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Consumer leads the way

Ten million Apple iPod MP3 players, 680 million mobile phones, 60 million digital still cameras and over 50 million game consoles were sold worldwide in 2004 alone. Other consumer products also selling like hot cakes are widescreen TVs – plasma, LCD or CRT, projectors and home cinema systems. By 2006, IDC research states that some 450 million households will have a DVD player.

What a staggering amount of consumer devices that represents. And yet, despite the overwhelming evidence of the importance and impact of home electronics on our industry, some people still refuse to believe that this area of electronics is the key driving force today and obstinately continue to dismiss this vein of the industry as a "fashion fad", not worthy of being even associated with the "true" electronics of yesteryear.

Things were undoubtedly different in the past. New technologies were created for (more or less) the sake of it: developers proved how well they could push the boundaries of physics.

Nowadays, that technology push has been replaced by ever-growing demands from the consumers themselves. There's been a clear change in the way the electronics industry functions compared to the past and that change has been driven by the consumer.

Consumers' demands for convenience (easy connectivity, communication, portability) and low cost are certainly driving innovation in the electronics industry.

Nearly all portable, consumer devices sold on the High Street today have high-resolution colour screens, high energy-density batteries and chips supporting several different types of communication protocols. There are new coding/decoding technologies, lower-cost yet significantly improved microprocessors, DSPs, FPGAs and even new breeds of programmable logic devices (such as structured ASICs). New power and battery management techniques, new interfaces and lower supply voltages driving even more complex circuits are just some of the innovations being rapidly adopted in this space.

How can anybody refuse to see that as a positive trend: it drives innovation, it drives productivity, it creates jobs and stimulates the imagination?

Anybody who remains insensitive of the consumer gadgetry that surrounds us in every sphere of our daily lives and who continues to dismiss the importance of such gadgetry to driving innovation – is simply out of touch with the industry today.

Svetlana Josifovska
Editor
Motorola backs PCleXpress for VME platform

Motorola’s new Embedded Computing and Communications Group (ECCG) is backing the PCI Express protocol for its VMEbus Switched Serial (VXS) interconnect, in a move that gives the technology a significant boost and hits at the competing RapidIO technology. The group is the largest embedded board maker following its takeover of Force Technologies last year.

The new VXS technology (previously called specification 4.1 from the VME Industry Trade Association — VITA) adds switching connectors to existing VME64 board designs but does not specify which protocol should be used. RapidIO had seen it as a natural application area, but has been hit by delays over the last year and board makers such as SIIS Technologies supporting InfiniBand and now Motorola supporting PCI Express.

“Selecting PCI Express as our VXS (VITA 4.1.4) implementation is an important extension of the application of PCI Express,” said Wendy Vittori, Motorola senior vice president and general manager of ECCG. “We are bringing the benefits of this standard, broadly-available technology to the new embedded communications computing segment, creating more effective, highly integrated platforms upon which our customers can quickly build applications.”

“A primary market for PCI Express is in the defense and aerospace systems,” added Vittori. "Motorola has received a contract to use PCI Express Technology in the next generation of military electronics, and we are working with the Department of Defense to ensure that our products and solutions support their specific needs.”

New technologies push VME roadmap

Following the success of the high-speed variant of 64-bit VME, there are new specifications emerging for different parts of the embedded market. While the VITA41 (VME Industry Trade Association) specification, VXS, provides a limited amount of switching between VME cards in an existing VME rack, the VITA46 specification aims to provide significantly more switching via dozens of serial links, with enough combined bandwidth to make distributed switching viable for high-performance applications.

VXS is set to be a general purpose specification, while, at this point, VITA46 is aimed more at the military and aerospace applications. The problem is that not entirely backward-compatible with VME64, as it has to use a hybrid chassis with separate connectors for VME64 and VITA46 cards. This has a series of VITA46 connectors and a series of VME64 connectors, and cards for one specification will not fit in the connectors for the other. The backplane then consists of both the VME64 lines and the VITA46 lines, making this more complex to produce.

This means that there isn’t the traditional flexibility of any card in any slot, but system developers see the VITA46 systems as being custom developments with a set number of each slot for a particular application. The strength is that existing VME cards, especially custom I/O cards, can still be used in the system, preserving the previous investments and cutting the cost of the development. The VITA46 specification also includes a 3U format for more compact systems that are being demanded in military and aerospace applications, rather than the existing 8U VME systems. It also provides I/O connectors at the rear of the cards so that I/O can be run over the backplane, rather than having to come out in cables from the front of the card, making the systems more rugged.

Yet another variant, VITA48, is coming through as critical for providing the thermal management to take full advantage of the next generation of hot processors, many with dual cores. VITA41 VXS systems are emerging this year from manufacturers such as Motorola, while VITA46 and VITA48 are emerging in systems from companies such as Mercury Computer Systems by the end of the year.
**Switch marks take off for RapidlO infrastructure**

Tundra Semiconductor has launched the first RapidlO switch chip that marks the start of the real development of this standard’s infrastructure. While there have been some chips with RapidlO interfaces, linking them together has required FGAs or custom ASICs. The Ts668A serial switch chip is being used to provide RapidlO switching on different platforms, from VME to Advanced TCA, with an aggregate bandwidth of 80Gbit/s. The non-blocking switch buffers at the output and so can stream a packet directly through the switch – packet cut-through – to reduce system latency. It supports up to eight 4x links or sixteen 1x links through a SerDes interface.

"The Tundra switch marks the beginning of a significant year for RapidlO, with more than 20 RapidlO-based products scheduled for introduction including switches, processors, bridges, FGAs, silicon IP, boards, software and tools," said Iain Scott, the new executive director of the RapidlO trade association. "The debut of these products throughout the year will ensure OEMs have the devices they need to speed development of RapidlO-based solutions for the embedded market."

The Association points out that it is ahead of other technologies such as the ASIC (Advanced Switching Interconnect). "The release of Tundra Semiconductor’s Ts668A Serial RapidlO Switch provides RapidlO a significant head-start over ASi, which is not expected to be releasing first silicon until the third quarter of this year," said Eric Mantion, senior analyst at market researcher In-Stat.

"The RapidlO technology is an open standard and is already included as an interface on some PowerPC-based processors from Motorola, such as the dual core MPC8641D. This is aimed at the networking, telecom, military, storage and pervasive computing applications, with two PowerPC 600 cores, each with the Altivec DSP coprocessor. Texas Instruments has also launched a digital signal processor with built-in RapidlO interface, the TMS320C6482. This supports four serial 1x links that can be combined to form a single 4x link, allowing connectivity to multiple RapidlO-enabled devices or to one high bandwidth RapidlO device. Link data rates support data bandwidth from 1Gbit/s to 10Gbit/s. The TMS320C6482 is an important component that facilitates higher speed interconnectivity and more reliable performance in the design of advanced communications systems," said Scott.

**PCIe moves into embedded**

PClExpress is starting to move from the high-end PC and server market into the embedded world, say its supporters. The COMExpress specification for Computer-On-a-Module is set to be released in April or May this year, with revision 1.1 of the PCIeExpress base specification (approved early this year) and compliance testing starting before the summer. The first standard COMExpress products are expected as soon as May, although there are already pre-compliant products from manufacturers such as Kontron and RadiSys.

To boost the infrastructure for PCI Express (PCIe) embedded designs, US-based PLX Technology has been sampling a 16-lane switch to customers over the last few months, which it demonstrated at the Embedded Young’s senior product marketing manager at PLX.

"Sampling of the PEX 8111 and the availability of development tools, such as the development kit for the bridge, marks a significant point in the deployment of PCIe Express; manufacturers now have the ability to evaluate PCIe new.

**ADI technique makes even smaller radio chips**

Analog Devices has showcased its new Othello-G radio chip for GSM/GPRS applications at the 3GSM World Congress. The chip uses 75% fewer components than its previous version. Nevertheless, it supports full quad band operation and integrates nearly all the components for a complete cellular handset radio design onto the single chip with a sensitivity of around -109dBm. The only components that are required are four non-critical decoupling capacitors, SAW filters and matching components, and a power amplifier.

"The radio uses direct conversion, zero frequency IF techniques, which ADI pioneered in 1999. Initially, many thought it would impossible to utilise this technique because of the large DC offsets that would appear after amplification. However, by incorporating many new design features, including ADCs and DACs to monitor and compensate for these offsets and the use of differential signal paths, the system has been successfully implemented. A further problem envisaged was that of the mixer breakthrough of the local oscillator signal that would interfere with mobile handsets in the vicinity. This has been overcome using a technique known as a regenerative divider, also pioneered by ADI.

One of the big advantages of using direct conversion techniques is that it is very easy to incorporate multimode operation of the phone as well as multiple bands because filtering is easier. As a result, it is possible to construct the complete radio section of a quad band mobile handset including the synthesiser, RF section, PA and all the filtering within a board area of 1.5cm2."

**New touch control system**

US firm Attus Technologies has demonstrated an innovative control system for use in mobile phones. With the man-machine interface on handsets becoming more important as their functionality increases, new ways are required to be able to control them easily. Attus has developed the "Wings" intelligent touch-processing system, which converts finger movements easily into commands for the phone. The system is based on a small, thin sensor (typically less than 15x5mm in size) and specialised processing software. Attus even has a fingerprint with a robot finger that can be used to unlock the phone and other security features. When the fingerprint is recognized, it is able to unlock the phone and other security features. By printing a finger over the sensor, the phone is able to access the owner's fingerprint. This can be used to unlock the phone and other security features. Using the prints from different fingers on the phone can be used to unlock the phone and other security features.
Zoran moves to Approach 4c

Based on the already successful ZR34525, the new ZR34527 improves system aspects such as power consumption, board space and cost, all of which are crucial in the design of mobile phones. The processor provides integrated SDRAM, MPEG-4 video decoding, 3Mpixel camera capability, 3D games and 3D audio effects, MP3 and AAC+ playback.

For these capabilities, Zoran used advanced imaging, video and graphics hardware accelerators and a comprehensive set of interfaces. Among them are

- Integrated SDRAM to provide comprehensive set of interfaces.
- Comprehensive set of accelerators and a graphics hardware module for mobile phones that would allow the design of mobile phones.
- Improved antennas - or advanced antennas - or two-halves antenna, we have a two-part antenna, or a dipole, or a balanced dipole, or two monopoles - you have to redesign the antenna because when you put it into torque (when the phone is held in hand), they de-tune and that makes them inefficient.

