many RTTY signals to be heard on the amateur bands. A few radio amateurs continue to use mechanical printers but the majority use a computer and software. Indeed it is because RTTY signals can be produced and decoded entirely by computer software, and ease of operation, which has contributed to its continued use.
The ‘MAcroscope’: a didactical version of the Scanning Force Microscope

A homemade device that mimics, at macroscopic level, the behaviour of an SFM (Scanning Force Microscope) that may be used for didactic purposes aimed at clarifying genesis and meaning of electronic micrographs. Giacomo Torzo, Barbara Pecori, Pietro Scatturin and Giorgio Delfitto elucidate.

Our world is full of images. Some of them, like the image of a coin, are part of a general background knowledge and, appearing 'natural', do not raise any curiosity about the mechanisms generating the image. But if we try to find out the value of a coin inside our pocket by hand inspection only, the process involved in our fingers collecting data and our brain transforming data into a 'coin image' is different from the usual way of transforming the eye's signals into images. It is more similar to the process used in modern scanning force microscopy (SFM).

These considerations brought us to design a device that could be used, even by students with a poor physics background, to help understanding the basic processes through which images are normally built from electric signals acquired by sensors. The basic idea is to use a device working at macroscopic level with techniques similar to those used investigating the microscopic world.

How are topographic images produced?

Electronic images may be of a different type. The simplest is the 'bit-mapped' one, i.e. matrix of dots of different colours that may be printed or displayed on a computer screen. Each pixel is a numeric value in the matrix stored in the computer memory. Topographic images are special images, that give a quantitative representation of the surface of an object, where the colour of each pixel 'measures' the distance z from a geometric plane parallel to the average surface of the object (z=z₀).

If we pick up only a row of the matrix, we obtain a vertical cross-section of the topographic image. By plotting this set of numbers versus their position along x, with segments joining the nearby dots, we get an x-line profile. Putting in the same plot all the x-line profiles corresponding to the various y positions (each one shifted upward of the same quantity Δy) we obtain a 3D representation of the surface that is named 'wire-frame'. The azimuthal 'angle of view' of this 3D image is determined by the shift value Δz, while a polar rotation of the angle of view may be obtained by applying a shift Δx to each x-line profile.

In Fig. 1, we report an image obtained with commercial SFM operating at constant force (square matrix of 256x256 pixel where lighter dots indicate larger z values): the single atomic layers in a Gallium Arsenide single crystal substrate are evident, as well as some Indium.
Arsenide nanostructures (white dots) grown onto the substrate by Metal Organic Vapor Phase Epitaxy.

**Working principle of the 'macroscope'**

Our device is based on the technology of 'stylus profilometers'. The commercial profilometers work in one dimension, generating a line-profile of the investigated sample, while our device must scan a surface by moving the probe along a series of parallel lines (the raster scanning normally used by SFM when storing bitmapped images in a matrix). A simple software for real-time data acquisition may be used to build a profilometer by using as a vertical displacement probe (z-axis) a tip soldered at the end of a cantilever whose deflection is measured by strain gauges and as a horizontal displacement sensor (x-axis) a micropositioner whose driving screw rotation angle is measured by a potentiometer.

Our device is able to record two series of values (vectors) corresponding to the signal $V_{z}=V(z)$ of the vertical displacement of the tip following the sample topography and to the signal $V_{x}=V(x)$ of the potentiometer measuring the displacement along the x-axis. On the computer screen it is therefore possible to trace the plot $V_{z}=f(V_{x,y})$ reproducing the sample profile along a line parallel to x.

A series of scans (each one made for a different position along y-axis) contains information on the whole sample surface, but if we placed them all together in the plot $V_{z}=f(V_{x,y})$ the result would be unreadable, due to the overlap. We therefore used a simple 'trick' in order to make visible the sample topography and to produce a 'pseudo-3D' image. The trick consists of mounting the sample onto a tilted plane so that every displacement along the y-axis produces a vertical shift $\Delta V_{z}=V(\delta y \tan \alpha)$. The tip-cantilever system (z-axis displacement sensor) is mounted on a metal holder that may be moved along the y-axis by rotating a driving screw, while the sample-holder performs the x-axis scan. The x-axis movement is obtained using a cheap trolley (a Domino 50, produced by Schluderbacker) whose knob is ganged to the axis of a potentiometer by means of a pulley.

The maximum scan width is limited by the range of x and y screws (in our case about 20mm in both directions). A sketch of the device is shown in Fig. 2.

**The Z-detector**

The strain gauge is made of a thin film resistance incorporated into a plastic strip to be glued to the object whose strain has to be measured. Applying to the film a tensile (compressive) strain increases (decreases) its resistance. The change in resistance $\Delta R$ is proportional to the relative length change $\varepsilon=\Delta L/L$, with a gauge factor

$$G=(\Delta R/R)/\varepsilon=2.$$  

For example, with $\varepsilon=1\%$ and $\Delta L=0.1\%$ we get a signal $\Delta V=1\mathrm{mV}$, requiring a gain of about 1000 in order to match the input voltage range of the used interface (0-5V).

The Wheatstone bridge configuration of the strain gauges is shown in Fig. 4. It consists of an active bridge, built around IC3, biased by IC1, a REF03 2.5V voltage reference buffered by IC2. The output $V_{o}$ is amplified to obtain a signal suitable to the input range of our Data Acquisition System (0-5V).

**The X-detector**

A sketch of the device is shown in Fig. 2. The Wheatstone bridge configuration of the strain gauges resistances $R_{1}$ and $R_{2}$, and sketch of the cantilever geometry. The actual probe is a needle soldered at one end of the cantilever. When the tip is pushed upward, with a vertical shift $\Delta z$, the cantilever deflection produces the relative change $\varepsilon$ in lower strain gauge and $-\varepsilon$ in the upper one. The value of the shift may be written (see Text Box 2)

$$\Delta z=\varepsilon(2L/3a),$$  

where a is the cantilever thickness and L its length, so that the relative change is $GR=R(\Delta a/3aL)$. For example for $a=50\mu m$, $a=0.3\mu m$, we get $(\Delta R/R)/\varepsilon=10^{-3}$, a sensitivity comparable with the thermal drift of metallic resistances $\beta=(\Delta R/R)/\Delta T=10^{-3}$. This explains why we use two strain gauges instead of one: besides the gain of a factor of two in sensitivity, with matched gauges we make the system unaffected by thermal drifts. The voltage $V_{a}$ at the strain gauge’s midpoint depends on the bridge bias voltage $V_{g}$ and on the values of the two resistances $(R-\Delta R)$ and $(R+\Delta R)$:

$$V_{a}=V_{g}A_{2}/2+V_{g}A_{1}/2, \text{ so that the bridge output signal is } \Delta V=V_{g}A_{2}/2-V_{g}A_{1}/2.$$  

For example, with $V_{g}=1V$ and $\Delta a=0.1\%$ we get a signal $\Delta V=1\mathrm{mV}$, requiring a gain of about 1000 in order to match the input voltage range of the used interface (0-5V).

The signal conditioning circuit is shown In Fig. 5. It consists of an active bridge, built around IC3, biased by IC1, a REF03 2.5V voltage reference buffered by IC2. The output $V_{o}$ is amplified to obtain a signal suitable to the input range of our Data Acquisition System (0-5V). One
The BASIC Stamp II code for the stepping motors controller

**STEP31.BS2**

```basic
dx var
sx var
ay var
by var
au var
i var
j var

input 0
input 1
input 2
input 3
input 4
output 8
output 9

signal
output 10
output 11
dx=0
sx=0
ay=0
by=0
au=0
low 10
low 11

loop:
button 0,0,255,1,dx,0,skip1
gosub dex

skip1:
button 1,0,255,1,sx,0,skip2
gosub six

skip2:
button 2,0,255,1,ay,0,skip3
gosub aly

skip3:
button 3,0,255,1,by,0,skip4
gosub bay

skip4:
button 4,0,255,1,au,0,skip5
gosub aut

skip5:
goto loop

dex:
high 10
high 9

dex1:
button 0,0,255,1,dx,1,dex2
low 10
return

dex2:
pulsout 8,100
goto dex1

six:
high 10
low 9

six1:
button 1,0,255,1,sx,1,six2
low 10
return

six2:
pulsout 8,100
goto six1

aly:
high 11
high 9

aly1:
button 2,0,255,1,ay,1,aly2
low 11
return

aly2:
pulsout 8,100
goto aly1

bay:
high 11
low 9

bay1:
button 3,0,255,1,by,1,bay2
low 11
return

bay2:
pulsout 8,100
goto bay1

aut:
for j=1 to 20
high 10
low 9
for i=1 to 4100
pulsout 8,100
next
```

*Pin 5 of BS2-IC; RIGHT BUTTON
*Pin 6 of BS2-IC; LEFT BUTTON
*Pin 7 of BS2-IC; UP BUTTON
*Pin 8 of BS2-IC; DOWN BUTTON
*Pin 9 of BS2-IC; AUTO SCAN BUTTON
*Pin 13 of BS2-IC; CK
*Pin 14 of BS2-IC; CW/CCW

*Pin 15 of BS2-IC; ENABLE signal for horizontal displacement
*Pin 16 of BS2-IC; ENABLE signal for vertical displacement
arm of the bridge is made of the two strain gauges (120Ω) and the other one is made of two fixed resistors (10kΩ) and a balancing potentiometer (500kΩ), which allows zeroing of the system before starting scanning a sample.

The strain gauges midpoint is kept at virtual ground by the operational amplifier IC3. The bridge is therefore biased by two signals: \( V_s \) and \( V_0 = \frac{R_2}{R_1} V_s \), where \( R_2 = R + G_e \) and \( R_1 = R - G_e \) are the gauge resistances and \( G_e = AR/R \) their relative resistance changes. The output signal \( V_o = \frac{1}{2} (V_s + V_0) = 2V_s \), taken at the sliding contact of the potentiometer, is amplified by IC4 and IC5: a differential amplifier is not necessary to amplify the bridge output voltage \( V_o \), given that it is referred to ground. As IC2+IC5 we have used four OP177 precision low voltage offset and low drift op-amps.

**The stepping motors controller**

To make the displacements automatic in the x and y axis during the sample scan, we have used for our device a BS2-IC (BASIC Stamp II produced by Parallax, Inc. http://www.parallaxinc.com), a simple and versatile PIC-based microcontroller with a BASIC interpreter on board. The BASIC Stamp II program is shown in Text Box 1.

The BASIC Stamp II has 16 Digital I/Os that can be software configured as input or output. We needed five inputs, to sense the state of five buttons (UP, DOWN, ...
LEFT, RIGHT, AUTO SCAN), and 4 outputs, to drive the stepping motors. A sixth button, connected to the RESET pin of the BS2-IC makes possible to stop the scan process. Figure 7 shows the interface circuit that we have used to drive each stepping motor. It is composed by an L297, that integrates all the control circuitry required to control bipolar and unipolar stepping motors, and by an L293E, a quad push-pull driver capable of delivering output currents to 1A per channel. Both pins 17 (CW/CCW; clockwise/counterclockwise) of the two L297s are connected together. The same for pins 18 (CK).

The CW/CCW and CK signals are generated by the BS2-IC pins 14 and 13 (P8 and P9, respectively). The ENABLE signals, for the two L297s come from pins 15 and 16 (P10 and P11) as can be seen in the programme (Text Box 1).

H/F (half step or full step) is directly connected to the 'high' logic state. The interface output signals A, A, B, B, drive the windings of the stepping motors. We chose the model 15PM-K004 low cost, unipolar, small angle motors by MINEBA CO. LTD. Their holding torque is 650gcm and their current per winding is 0.36A with 8.6V applied. The 27Ω power resistors between the windings common leads and the 18V power supply are necessary to set the current at the correct value.

Some images
To give an idea of the capabilities of this device we present in figure 7 some images of coins obtained using 40 lines of 100 points per line; with a sampling frequency of about 4 points per second a total acquisition time of about 10 minutes is required.