The module that also contains the radio, baseband and transceiver, sits on top of the lower module, which is virtually independent of the ground plane. Additionally, being placed into a single module, the transmission line between the antenna and the radio is a lot shorter, too.

The module also contains the radio, baseband and transceiver, sits on top of the lower module, which contains the radio. The lower part is refloved onto a PCB plane.

Better phone efficiencies promised by a dipole

Antenna, the Cambridge-based developer of high-directivity antennas, has created a drop-in antenna module for mobile phones that offers higher efficiency under torque and an improved specific absorption rate (SAR).

When you put it into torque when the phone is gripped, or the phone is gripped, or the chassis/ground contact with the chassis of the function, you have to redesign the antenna because when you put it into torque (when the phone is held in hand), they de-tune and that makes them inefficient," said Simon Kingsley, Antenova's chief scientist and lecturer at Sheffield University. "With our two-halves antenna, we have a balanced dipole, or two carefully balanced, unbalanced antennas."

Kingsley said that the torque efficiency would be up by at least 30%. This could lead to a 50% longer talk time.

Mobile phones typically use monopole-type antennas, which use the phone's chassis as a ground plane. But once the phone is gripped, or the chassis redesigned, its resistance changes, which, in turn, detunes the antenna. Since Antenova's solution is a balanced self-complementary two-part antenna, or a dipole, the impedance is virtually independent of the ground plane.

Additionally, being placed into a single module, the transmission line between the antenna and the radio is a lot shorter, too. The module also contains the radio, baseband and transceiver, sits on top of the lower module, which contains the radio. The lower part is refloved onto a PCB plane.

Electromagnetic Compatibility

- Consider EMC at the design stage to stop interference at the source.
- When designing PCBs, avoid long tracks, use consistent and unbroken ground planes and decoupling capacitors.
- Shield the PCB where possible.
- Shield the enclosure wherever possible.
- Use shielded cables where necessary and terminate the shield at both ends.
- Avoid large apertures and holes in the enclosure.
- Remove the paint from unwelded points in enclosures, i.e. I/Os.
- Use EMC gaskets for uneven points.
- Ensure all input/output metallic connectors have good all-round contact with the chassis of the host unit.

Lloyd Research Ltd has been designing gang programmers since the early 1980s. The M9000 is an advanced version of the 'industry standard' L9000 which has been used extensively for high volume programming in the telecommunications, automotive and TV manufacturing industries.

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Structured/platform ASICs have arrived

With the current buzz going on about structured/platform ASICs, the question many have been asking is, "Will this new breed of ASIC be successful?" The answer is, "Absolutely." The era of structured/platform ASICs is here with a growing number of customer success stories across the globe, major system customers engaging multiple designs and new vendors entering the field each year.

This middle ground between standard cell ASIC. The up-front structured/platform ASICs are not just a buzz word, but a technology offering real benefits, says Gary Meyers. They are no more and no less than a natural fit for timing problems that have resulted in cost savings alone makes structured/platform ASICs a very attractive alternative for many design teams. Customised design tools that directly target and understand each unique structured/platform ASIC, typically enable 15-20% better speed and area improvements over conventional design flows and, thereby, bring results much closer to that of standard cell ASICs. They also solve the timing closure problem through the use of physical synthesis techniques that are tightly correlated to the final place-and-route timing. In addition, they ensure that the designer obeys vendor-specific design rules, which requires extensive signal integrity checking. High performance, low cost and shorter time-to-market with greater schedule predictability cannot be provided by generic tools. This is why all major structured/platform ASIC vendors have ensured that customised physical synthesis tools are available for their architectures.

Early on, it was predicted that structured and platform ASICs could resuscitate the ailing ASIC business by making deep submicron ASIC technology available to smaller companies. It was predicted that structured and platform ASICs could resuscitate the ailing ASIC business by making deep submicron ASIC technology available to smaller companies.

Structured/platform ASICs are also benefiting from a major shift in semiconductor end markets. The Semiconductor Industry Association (SIA) states that 50% of semiconductors shipped in 2004 will end up in the hands of individual consumers: from digital cameras to DVD players to increasingly cheap storage devices and cable modems. In the consumer markets, performance, low bill of materials, small form-factor and long battery life of the end device are vital. Structured/platform ASICs have indeed arrived.
Relays

The silicon path of relay technology

Richard Thornton, senior general manager at Matsushita Electric Works in the UK, discusses the development and features of modern switching solutions.

Any engineers believe that in an age of the microchip and its modern electronic circuits, relays no longer have a role to play. But, this is not the case, since electrically-controlled switches are still used in many applications due to their relative simplicity, long life and reliability. Moreover, recent semiconductor technology has provided significant changes to the switching output circuits. This article discusses the development and features of different switching solutions and explains in-depth two different semiconductor-based relay types: the MOSFET-based (PhotoMOS) and triac-based (SSR) relays.

An indispensable part

A relay is an electrical component which output circuit(s) is closed and/or opened depending on application or removal of a suitable voltage to the electrically insulated input circuit.

Relays are, in fact, the optimal switching solution for a wide variety of applications in industrial, consumer, telecommunications, measurement, automotive and other sectors. Many industry applications are completely based on the use of the ubiquitous electromechanical relay. Telecommunication line switching for instance is an area that, against all predictions, has continued to rely on the 2-pole change over electromechanical relay to make and break line circuits reliably. Admittedly, the size of the relay has dramatically reduced from the old PC03000 design that was the mainstay of the BT network (until the introduction of System X in the mid-1980s that used miniature BT47 relays), to the current micro relays that allow 64 lines per switching card. However, the relative low unit-cost, reliability of contact resistance, electrical and mechanical life factors, durability under overload conditions and ease of supplying the necessary control factors have made the electromechanical relay an indispensable part of the modern telephone exchange.

Modern test equipment requires many of these features, along with the added qualities of reliable low-level signal switching and electrical isolation, in order to allow distortion-free paths to the measuring circuits. For many years, the electromechanical relay was the only choice for realising such a switching function for an electrical output circuit, which results from the relative movement of mechanical parts.

Semiconductor technology has, however, started to catch up with its electromechanical counterpart. During the last two decades, thanks to the emergence of semiconductor technologies, switching output circuits with an electrical control signal have also been realised by electronic, magnetic, optical and other means that require no mechanical movement.

Non-polarised power relay

The basic function of a non-polarised power relay can be described quite easily: voltage applied to the coil produces coil current that leads to a magnetic flux. Since the armature is mounted near the coil, there is no significant stray flux and the excitation flux encloses the system. Since the relay is excited, the corresponding contact system is actuated and the contact is opened or closed accordingly. While the relay is excited, the tension of a reset spring increases, leading to a reservoir of stored energy. When the coil applied voltage decreases, this stored energy causes the armature and the contact spring to return to the rest state. This is a simple example of a non-polarised relay.

Today, non-polarised relays employ an increased number of design details in order to offer advanced features. By employing permanent magnets in the magnetic circuit of the relay, efficient polarised relays offer increased advantages, such as reduced coil power consumption, higher contact force and bistable behaviour.

Due to arcs created during switching and mechanical effects, the electromechanical relay suffers wear during its lifetime. In order to prevent this, much consideration was given to the design of...
Relays

Overview of SSR relays

a contactless relay system using semiconductor technology. However, until relatively recently, the characteristics of a silicon-based electromechanical relay-equivalent could not match the required levels. Although in terms of life operations and speed of switching the silicon relay could offer improvements, it fell short in the critical areas of isolation, overload characteristics, contact arrangement and costs.

There are many circuit applications where older designs of silicon-based relays were ideal - for example, petrochemical plants, where intrinsically safe signals and power were used. Nevertheless, until recently, most applications were restricted to these core applications, where the requirements were for control of low-power loads. However, once moved away from these core applications, semiconductor relays could not be considered as a viable option.

Triac-based and MOSFET-based models

Modern applications use complex controls to enhance safety, implement convenient features and save energy. Control units use switches to control the sensors and actuators in a system. Since most applications are powered from the AC mains network, several AC voltage loads have to be controlled, e.g. heaters, lamps, motors, fans or valves. Switching used to be done with electromechanical relays, but these have recently been replaced with triacs because of their smaller size, longer lifetime, better switching speed and lower power consumption.

Several manufacturers, including Matsushita Electric Works, pursued various paths during the evolution of semiconductor relays and came up with two distinct product groups: MOSFET-based (PhotoMOS) and triac-based (solid state relays, or SSR). One system's strength is the other's weakness. Although based on different working methods, both types of semiconductor relays have galvanically isolated input and output circuits, whereby the output side optically detects the control signal from the input side, hence triggering the switching operation.

However, different technologies can be found in the semiconductor device for switching the output. PhotoMOS relays employ two MOSFETs. The construction of a PhotoMOS relay is, in principle, based on a light transmitting construction. The input pins are connected to a light-emitting diode (LED). This LED is located on the upper part of the relay and if a light signal is detected, the circuit is triggered. Three MOSFETs are used for the output, as is the case for the input. The output is activated in one of two ways: zero-crossing and non zero-crossing.

Zero-crossing: when the input signal is activated, the internal zero-crossing detector circuit triggers the triac to turn on as the AC load voltage crosses zero.

Non zero-crossing: when the input signal is activated, the output immediately turns on, since there is no zero-crossing detector circuit.

Care has to be taken when inductive loads are involved. Voltage spikes may appear across the output when switching to the 'off' state, as the SSR turns off when the load current is zero (which is not necessarily the case for the load voltage due to the phase difference of inductive loads). The generated voltage spike must not exceed the maximum load voltage rating or the dv/dt rating, which is the ascending slope of the voltage spike. The constructional distinction of the output element of PhotoMOS and SSR causes different preferred applications for the two semiconductor relay types.

Nevertheless, there are also common characteristics between the two types of semiconductor relays. Both are sensitive to over-voltages and excessive currents, which leads to power dissipation and triggering current, which can result in a snubber circuit being required (e.g. for a non zero-crossing phototriac (e.g. APT1221)).

As long as the relay operates in the 'on' state, the triac maintains this state until the load current crosses zero and the trigger pulse on the input is absent. Upon activation of the input signal, the output is activated in one of two ways: zero-crossing and non zero-crossing

The triac driver

A characteristic that is singular to the semiconductor relay is the possibility that the phototriac may be triggered to 'on' state accidentally. This can happen by exceeding the maximum blocking voltage or by applying very steep rising signals to the output. Such transient signals or noise may exceed the dv/dt rating of the triac and, hence, cause the device to proceed into 'on' state.

The dv/dt ratings of the triac and its driver are very important when switching inductive loads, since load voltage and current are not necessary in phase. Since a triac turns off when the load current is zero, the load voltage is not necessarily zero. Due to this, the triac may produce a sudden rise in load voltage to its own output, which may exceed its dv/dt rating. In order to increase voltage rise-time, a snubber circuit can be used.

In most cases, one snubber circuit will protect the main triac and the phototriac. It is helpful to look at designing a snubber circuit for a non zero-crossing phototriac (e.g. APT1221), which also protects the main triac in most cases.

Table 1: Differences between Electromechanical Relays and Semiconductor Relays

<table>
<thead>
<tr>
<th>Advantages</th>
<th>PMOS &amp; SSR</th>
<th>ESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact reliability</td>
<td>High breakdown voltage</td>
<td></td>
</tr>
<tr>
<td>Contact life</td>
<td>Low power consumption</td>
<td></td>
</tr>
<tr>
<td>Overcurrent protection</td>
<td>The circuit is protected against overload</td>
<td></td>
</tr>
<tr>
<td>Overvoltage protection</td>
<td>The output side protects against overvoltage</td>
<td></td>
</tr>
<tr>
<td>Overcurrent protection</td>
<td>Overload current protection</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection circuit necessary</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Protection circuit</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Differences between PhotoMOS and Solid State Relays

<table>
<thead>
<tr>
<th>Advantages</th>
<th>PMOS</th>
<th>SSR</th>
</tr>
</thead>
</table>
| Contact life | High 
| Contact life | High contact resistance | |
| Overcurrent protection | Overcurrent protection | |
| Protection circuit | Protection circuit | |

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>PMOS</th>
<th>SSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage current</td>
<td>High volume</td>
<td></td>
</tr>
<tr>
<td>Voltage sensitivity</td>
<td>High sensitivity to voltage sensitivity</td>
<td></td>
</tr>
<tr>
<td>Overvoltage protection</td>
<td>Overvoltage protection</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Overview of SSR relays

The optoelectronic device, in turn, serves as a control circuit for switching the power MOSFETs (and therefore the load circuit). These DMOS transistors are source-coupled, because of their intrinsic bulk-drain-diode in connection with drain and source. Thus, a single transistor is only capable of switching a DC voltage, since the diode will become forward-biased if load polarity reverses. So, using a PhotoMOS relay for switching AC voltages requires two source-coupled DMOSFETs. The output MOSFET's on-resistance and maximum load voltage are a trade-off. For this reason, load current (limited by on-resistance and the resulting power dissipation) and load voltage are related to each other. Corresponding PhotoMOS relays either have a relatively high load-voltage with a smaller load current, or vice versa.

Solid state relays

When it comes to switching main network voltages and high currents, SSRs surpass PhotoMOS relays. The SSR is composed of a low current control input side (typically 5mA to 20mA, depending on the type of SSR) and a high current load side, whereby the relay provides an electrical I/O isolation of several thousand volts. When current flows through the LED on the input side, it emits light, which is detected by a photo diode (e.g. APT1221) and is used to trigger the gate of a larger triac that switches the load in the presence of a load voltage and load current. The ISO (input to output) is activated in one of two ways: zero-crossing and non zero-crossing.

Non zero-crossing: when the input signal is activated, the output immediately turns on, since there is no zero-crossing detector circuit. Care has to be taken when inductive loads are involved. Voltage spikes may appear across the output when switching to the 'off' state, as the SSR turns off when the load current is zero (which is not necessarily the case for the load voltage due to the phase difference of inductive loads). The generated voltage spike must not exceed the maximum load voltage rating or the dv/dt rating, which is the ascending slope of the voltage spike. The constructional distinction of the output element of PhotoMOS and SSR causes different preferred applications for the two semiconductor relay types.

Nevertheless, there are also common characteristics between the two types of semiconductor relays. Both are sensitive to over-voltages and excessive currents, which leads to power dissipation and triggering current, which can result in a snubber circuit being required (e.g. for a non zero-crossing phototriac (e.g. APT1221)).

As long as the relay operates in the 'on' state, the triac maintains this state until the load current crosses zero and the trigger pulse on the input is absent. Upon activation of the input signal, the output is activated in one of two ways: zero-crossing and non zero-crossing.

The triac driver

A characteristic that is singular to the semiconductor relay is the possibility that the phototriac may be triggered to 'on' state accidentally. This can happen by exceeding the maximum blocking voltage or by applying very steep rising signals to the output. Such transient signals or noise may exceed the dv/dt rating of the triac and, hence, cause the device to proceed into 'on' state.

The dv/dt ratings of the triac and its driver are very important when switching inductive loads, since load voltage and current are not necessary in phase. Since a triac turns off when the load current is zero, the load voltage is not necessarily zero. Due to this, the triac may produce a sudden rise in load voltage to its own output, which may exceed its dv/dt rating. In order to increase voltage rise-time, a snubber circuit can be used.

In most cases, one snubber circuit will protect the main triac and the phototriac. It is helpful to look at designing a snubber circuit for a non zero-crossing phototriac (e.g. APT1221), which also protects the main triac in most cases.
Relays

(see Figure 1). When using a zero-crossing phototriac (e.g. APT1211), the snubber network may be designed to meet the needs of the main triac, since the phototriac will only switch to 'on' state when the voltage across its output is nearly zero.

When designing the RC snubber network for non-zero-crossing triac drivers, detailed knowledge about the load is necessary. By knowing the power factor PF, one can easily calculate the maximum turn-off voltage that may appear across the output. Consequently, a more sensitive triac will require a lower gate current and a higher resistor value. This will force the value of the capacity to increase.

The snubber circuit in this example is designed to meet the dV/dt rating of the phototriac. If the dV/dt rating of the main triac is different, the worst-case value has to be chosen for designing the snubber network.

As can be seen above, there is no easy method for selecting the parts and their values for a snubber network. In particular, detailed knowledge about the load circuit and the power factor is required. These facts make snubber design empirical and result in detailed measurements to verify the parameters calculated. If the user wants to save work when designing the circuit, or has fewer parts and more space on his PCB board, they can choose an SSR.

Besides the phototriac and a main triac, these relays may have an input protection circuit, integrated snubber circuits and a varistor inside. It is possible to choose from various alternatives, based on particular design needs, e.g. space, number of parts, costs, input/output conditions etc.

Silicon supports relays

In summary, the advances in silicon technology achieved during the past decade have allowed a range of semiconductor relays to be manufactured that start to offer both, replacement and complementary product to existing electromechanical product. Only in one area – that of contact configurations – have designs still to be qualified in order that a comprehensive alternative can be offered in the majority of relay switching applications.

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Pb free - or not Pb free?

...asks the US military

By Keith Garnett and Tom Adams

The US military looks - cautiously - at lead-free soldering

While the world of electronics manufacturing is turning its attention - if not its enthusiasm - to lead-free processing, the US military is taking a somewhat different view. The US military establishment may, at some point, begin accepting Pb-free as a fact of life, but that time is not likely to arrive soon.

In terms of technology, the military is concerned with the same three Pb-free items that the rest of the world is focused on: the finish on lead frames, the joints between the component and the board, and the plating on the board itself.

The Defense Supply Center in Columbus, Ohio, known as DSCC, has responsibility for specifying parts, taking delivery from suppliers and stockpiling parts for use, as needed. The military perspective, though, is far more conservative than the consumer perspective. New consumer products have radically new designs appear daily, while the military, and DSCC in particular, is responsible for maintaining military electronics systems over periods of decades. A replacement for a navigation system for a helicopter, for example, needs to be available at any time during the service life of the helicopter and the replacement cannot incorporate any changes, however subtle, that make it unusable in the field.

Unlike Europe, the US currently has no federal guidelines mandating the use of Pb-free soldering in electronics, so the US military is under no legislative pressure to make the transition. That pressure is more likely to come indirectly from world markets. DSCC has hundreds of suppliers of components, subsystems and systems. Many of these suppliers also manufacture electronics systems that are marketed globally and for these suppliers the switch to Pb-free solders is a necessary element in maintaining their global competitiveness. For example, the great majority of US component manufacturers are currently involved in the research and pilot production needed to begin full-scale Pb-free component production. For DSCC, this broad move toward Pb-free processing means that the supplier of a particular component may one day be able to supply that component only in a Pb-free version.

Part of the current research by component manufacturers involves finding new non-Pb finishes for component lead frames and new molding compounds that will both adhere strongly to the new finishes and survive the higher reflow temperatures of Pb-free processing. As in Europe, US component manufacturers guarantee their components as long as they are reflowed under specified conditions. The critical temperature is 260°C, the temperature above which component damage becomes far more likely. Since reflow temperature is not uniform across a board, a small component in an exposed location might experience 260°C, even during conventional reflow using leaded solder. Manufacturers' guarantees typically account for this possibility by permitting exposure to 260°C for a period of four seconds.

"We expect to see the push for Pb-free to come first in the surface mount area - chip resistors, chip capacitors and ICs," said Dan Moore, chief of document standardization, DSCC.

But Moore points out that a Pb-free component will be handled by DSCC as a new component and that it will have to pass the same battery of qualification tests that would be required of any new or redesigned component. "These are the tests that a manufacturer must perform when there is a design change, so that we are assured that the risk is low," he notes.

A lead-free component coming into DSCC will also have its own part number, inscribed on the component by the manufacturer. This is what DSCC requires for all components except for those that are physically too small to be labelled - some resistors, for example.

However, the unambiguous labelling of Pb-free components has not met with unanimous approval from US component manufacturers. Although nearly all US component manufacturers are planning to introduce Pb-free components, only slightly more than half of the component manufacturers plan to give those components new part numbers. Instead, they may label the box as Pb-free, or they may refer the user to the manufacturing date range to determine whether a component is Pb-free or not.