A photo of the sample coins (50, 5 and 1 Pfennig, chosen for their small diameter and simple design) is shown in Fig. 8.

The images shown in figure 7 were taken using a wool-needle, with a not too sharp tip (whose radius of curvature R=0.28 mm is shown in figure 9a), thus reducing the risk...
of chokes and lateral deflections of the cantilever when crossing sharp steps on the sample. Our device is affected by this problem because it does not have the feedback mechanism that allows SFM to work at constant force: in that case when the tip meets a sample relief, the sample holder is suitably displaced along z to keep constant the cantilever deflection.

Obviously the lateral resolution is better the smaller the tip radius of curvature. To show this effect, in the language of probe microscopists is named 'tip convolution', we recorded two images, shown in figure 10, of the same sample first using a sharper sewing-needle (R=0.08mm) and then a ball-bearing sphere (R=1.5mm) as probe tips.

Using a curvature radius larger than the coin thickness, we can detect the sample borders (the tip can cross steps slightly smaller than R), but we spoil our lateral resolution. Using a smaller curvature radius we get better resolution, but the probe-sample interaction becomes important (note that in our devices the applied force increases with Δz), so that at the scan end the sample results are slightly damaged (see Text Box 2). The images shown in figures 7 and 10 report the x-axis calibrated in mm. How did we calibrated it? We simply measured the change ΔV corresponding to a known displacement Δz to calculate the conversion factor Kz= Δz/ΔV (mm/V). To calibrate the y-axis we measure the change in the V' signal produced by a known shift Δy along a flat region of the sample surface: the conversion factor is Ky= Δy/ΔV (mm/V).

For the z-axis we have Kz= Ky tanα, where α is the tilt angle between the sample surface plane and the x-y scan plane.

References
1 Giacomo Torzo: Dipartimento di Fisica, Università di Padova, INFN and CNR
Barbara Pecori: Dipartimento di Fisica, Università di Bologna
Pietro Scatturin: Dipartimento di Fisica, Università di Padova
Giorgio Delfitto: Dipartimento di Fisica, Università di Padova and INFN

2 For a bibliography on SFM see the websites:
http://www.park.com/spmguide/contents.htm, or
http://www.spm.genebee.msu.su, or the book Yaminsky LV.,
Elenksy V.G. Scanning Probe Microscopy: Bibliography
Scanning Probe Microscopy; Vol. 2)

3 See G.Torzo and D. Cerolini: SFM image reconstruction
reducing tip artifacts, Microscopy and Microanalysis, May
2000.

Calculus of the strain produced by the cantilever deflection Δz

The strain in elastic bodies is described by the relation ε = 1/E · (F/S) relating ε=ΔL/L to the applied force F, the section S and the Young modulus E (for steel E = 22.106 N/cm²).

We are looking for a relation between the displacement Δz of the free end of a cantilever and ε. Thinking the cantilever (horizontal in equilibrium) as a beam of fibres, a deflection produces an increase of the fibres length on the convex side and a decrease on the concave side, with respect to the median fibre. Now, the length dx of an arc P-Q (figure 11) of the median fibre may be written as product of the curvature radius p and angle α: dx = p α .

The relative length change, at the generic distance y from the median fibre is therefore ε = ±y/p, corresponding to an applied tangent force dF=EdS(y/p), where dS=bdy is the cross section of the fibre. A cantilever deflection corresponds to an applied torque given by the integral:

\[ \Gamma = \int y \, dF = \int y \cdot (E/\rho) \, dy = (E/\rho) j \]

where \( j = \int y^2 \, dS = ab^2/12 \).

Because the angle between tangents to the fiber in P and Q is α, the differential contribution to vertical displacement is dz = xdx/ρ, where x is the distance of P from the cantilever end (tip position). By substituting ρ we get dz = (F/E)x dx. Neglecting the cantilever weight, the equilibrium between applied torque Fx and the restoring elastic torque F gives dz=(F/E)x x dx. The total displacement is obtained by integrating along the cantilever length: Δz=(F/E)L/3=(F/E)(4L/3b).

The strain ε changes along x growing with curvature 1/ρ, reaching a maximum close to x=L, where the gauges are glued. Here ε=(a2/2ρ)=a2(1/2Eρ), and the torque is Γ=FL. From Δz=(F/E)L/3 we get (FL/E)=Δz/(3L²) and finally ε=(a2)(FL/E)=Δz(3a2L²). Higher sensitivity (ε=Δz) can be attained by increasing thickness a and reducing length L, but this also increases the tip to sample force F= εaE²b/6L=EΔz a²b²/4 L². With a=0.3mm, b=10mm, L=30mm, the applied force with a deflection of 1mm is F=0.25125g, already sufficient to slightly scratch a metal with a sharp needle.

Fig. 11. Schematics of the cantilever deflection.
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White LEDs have 35mcd brightness
Rohm has expanded its family of miniature surface mount white chip LEDs with three devices that combine high brightness with low typical and maximum forward voltage (V_f) ratings of 3.0V and 3.3V respectively. Designed to provide enhanced PCB mounting flexibility, the new parts have dimensions down to 1.6 x 0.8 x 0.55mm and are ideal for consumer and telecoms applications, said the supplier. Typical brightness levels for the new devices are in the region of 35mcd at a forward current (I_) of 5mA. Maximum I_ is rated at 20mA, while each LED will handle a peak I_ of 100mA (pulse duration 30ms).

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Voltage regulator can be buck or switch
Semtech has a low-voltage current-mode regulator controller that can be configured into a buck, buck-boost (inverter) or zeta (step-up or step-down) switching-regulator topology. The SC4508 is for driving p-channel power Mosfets to supply up to 6A output current. It accepts inputs from 2.7 to 15V. Its programmable switching frequency, up to 1.5MHz, allows for small capacitors and coils. Output voltage is programmable, through a resistor divider over positive voltages from V(Ref) to 0.9 x V_ or, on the negative side, from -1 to -200V. It typically draws about 3mA in normal operation, which drops to 200µA in shutdown mode.

MPC5200 PowerPC gets RTOS support
Green Hills Software is supporting Motorola's MPC5200 PowerPC processor with its Integrity RTOS, multi integrated development environment and C, C++ and Misra C compilers. This software is for developers of embedded systems for mobile and fixed applications in telematics, gateways, industrial control and electronic and medical instruments. The deterministic RTOS builds on the hardware memory protection facilities of the MMU. It provides a firewall between the kernel and user tasks that prevents errant or malicious code from corrupting user data, the kernel, inter-process communications, device drivers and other tasks. It also runs with interrupts continuously enabled, guaranteeing access to the CPU and memory for critical tasks, even during RTOS system calls. The 400MHz device delivers...
**Power supply packs it with plug-in modules**

A configurable power supply that packs up to 700W into a chassis that measures 266.7 x 127 x 63.5mm has been introduced by XP. The F7 modular AC-DC power unit uses plug-in modules to provide up to nine floating outputs between 1.9 and 150V DC. Outputs can be connected in series or parallel, the latter using active current sharing. The rugged design has a universal AC input with integral power factor correction and 40A maximum peak inrush current. The outputs are adjustable by ±5 per cent and have maximum ripple and noise of 50mV or 1 per cent peak-to-peak, whichever is greater. Line regulation is typically 0.1 per cent and load regulation is 1 per cent maximum for single output modules and 2 per cent for dual or triple output modules. It has over-voltage protection at 115 to 140 per cent of nominal, depending on the individual module and output, and overload protection which operates at 140 per cent of nominal rating. The signal set includes a TTL-compatible inhibit function, DC OK signal, power fail indication and a 5V 1A housekeeping rail. XP

**Resolver-to-digital converter option improves accuracy**

Data Device has announced an option for its RD19230FX resolver-to-digital monolithic converter that provides an accuracy of one arc minute. Resolver-to-digital converters take analogue AC inputs from resolvers, which are rugged angular transducers, and convert them to digital angular format. The device also provides programmable 10, 12, 14 and 16-bit resolution, dual bandwidth and tracking rates, +5V only input power, internal synthesised reference, and A quad B encoder emulation. Applications include motor control, radar antenna position, machine tool control, robotics and process control. Available with operating temperatures of -40 to +85°C (FX-205) and 0 to 70°C (FX-305), the converter is in a 10 by 10mm, 64-pin, plastic quad flat pack. Data Device

**Tiny dual PLL runs up to 6GHz**

Fujitsu Microelectronics Europe has announced the MB15F7xUV series, sub-miniature dual PLL frequency synthesisers for high frequency mobile comms. The design of the PLLs enables the devices to be housed in the industry's smallest PLL enclosure, claims the firm, an 18-pad ‘bump chip carrier’ measuring 2.4 x 2.7 x 0.45mm. Fabricated in Fujitsu’s 0.35μm BiCMOS, the family is capable of operating from 2.4 to 3.6V.

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**Headphone amp for single-cell designs**

National Semiconductor is offering a version of its Boomer stereo headphone amplifier to operate from a one cell 1.5V battery. The LM4916 is unity gain stable. It is a mono differential output (for bridge-tied loads or BTL) audio power amp and a single-ended stereo headphone amp. Operating from a 1.5V supply, the mono BTL headphone amp delivers 85mW into an 8Ω load at 1 per cent THD+N.

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**Modular PSUs with increased output**

Astic Power has added new output power ratings to its MOP modular power supply series. The existing four MP models now deliver an extra 200W of output power at high line voltage when compared to their universal voltage ratings. Four chassis sizes are available. These enable installed output modules to deliver maximum power levels of 600W, 800W, 1,000W and 1,200W to their designated loads when operated at high line. Each chassis can be configured with almost any combination of more than 25 commercial-off-the-shelf output modules to provide a variety of output voltage combinations from 2V to 60V with output current capacities from 0.5A to 120A. Each chassis can accommodate up to seven output
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BSS BSV BSX BT BTA BTB BRW BU BUK BUT
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**Mobile test platform for 3G troubleshooting**

Tektronix has available a mobile protocol test platform equipped with application software to test complex third-generation (3G) systems and data to computing, networking, office modules. The modules are suited to small appliances, instrument panels, industrial controls, floor care products, and computers and peripherals. The CG series can be supplied with a two tone actuator or can be illuminated with white, red, amber, or green actuators. Additionally, the actuators can be marked. The CL series feature a positive detent and were designed for easy snap-in mounting. With constant ratings of 16A at 125VAC or 10A at 250VAC, both series have UL and CSA approvals. The CG series also have VDE approval.

**Power rocker switches**

The CG and CL series of panel mount power rocker switches from ITT Industries, are targeted at small appliances, instrument panels, industrial controls, floor care products, and computers and peripherals. The CG series can be supplied with a two tone actuator or can be illuminated with white, red, amber, or green actuators. Additionally, the actuators can be marked. The CL series feature a positive detent and were designed for easy snap-in mounting. With constant ratings of 16A at 125VAC or 10A at 250VAC, both series have UL and CSA approvals. The CG series also have VDE approval.

**Kits adapt test equipment for cars**

Fluke has introduced two kits aimed at technicians working on automotive systems. Designed for use with any handheld Fluke ScopeMeter, the kits include suitable shielded and heat resistant test leads, probes and clips together with PC compatible software. The SCC128 Auto Kit is designed for use with a 20MHz or 40MHz bandwidth, 5000 counts true-RMS 120 Series ScopeMeter, and the SCC198 Auto Kit for use with a ScopeMeter from the up-to-200MHz and 2.5Gsample/s 190 Series. Both kits contain FlukeView for Windows software and an optically isolated connecting cable. A library of named test set-up waveforms and measurements can be built up and uploaded to the ScopeMeter for comparison in the field. Captured waveforms, screens and measurement data can be downloaded to a PC for archiving, printing or importing into reports.