The situation differs markedly from Europe, where ISO 9000 standards and quality controls govern labelling and traceability of components. What DSCC wants to avoid, of course, is the situation in which a conventional leadsolder winds up on a Pb-free board, or the reverse, a Pb-free component sitting on a leaded board. In the first case, the component might suffer damage, but might not fail until it is in the field - the sort of mishap that it is DSCC's mission to avoid. In the second case, the Pb-free component might be only loosely connected to the board - able to pass initial electrical tests, but likely to fail at some unknown point in the future.

Various industry observers point out that a situation in which the wrong type of component winds up on the wrong board is certain to occur occasionally and that it is much more likely to occur if labelling is less than precise. Other problems also present themselves. For example, assemblers normally return a percentage of components to the component supplier, often without the original package. If only the package bore the Pb-free identification, how will these components be identified?

What happens if they are re-sold?

DSCC has been encouraged, but not made less conservative, by scattered reports of tests in which Pb-free components have shown greater reliability than leaded components. Eventually, DSCC will begin qualifying and using Pb-free components. But in military applications in the US, conventional leaded solders will not disappear any time soon and DSCC anticipates having suppliers of leaded components and systems well into the future.
Data manipulation co-processor

Gamal Ali Labib introduces his own design of a co-processor dedicated for data manipulation

Despite the recent boom in processors and memory technology, new challenges to computer performance still evolve. Some applications require write speed searches of a database, list or pattern. The searches would normally involve simultaneous comparison of the desired information against the entire list of prestored entries. Image or voice systems, computer and communication systems are possible platforms for such applications. For example, ATM switches, due to their connection based protocol, must translate each ATM cell address at every point along the routing path into one of a few thousand possible output identifiers and port values. The switch maintains a table in memory of outbound identifiers and values, and uses the translated cell address as an index for that table. Cell address translation poses a challenge to hardware performance in order to maintain switch throughput.

On the other hand, manipulating user-defined data complex types and objects in modern programming languages and the increasing reliance of web-enabled and legacy applications on large databases sight additional challenges to hardware performance to cope with software demands. In this article, I review different processor architectures and introduce my design of a co-processor dedicated for data manipulation. The co-processor hits the key performance issues indicated above and simplifies the manipulation of complex data objects.

Associative memory vs conventional memory

There is a fundamental distinction between associative memory (AM), also called content-addressable memory (CAM), and conventional memory. Associative memory is content addressable, allowing parallel access of multiple memory words. Some implementations of CAM accept search predicate data as input and produce the address of qualifying words as output (see Figure 1).

By comparing the input predicate data against the data in memory, a CAM determines if an input value matches one or more values stored in the array. If the comparison is done simultaneously, the CAM is said to be performing at maximum efficiency. On the contrary, conventional memory such as RAM, must be accessed sequentially by specifying the word addresses. The output of RAM is normally data contained in the addressed location. A CAM, on the other hand, has the ability to signal the absence of a piece of data (indicated by the ‘Match’ output line in Figure 1), unlike an explicitly addressed memory, where some data is always read, whether or not it is what is wanted.

Associative memory architectures

The basic associative memory is a two-dimensional array of identical processing cells. The cell unit of the AM is several bits long and is capable of performing the standard functions of read/write like a RAM cell, but also contains sufficient logic to enable its bit content to be compared with the corresponding bits in a Comprand Register, or ignored depending on the setting of the corresponding bits of a Mask Register (see Figure 2). Information and commands are broadcast from the Central Control Unit (CCU) to all cells of memory in parallel. Each cell unit has associated with it a tag bit (response store). A matching cell unit will set a compare command issued by the CUU will set its tag bit, while a non-matching cell unit will reset that bit. As commands issued to memory cell units will only affect those with set tag bits, additional capability can be introduced to the AM by giving each tag bit to its immediate neighbours so that transferring (shifting) the activity from one cell unit to its neighbour becomes possible. The Global Tag Operations Unit (GTOU) controls tag bit activities, according to commands issued by the CCU. It also informs the CCU with Response Store status.

The previous features were realised in different implementations of the AM. For example, there is a design capable of performing associative operations on data extending over eight successive cell units. Other design supports forward linking of tag bits, for unlimited number of cell units. AM organisation may be categorised into four different types, based on how bit/word slices are involved in the operation:

- The bit serial: operates with one bit slice at a time across all the words. The time required for an operation to complete (also called the cycle time) using devices of this type is a linear function of the number of bits involved in the operation (except possibly for read and write).
- The word serial: operates with all bits of one word slice at a time. The speed of operation in such devices depends on the depth of their memory array.
- The fully-parallel: operates with all bits of all word slices simultaneously. The speed of devices of this type depends on the operations implemented in hardware and on the hardware elements used. The cycle time of such devices increases as more complex search and arithmetic operations are to be supported because of carry or borrow propagation.
- The block-oriented: operates on mass storage as data is being read (i.e. on-the-fly). The speed of this type depends mainly on the access time of the storage device involved and the used search criteria.

There should be a trade-off between storage capacity, speed and cost when choosing CAM organisation. For example, comparing these four organisations suggests that fully-parallel CAM provides the highest speed (least cycle time) and the least storage capacity.

We may improve the computer performance even further if the processor is designed to perform navigational as well as the pattern-matching operations on structures and objects of business data.

The principles of the co-processor

In this proposal, I follow the direction of adopting associative memories (AM) in supporting querying and manipulating data structures. The proposed co-processor, which I call Associative Co-Processor (ACP), is not a stand-alone back-end structure, but is intended for integration in processor nodes of multiprocessor machines, or with the CPU in single-processor machines (see Figure 3).

The co-processor receives data blocks (or data pages) to be processed alongside user-queries or operations to be performed. The CPU is then freed to execute other tasks while the co-processor crunches cached data. The co-processor module would have direct memory access (DMA) to the node/computer's local memory and have access to the secondary storage via the node/computer's I/O controller. Such architecture accelerates data movement to/from the co-processor without posing an overhead on the CPU.

Some AM designs impose a restriction on data by reserving a specific bit pattern for data element headers. Others limit the movement of activity to one direction. The proposed co-processor design presents a solution to those limitations as I will explain in the following sections.

The co-processor architecture and operation

The main functional blocks of the co-processor are similar to...
those of the basic AM, namely: the Comparand, the Mask, the control unit and the associative words (see Figure 4). Directing input commands to Data words, the Mask, or the Comparator is achieved by issuing the proper selection command to the co-processor device(s).

The co-processor incorporates in each data word/cell unit (which is basically 8-bit long) additional associative cells of two types: the structure-delimiter type, used to mark the first word of structure header (and optionally its trailer) and the element-delimiter type, used to mark the first word of each element and to navigate throughout structures.

The structure and element-delimiter cells can be manipulated as normal data cells. However, the element-delimiter cell has additional feature of combining its state outputs in the word control circuitry that incorporates the tag bit. A memory word may have one element-delimiter cell at the most, but may have more than one structure-delimiter cell. Allocating a structure-delimiter cell to each constituent-structure would provide optimum performance for accessing complex-structure's components.

However, a single structure-delimiter cell per word would suffice to minimise the overhead of control gates per associative word, but with increased navigation overhead.

Backward navigation:
- link-previous/word (LPW) to select the previous-to-current selected word and de-select the current one.
- link-previous-element (LPE) to select the previous-to-current selected element and de-select the current one.

With such flexibility of navigation within the stored structures in the forward/backward direction, the predicates in a multiple-element search condition can be evaluated in any order, irrespective of their physical locations within structures.

The co-processor has two modes of operation that determine how the associative words are affected by the launched operations (either navigational or data manipulation). The sequential mode causes only the top-most selected word in the co-processor to be affected; the parallel mode affects all selected words, simultaneously. Controlling the mode of operation is realised by the Mode line input to the co-processor. Intermixing sequential and parallel modes of operation is supported within the same transaction.

Circuit design
Figures 5 and 6 show the circuit design of the Comparand, Mask and Data cells mentioned earlier. The data cell is composed of nine gates, which can be reduced to seven (as opposed to five in RAW) if all allow gates O1 and O2 to be implemented as wired-ORs. As I indicated before, the co-processor also incorporates in each memory word additional associative cells of two types: the structure-delimiter type, used to mark the first and the last words in the data structure and the element-delimiter type, used to mark the first word of each structure-element.

Since delimiter words (those having either of their delimiter cells set to ‘1’) are likely to be separated by a number of data words (non-delimiter words), i.e. a structure-element is likely to occupy more than one word, so I introduce a minimised version of those cells that comprises none or a single gate (see Figure 7) depending on the word type, that is: structure/element-delimiter or data word.

The built-in control unit of the co-processor device decodes input commands into nine control signals. These are Compare (CMP), Select Data (SD), Select Mask (SM), Select Comparand (SC), and Set, Link Next Word (LNW), Link Previous Word (LPW), Link Next Element (LNE), Link Previous Element (LPE).

The tag bits manipulate some of the decoded control signals as well as some internal control signals which link the associative words together. Table 1 describes the functionality of each signal and its source.

The Delimiter minimisation concept also applies to the tag bits, resulting in two versions comprising 18 and 13 gates (see Figures 8, 9). Note that gate O2 is counted as three 2-input OR gates in Figure 8 with inputs from A1 and A2 being wired-ORed, and is counted for two 2-input OR gates in Figure 9. Gate O3 is also counted for two 2-input OR gates. Gate O4 can be implemented as wired-OR to improve cycle time so that RESULT line can convey the tag setting to the chip output as fast as possible. Mentioning the RESULT line, the NONE/SOME line (denoted by N/S) does the same function of the former and in addition it controls word selection in Sequential Mode. This incurs a propagation delay of one gate per associative word making the NONE/SOME line much slower to rely upon for checking comparison results.

Based on the previous optimisations, the co-processor can be manufactured with four intermixed types of words as shown in Table 2. Depending on the distribution of those types of words in the co-processor, the average control gates overhead (ACGO) per associative memory word and the maximum number of unused words (MNUW) - fragmentation between structures or structure-elements - can be determined. For example, choosing an organisation pattern of one type-I word followed by seven type-N words gives an ACGO of 16 and a MNUW of 7. Thus, tailoring the organisation of the co-processor may be required to suit a particular application.

Operating the co-processor
- Retrieval operation

Qualifying structures are retrieved starting with the topmost structure and according to the designated direction (i.e. forward or backward) depending on the word-linking command used (i.e. LNW or LPW). Also, the retrieval process can start at any point in the data structure.
structures at fixed intervals (equal to the maximum possible delay), the co-processor controller may sense the setting of the carry the contents of the topmost selected word, while the delays vary according to the distance (counted by associative large number of selected structures.