**Custom oscillators up to 2.4GHz**

RFX use PLL techniques to produce custom oscillator modules, with frequencies up to 2.4GHz, from a high base oscillator. The oscillators may be locked to an internal or external high precision reference resulting in a very high precision clock. Jitter levels of 0.5ps can be achieved together with excellent phase noise and low ageing characteristics producing accuracies to 0.005ppm max/day. Modules are available with ECL or sine wave output. Applications are communications equipment, instrumentation and system synchronisation.

**Battery-backed PSU has modbus functions**

The Oracle 111 200 battery-backed switch-mode power supply from VXI Power has a built-in RS232/RS-485 interface with modbus functionality, so it can be controlled or monitored remotely. As well as logging data on historical holdup events, the PSU lets the user monitor parameters such as system load.
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"Leitgang digital" automatic slide viewer with built-in high quality TV colour camera. It has a complete video output to a phono plug (BNC & BNC connectors are available). They are in very good condition with low signs of use. For further details see www.leitgang.co.uk

£220 + vat = £264

Board cameras all with 512x512 pixels 8.5mm f/1.2 lens sensor and composite video output. All need to be housed in your own enclosure and have fragile exposed surface mount parts. They all require a power supply of between 10 and 12v DC.

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£74.00 + vat = £88.80

Do not hallucinate.
or battery test cycles. The power supply incorporates a two-stage charger with power shift software to reduce battery recharge time. Operating from an 85-264V AC input, the PSU is available in 12 and 24U versions.

VXI Power
www.vxipower.com
Tel: +44(0) 1522 500511

**White LED for high end lighting**

Vishay Intertechnology has added to its TLCx5100 LED series with the TLCW5100, a 5-mm white LED for high-end lighting applications. The TLCW5100 is a clear, non-diffused LED with 0.33 chromaticity and typical luminous intensity of 4000 mcd. The LED has a 9° angle of intensity and an untinted plastic lens. The TLCx5100 series serve as energy-saving alternatives to incandescent lamps in a broad range of applications.

Vishay
www.epson-electronics.de.
Tel: 49 8914 005363

**Humidity controllers blow hot and cold**

Available from distributor Switchtec, Verner measurement and regulation controllers for temperature, humidity and pressure can be used for most industrial applications, but particularly the air conditioning, heating and refrigeration industry. Such applications include chill cabinets as used in delicatessens and supermarkets. The controllers offer mounting options including 72 x 72mm, 32 x 74, panel, and DIN mount. Models with highly visible displays are available, comprising three digit, seven segment units. Additionally, one, two or four relay output versions are available for controlling multiple external devices and equipment.

TDK Electronics Europe GmbH has started mass production of its PC95 ferrite core material for use in power supply transformers. The PC95 ferrite addresses the increase in demand for smaller and higher efficiency transformers used in DC-DC converters and inverters, as well as in the need to comply to a broader range of temperature conditions. Designed for use in near-optimal conditions over a broad temperature range of 25°C to 120°C, the PC95 is for use in conventional switching power supplies, as well as in the main transformers of DC-DC converters of electric automobiles.

Ferrite for transformers

TDK
www.tdk.de
Tel: 49 211 9077 183

**Boxes suit handheld or desktop devices**

Serpac’s range of enclosures has been updated with the S, SL and A series cases for housing handheld, portable and desktop devices, and consisting of two or four piece design, assembled with four or six self-tapping screws. The top panel of the SL series is inclined for improved ergonomics when used on a deck, said the supplier. The enclosures come with or without a battery compartment for a 9V PP3 cell. All ranges are made in ABS plastic (UL94 HB) in standard colours of black, grey or almond. Other colours are available on demand. As an option, the S series top panel can be recessed for mounting a membrane keypad or a product label. All include internal screw bosses for mounting PCBs. Accessories include a pocket clip that is welded to the base, replacement A series end panels in infra-red, clear and red Flexiglass, and black or clear self-adhesive feet Serpac

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Processor with IPsec accelerator

Renesas Technology has announced the SH7710 32-bit Risc microprocessor with an IPsec accelerator for fast encryption and communication processing. The device also has two on-chip Ethernet controllers that enable connection to two Ethernet LANs. Both peripherals make it suitable for security enabled devices for networks such as VPN dedicated boxes, home gateway servers, surveillance cameras and IP phones. The SH7710 is based on a SuperH Risc SH3-DSP CPU core that operates at up to 200MHz and achieves a processing capability of 260Mips. The on-chip DSP supports various kinds of middleware, such as a voice codec and echo canceller, and enables fast execution of multimedia related processing such as VoIP. The IPsec accelerator implements security in the IP or network layer and supports Des and 3Des encryption and decryption methods and MDS and SHA-1 authentication data generation methods. As well as the encryption circuitry, buffer memory and dedicated data transfer DMACs are provided, allowing data transfer directly between external memory and the buffer memory, and between the buffer memory and encryption circuitry, without CPU load and enables communication processing to be executed at speeds upwards of 20 Mbit/s with a VPN configuration when using 3Des processing. Evaluation boards – such as the Hitachi ULSI Systems’ Solution Engine and Renesas Technology’s E10A simple emulator – are supported as development environment tools. User development of various protocol stacks is supported by the third-party providers. Renesas Technology
www.renesas.com
Tel: +44(0) 1628 585100

Claim for smallest Schottky diode

The IR140CSP Flipky device in a standard ball-grid-array (BGA) package occupies 2.25mm². According to the supplier, this is 86 per cent smaller than the standard SMA package. The 1A, 40V Schottky diode is a four-ball, 1.5 x 1.5mm device with a height of less than 0.8mm. The BGA package enables size reduction and better heat transfer away from the die junction to the circuit board. Since this device is made with chip scale packaging, it dissipates heat directly from the die into the air, increasing thermal efficiency. Thermal resistance junction-to-ambient is 75°C/W maximum and thermal resistance junction-to-PCB is typically 55°C/W. International Rectifier
www.irf.com
Tel: +44(0) 208 645 8003

Filterless class D audio amplifier

Maxim Integrated Products is offering a filterless class D audio amplifier. The Max9712 offers class AB circuit design with no output filters and class AB audio performance (0.06 per cent THD+N), with 90 per cent class D efficiency, says the company. The device uses a modulation scheme that meets FCC radiated emissions standards without the need for an output filter or ferrite beads. It operates over a 2.4 to 5.5V supply, has a fixed gain of 12dB and produces up to 500mA per channel into an 8Ω load. High 70dB PSRR at 217Hz allows operation directly from a single lithium-ion cell without the need for additional supply conditioning. It includes four clocking options to optimise the noise spectrum for a given application. These include three internally generated clock rates and a fourth unique external-clock mode, letting the user control the exact placement of the switching energy. Multiple device scan operate in a master-slave configuration. It comes in 12-pin UCSP (1.5 x 2 x 0.6mm), ten-pin DFN (3 x 5 x 1 mm) packages. Maxim
www.maxim-ic.com
Tel: +44(0) 118 930 3388

Circular Dins for automotive use

ITT Cannon’s APD circular DIN72585 connectors are for automotive, transport and industrial environments, including those subject to shock and vibration. Available in one, two, three, four, six and seven way configurations, the connectors come with a bayonet coupling or as a flanged version. The one way circular connector can handle up to 245A using a 50mm square wire cross section. The dual way has two cavities that can accommodate 16mm square wire cross section with a current capability of 74A. Two, three and four contact connectors have a maximum current rating of 30A, while six and seven way products handle 16A. ITT Cannon
www.ittcannon.com
Tel: 49 7151 699 252

Thermistors are linear

Betaltherm has introduced what it believes is the world’s first standard linear series of NTC thermistor sensing elements. Betaltherm, available from Sequoia Technology are based on a combination of precision resistors and thermistors, which together generate a linear response to temperature. The linear composite typically consists of two or three sensor elements; the most popular being 36K53A1, which uses two thermistor elements (30K5 and 6K3) and appropriate resistors to give a linear output between 0 and 100°C. The circuit designs can accommodate various circuit mounting options. These include custom probe assemblies for the thermistor sensing elements and mounting precision resistors at board level in a control module. It is also possible to package the thermistors and resistors that form the linearisation circuit into one probe construction. The networks are suitable for temperature measurement and control from –30 to +100°C and can be configured in either resistance or voltage mode where they can provide up to ten times the voltage output of a thermocouple sensor. Betaltherm
Tel: 353 91 753238

ITT Canon
www.ittcannon.com
Tel: 49 7151 699 252
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Send your ideas to: Phil Reed, Highbury Business Communications, Nexus House, Azalea Drive, Swanley, Kent, BR8 8HU email ewcircuit@highburybiz.com

**Bipolar reference generator from a printer port**

Using a small and low cost circuit Fig. 1, with simple control software, you can extend the utility of your PC’s printer port for yet another purpose. With your printer port, you can implement a versatile programmable bipolar reference generator by using this circuit. Built using a few readily available low cost components, the circuit occupies a very small space and can be easily attached to the printer port of your PC. You can effectively use this programmable reference generator as a ‘stable reference source’ for testing your circuits without going for a big, mains powered general-purpose reference generator or any PC add on cards. Further, with this design, you need not turn pots or set thumb wheel switches for setting or changing the reference output to any desired value. All you need to do is just enter the desired voltage and the PC does the rest to set the reference output to the desired bipolar value!

As shown in Fig. 1 the circuit uses a low power, programmable 13-bit DAC (IC1, MAX5130), a programmable inverting amplifier (IC2, OP07) and a polarity control switch (IC3, MAX4541CPA). The PC, depending on the reference output required by the user, controls the DAC using three-wire serial interface. Thus the data lines D0 to D2 of the data port (0x378h) of printer interface are used by the PC for sending the Chip Select (CS), data(DATA) and clock (CLK) signals to the DAC. Depending on the data sent by the PC, the DAC produces a voltage output in the range of 0-4.0955 volts in 8192 steps with a step resolution of 0.5mV. Thus data of 0x4000h to the DAC produces the DAC output of 0.00volts while the data of 0x5fffh results in the DAC output of 4.0955volts. Using the 2.5 volts internal reference available in the DAC itself, the output of the DAC and the data input are related as per the following equation:

\[
V_{\text{out}} = \pm (2.5 \times \frac{\text{DATA}}{8192} \times \text{GAIN})
\]

where DATA is the decimal equivalent of binary data sent to the DAC and GAIN is the gain of the DAC's

**Fig. 1. Using this simple circuit, a printer port makes a versatile PC based programmable bipolar reference generator.**
Listing 1

```c
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<bios.h>
#include<dos.h>

#define CLK1 0x04 /* Clock Pulse High*/
#define CLKO Oxfb /* Clock Pulse Low*/
#define CS1 0x01 /* Chip Select high to deactivate DAC*/
#define CSO Oxfe /* Chip Select low to activate DAC*/
#define DATA1 0x02 /* Data Pulse High*/
#define DATA0 Oxfd /* Data Pulse low*/
#define PLUSVREF Ox00 /*Vref positive*/
#define MINUSVREF 0x08 /*Vref negative*/

int c[16], dport, ACTUALDATA, out, k; /*Global Declarations*/
float Vref; /*Desired Reference output*/
void d2b(unsigned int x, int*c) /*Routine for Decimal to Binary Conversion*/{
    int i;
    for(i=0;i<16;i++) *(c++)=(x>>i) & Ox1;
}

float SETREF(void) /*Routine for getting the required reference output from the user*/{
    int Vin;
    printf("Enter the desired reference output Vref (-4.0955 V to 4.0955 V): ");
    scanf("%f", &Vin);
    while((Vin<-4.0955) || (Vin>4.0955))
        printf("ERROR!!! Vref Out of Range (-4.0955 V to 4.0955 V)!");
    Vref=Vin;
    printf("Your Desired Reference is =%f
", Vref);
    return Vref;
}

void SETPOLARITY(float Vref) /*Routine for setting the Vref Polarity*/{
    float y, number, fraction, integer, VrefIn; 
    if (Vref<0.0) 
        out=MINUSVREF;
    else
        out=PLUSVREF;
    outportb(dport, out); /* Set the Vref polarity as negative*/
}

void CLOCK_DAC(void)/*Routine for clocking the DAC*/{
    out=CLK1;
    outportb(dport, out); /*Setting the clock high*/
    delay(1);
    out=CLKO;
    outportb(dport, out); /* Setting the clock low*/
}
void LOAD_DACDATA(int*c)/*Routine for loading actual data into the DAC*/{
    out=CS1;
    outportb(dport, out); /*Chip Select high to disable DAC*/
    delay(1);
    out=CSO;
    outportb(dport, out); /*Chip Select low to enable DAC*/
    delay(1);
    printf("Data loaded into the DAC=");
    for(k=15;k>=0;k--)
        out[c[k]];
    outportb(dport, out);
    printf("%d", (c[k]<1));
    delay(1);
    
    out=CS1;
    outportb(dport, out); /*Clock the DAC*/
    delay(1);
}

main() {
    int v, inc;
    float y;
    unsigned int x;
    double fraction, integer, number;
    clrscr();
    printf("Printer Port as a Programmable Frequency Generator");
    printf(" by
K.Suresh, MSD, IGCAR, Kalpakkam, Tamil Nadu - 603102, India");
    dport=peek(0x40,8); /*Check up for availability of Printer Port*/
    if (dport==0)
        printf("LPT NOT AVAILABLE! EXITING"): exit(1);
    printf("Address of the printer port found =Ox%X", dport);
    SETREF();
    out=0x00;
    SETPOLARITY(Vref);
    y=(Vref*8192)/(2.5*1.6384);
    v=y/1;
    number=y;
    fraction = modf(number, &integer);
    if (fraction<0.44)
        inc=0;
    else inc=1;
    ACTUALDATA=16384+v+inc; /*Actual data including the Control Word for DAC*/
    d2b(ACTUALDATA, c);
    LOAD_DACDATA(c);
    return 0;
}

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internal amplifier, usually set to 1.634.

Normally the DAC output is unipolar (positive) only. As is normally done, you can also operate the DAC in bipolar mode with internal reference with an additional op amp as specified in the device data sheet. But here the range of the output is limited to -2.499V to +2.499V (for MAX5130) only. However, the present design enables you to overcome this and get an extended range of reference of -4.0955V to +4.0955V with a step resolution of 0.5mV. As shown in the Fig. 1, you can achieve this extended bipolar output by using the programmable inverting amplifier (IC2) and the polarity control switch (IC3) combination. Depending on the control signal output at Pin 5(D3 of Data Port 0x378), the polarity control switch is either closed (D3=logic 1) or open (D3=logic 0). This makes the programmable inverting amplifier function either as a unity gain inverting amplifier or as a unity gain buffer. If a positive reference output is required, the switch is opened by sending 0V (<0.8V, logic 0) at D3 making IC2 work as a unity gain buffer. Then the DAC positive output is buffered by IC2 before being available at the output as +VREF. When a negative reference output is needed, the switch is closed by sending a +5V(logic 1) at D3 and the positive DAC output is amplified by IC2 with a gain of -1. The desired -VREF is now available at the output. Thus by controlling the 16-bit data sent to the DAC and the polarity control switch, the programmable reference generator can be made to output any user desired output.

The control software for this bipolar reference generator written in Turbo C is given in Listing 1. The software obtains the desired Vref from the user, checks the set value lying within the range of -4.0955V to +4.0955V. If it lies within the range, the program proceeds further. However, if the set value lies outside the allowed range, an error message warns the user about the over range and asks the user to input a correct Vref. When the desired Vref lies within the allowed range, the program first sets the polarity of the desired Vref by sending appropriate logic signal at pin 5 of the printer port and then calculates ACTUALDATA to be sent to the DAC. The d2b routine converts the ACTUALDATA into 16-bit binary data. The program then enables the DAC (CS= low) and then serially clocks the binary equivalent of ACTUALDATA, starting from MSBit to LSBit, one by one, to the data pin of the DAC. With LSB set at the data pin, the low to high transition of the clock latches the ACTUALDATA completely into the DAC. Now the user set Vref is available at the output!

Current-to-current converter

A current to current converter may often be needed if you have a fixed reference current source of current of the order of say, tens of microamperes and would like to have a current higher or lower than this for your application and to switch or change the direction of the input reference current.

Non inverting Current-to-current converter

You can build a programmable current source of any value higher than input current just by adding two resistors R1 and R2 to a unity gain buffer/voltage follower as shown in Fig 1. a & b.

The input current I1, from an external current source that is to be scaled up flows through R1 (assuming that the bias current of the op amp is negligible) and creates a voltage drop I1R1 across R1. Since the voltage follower has a severe negative feedback, the error voltage across its inverting and non-inverting input terminals should ideally be zero. Therefore the potential at the output of the op amp has to be same as the potential at the non-inverting input. Since one end of R1 and R2 are tied together, the potential across R2 has to be same as the potential across R1. Potential across R2 = I2R2 = I1R1

The output current is sum of the input current flowing through R1 and the current supplied by the op amp flowing through R2

I0 = I1 + I2
   = I1 + (I1R1)/R2 = I1(1 + R1/R2)
   = I1(1 + R/R2)

The current gain is always greater than unity, which means that the output current to the load RL is always

---

K. Suresh
Kalpakkam
Tamil Nadu

---

Fig.1b.Current Sink

Fig.1b.Current Sink

Current gain = 1+(R1/R2)

Current gain = 1+(R1/R2)

I0 = I1 + I2

I1 = I1(1 + R/R2)
greater than the input current. The direction of the current that is delivered to the load is same as the direction of the input current.

The bias current of the op amp determines the minimum value of input reference current that can be handled. An FET op amp with very low input bias current and offset voltage would be a suitable choice for this application C1 & C2 are the recommended decoupling capacitors for the op amp.

Inverting current-to-current converter

Fig. 2. is another current-to-current converter where output current to the load RL can be greater or lesser or equal to the input current with the direction of the output current changed.

The input current from a current source (assuming that the bias current of op amp is negligible) flows through R1 and creates a voltage drop I1R1 across the feedback resistor R1. The negative feedback forces the potential across inverting and non-inverting input to be zero. Therefore the potential across R2 has to be the same as the potential across R1.

\[ I_1R_1 = I_2R_2 \]

If the bias current of the op-amp is negligible, the current through the resistor R2 and the current through the load RL is same.

\[ I_0 = I_2 \]
\[ I_0 = I_1 \left( \frac{R_1}{R_2} \right) \]

An input current I1 that is sourced out from a current source causes a current I0 to sink into the load R2, and vice versa as shown in the Fig.2. a & 2b. Therefore I0 may be written as

\[ I_0 = I_1 \left( \frac{R_1}{R_2} \right) \]

The bias current of the op-amp determines the minimum value of input reference current that can be handled. An FET op amp with very low input bias current and offset voltage would be a suitable choice for this application C1 & C2 are the recommended decoupling capacitors for the op amp.

V. Manoharan
Kochi
Kerala
India

Using Multiple-purpose Timer Chip to Build Inverting SMPS

Both positive and negative supply voltages are usually required for driving most op-amp circuits, RS-232 line drivers, A/D and D/A conversion circuits, etc. As the power requirement of these circuits is generally small, an inverting regulator that generates negative supply from the positive one is a preferable alternative rather than employing a full line dual power supply. Despite the fact that this task can be easily accomplished by using a single-chip charge-pump, building an inverting switched mode regulator using an off-the-shelf multiple-purpose chip is interesting as it incorporates the educational aspects of understanding the principles of switched mode power supply.

The circuit being described in this article uses the popular 555 timer chip as a controller for inverting switched mode power supply to generate -5V from +5V supply. The timer is configured as an astable multivibrator with timing controlled by R1, R2, C1, VCC, and upper threshold voltage VTH. The output high time of the timer is determined by the time required to charge C1 from \(-V_{TH}\) to \(V_{CC}\) through R1, R2 that can be expressed by:

\[ t_h = \frac{1}{\frac{1}{V_{TH}} - \frac{1}{V_{CC}} \left( \frac{R_1 + R_2}{R_1} \right)} \]

The output low time of the timer is determined by the time required to discharge C1 from \(V_{TH}\) to \(-V_{TH}\) through R2 and the internal discharge transistor of the chip which can be expressed by:

\[ t_l = \frac{1}{\frac{1}{V_{TH}} - \frac{1}{V_{CC}} \left( \frac{R_4 + 10k\Omega}{15k\Omega} \right) \left( \frac{R_4 + 10k\Omega}{15k\Omega + 5k\Omega} \right)} \]

The output low time of the timer is determined by the time required to discharge C1 from \(V_{TH}\) to \(-V_{TH}\) through R2 and the internal discharge transistor of the chip which can be expressed by:

\[ t_l = \frac{1}{\frac{1}{V_{TH}} - \frac{1}{V_{CC}} \left( \frac{R_4 + 10k\Omega}{15k\Omega} \right) \left( \frac{R_4 + 10k\Omega}{15k\Omega + 5k\Omega} \right)} \]

The output low time of the timer is determined by the time required to discharge C1 from \(V_{TH}\) to \(-V_{TH}\) through R2 and the internal discharge transistor of the chip which can be expressed by:
The buck-boost switched mode regulator circuits consist of $Q_2$, $L_1$, $D_1$, $C_2$, and $C_3$. When the output of the timer chip is high during $t_{on}$, $Q_1$ and $Q_2$ will be turned on and energize inductor $L_1$. When the output of the timer chip is low during $t_{off}$, $Q_1$ and $Q_2$ will be turned off and $L_1$ releases its energy to $C_2$ and $C_3$ through $D_1$ and thus generates negative voltage $V_A$. The value of $V_A$ depends on $V_{CC}$ and also the on and off time of $Q_1$ through following relation.

$$V_A = V_{CC} \frac{t_{on}}{t_{off}}$$

As $t_{on}$ itself depends on $V_A$, the timer chip serves as an active low pulse position modulator that regulates the output voltage. If $V_A$ decreases (becomes less negative), VTU will increase and yield larger $t_{on}$ that implies higher energy to energize the inductor. This increase in $t_{on}$ will then restore the intended value of $V_A$ back. The opposite story will take place when $V_A$ increases. Additional ripple filtering and voltage regulation are then carried out by $R_7$, $D_2$, $C_4$ and $C_5$.

Henri P. Uranus
Enschede Netherlands

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- **Supply Current:** 15mA typical
- **Dimensions:** 99 x 82 mm

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Alternatively call 01225 704631
or fax your order to 01225 708618.

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Method of payment (please circle)

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**Specifications**

**Switch position 1**

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<th>Bandwidth</th>
<th>DC to 10MHz</th>
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<td>Input resistance</td>
<td>1MΩ</td>
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<tr>
<td>Input capacitance</td>
<td>40pF</td>
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<td>Working voltage</td>
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**Switch position 2**

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<th>DC to 150MHz</th>
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<tr>
<td>Rise time</td>
<td>2.4ns</td>
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<tr>
<td>Input resistance</td>
<td>10MΩ ±1% if oscilloscope i/p is</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>12pF if oscilloscope i/p is 20pF</td>
</tr>
<tr>
<td>Compensation range</td>
<td>10-60pF</td>
</tr>
<tr>
<td>Working voltage</td>
<td>600V DC or pk-pk AC</td>
</tr>
</tbody>
</table>

**Switch position ‘Ref’**

Probe tip grounded via 9MΩ, scope i/p grounded
Cyril Bateman uses his real-time distortion measuring system to investigate capacitor distortions in audio power amplifiers.