The co-processor has two modes for the write operation: single-word (Sequential Mode) and multi-word (Parallel Mode). The first mode is realised while the Mode line is reset to '0' during the write operation. In this case, only the topmost selected word will be affected as the N/S-1 line is reset to '0'. By activating the Mode line (setting it to '1'), the second mode comes in effect. Depending on the control command issued, namely SD, SM or SC, the write operation is directed to the required cells.

Loading the co-processor with a data page is executed by first selecting all associative words using the SET command. While in the Sequential Mode, data is written to the topmost selected word, then the word is de-selected (by comparing it with an illegal value). The latter sequence of operations would be repeated for each word of structure data.

Deleting selected structure(s) can be performed by writing a special bit pattern in the structure header (for example '0's in its first word). Structure freed space can be referenced by the structure's own ID or by replacing it with a special ID introduced specifically for memory management.

Managing free space

The co-processor should be initialised prior to loading it with data. During initialisation, all words are reset to '0's while structure- and element-delimiter words are set to '1's. So, by selecting the first empty structure-delimiter word (containing '0's in its data cells), while in the sequential-mode, each word of the structure header can be written with SD, followed by a LNW command to select the next empty word. To insert a new element, the LNE command should be issued to select the first available element-delimiter word, and then followed by a SD and LNW to insert each of the element's data words. In this way, the free space is always kept at the bottom of the co-processor as a contiguous area. In update-intensive applications, relocating structures due to their need of acquiring extra space is possible. This would require freeing previous space occupied by the structure. Such mode of operation would cause fragmentation of free space. Reallocating freed structure space to other structures is possible by introducing a management technique for free space. One example of such techniques is the binary buddy system, which was adopted for an object memory. It might also be required to compact free space if memory utilisation falls below a certain threshold while fragments become too small to accommodate any structure. This in turn requires reorganising the structures in the co-processor.

Flexible co-processor

In this article, I presented the design of an associative memory based co-processor (ACP) that can perform search and update operations, involving multi-word structure-elements, in parallel or sequentially. Unlike existing associative processors, the co-processor supports bi-directional navigation (forward and backward) within structures and facilitates direct manipulation of structures and their elements with minimal navigation overhead. The co-processor does not impose restriction on structure or element size or reserve any bit patterns to identify data structure or structure-element headers. Co-processor devices can be cascaded to achieve the required cache frame or data-page size. Rather than using separate specialised processors for operations such as data object selection and join operations, the co-processor performs such operations in addition to a variety of logic and mathematical algorithms. Data structures can be relocated in the co-processor without the need to change their references or employ indirection in contrast with RAM-based systems. Supporting navigation between and within structures eliminates the need for storing intermediate query results (in some cases) and provides better performance for nested and complex queries. The associative operation of the co-processor eliminates the need for maintaining multiple indices on objects data in a database.

Such features make the co-processor capable of resolving user queries and manipulating data structures locally instead of transferring them to the host main memory for processing. The co-processor accelerates data selection and table join operations, a speed-up of several tens-fold can be achieved over typical RAM-based system.

See next page for Table 1.

Table 2: Associative word types (all sizes in gates)

<table>
<thead>
<tr>
<th>Type</th>
<th>Tag</th>
<th>Data Cell</th>
<th>Tag Cell</th>
<th>Word Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>7</td>
<td>18</td>
<td>56</td>
<td>80</td>
<td>Fully relocatable word</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>18</td>
<td>56</td>
<td>82</td>
<td>Can be an element-delimiter word</td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>13</td>
<td>56</td>
<td>76</td>
<td>Can be a structure-delimiter word</td>
</tr>
<tr>
<td>IV</td>
<td>7</td>
<td>13</td>
<td>56</td>
<td>70</td>
<td>Non-delimiter word</td>
</tr>
</tbody>
</table>

Figure 7: Modified delimiter cell circuitry of a non-delimiter word (type I)

Figure 8: The basic tag control circuitry

Figure 9: Modified tag circuitry for non-element delimiter words
Table 1: Signal legend for the ACP

<table>
<thead>
<tr>
<th>Signal</th>
<th>Description</th>
<th>external</th>
<th>internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>SET</td>
<td>Set tag bits of all words to 1</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>LW</td>
<td>Link activity to read word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>LPW</td>
<td>Link activity to previous word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>LNE</td>
<td>Link activity to next element</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>LPE</td>
<td>Link activity to previous element</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>Select input from the data bus as data to associative data cells</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Select input from the data bus as data to Comparand cells</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>Select input from the data bus as data to Mask cells</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>DMP</td>
<td>Compare data cells with the corresponding unbiased Comparand cells</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>State of element delimiter cell of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>GEF</td>
<td>State of forward navigation line of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>GES</td>
<td>State of backward navigation line of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>NF</td>
<td>Select word (i)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td>State of element delimiter cell of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>QF</td>
<td>State of forward navigation line of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>QB</td>
<td>State of backward navigation line of word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>Select word (i)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>1=no matching found in words (0-i)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>0=no matching found in words (0-i)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEMO</td>
<td>Accumulated Mismatch results of bits</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>FSET</td>
<td>Realised forward navigation in conjunction with LW. Sets Tag cell of next word (i+1)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>RES</td>
<td>Realised backward navigation in conjunction with LPW. Sets Tag cell of previous word (i-1)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>RESULT</td>
<td>Accumulated state output of Tag cells of words</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>READI</td>
<td>Input data to bit j from the data bus. It is split into two adjacent lines</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>READJ</td>
<td>Input data to bit j from the data bus. It is split into two adjacent lines</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>Bit j reads from bit j of each word</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>Bit j reads from bit j of each word</td>
<td>✓</td>
<td></td>
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<tr>
<td>BS</td>
<td>Bit j reads from bit j of each word</td>
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<td>BS</td>
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<tr>
<td>BS</td>
<td>Bit j reads from bit j of each word</td>
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</table>

Note: j refers to bit sequence within the word, where i refers to word sequence within the co-processor.
Adventures in electronic noise

The design of turntable and stereo pre-amp is more important than the price. The choice of equipment and components is the key to the performance of the system. The noise performance of the system is crucial for achieving high-fidelity sound reproduction. The noise performance of the system is determined by the noise sources in the system and the noise characteristics of the components.

The noise performance of the system is determined by the noise sources in the system and the noise characteristics of the components. The noise sources in the system include the noise of the power supply, the noise of the input stage, the noise of the feedback loop, and the noise of the output stage. The noise characteristics of the components include the noise of the transistors, the noise of the capacitors, and the noise of the resistors.

The noise performance of the system can be improved by reducing the noise sources and improving the noise characteristics of the components. This can be achieved by using high-quality components, selecting the right components for the application, and using proper design techniques.

For example, reducing the noise of the power supply can be achieved by using a high-quality power supply, selecting the right power supply components, and using proper design techniques. Reducing the noise of the input stage can be achieved by using high-quality transistors, selecting the right transistors for the application, and using proper design techniques. Reducing the noise of the feedback loop can be achieved by using high-quality capacitors, selecting the right capacitors for the application, and using proper design techniques. Reducing the noise of the output stage can be achieved by using high-quality transistors, selecting the right transistors for the application, and using proper design techniques.

The noise performance of the system can be improved by reducing the noise sources and improving the noise characteristics of the components. This can be achieved by using high-quality components, selecting the right components for the application, and using proper design techniques.
Pre-amplifiers

2) A second amplifier stage (AMP) with a gain of +12 dB lifts up the output level of the first stage to a typical driving level (0dBV) for power amps. To avoid overload it makes sense to design the output level of the first stage as low as possible (say, 12.5-300mV(rms)).

3) To enable measurements with RIAA equalisations, a low tolerance (±0.1 dB) RIAA equalising stage with a gain of 0dB at 1kHz can be switched to the output of AMP.

4) To lift the very low-level noise signals an extremely low-noise variable gain (0-100dB) stage with 3x10² OPAs follows.

5) A 3-position switch allows the selection of several weighting possibilities:
   a) NAB-A-Filter (±0.1 dB)
   b) 5th order ±0.1 dB Chebyshev high-pass filter (f = 355Hz), to enable measurements without hum interference. However, the shielding efforts for the whole measurement arrangement should not be underestimated.
   c) No weighting.

6) Finally, four different measurement tools show results:
   a) CLI040 is a 16-bit signal generation and measurement system for FFT, frequency response, RTA and much more. It also has a built-in low tolerance NAB-A-Filter,
   b) RMS-voltmeter with AD536, followed by an analogue DC-meter,
   c) The voltmeter section of a HP 331A distortion analyser,
   d) Hameg HM 412 scope.

7) All resistors, inductances and capacitors were measured with an 'Electronic L-C-R' meter (±0.5% tolerance) made by ESCORT.

A Mathcad mathematical model

You can easily calculate impedance networks with Mathcad. In addition, elements once defined on the worksheet keep their value until the end of that worksheet. For example, if the value of R1 (some lines down this page) got changed to another value, all level: 0dBV

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The Handyscope 3 is a powerful and versatile two channel measuring instrument with an integrated function generator.

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- several trigger features
- auto start/stop triggering
- auto disk function up to 1000 files
- auto setup for amplitude axis and time base
- auto trigger level and hysteresis setting
- cursor measurements with 21 read-outs
- very extensive function generator (AWG) 0-2 MHz, 0-12 Volt

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following calculations on the worksheet will change accordingly. The input impedance network \( Z_{\text{tot}}(f) \) shown in Figure 1 (mm-cartridge, C1, Rin) can be written as the sum of admittances, which is in mcd style:

\[
\frac{1}{Z_{\text{tot}}(f)} = \frac{1}{R_1 + 2j\omega C_1} + \frac{1}{R_{\text{in}}} - 1
\]

To calculate the magnitude of \( Z_{\text{tot}}(f) \) and its phase angle, all values of the components and the plot frequency range \( f \) (e.g. 10Hz steps from 1kHz-20kHz) have to be defined first, in this example case for the Shure V15V MR cartridge. The calculation results can be plotted in diagrams (Figures 7 and 8). All values in the diagrams can be read out by applying the mcd-tool "x-y trace". Values (without units) written in mcd style look as follows:

\[
R_1 = 793, C_1 = 3318 \text{ nF}
\]

In Mathcad, phase angles of complex figures are expressed as radians (rad) of the argument (arg). To get "degrees", the results in "rad" have to be divided by "deg"

\[
\text{Degrees} = \frac{\text{Radians}}{\text{Deg}}
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\]
The sum of all relevant noise voltages squared will lead to the input referred and frequency dependent noise voltage $e_{N_{to t}}(f)$. Its rms value is the basis of the signal-to-noise ratio $SN_{n e}$ with reference to an input voltage of $S_mV(rms)$ (-46dBV). Consequently, signal to noise $SN_{n e}$ can be defined as $SN_{n e}$ of the unweighted and unequalised noise signal (ne = non equalised) $e_{N_{to t}}(f)$, which includes noise from the cartridge as well as from the pre-amp. $SN_{riaa}$ is the $SN_{n e}$ of $BN_{to t}$ after equalisation with the RIAA transfer, $SN_{riaa} = SN_{n e} + A$-Filter weighting. See Equation 12 above.