Assembled using polar aluminium electrolytic capacitors for C1, 3, 9 and 11, my workhorse 100 watt Maplin Mosfet amplifier, tested at 1kHz and 25 watts into an 8Ω load, measured -81.5dB second harmonic, -91.4dB third harmonic, clearly meeting its claimed less than 0.01% distortion. Fig. 1.

Replacing the four polar aluminium electrolytic capacitors in this schematic, with the same value and voltage rating bi-polar electrolytics and no other changes, amplifier distortion improved dramatically, becoming -92.1dB second and -94.3dB third harmonic, re-measured a few minutes later.

My original Capacitor Sounds series found measurable distortions occurring in un-biased polar aluminium electrolytic capacitors tested at 0.1 volt AC, my smallest practical test voltage. With signals this small, second harmonic of the lowest distortion 100μF 25 volt DC rated polar capacitor I tested, measured -99.5dB with 6 volt bias and -94.4dB with 12 volt bias. Using 0.2 volt AC and larger test voltages, second and third harmonic distortions in polar aluminium electrolytic capacitors increase dramatically, measured with and without DC bias voltage.

Tested using a 1 volt signal, this capacitor's third harmonic remained close to -100dB, with no bias its second harmonic was -93.2dB, increasing to -77.9dB at 6 volt bias and -72.9dB with 12 volt bias. Application of a very small, optimal bias, typically less than 3 volts DC, to selected capacitors may minimise the second harmonic, however for every electrolytic capacitor I tested, further increase of bias voltage resulted in increased second harmonic distortion.

Contrary to the popular belief that a polar aluminium electrolytic capacitor should be biased to 50% rated voltage for minimal distortion, my measurements show that second harmonic distortion can only be minimised by using very small or no DC bias. Any further increase in DC bias increases the second harmonic generated by the capacitor. Application of DC bias at 50% of the capacitor's rated voltage as shown in the figure, results in exceptionally large second harmonic distortions, even for this, the lowest distortion, the best polar capacitor, of those measured. Fig. 2.

At very low frequencies, as capacitor impedance increases, signal
voltage could occur in the circuit sufficient to measure an increased distortion. However at my 1kHz distortion measurement frequency, all four capacitors have low impedance, so are subject only to small AC signal voltage drops, apparently not sufficient to explain my measured reduction in distortion when replaced by the same value and voltage bi-polar types.

At a given test frequency, capacitor distortions do vary with capacitor AC voltage bi-polar types. When replaced by the same value and my measured reduction in distortion apparently not sufficient to explain low impedance, so are subject only to frequency, all four capacitors have increased distortion. However at my voltages could occur in the circuit designed and built to measure harmonic distortions. It seemed possible that distortions harmonic distortions do increase with capacitor current, voltage drop and second harmonic with DC bias. Clearly both second and third harmonic distortions increase with capacitor current. A few simulation runs using measured capacitance and ESR values by frequency, would establish second harmonic distortion increases rapidly with DC bias voltage.

Capacitor C3 conditions
I ran a few simulations to identify the capacitor most likely to influence this amplifier's distortion. As in many power amplifiers, a 47µF polar aluminium electrolytic capacitor, C3, is used in the feedback network, to roll off amplifier gain at low frequencies, minimising DC offset at its output. With 33kΩ for R7 and 1kΩ for R6, this capacitor is presented with a high impedance for charge and discharge currents. My original Capacitor Sounds measurements used lower impedances. Might this high impedance condition affect the capacitor's distortion contributions?

It seemed possible that distortions generated in the capacitor result from two mechanisms, a current dependant component in addition to the voltage component already identified. Throughout that series, I related distortions measured in capacitors to their signal and bias voltages, using test circuit source impedance some two thirds that of the capacitor's at 1kHz for values to 1µF, 100Hz for 1µF and larger values.

I expected to find some third harmonic current dependency from non-ohmic resistances in the capacitor internal connections. Second harmonic distortions in capacitors result from dielectric absorption effects, DC bias and test voltage level, so I wondered whether a change of measuring current with constant bias and test voltage, would reveal changes also in the second harmonic?

In my original Capacitor Sounds series I described test equipment designed and built to measure capacitor distortion at 100Hz and 1kHz. For another project last year I assembled a 5kHz test oscillator, buffer amplifier, notch filter/preamplifier, using 1kHz PCBs with smaller tuning and filter capacitors.

Following a few tests, I found this equipment could develop an undistorted 0.5 volt 5kHz signal across my 1µF FKP reference capacitor using 100Ω source impedance. I could measure distortions produced by a 1µF polar aluminium electrolytic capacitor at three test frequencies, 100Hz, 1kHz and 5kHz, using 100Ω source impedance, increasing capacitor test current from 314µA at 100Hz to 15.7mA at 5kHz at constant test voltage. Perhaps that would clarify any capacitor current dependant component.

Using 100Ω source impedance and no bias, I adjusted test levels to develop a 0.5 volt AC voltage across the capacitor at each frequency. Second harmonic distortion increased by 8dB and third harmonic 4.3dB with this change of capacitor current. Clearly both second and third harmonic distortions do increase with capacitor current and AC voltage drop.

Table 1: With 0.5 volt AC test voltage, 100Ω source impedance and no bias, I found second and third harmonic distortions increase with capacitor current. Clearly both second and third harmonic distortions do increase with capacitor current, voltage drop and second harmonic with DC bias.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Impedance</th>
<th>Test Current</th>
<th>Second Harmonic</th>
<th>Third Harmonic</th>
<th>% T.H.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td>100Ω</td>
<td>314µA</td>
<td>-107.8dB</td>
<td>-115.7dB</td>
<td>0.00047%</td>
</tr>
<tr>
<td>1kHz</td>
<td>100Ω</td>
<td>3.14mA</td>
<td>-102.4dB</td>
<td>-111.6dB</td>
<td>0.00083%</td>
</tr>
<tr>
<td>5kHz</td>
<td>100Ω</td>
<td>15.7mA</td>
<td>-99.8dB</td>
<td>-111.4dB</td>
<td>0.00117%</td>
</tr>
</tbody>
</table>

Fig. 2. Distortion results for a Silmic 100µF 25 volt rated polar aluminium electrolytic capacitor, with 12 volt DC bias and tested using 10Ω source impedance generating 1 volt across the capacitor. With no bias, second harmonic distortion for this capacitor was -93.2dB and -77.9dB with 6 volt bias.

Fig. 3. To simplify my simulations, I extracted the C3 and C7 capacitor sub circuits from the Figure 1 schematic and used the amplifier output voltage as my calculation stimulus. Much simpler, quicker and less prone to simulation errors than when modelling the amplifier.

Table 1: With 0.5 volt AC test voltage, 100Ω source impedance and no bias, I found second and third harmonic distortions increase with capacitor current. Clearly both second and third harmonic distortions do increase with capacitor current, voltage drop and second harmonic with DC bias.

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<td>-99.8dB</td>
<td>-111.4dB</td>
<td>0.00117%</td>
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</table>

November 2003 ELECTRONICS WORLD
I extracted the feedback resistor network with this capacitor from the main circuit and used the amplifier's output voltage for 100 watt into 8Ω as the stimulus. I measured a radial lead, 47µF 50 volt Panasonic 'S' bi-polar electrolytic, the type used when exchanging the capacitors, for capacitance and ESR by frequency. Self resonance was 300kHz, so estimating 10nH for its self inductance, typical of many radial lead aluminium electrolytics in a 20 x 10mm case, completed the model.

Using my Hewlett Packard reference test jig and Wayne Kerr B6425 precision digital LCR meter, I measured this capacitor from 10Hz to 30kHz, for capacitance value and ESR. These pairs of values were inserted into the model in turn for each of eight simulation runs, noting the voltage drop across the capacitor model, from the negative side of the 10nH to the junction of ESR and R6, also C3 through current.

For each run, similar voltage and current plots were observed with subtle changes at the frequency of interest, for the capacitor parameters used. Clearly capacitor signal voltage does reduce with increasing frequency but capacitor current remains almost constant, generating a near constant level of current dependant distortion.

**Protection Diodes**

Most published amplifiers using a polar aluminium electrolytic capacitor for this C3 position add a diode or pair of diodes in parallel, to

![Fig. 4](image)

*Fig. 4. One of eight simulations needed to accommodate C3 measured parameters by frequency, showing the 1kHz results. Voltage across C3 reduces with frequency but current through C3 remains almost constant regardless of frequency.*

![Fig. 5](image)

*Fig. 5. A Rubycon YXF 47µF 25 volt rated polar aluminium electrolytic capacitor tested at 100Hz and 200mV with diodes. Without diodes, third harmonic was -122.67dB, a more than 20dB improvement. At this test voltage, low level AC mains harmonics cannot be eliminated, for clarity test frequency was 103.8 Hz and mains peaks labelled.*
propose the capacitor should always the amplifier 'go DC' with as output voltage 'stuck' to a supply rail. It has often been claimed such diodes do not distort at the capacitor's signal voltage levels, but I wondered if that were correct. Using a pair of IN4448 diodes and my 1µF FKP reference capacitor, I made measurements at 1kHz with 100Ω source impedance and test voltages of 75mV, 100mV, 150mV and 200mV, comparing distortion results with and without diodes.

Measured with diodes, third harmonic distortion was visible at -110dB for the 75mV test, increasing to -100dB for 100mV and -84.9dB tested at 200mV, when a fifth harmonic at -100dB was seen. These harmonics result from the diodes conducting slightly at these test voltages since without diodes, my FKP reference capacitor was distortion free.

I measured distortions at 100Hz, with and without diodes, for a variety of 47µF and 100µF polar aluminium electrolytic capacitors, rated at 25 volt and 50 volt, comparing these results with those for the same value bi-polar electrolytics. The results were overwhelmingly conclusive: At 200mV with diodes, third harmonic distortion increased by 20dB with polar and bi-polar capacitors. At 100mV I found smaller increases of third harmonic, depending on the level of distortion generated by the capacitor without diodes. Tested at 0.1 volt with diodes, this capacitor generated -96.8dB second and -108.2dB third harmonic distortion. Fig. 5.

I question whether these protection diodes are necessary for polar aluminium electrolytic capacitors in this circuit. They certainly are not needed using a bi-polar aluminium electrolytic capacitor of rated voltage similar to the amplifier's power supply voltage. That capacitor will happily survive indefinitely, regardless of whether the amplifier has 'gone DC' or is working correctly. More important it will generate almost no measurable distortion. Fig. 6.

All polar aluminium electrolytic capacitors inherently include a reverse polarity diode so should an amplifier 'go DC', reverse polarising the capacitor by more than 1 volt, capacitor reverse leakage current increases causing a voltage drop across R7. With ±50 volt power supplies and 10kΩ for R7, current cannot exceed 4.8mA. This reverse current may degrade the capacitor which should be replaced during repair, but is most unlikely to result in capacitor failure.

Zobel circuit
Many designers have expressed concern to me about the output stage CR Zobel network, that the signal voltage across resistor R15 with this resistor's voltage coefficient might generate audible distortion. With C7 and R15 already modelled, we can quickly explore this Zobel network.

With typical component values of 0.1µF and 4.7 to 10Ω, the 0.1µF capacitor sustains almost all the amplifier output voltage at least to 10kHz and is more highly stressed than the resistor. At higher frequencies, resistor voltage increases but capacitor voltage reduces little.

Fig. 6. Without diodes, but otherwise exactly as Figure 5, this Panasonic 'S' 47µF 50 volt bi-polar aluminium electrolytic capacitor shows the distortion reduction available by changing a polar capacitor for a bi-polar type. With diodes, third harmonic increased more than 20dB to -99.24dB, further proof of the diode effect.

Technical support
Full details of the 'Real Time' hardware test method and my original Capacitor Sounds low distortion oscillator, buffer amplifier, notch filter/preamplifier and DC bias assemblies, complete with parts lists, assembly manuals and full size printed circuit board drawings, as PDF files arranged for easy viewing of the figures, on screen or hardcopy, are provided in my CD.

This CD includes updated and much expanded re-writes with very many more figures, of my first series Capacitor Sounds articles, supported now by some ninety capacitor distortion measurement plots as well as articles from this new Capacitor Sounds II series.

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With 100 watts output into 8Ω at 20kHz, the capacitor must still withstand more than 28 volts while the resistor is subject to less than 2 volts or 0.6 watts. At such voltage a metallised PET capacitor can generate significant distortion. Fig 7. My test equipment cannot generate such voltage so I measured C7 distortions using an eight volt signal and 100Ω source impedance, equivalent to 8 watts power output, representative perhaps of normal listening. I measured a 0.1µF ‘stacked’ metallised PET capacitor, the unused spare for my ‘Self’ amplifier. At 8 watts output this capacitor generated -113.5dB third and -126.3dB fifth harmonic, distortions which would be reflected into the feedback network. Fig. 8. Apart from this distortion, at 20kHz and 100 watts, this capacitor is subjected to more than twice the permitted sine wave rating for an Evox-Rifa MMK 0.1µF 63 volt metallised PET capacitor while almost any resistor easily manages the less than 2 volt and 0.6w R15 dissipates. To minimise distortion in normal use and survive no-load sine wave testing, the capacitor choice for this network is important. I prefer a foil and Polypropylene or Polyphenylene Sulphide capacitor.

**Input capacitor C1**

Many designs use an unbiased 10-22µF polar aluminium electrolytic capacitor, C1, to input the signal and block unwanted DC from entering the power amplifier, assuming that if sized to ensure minimal signal voltage across the capacitor at low frequency, low distortion is guaranteed. That may well be correct provided the capacitor is not subjected to DC bias. More than a few volts bias will result in second harmonic distortion which will be amplified.

I believe a polar aluminium electrolytic capacitor is false economy since quite small metallised PPS or PET capacitors are available. Polypropylene capacitors produce much lower distortion but are larger and expensive. An inexpensive bi-polar electrolytic is small and produces little distortion unless subject to significant DC bias voltage. For the best performance use a film capacitor.

**Class B bias stability networks**

Many power amplifiers include another significant capacitor we should explore. Typically a 10-47µF is used to bypass the signal across the bias current stabilisation network. For values up to 22µF the lowest distortion most economic choice is a metallised PET style, closely followed by the ‘double bi-polar’ electrolytic capacitor. For larger values, unless cost and size is no object, chose this electrolytic.

Many readers are familiar with the Douglas Self ‘Blameless 50 watt class B’ design, published in Electronics World February 1994. I have a pair, assembled on printed boards purchased from the magazine, which measured some 2.6 volts of DC bias voltage across their 47µF polar aluminium electrolytic capacitor C4, the bias current stabilisation network bypass capacitor.

Measurements of the AC voltage across C4, with the amplifier driven to 50 watts into 8Ω shows its AC voltage increasing significantly with frequency. At low frequencies, while the amplifier still has substantial open loop gain, this voltage remains small. As the amplifier open loop
gain reduces with increasing frequency, C4 is subjected to a significant signal voltage. At 10kHz I measured 1.15 volt AC using an AC coupled DVM to ignore the DC voltage. Any polar aluminium electrolytic capacitor subject to such AC voltage will generate very large second and third harmonic distortions.

The very best and quite expensive, specialist polar aluminium electrolytic capacitor of those I tested at 1 volt, generated some -93.2dB second and -100dB third harmonic with no bias. With 6 volt DC bias distortions increased dramatically, the second harmonic now -77.9dB. With 12 volt bias second harmonic increased tenfold to -72.9dB. Other polar aluminium electrolytics generated even more distortion when tested using a 1 volt signal.

The only cost effective, low distortion solution for this 1 volt signal level and DC bias voltage, is to use two double capacitance, 63 volt rated bi-polar aluminium electrolytic capacitors connected in series, the ‘double bi-polar’ configuration recommended in the last article of my first Capacitor Sounds series, Electronics World January 2003. Measured using 1 volt and no DC bias, this ‘double bi-polar’ capacitor combination measured -117dB second and -123dB third harmonic.

With 6 volt bias, second harmonic became -102dB and -97.2dB biased to 12 volt DC as shown in this plot. An almost twenty times smaller distortion than measured using the best polar capacitor I tested, with or without bias. Fig. 9

Contrary to common belief, using an electrolytic well below its rated voltage does no harm, in fact it is beneficial, reducing leakage current, like choosing a more expensive, professionally rated, long life capacitor. Production electrolytic capacitors rated at 25-63 volt, provide better performance than lower and higher voltage types. In past years ‘underrunning’ was frowned on because some badly designed electrolytes degraded the aluminium oxide dielectric. Subsequent application of rated voltage resulted in leakage current exceeding the maker’s claim.

Installed in circuit and underrun for some time, a capacitor would not usually become subjected to rated voltage. Underrunning never was a problem, rather a misunderstanding of capacitor and circuit behaviour.

Valve amplifiers
To date I have avoided discussing valve amplifiers because I do not possess one and so cannot make any confirming measurements. However, I believe the DC blocking AC signal coupling capacitor used between a valve anode and subsequent grid, subjected to large DC bias and AC signals, can create distortion.

I decided to measure a specialist metallised Polypropylene 1µF 630 volt MKP capacitor and the 1µF paper capacitor reported in my August article, using a 6 volt test signal, the largest very low distortion signal I can generate across a 1µF capacitor using 100Ω source impedance, with DC bias from 0 to 100 volt, then compare the results.

The MKP capacitor performed as well as expected, second harmonic increasing from -132dB with no bias to -123dB with 100 volt DC bias, a superb result. In contrast the paper capacitor behaved rather less well, illustrating perhaps why second harmonic distortion often dominates a valve amplifier output.

With no DC bias, second harmonic of this paper capacitor measured -128.8dB but biased to 30 volts DC its -116.5dB second harmonic was worse than the MKP at 100 volts. Biased to 100 volts this paper capacitor performed badly, generating an enormous -108dB second harmonic. Third harmonic for both capacitors changed little with bias, staying close to -130dB. Second harmonic distortion for this and similar paper capacitors increases with DC bias or AC signal voltage. Fig. 10

Power Rail Capacitors
The four polar electrolytic capacitors I exchanged for the bi-polar types included two 220µF power rail capacitors which are irrevocably linked with the power supply so cannot easily be evaluated in isolation. I plan to explore these as part of a future article.

In my next article, the last for this series, I measure distortions in low-level IC op-amp circuits and include a novel circuit technique that allows a modest op-amp to produce lower than usual distortion driving a low impedance load. In response to reader’s requests, I also include a brief look at possible resistor and potentiometer distortions.

Conclusion
Having examined a variety of capacitor styles and their audio frequency distortions over the past two years, it is perhaps appropriate with the benefit of hindsight to summarise some findings.

For low level and pre-amplifier circuits but ignoring supply rail decoupling, most capacitors used will be small value and many will need

![Table 3: AC and DC voltages measured on C4, with the amplifier set to generate 50 watts into 8Ω. This amplifier was assembled using printed circuit boards purchased from Electronics World.](image)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>100Hz</th>
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<th>10kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC bias volts</td>
<td>2.6v</td>
<td>2.6v</td>
<td>2.6v</td>
</tr>
<tr>
<td>AC signal voltage</td>
<td>0.095v</td>
<td>0.158v</td>
<td>1.15v</td>
</tr>
</tbody>
</table>
FFT Software

Throughout my Capacitor Sounds series except the first two articles, I used the SpectraPlus232 software for my distortion plots. This software is easy to set up and has served well. However some readers have asked whether lower cost software might be used, since a full set of options can become expensive.

I have now found two alternatives. Provided the reader can accept not having the on screen THD% display, all other facilities I used are provided by purchasing only the Spectra base module, almost halving the cost. The on screen THD% option can be purchased later.

My second alternative is 'WinAudioMLS Pro', I evaluated version 1.66, a new version having its microphone correction ability updated for use with my test equipment, or a conventional microphone. It can be obtained from the Dr. Jordan web site.

As standard this software provides a THD+N display and cursor controlled readout of harmonic levels. It accepts the microphone correction file, essential when using my notch filter/preamplifier assembly. In addition to all the features needed for my measurements it also provides an MLS measuring facility. This can be used to measure loudspeaker and room responses as well as the impedance and phase of low impedance components, especially those used in loudspeakers. All this for less cost than for the basic SpectraPlus232 module, makes this software well worth your evaluation.

This software also has a range of additional upgrade options, but I found the base WinAudioMLS Pro version with their THD% option, sufficient for my needs.

Contact
WinAudioMLS Pro
http://www.dr-jordan-design.de
SpectraPlus232
http://www.soundtechnology.com

1% tolerance. For values up to 47nF we have a choice of near perfect, very low distortion, extended foil and Polypropylene capacitors, available at 1% in both axial lead and 'tombstone' styles. COG ceramic capacitors at 5% tolerance, as low cost discs for small values and multilayer capacitors to 100nF, are distributor items. Larger capacitance values and closer tolerances are manufactured. COG ceramic provides low distortion, unsurpassed capacitance stability with voltage, temperature, time and frequency, the almost perfect capacitor.

For values of 100nF and above, we could use multiples of the above types but foil and Polypropylene styles are available to 10μF, regardless of DC bias they assure very low distortion. Metalised PPS types produce little distortion unless subject to significant DC bias. Available to 10μF and 1% tolerance, PPS capacitors provide excellent temperature and long-term capacitance stability in smaller case sizes than Polypropylene types.

Power amplifiers needing larger value signal path capacitors, should use bi-polar aluminium electrolytic capacitors, avoiding the conventional polar aluminium electrolytic capacitor for audio signals. With signal voltages across a large capacitor of 0.5 or more volts, the 'double bi-polar' aluminium electrolytic capacitor, two double value conventional bi-polar aluminium electrolytic capacitors in series, is demonstrably the most economic low distortion choice.

Many writers advocate using lesser value film capacitors, to bypass a polar aluminium electrolytic capacitor to reduce its distortion. My measurements show this has little effect, compared to using the bi-polar style, which produces much lower distortion at less cost.

Distributor stocks of bi-polar aluminium electrolytic capacitors rarely exceed some 470-1000μF at low voltage, this results from customer demand and not capacitor technology, manufacturers will respond to market demand as will distributor stockholdings.

More than 30 years ago I developed a range of bi-polar or reversible electrolytic capacitors up to 10,000μF at 63 volt and the Erie Company manufactured many thousands. The largest example which I still have today, a 2,000μF 30 volt in a 115 x 45mm case, was developed as the output coupling capacitor for a very high power audio amplifier.

References
2. Capacitor Sounds. C. Bateman. Electronics World, July, September 02, through January 03
5. Audio-Grade Polypropylene axial capacitor. Maplin Electronics part no. KR78K.

Fig. 10. A typical 1μF paper capacitor, with 6 volts AC at 1kHz and 100 volt DC bias, produced this excessively large second harmonic distortion. The 630 volt 1μF MKP Polypropylene capacitor was five times better with second harmonic -123dB, third -130dB, just 0.0008% distortion. This plot was measured using the Dr. Jordan software, the SpectraPlus232 gave almost identical results.
Historic receivers
I was reading the article by Jeremy Stevens on 'Receivers of the Third Reich', which I found most interesting, but the marking of the capacitors reminded me of a similar situation in British military radio history.

Many years ago, I was employed by a TV sales and service company owned by an ex-army (probably REME) officer who had served in WW2. He loaned me some books entitled "Handbook of Wireless Telegraphy", the Admiralty Radio Handbook, published by HMSO in 1938. These toms covered every detail of technology at the time, in fascinating detail.

The thing which sticks in my mind the most is that all capacitor values (or condensers, as the term was then) were given in 'jars'. Somewhere there was a note explaining that "the jar is now obsolete as the service unit, having been replaced by the Farad and sub-multiples thereof.

Despite this statement, all the worked examples are done in terms of jars! Fortunately a colleague has the same manuals, and has loaned them to me to do this little piece of research.

The jar, based on early capacitors built in 'standard' Leyden jars was equivalent to 1000cm. It goes on to give conversion factors to and from micro-Farads where 1µF = 900 jars¹.

The same paragraph states that a cm (centimetre, yes really) is that value of capacitor which when charged with 1 Electro Static Unit of charge, has a potential of 1 ESU of PD (voltage) between its plates. Further references define the ESU for charge and ESU potential difference.

Charge is defined in terms of force in dynes exerted between two unit charges at 1cm distance in vacuo. This evaluates as 1 coulomb = 3 x 10⁹ ESU. The ESU² of PD is defined in terms of coulombs and ergs, and evaluates to 300volts³.