The rms form $e_{N_{ne}}(f)$ of a noise voltage $e_{N_{ne}}(f)$ in a definite frequency bandwidth can be plotted:

$$e_{N_{ne}}(f) = \sqrt{\frac{1}{T_{20Hz}}} \int_{T_{20Hz}}^{T_{10kHz}} e_{N_{ne}}^2(f) df$$

Thus, $SN_{ne}$ referred to $S_mV(rms)$ becomes:

$$SN_{ne} = \frac{1}{5mV} \int_{20Hz}^{10kHz} e_{N_{ne}}^2(f) df$$

$SN_{ne} = 65.1$dB Measured $SN_{ne} = 67.2$dB

Before going further on at this point I have to go back to Figure 9: there are two reasons for the inclusion of a hp pole (formed by $R_3$ and $C_3$) into the circuit:

a) Heavy changes of DC voltages at the output can be minimised (caused by impedance changes at the input when measuring with different input loads). 

b) This is an additional time constant, simulating the RIAA roll-off frequency at 20Hz. I've chosen to shift this frequency to 10Hz, because my V15V and V151V driven RIAA pre-amps sound optimal with this configuration. Generally, this frequency doesn't give any heavy extra disturbance. It is kept at 10Hz throughout the whole calculation and measurement process.

RIAA transfer function

The magnitude of the RIAA transfer function is $R(f)$ and is a combination of two low-pass filters ($T_1=3180\mu s$ and $T_2=75\mu s$) and one differentiator ($T_3=318\mu s$). To make certain that $R(f)$'s gain at 1kHz will become 0dB it is necessary to include a 2nd term $R(1000)$ into the formula of $R(f)$. This term is nothing else but the reciprocal figure of the original transfer function with $f = 1000Hz$. A plot (Figure 13) allows to pick all values with the help of the respective mcd-tool:

$e_{N_{to t}}(f) = \sqrt{\frac{1}{B}} \int_{B}^{\infty} e_{N_{20Hz}}^2(f) R(f)^2 df$

$SN_{riaa} = \frac{1}{5mV} \int_{B}^{\infty} e_{N_{20Hz}}^2(f) R(f)^2 df$

$SN_{riaa} = 78.6$dB

Measured $SN_{riaa} = 78.6$dB

A-filter transfer function

RMS noise voltages passing through an A-filter according to NAB/ANSI standard (or IEC/CD 1672) with reference to a definite rms voltage level ($5mV(rms)$) produce the A-weighted $SN_{a}$.

$SN_{a}$ for $e_{N_{to t}}(f)$ A-filter weighted becomes:

$$SN_{a} = \frac{1}{5mV} \int_{B}^{\infty} e_{N_{20Hz}}^2(f) A(f)^2 df$$

$SN_{a} = 70.1$dB

Measured $SN_{a} = 70.9$dB

and $SN_{riaa}$ for $e_{N_{to t}}(f)$ equalised with RIAA transfer plus A-filter weighting becomes:

$$SN_{riaa} = \frac{1}{5mV} \int_{B}^{\infty} e_{N_{20Hz}}^2(f) R(f)^2 A(f)^2 df$$

$SN_{riaa} = 81.9$dB

Measured $SN_{riaa} = 81.4$dB
It seems that RIAA equalisation "smooths" the mathematical SN results more towards the measured ones in comparison with the nonequalised cases.

**Measurement circuit**

The measurement circuit consists of three different blocks. They are all located on one small PCB that is fixed in a shielded A-box with the dimensions of 170x120x50mm. Block 1 (Figure 15) is the adaptation of a RIAA pre-amp circuit design described in National Semiconductors Application Note An-222. Block 2 is AMP according to Figure 6. To keep noise on the power supply lines as low as possible, all R's 1% metal form an extra power supply filter. The separate power supply unit (not shown here) consists of one toroidal transformer, two rectifiers and two high-value Cs followed by two additional gyrators with high h2 Darlington transistors BD679 and BD680.

The mm-cartridge is attached to its headshell, fixed by an SME connector to a very short piece of forearm pipe on the top of a separate shielded A-box (115x65x50mm). The signal lines go out via BNC connectors, off coated through a BNC-L-connector into block 2 and cartridge box (Figure 2) enables impedance measurements, while a very short BNC coupler connects block 1 with the cartridge box for SN measurements.

The circuit diagram of block 2 is shown in Figure 16. For other measurement purposes, S3 switches the input resistance from 10M to 47k. The 1Hz cut-off frequency of the high-pass filter C3, C4 & R15 is low enough to keep the amp free from gain errors in the 20Hz-20kHz frequency band.

Block 3 (AMP) is a simple low-noise amplifier with its gain setting components. R18 simulates the resistor that might play a role in a two-stage RIAA pre-amp arrangement (75uA low-pass filter, e.g. 750+100). This stage's contribution to the overall noise is totally negligible. A rule of thumb says that, "if the input referred SN of an amplifier stage is more than 20dB below the SN at the output of the stage in front of it, then this noise contribution can be neglected" (a calculation gave a 0.0001dB deterioration factor).

**Results**

Calculation and measurement results are listed in Table 2. The most important lines are number 13 (IAA-equalised noise: SN_ref) and 16 (IAA-equalised and A-weighted noise: SN_rating). These deltas indicate that the claim at the beginning of this article becomes true that a maximum 1.0dB variance between mathematics and measurements could be possible. Another interesting point is that the measured results for the 1k and 12k resistors (lines 6, 9, 12,15) match perfectly with the calculated ones, which is a nice proof of the mathematical model for white noise. The results of the 800 and 100R resistors (lines 7, 10) indicate the problems shown in Figure 10, 11, 12: very low source resistances and a low collector current (100uA) don't match and will lead to additional noise, which is not reflected in the chosen mathematical approach.

For comparison reasons, column "L" shows the calculated results of a so-called "standard" cartridge, which is used in test magazines to check SNs of RIAA amplifiers (e.g. stereo play). It consists of a 1k resistor series-connected with a 0.5H inductance (which, of course, is not the same as mm-cartridge inductance of 0.5H with its resistance of 1k. It's nearer to the truth than a resistor alone). But it might not be a good idea to compare test magazine results (with "standard" cartridge) with self-generated ones because there isn't enough information about C1's value in the measurement setup. This capacitor has a great influence on SN, which will be lined out a bit later. The SNs shown in Table 2 are not the whole truth because each of the tested mm-cartridges has its definite sensitivity U, expressed in mV output voltage at 1kHz at 5cm/s peak velocity. Taking this into account, all SNs in Table 2 will be improved: e.g. \( U_{\text{V15V}} = 3.2\text{mVrms} \) at 5cm/s, on an LP-disc the 0dB level is at 8cm/s peak velocity, therefore, with the rule of three \( U_{\text{V15V}} = 5.12\text{mVrms} \) and thus, the V15V SNs improve by \(-0.21\text{d}B\). The M44G is much better: with it's output voltage of \( U_{\text{M44G}} = 9.6\text{mVRms} \) at 6cm/s it improves all SNs by the factor of 20*log(9.6mV/5mV) = 6.7dB.

In line four of Table 2 there are different values of C1. For mm-cartridges its 30pF higher than for resistors because of the addi-
to an SN improvement of only +0.5 dB for that CI
1 and CI 2 and R5+P3 or P4 have been changed ade-
quate a change from 130R to 1 OR improves the SNriaa of a
respective figures are +0.1 dB/-0.5dB.

SN (250p) to -68.5dB (3p), which is an im-
provement of +3.4dB, into account. The SN of
V15V changes from -65.1 dB to -81.4 dB.

A rather significant effect can be observed if you don't take C1
R7 of the BNC connectors and cables inside the
cartridge box. A test-wise increase to 250pF for resistor mea-
surements didn't change anything except for input loads >15k.
A rather significant effect can be observed if you don't take C1
into account. The SN of the V15V changes from -65.1dB
(250p) to -66.5dB (3p), which is an improvement of +3.4dB, SNs
improvement will be +1.2dB. Similar improvements will
come up in the A-Filter case.

R7 of Figure 15 has an influence on the SNs too. Provided
the mm-cartridge's noise reality and those carried out with
values <10k will lead to SNs that are too optimistic.
Doubling of the input transistors or minimising the resisors
in the feedback network (e. g. in Figure 15: R7 = 1R0) does
not produce that big difference in noise reduction, at all.

Table 2: Results

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<th>A</th>
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<th>C</th>
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Pre-amplifiers

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OSCILLOSCOPE

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<td>Vertical Mode</td>
<td>CH1, CH2, Dual, ADD</td>
</tr>
</tbody>
</table>

SPECTRUM ANALYZER

2-channel, Fast-Fourier Transform, Range: 0Hz-50MHz (DSO-2100USB), 0Hz-10MHz (DSO-220), Cursor: Frequency, Data Point: 32K/chan

Unbeatable Price: DSO-2100 (30MHz): $350.00, DSO-220 (5MHz): $250.00

ORDER VIA: www.pc-instrumentmart.biz
Firstly, solid-state charge-coupled devices (CCD) have now overtaken tubes and analogue circuit techniques of the day, HDTV was born with it resultant bandwidth of around 30MHz, thermionic camera tubes being developed to a sophisticated television and film origination roadshow. Since then, two main factors have lead to HDTV: firstly, the widescale introduction of digital technology and, secondly, the real big noise in television and cinema production circles is high definition television (HDTV), even though this has not been an overnight phenomenon. Plans were started back in the early eighties under the European Eureka EU95 project.