For the younger reader, the Leyden jar is a bit like a square glass jam-jar with a lift out metal centre and a metalised outer shell. The unit can be charged, separated, handled, then re-assembled and discharged. The only time I have ever seen one was in my physics lessons at school, where the thing was charged from a Van-der-Graaf generator, duly dismantled (using a long, insulated rod) and played with by the whole class, eventually to be re-assembled and then discharged with an impressive 'crack'.

It was used to clearly demonstrate that the charge was stored in the dielectric, in this case, the glass. The metal parts from a fully discharged jar were then assembled around a previously charged and dismantled glass jar, with the same satisfying result.

Following on from the great EMC debate, most of us appreciate the thinking behind the CE marking of electronic equipment, but it is ludicrous to try to implement the regulations imposed in the manner that they have been. With so many loopholes and escape clauses, a carefully worded paragraph in the CE statement will let most things off the hook.

The tests applied can be quite selective. For example, electrically a kettle has a resistive element, is unlikely to be susceptible to RF emissions (short of a nuclear explosion) and providing that the switch has some spike suppression, is unlikely to emit much radiation. Is this device justified in being subjected to a full product spec EMC test similar to that for a complex multi-way fire alarm system?

Similar reasoning can be applied for a 'likely use' aspect of a piece of equipment. A simple battery and bulb torch can carry a CE mark. If one were to build a similar torch, but using an inverter and white LEDs, should this have the same or a more stringent test applied? These decisions are left to the manufacturer, but if we get it wrong what then? Fines, confiscation of equipment, each director held singly and jointly at fault. What a minefield!

The great CE con is in full swing.

---

1000 lines, Green
Leslie Green’s article on Calculus was well written. The answers had 3 typos.

(1) answer 1 is 26.66 V / microsecond
(2) head of answer 3) missing
(3) answer 4) mean power in resistor is 25.75 W

George Barnes
Hunter Institute
Newcastle TAFE
Australia

Green II
Leslie Green’s article on basic maths is admirable. Perhaps someone should likewise take up cudgels on behalf of logarithms. It’s quite amazing (to the calculator-bound majority) what can be done with mental arithmetic and logarithms.

I should like, if I may, to propose a small clarification. ‘RMS power’ is of course calculable but is, as the article states, neither valid nor useful. What’s invariably meant is quite simply average power. Voltage or current is measured as Root Mean Square and is then squared in the process of calculating power. ‘Root mean’ squared becomes simply mean, a.k.a. arithmetic average. I suspect that to most of us plain ‘average’ simply sounds instinctively too vague, accurate thought it may be!

Re: Catt etc., please keep this stuff coming. It clearly makes a lot of us think and that’s no bad thing! But could letter-writers on audio please read Doug Self’s articles (or books) before armchair theorising? Usual disclaimers - I’ve never met him etc. etc. - but he’s already invented the wheel and credit to him for telling us exactly how.

Richard Black
London
UK
now. Have you found a piece of equipment with a mains lead attached lately? It would appear that if the unit radiates undesirable RF signals from the lead, then technically it fails the EMC emissions test. On the other hand, if the lead can be unplugged, and the lead is CE marked (and most mains leads are fairly benign when not plugged in or connected only to a resistive load after all) then they are classed as separate items, and the unit with no lead can be certified. Hence the rise in equipment supplied with 'kettle' leads. Of course, having connected them together and switched on the unit, does the whole assembly fail to comply, and who could be held responsible for any undue emissions? Both the device and lead are CE marked and therefore can be supplied legally, but who is at fault - the customer? "I know nuffink, Guv! That's how it came in the box."

Similar reasoning is applied to 'plug top' power supplies. On its own, the PSU passes the relevant tests for its class of equipment. Similarly, on its own, the powered equipment passes, except for radiation from the power lead. So: fit a DC socket and CE label, and supply a CE marked PSU. Job done!

Perhaps the faceless men in Brussels should stick to defining the size of the Euro-apple, or the colour of the standard Euro-tomato, or even the shape of the standard Euro-car, and let our industry do what it does best - make working, reliable products with minimal interference radiation and absorption problems. After all is said and done, Joe Public will let us know, for certain, that his new video, TV, computer, radio etc. does not work, so we have to design in interference suppression anyway.

As for EMC susceptibility, again J.P. will avoid the radio that he has heard will only receive Radio 2 LW if it is in a steel shed down the garden!

References taken from "Handbook of Wireless Telegraphy Volume 1" published by HMSO 1938 paragraph. 167 paragraph. 95 paragraph. 102

Andrew Denham
By email

More history
I thoroughly enjoyed reading the well researched and illustrated historical article in the August 2003 EW issue on the VE301 valve radio receivers of the Third Reich. It is revealing to look back at the often elegant techniques used to solve design problems despite the limitations of the components available at the time.

What is also striking is that the valve design goals where achieved with a very low component count - size and cost prevented 'Norwegian coast' designs (apologies to the late D. Adams!).

The nostalgic days of World War II were well before my time. I passed my formative years in the transition from valve to semiconductor technology in the 1960's and remember well the problems these fragile germanium newcomers provoked - do you remember the OCl series ??? It is amusing now to look at such details as the influence of valve chassis design culture on the early attempts at portable transistor radios, each stage often being an isolated island of components as if there was a phantom valve base. Compare that to a modern digital PCB of today!

There is much wealth and wisdom in the fascinating legacy of a century of electronics development. The scope for further historical articles drawn from this heritage can only be limited by your enthusiasm to print them, so please, more of that kind of thing!

Peter Sullivan
Geneva
Switzerland

Content and Focus
I have been reading WWW, E & WW and now EW as my magazine of choice since 1957 and have seen many changes in its presentation and content! Normally I'm one of the silent majority, but now feel the need to comment on this apparently vexatious matter. My latest copy is July due to normal subscription delays to NZ, so I hope that my comments are still appropriate.

Whilst I accept that change is constant and that any magazine, journal or periodical must adapt to survive, there are, I submit, some notable aspects that must never be seen as compromised. These would include technical accuracy and timeliness. Two areas that EW seems to handle well I think. There also, seems to be a fair balance between non-computer based and computer based articles or those with a high degree of academy. If there's a lacking in any way, for me, it would be in the areas of 'High End' projects, especially those of the calibre of Cyril Bateman's "Capacitor Sound", or Doug Self's Audio projects and J.L. Hood's work.

An area that EW can serve well is to support solid discussion on the many contentious issues often given only a relatively fleeting coverage in Letters. With the many skilled writers and contributors at the disposal of EW, I could imagine some lively, interesting and engaging articles. There is no other technical journal that does this that I know of.

Looking back and doing a brief check of my library, between 1957 and when WWW became E&WW, the things most evident were its thickness and the relatively constant proportionality of articles to total pages along with the preponderance all thing British. In 1978 there were 128 pages and 44 of them were technical, in 1986 perhaps the publisher was hard up as it only had 96 pages and a similar proportion of technical, and in more recent times 2002 there were 55 pages of which 25 were technical. The other notable aspect is the value for money - this appears not to have markedly changed in relation to technical content. Say 40 pages for £2.95, which equates well to the costs of living during the past 20 years or so - in May 1981 it was 60 pence. Also noteworthy in terms of value for money is my current issue (July) of the journal, for of its 64 pages, no less than 40 are technical if you count the letters! Value increased?

However, looking back again over that period, there seems not to be any replacements for regular small feature writers like 'Vector', 'Cathode Ray' and SW Amos or indeed the Lab Technician/projects manager. I note that many technical magazines have their own Lab and most have articles written from, or at least verified from their specific labs. Perhaps EW's lab would have a lot to do with proving some of the letter discussions as mentioned. It could also enhance the credibility of some projects and become a reference point for those seeking advice on a project.

One of the dangers of change from a readership point of view, might be evident if the journal were to become too market oriented, by having larger numbers of advertisements or become a medium for specialised promoters like test gear manufacturers. For me, the current exposure of such material is now borderline. I know it helps to pay the bills, but we the readers, should not have that foisted upon us simply because of costs. I would be one of those who would approve an increased subscription rather than see the magazine degrade in that way. As an aside to this issue, are there any possibilities of any kind of relatively neutral
LETTERS

Automotive audio systems

I have enjoyed very much Mr. Catt returns in March issue and that Electronics World is appealing. Not a subscriber as yet but a buyer at the bookstand. When is the time that some writers will contribute to the automotive audio systems? The in-car-entertainment, manufacturer basics, like DIN connectors used and to interface such a task. Computer has so much learning criterion than I will see in automotive audio system. In bookstores are many computer books than any other books on the stand. Where is auto audio? Thank you for the great work.

Tony Neiburg
St. Paul
Minnesota
US

Sounds like a gauntlet being thrown down to me - Ed

De-bounce II

With reference to Alan Bate’s comments on Deng Yong’s switch de-bouncing circuit (Letters, September 2003), would it be stating the obvious to point out that Mr. Yong’s circuit will work with a simple ON/OFF switch, whereas the standard bistable circuit requires a two-way switch? The more complex circuit would be useful when adding-on circuitry to an existing piece of equipment, or in situations where a two-way switch is not feasible.

Ronald Ogilvie
Killearn
Stirlingshire
UK

Design for EMC

In his letter “Student knowledge and EMC” (EW Sept. 03), Cyril Bateman identifies one of the most significant sources of interference - EMC filters. These devices are designed to reflect unwanted energy back into the conductors. Since this energy is not dissipated in the conductor resistance, it radiates into the environment and reappears as unwanted interference. The culprit circuit may be immune, but what about other equipment in the vicinity of the supply line?

Mr. Bateman treats the topics of ‘student knowledge’ and ‘EMC’ as two entirely separate issues, thereby highlighting the fact that no one really expects young graduates to have any useful knowledge of electromagnetic compatibility. It is assumed that such knowledge can only be gained the hard way - through experience.

This situation exists in spite of the need for a clear understanding of the phenomena by anyone who designs or uses electronic equipment. If no one is provided with the basic analytical tools when they are introduced to the subject, then very few are likely to discover those tools for themselves when faced with a real problem, especially when the budget is tight and the timescale is limited.

The young engineer is confronted with a virtual mountain of literature on the subject of EMC and is all too easy a prey for those who provide courses and seminars of dubious value at extortionate prices. The result is a sense of extreme frustration. Ivor Catt indicated this in his article in the March 03 issue of EW.

Bateman in error - shock

Your current EMC debate is unlikely to resolve satisfactorily when even (respected) Cyril Bateman seems to be in error. In his letter of your September issue he states, “An EMC filter in contrast, while it may still produce 50dB attenuation, dissipates almost no energy.” Well, no, actually. A correctly designed EMC filter absorbs energy with a frequency proportionality inherent of ferrite loss characteristics, and after ferrimagnetic resonance the impedance becomes ostensibly resistive. Check out ‘Ferroxcube’ (now Yageo apparently) publications for elucidation. Of course pure reactance can play a part whereby the energy is reflected back to from whence it came, hopefully a sealed unit, but this is a very dangerous practice upon which to rely. My July 2001 article “Elastic Capacitors” alludes to the pitfall, as does Cyril, of the dubious practice of slapping in inductors in the blind belief that it will probably help.

The efficacy of the absorption is easily demonstrated. For instance, many years ago I designed a switcher of only a few watts and cleaned the spikes with a ferrite bead. It got reasonably warm. On a more recent 60 watt design, I burned a finger tip on an inappropriately selected filter ferrite when searching for what was smelling, and no it wasn’t copper loss.

Regarding Cyril’s appraisal of domestic washing machines having included EMC filter solutions for the last 30 years, I don’t think my last machine was aware of this. My scope protested audibly when the thyristor spike generator kicked in. Could have fried pies on the radiators.

A S Robertson
Girvan
Ayrshire
Scotland

technical sponsorship?

There would I suggest, be a quite a large readership who read this Journal, purely for its technical content and detailed approach without ever making a project, often using it to keep up to date by, or as reference. For these readers the broadest technical content will always be welcomed and to limit it by concentrating on what is purely vogue or topical might not be useful.

In general, I applaud EW for its breadth and depth and hope that it will continue to maintain its standards and even improve upon them with a resident Laboratory and Manager.

Terry Bicknell
Waikanae
New Zealand

Glass Houses

I would not judge Alan Bate MIEE as suitably qualified to comment on the contributions of others (Letters, EW, September 2003). I base this judgement on his description of a simple(sic) two-gate latch. He explains its operation using three statements - and all three are wrong.

The latch (as drawn) does not set at power up - it resets. The latch does not change state as soon as contact A momentarily opens - it changes state when contact B momentarily closes. The latch has not already set by the time the switch pole is contacted B - it is still reset.

In the same issue R Harris concludes his(?) letter berating Electronics World for ‘... rather sloppy English...’ (citing a recent spelling error). However, his previous paragraph ends with a far worse example of sloppy English - ‘...any potential contributors out there.’ The grammar is passable but worse example of sloppy English -‘The young engineer is confronted at all, the correct word is 'prospective'. This is because we are all potential contributors by virtue of being able to write in English but, since most of us are insufficiently informed on the subject matter, we would first require a considerable period of study, so few of are prospective contributors.

I don’t object to criticism but I do think that it should be properly informed.

Richard Burlfoot
Yate
Bristol
UK
Errors, nonsense and 'The Question'

It’s not only my handwriting that gives rise to errors. John Barrow explained in his article ‘Glitch’ (New Scientist, 7th June 03) that superior intelligences in a multiverse model – an extension of DeWitt’s ‘many worlds’ interpretation (1973) are not immune from this phenomenon. Not only are they inevitable; they are necessary: for economical reasons (in terms of computing resources needed) and for survival (IGUS Information Gathering and Utilising System, Gell-Mann and Hartle, 1989). Paul Davies believes that “our living in a fake, simulated reality is a nonsense”, although the model is popular with many theorists.

If qPCs (quantum personal computers) become available we won’t even need to switch them on – or buy them! Whether or not we’ll need VDU/Word/email with this set-up is beyond my ken. Perhaps Ivor could explain?

Sébastien’s observation that “0.5% distortion is more appealing than (nearly) none at all” is something to think about, especially when you consider all the time and effort that has been devoted to eliminating it!

When you wrote that you “will draw a line under the EMC debate” at the end of Ivor’s letter about the Catt Anomaly, I got a bit confused! No big deal.

The EMC debate has had a good airing and probably deserves a rest, but the same cannot be said of the ‘Catt Anomaly’ which may be closely associated with one of the strangest problems that has cropped up in theoretical analysis to date, that is: - time reversal, or ‘time runs backwards’. Martin Gardner has tackled this problem in his latest book “Are Universes thicker than blackberries?”

The idea stems from the work of Kornhuber (1976) and Libet (1979), which Roger Penrose discusses (at the end of his books) in conjunction with consciousness and language. The main findings are that (i), a and individual’s brain response precedes a stimulus; and (ii), there is a ‘dead time’ of about 0.5 second. Little or no mention has been made to the relationship between 0.5s and 2Hz –

except in EWP! The findings of brain research - in some cases, using electrical probes - was summarised by Susan Greenfield in The Mind Game (BBC 2 TV) in 2002: -

(i) time runs backwards
(ii) all history is pre-recorded in the brain
(iii) the brain samples the record at intervals to create a sense of time, objective or whatever?

These ideas are not new! (vide refs 2,4)

One of the most exciting developments comes from the findings of Vitor Ramachhandran, who appeared in The Mind Game. In the last of the Reith Lectures (BBC Radio 4) for 2003, he suggested that “the origin of cognition lies in the sounds found in the language centre of the parietal lobe... and probably, quite a small number”. Curtius listed 664 basic phonemes (roots and stems) of which 17.3% involve Kappa and most conform to Zipt’s law and Shannon’s Eutropic order for intelligent interaction. ‘Kai’ is the locative pronoun from the Skt. ‘kas’, still used in Cyprus, which lends itself to the Latin ‘que’ (kwa); Italian lost the ‘w’ whilst German and English lost the ‘k’.

Tracing ‘kai’, ‘su’ and ‘tte’ to its roots is easy – ‘Bruton’ (fermented wine) is more involved. If it’s from Sanskrit ‘brahm’, by loss of aspirate (h), it should have carried the meaning ‘whirring whirling motion’ rather than ‘whirring sound’ or ‘breath’. Hebrew, however, uses HeBel and HeVeLe for ‘whirling whirling motion’ in Ecclesiastes 1:2 “Vanity of vanities... all is vanity” (KJ), but retains ‘h’ in BaHiR. 'Kai' may be quite common, however, even in ‘normal’ people! – including physicists. If this mechanism is coupled with the many-minds interpretation of Everett, elaborated by David Deutsch (in 1985) in a bifurcating model, as against the many worlds interpretation of DeWitt (multiverses), which Paul Davis thinks is nonsense, it’s possible to see how the contradictions in modern physics may be resolved. This will create problems, however, for electronics theory where frequency and time are inversely related in standard models, which brain researchers assume! In bifurcating brain processes, period doubling is ‘perceived’ as frequency doubling. This is ‘real time’.

To a certain extent, the reasoning in ‘The Question’ and in Nigel Cook’s articles (The Electronic Universe) about ‘awareness’ of an open circuit are soundly based – it’s not nonsense. Electrons, photons, beables (John Bell’s), Hu particles are aware. That’s what many leading physicists believe. David Bohm and Basil Hiley discuss this in ‘The Undivided Universe’, Routledge, (1993) in chapters 13, 14 and 15.

Lit

G3OMD
Tony Callegari BSc., MPHIL., (Lond) Much Hadham Hertfordshire UK

A model handwritten letter complete with an ‘error code’ column! My wife much appreciated it! – Ed.
to go hunting for back issues, the information is available at the website www.designemc.info.

The suggestion that any EMC problem could be analysed by any electronics engineer will be greeted with extreme scepticism; especially by those who have been steeped in the propaganda that it is an arcane subject whose secrets are available only to the gifted few. However, anyone who overcomes this scepticism will be able to visit the site. It contains an e-mail address for any comment.

Ian Darney
Kingswood
Bristol
UK

Google search
Ivor Catt suggested (EW Sept 2003 p.57) a Google search on "Pepper FRS". I did this and am pleased to have taken his advice; I spent the next three days virtually glued to my screen! Incredible stuff.

Charles Coultas
Wokingham
Berkshire

Self replies
In answer to William C. Cross' letter last month - if I understand this suggestion correctly, it could indeed be set up to make the input FET drains track the gates and so render non-linear capacitance here innocuous. This does however still leave you with the greater non-linearity of a FET input stage to grapple with, plus the need to use expensive dual devices to cope with the input offset voltages.

Douglas Self
London
UK

Meaningless algebra
I must apologise that until now I have not had time to respond to Mr. Koren's letter published in the August EW.

That someone can dismiss algebra as 'meaningless' needs no observation from me but Mr. Koren's misunderstanding regarding experimental error does need comment. Since he has declared his algebraic scepticism, let us work in the numeric field.

Suppose a Wheatstone Bridge uses all 1% resistors and in a particular job is balanced at 4321 ohms. At most this value could be 4364.21, an inflation of 43.21 ohms. Of this the error in the thousands is 40, in the hundreds is 3, in the tens is 0.2 and the units contribute 0.01.

However, if only 10% resistors can be found for use in the units decade, the 1 ohm resistor could have a maximum value of 1.1, which would now contribute 0.1 ohms to the total of 4364.3. Thus the overall accuracy would change from 1% to a maximum percentage error of 1.002%, i.e. practically no change at all.

Consequently there is every reason to have high specification resistors in the upper decades while lower tolerance components can be used in the units decade since they will contribute less significantly to errors overall.

It is with this in mind that manufacturers of test gear which use digit displays often declare their equipment to be '1% accurate, plus or minus one digit'.

The only time that using 10% resistors in the units decade would be significant is when the bridge is balanced at 000X (X between 1 and 9) but this would represent poor use of the divide-by-1000 facility designed as part of the bridge circuit in the published article.

David Ponting
Clutton
Bristol
UK

Understanding ADCs
I am referring to the article "Understanding inputs to ADCs" by Mr. Daniel Malik in the June 2003 issue.

In the example given of the change in potential (voltage) when a 5pF charged condenser (capacitor) is connected in parallel with a discharged 0.5pF. It is stated that the potential will drop to 95% of its original value.

My calculations below disagree. Assuming the condenser was originally charged to 1V.

Ct+Cp=5pF (charged to U=1V)
Ct=0.5pF (discharged, connected in parallel)
Q=U'C=5e-12 C (original and final total charge)
U'=Q/(Ct+Cp)+Cx U'=5e-12/5.5e-12 U'=0.91V (final potential)

Also it is stated that 1/2(Ct+Cp)*Un2=1/2(Ct+Cp+Cx)*U'n2. This implies that the energy is preserved after connecting the charged and discharged condensers in parallel. To the best of my knowledge, this not so.

I have not read the whole article, so I cannot comment any further.

George Nole
Wytaliba NSW Australia

July cover
No doubt you have been asked this many times, but I haven't spotted any reference.

What is the location of the spectacular storm photo (cover and inside article) in the July issue?

Alan Watling
Colchester
Essex
UK

Unfortunately, the image came from a generic picture CD that did not have any info as to the whereabouts of the satellite - Ed
When trying to calibrate a watch or any other device that produces a one cycle per second pulse it becomes very difficult, if not impossible, to measure and adjust using standard 'off the shelf' equipment. The oscilloscope is of no use as the graticule spacing resolution is unreadable when trying to calibrate to 0.001 of a second in the 0.2 – 0.5 scale. A similar problem occurs with the frequency meter, as frequencies below 10Hz cannot normally be measured.

However it is possible to make a low cost unit that can measure 1Hz to a resolution of 1000th of a second.

Measurement basics
If the pulse to be measured is used to turn a fixed frequency count on then off at, for example, 2000cps, then the count available at the end of one second should be 2000.

If the pulse to be measured produces a count that is above or below the 2000 expected - then the pulse is either slower or faster than one second. Note: a slow pulse will give a number greater than 2000.

By using a homemade pick-up coil and an op amp, pulses can be detected from most quartz clocks that have hands. These clocks operate by pulsing a small solenoid at one-second intervals.

The pulse to be measured may not be an exact square wave, as in the clock example, so the unit must take this into account.

The pulse width shown in Fig 1(B) is 1 second overall, but looks very different to A.

To measure the counter is cleared every time the pulse goes low. There is no stop counter.

Some sort of display is required to show the results of the measurement. Using a 4-digit display would be overkill. A 10 segment Bar graph display is cheaper and produces an easier to understand readout.

The unit could be produced using several discrete devices including decimal counters, and IC gates but a better way is to replace most of these with just one microcontroller. The other advantage with this approach is that any frequency can be measured with extreme accuracy, simply by changing the software.

Micro-controller
There are many cheap micro-controllers on the market. This design needs one that can drive LEDs directly, has an internal timer and a prescaler. The one chosen meets this specification, a Microchip 16F84. This controller also has re-programmable code memory and is cheap and readily available.

If you have never worked with micro-controllers, this is an ideal choice as there is a huge amount of information and examples on the microchip website www.microchip.com.

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**Fig. 1. Pulse width comparison**

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**Fig. 2. 10 segment bar graph display.**

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**Fig. 3. Complete circuit.**

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