The complexity of the serialised signal renders conventional oscilloscopes virtually useless. Even when decoded, there is no easy way to observe what is, or not, happening to the actual data stream. The Tektronix WFM700 analyser permits the user to monitor the serial signal and then check the integrity of the various data channels, both in standard and high-definition formats. Optional plug-in cards dictate the level of monitoring for example the standard base model is suitable for compliance, i.e. video levels, 'illegal' colours and general picture impairments. Further hardware options allow the exact measurement of the HD-SDI signal and digital audio signals conforming to the worldwide AES standard. The model reviewed here features all of these options. The WFM700 analyser can be used either as a rack mounting or standalone desktop unit. When ordering, it is important to remember that the desktop model is supplied 'bare' and that the portable cabinet is an optional extra. When used on a flat surface, the unit can be angled upwards approximately 9cm by clicking down the two front legs. Personally, I don't find this gives a particularly comfortable viewing angle, although extra height can be added by propping the front legs underneath on a large book. The rear of the analyser houses the various modules with their respective BNC sockets (Figure 1).

Secondly, the widespread introduction of digital technology has simplified both equipment and studio topologies. Manufacturers are now able to bring to market advanced digital equipment for both the current standard-definition television (SDTV) and HDTV systems.

The Tektronix WFM700 analyser is a good example. It is aimed mainly at practising engineers involved in manufacturing R&D, broadcasting and studio project teams. The last category is one to which I belong. Over the last few months I have been using the WFM700 on a daily basis whilst designing and installing a new high-definition television facility for the University of Surrey, Guildford.

Various international bodies define standards for the digital interchange within studios and broadcast facilities; for HDTV the European ITU defines this serial digital interface (SDI) as recommendation BT709-5. Stated very simply, separate luminance and chrominance video signals are multiplexed together with synchronising and control signals (ANC), then forms an uncompressed 1.485Gb/s serial data signal that can be sent via a low-loss 75Ω coaxial cable.

The WFM700 analyser can be used either as a rack mounting or standalone desktop unit. When ordering, it is important to remember that the desktop model is supplied 'bare' and that the portable cabinet is an optional extra. When used on a flat surface, the unit can be angled upwards approximately 9cm by clicking down the two front legs. Personally, I don't find this gives a particularly comfortable viewing angle, although extra height can be added by propping the front legs underneath on a large book. The rear of the analyser houses the various modules with their respective BNC sockets (Figure 1).

Other connectors include IEC mains, CAT 5 Ethernet, USB, VGA and 9 pin D-Type. Main operation is from 100V to 240V and, rather inconveniently, the main fuse is not-user serviceable. The front of the unit consists of a TFT screen (approximately 17cm diagonal), three conventional knob-type controls and a selection of press-buttons. The general layout is quite intuitive, a definite advantage for engineers working in panic-stations scenarios. I regard digital displays a mixed blessing when used for accurate test and measurement. On the one hand, they offer a clear bright image with touch-screen button selection, on the other, I can't sometimes help feeling that sharp transient spikes are lost at certain timebase settings. Although I haven't actually experienced this with the WFM700, it is something I have noticed with some other digital oscilloscopes. My belt-and-braces solution, at least for critical standard-definition TV applications, is to use the WFM700 in conjunction with its earlier CRT incarnation, the WFM601.

Rather than laboriously explain every button and feature in turn, it is perhaps better to describe some real-world example applications. For the purpose of this review, I shall use the WFM700 to analyse a signal arriving down a 50m cable, check its integrity and potential reliability (digital video signals are notorious for the 'cliff-edge' effect, where signals can slowly degrade with no visible picture impairment, until a point is reached where a signal is suddenly completely lost).

I perform a quick analysis of a Thomson HDTV electronic-cinema photography camera. First, I examine a link, which consists of a colour-bar test signal transmitted via a 50m coaxial cable. Switching to the 'Eye' menu allows you to see the 1.485Gb/s signal directly. In order to determine the quality of the signal, it is necessary to create an eye-diagram that consists of three superimposed bit-cells. Measuring the eye-diagram aperture is a good (but infallible) indicator of the quality of the signal.

A well-formed eye-pattern indicates a reliable signal; alternatively, if the eye pattern is nearly closed there is a good chance that it will be unreliable. In this example, I can see that the opening is fairly good and, using the onscreen electronic graticule, the peak-to-peak level is to within specification (800mV ±10%) (Figure 2). As with a conventional oscilloscope, using the WFM700's 'Cursor' option will enable a direct textual readout of the voltages.

The HD-SDI signal is self-clocking, therefore, the amount of jitter is critical to the receiver's locking ability. Pressing the 'Jitter' on-screen soft button will give us a direct reading in terms of time. In this case, it was measured to be approximately 250ps and this would be considered quite good, well within specification for HDTV. Very quickly we already can see that this represents a healthy, reliable signal.

Having established the serial signal's integrity, it is now possible to check the individual video, audio and control signals through the analyser's waveform and measurement menus. A direct analogue representation of the video signals can be displayed under the WFM menu. Soft selection buttons allow you to select between luma, red and green channels, either displayed in a row or overlaid. There is also a 'Composite' option that will display the signal as a pseudo old-fashioned PAL colour waveform – very handy for broadcast engineers of a certain age! Signal levels can therefore be directly equated with values similar to those used for analogue television, i.e. 750mV peak white, 0mV black and -300mV for synchronising pulses.

I regard digital displays a mixed blessing when used for accurate test and measurement. On the one hand, they offer a clear bright image with touch-screen button selection, on the other, I can't sometimes help feeling that sharp transient spikes are lost at certain timebase settings. Although I haven't actually experienced this with the WFM700, it is something I have noticed with some other digital oscilloscopes. My belt-and-braces solution, at least for critical standard-definition TV applications, is to use the WFM700 in conjunction with its earlier CRT incarnation, the WFM601.

Figure 1: Optional modules may be plugged in at the rear of the unit. This example has additional inputs for AES digital audio.

Figure 2: Waveform of HD-SDI signal at the receiving end of a 50m coaxial cable. 'Eye' opening is still good, despite noise.
the WFM function. A check of the cameras' white-balance, i.e. just the WFM?OO plus suitable lighting and a test chart. Monitoring of video and black level controls is possible, using patience of the engineer to spot the dropped frames. Defined within the specification) OOOOh 3FFh 3FFh 260h 260h data immediately follows unique data identification words (as example, I now have displayed a waveform of timecode data ancillary signals located within the horizontal blanking period, I have to select the relevant starting pixel, number 19 34 in this textural form. The presence of embedded timecode and audio data are indicated and, most importantly, for checking frame(s), I could view the data words directly by choosing the 'Measure' menu and selecting TV line 10 . As it is one of several ancillary signals located within the horizontal blanking period, I have to select the relevant starting pixel, number 1934 in this example. I now have displayed a waveform of timecode data plus text readout of the data words in hex form. The timecode data immediately follows unique data identification words (as defined within the specification) 0000h 3FFh 3FFh 260h 260h 110h (Figure 3). After all that hi-tech, it's then all down to the keen eyes and patience of the engineer to spot the dropped frames. Basic television camera performance can be measured using just the WFM700 plus suitable lighting and a test chart. Monitoring of video and black level controls is possible, using the WFM function. A check of the cameras' white-balance, i.e. neutral colouration of the picture highlights, can be done by checking for equal peak-white outputs on the respective red, green and blue signals. The 'Vector' display, however, offers a far more accurate method, as the white point is displayed as a clustered 'dot' at the centre of a circular pattern (Figure 4). The centre cross represents neutral white; any deviation will literally 'point' in the direction of the colour error (Figure 5). A basic check of camera resolution and linearity can be achieved with a suitable test-chart using the WFM700's line selection facility. (Figure 6). Timebase magnification will reveal any timing/registration errors between each RGB channel as this can cause coloured fringes around an object's edges (yes, it does happen even with modern CCDs!). It is unfortunate that this can only be a quick tour of the WFM700 and, as such, it only scratches the surface of the equipment itself and video measurement techniques. On the plus side, the unit is intuitive to use with a logical menu-tree. It offers some highly ingenious measurement gaticules to check timing errors and 'illegal' colour levels. In addition, it is possible to have complete remote functionality (Figure 7) using nothing more than an Ethernet link and your favourite web browser. On the negative side, the touch-screen buttons require nimble fingers (the eraser end of a pencil used as a prod can help), and the audio input grouping and mapping menu I found very confusing. The HD-SDI input BNC sockets at the rear are not at the topmost of the frame - a bit frustrating when trying to connect a cable from the front by touch alone. Overall, this is an essential piece of kit for control-room, projects and maintenance engineers. For the 'Pros & Cons' table of the WFM700 analyser, see overleaf.
**PROS AND CONS**

- Clear and bright TFT display
- Intuitive operation
- Picture-in-picture display for confidence monitoring
- Automatic logging of video and audio errors
- Remote Ethernet operation
- Different SD/HDTV formats displayed all, in one self-contained unit
- Good build quality
- Front support feet create an inconvenient viewing angle
- Confusing audio mapping menu
- Mains fuse mounted inside the unit
- Course line-select control - scrolling through individual TV lines requires a deft touch
- Expensive

**MOST USEFUL FEATURE**

- Textual readout of the incoming signals’ line and frame rates - absolutely essential for monitoring or fault-finding within HDTV’s multiformat environment

**SUGGESTED IMPROVEMENTS**

- Built-in AES digital-to-analogue converter for audio monitoring
- More ANC analysis tools, particularly for nasty timecode problems
- Shallower cabinet version for portable use

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**Virtues and failings of C**

I was very surprised to see that it is apparently legal to produce computerised machines for medical applications, which are controlled by programs written in C. Although C has many virtues it also has many failings. Important in this kind of application are that explicit use of pointers can make code obscure e.g. pointers to pointers or def-referenced pointers to structs, or lead to writing or reading beyond the bounds of an array, and that improper and potentially dangerous type casts will probably be passed by the compiler.

Those managing the project, enforcing safer coding standards, can ameliorate these problems and/or by the use of programs like Lint, which can pick up many (possibly all) of the problems. Perhaps it would be better if ‘safer’ languages were used to program safety critical devices in the first place.

The on-board computer of the recently successful Titan lander was programmed in the language Ada83. Presumably, the team that specified this felt they had a good reason to use Ada.

The very least that we can expect is that medical devices will be specified with at least as much care as expensive one-off devices like spacecraft.

The usual reason for not using a ‘safer’ language like Ada or Modula 2 is that there are not enough programmers familiar with these languages. But this eventually becomes a self-fulfilling prophecy, because programmers will only develop expertise in these languages if there is a demand for them to be used.

This is one area in which governments can legitimately seek to influence market-driven decisions, by insisting that the programs for all safety-critical programmable devices are written in languages that meet the highest possible standards for safe usage. C and C++ do not.

**Dr Les May**

**Rochdale**

**UK**

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**Conceal don't encrypt**

Mark Chimley’s BIE system (EW March 2005, p22) is an interesting idea that may find useful applications, but I am sure that he is wrong to think that it will be used for email.

People who require moderate security typically use PGP or GPG, which have a slight difficulty with the distribution of public keys. However, that difficulty has never been much of an impediment.

The IBE system involves a third party having potential access to encrypted messages, which would be completely unacceptable to most users, as it defeats the object of encrypting a message in the first place. This is a matter that the author mentions only in passing. He is, therefore, proposing a cure worse than the disease.

The IBE system might be useful not as a replacement for such things as PGP, but as an additional method of distributing and verifying its communications.
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Here are just a few of our controller and driver modules for AC, DC, unipolar stepper motors and servos. See website for full details.

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Fight security breaches

Recent security breaches, such as the intruder in Channel 4's Big Brother enclosure and numerous attempts to scale the walls surrounding Buckingham Palace, not only encouraged more businesses to consider the potential threats these security breaches pose, but have also highlighted the debate surrounding intrusion detection techniques, questioning how important building this level of security actually is. Although these high profile cases of intrusion are not commonplace in an everyday business environment, the threat of someone tapping into communication lines coming in and going out of the building is a serious and very real issue.

Whereas, an intruder trying to break into an establishment like Big Brother House may be picked up on CCTV or by a security guard, someone tapping a phone line may be difficult to detect and may go unnoticed. Just because a cable is a fact that underground does not mean it is impervious to risk. For example, many businesses fail to recognise manhole covers as a serious threat to building security and information integrity. Businesses have mechanisms in place to make e-mails and information secure once they have entered the building, but surely these measures should be taken into account as information comes in and goes out of the building too.

Fibre intrusion technology is the next logical step in securing the flow of information and the business from physical attack. As soon as a cable of this type is touched it will raise an alarm and pinpoint exactly where the interference has occurred, meaning it can be dealt with immediately. This is valuable for not just underground cables but can be put at the top of razor or barb-wire fences to detect a disconnection or highlight an intrusion before someone manages to get over the fence and into the building.

Phillip Coombes
Managing Director
Fibre Technologies

Renewed interest in amps

Reading Mr. Stan Curtis's letter in the February 2005 issue [p48], in which he stated that designed amplifiers that emphasised bass, rekindled my interest in building my own. I'm interested in building three amplifiers for each 3-way speaker and connect each driver directly to its amplifier. An active 12dB per octave low-pass, high-pass and bandpass would provide the required signals for each amp.

I need a design of 30W to 40W rms for the woofer, maybe 25W for the midrange driver and 10-15W for the tweeter.

Better yet, what power ratings would you suggest for this arrangement? Should the tweeter be driven from a class A amp?

Robert Bink
Calgary

Cosmologists are desperate to find dark matter, because they cannot explain how stars can orbit faster and further than normal under Newton's laws. The alternative answer is that they are looking at either expanded space or dilated time. Of course, the approach that the universe is expanding, since the expanded space is far back in time where the big bang was. Expanded space would really explain the problem and the red shift of light that we assume is due to the big bang is light coming from expanded space, which might be travelling faster or slower, hence the observed distances may be wrong and, maybe, the energy too. Without the solution of hidden dark matter our current calculations are way, way off. If time is dilated too, observed stars are travelling at the wrong orbital speeds, and light coming from such a source would have the 'correct' speed either and may be red-shifted, hence our observation that the universe is expanding with distance or, time is changing across the universe since the 'big bang'.

Chris Doherty
UK
High-linearity 12-bit DAC with only two micro pins

Referring to the Circuit Idea (p. 48) I salute him for his elegant solution. I too have been working on this problem and would like to pass on an effective two-pin solution, which is even more efficient if wide bandwidth isn’t a requirement.

Precision frequency oscillator control can be achieved using pulse-width modulated DAC feedback, which gives very good linearity. The usual technique (Figure 1) involves one micro pin (P5) and a simple RC filter (R1/C1), which integrates the pulse-width modulated output and removes the “clock” frequency component. With one pin output, the PWM hardware available in several micros can be put to good effect. The upper frequency response is limited by the requirements of the RC filter, but is still appropriate for applications such as frequency control.

High resolution and good linearity are features of the PWM DAC, but a further problem is that the higher the required resolution, the slower the system response, since the PWM period is related to the power of the number of bits. For example, using a 10kHz PWM rate, 8-bit resolution results in a “clock” of 10,000/256 = 39Hz. This low PWM period is the major limitation of this technique.

My improvement allows higher resolution, modestly faster response, or both. Two (or more) separately (but preferably synchronously) PWM’d outputs can be combined to provide a single voltage on a single integrating capacitor. For example (see Figure 2), if R1 is 10k and R2 is 160k (ratio 1:16), the lower four bits of an 8-bit value can be PWM’d on R2 and the upper four bits on R1. The output has a resolution of eight bits, but most significantly, the PWM period is much faster. To use the previous example, 10,000/16 = 625Hz. This makes the PWM noise easier to remove and improves the frequency response of the DAC. If the micro has two high-speed PWM registers, the response could be even faster.

This very simple design is easily expanded to 12 or more bits, by increasing the number of bits per output, or the number of outputs. The 12-bit is best achieved with two 6-bit PWMs rather than three 4-bit PWMs. In a system requiring only 10kHz frequency response, I routinely use a two output 12-bit DAC, with R1 = 5kΩ and R2 = 320kΩ (ratio 1:64), and achieve extremely good 12-bit monotonic output with a PWM “clock” of 10,000/64 = 156Hz. The resistors need to be 1% to ensure an accurate transition at the centre of the range. I use two parallel 10k resistors for R1 and 100k + 20k in series for R2. The availability of accurate resistors ultimately limits the useful resolution of this technique and some trimming may be necessary to get the ratio exact.

Software PWM control algorithm is best used in a high-speed interrupt loop and dual PWM can be achieved using a single micro that has half as many bits as the output. A 12-bit example for the AVR is in Table 1.

<table>
<thead>
<tr>
<th>push</th>
<th>DAC_LO</th>
<th>6-bit mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>inc</td>
<td>PWMCNTR,</td>
<td></td>
</tr>
<tr>
<td>and</td>
<td>PWMCNTR,</td>
<td></td>
</tr>
<tr>
<td>lsl</td>
<td>DAC_LO</td>
<td></td>
</tr>
<tr>
<td>rol</td>
<td>DAC_HI</td>
<td></td>
</tr>
<tr>
<td>lsl</td>
<td>DAC_LO</td>
<td></td>
</tr>
<tr>
<td>rol</td>
<td>DAC_HI</td>
<td>6 MSBs now in DAC_HI</td>
</tr>
<tr>
<td>cp</td>
<td>PWMCNTR,</td>
<td></td>
</tr>
<tr>
<td>brcs</td>
<td>MSB_LO</td>
<td>DS, set hi PWM</td>
</tr>
<tr>
<td>jmp</td>
<td>MSB_LO</td>
<td></td>
</tr>
<tr>
<td>cb1</td>
<td>PORTD, 5</td>
<td>clear hi PWM</td>
</tr>
</tbody>
</table>

Table 1

As a final comment, this technique, which can easily provide 12-bit D-A output with only two micro pins and three passive components, also permits the outputs to be set in high impedance mode when no voltage change is anticipated (for example in phase-locked loop applications). This can further reduce the PWM ripple.

Murray Greenman
Popakura
New Zealand

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Specs

Switch position 1

| Bandwidth | DC to 10kHz |
| Input resistance | 1MΩ - i.e. oscilloscope i/p |
| Input capacitance | 40pF - oscilloscope capacitance |
| Working voltage | 600V DC or pk-pk AC |

Switch position 2

| Bandwidth | DC to 150kHz |
| Rise time | 2.4ns |
| Input resistance | 10MΩ - if oscilloscope i/p is 1MΩ |
| Input capacitance | 12pF - if oscilloscope i/p is 20pF |
| Compensation range | 10-60pF |
| Working voltage | 600V DC or pk-pk AC |

Switch position ‘Ref’

Probe tip grounded via 9MΩ, scope i/p grounded
Voltage-controlled optoisolated resistor

This is an idea of a voltage-controlled resistor that initially is not just very cheap and simple but also very flexible and optoisolated. To make it work right, you should use a photoresistance driven by an LED. Both components should have to be in the dark and placed close to one in front of the other. Varying gently the voltage in the LED (from 1.7V to 2.2V) I have made the plot of voltage versus current and resistance (see plot). It refers to two of those classic LDRs (for which I incidentally learned too late that have its peak light sensitivity around 550nm), one little and the other bigger than the first. I’ve done my tests in a controlled lab and varied LED voltage by steps of 0.01V and 0.02V for three different colours of LEDs, as it can be seen in the plot. Both LDRs react with a lower initial resistance with the red LED, but for "low" resistance (around 3k), the trend inverts and it’s the green that makes its way for a lower value. Obviously, different uses should have different combinations, and it would be interesting to see how they react to blue, white or orange LEDs. In any case, this combination is easily used to control AC connected devices like SSRs or tracs directly from a microprocessor’s output, for example. Control methods could be PWM’d by microcontroller, several digital outputs with a R2R resistor network, directly from a voltage source, or you can lower LED’s current needs for the controller by adding a BJT or a little power MOSFET (which I work with). Two of these arrangements working in opposite can form a full potentiometer.

As it can be seen, this circuit is easy to do, extremely cheap and very flexible. However, it should keep in mind that "precision" control would be hard to achieve with this arrangement (but not impossible), because of the differences in LEDs and the same reasons are valid for the LDR. These types of LDRs are not too fast (several ms to vary the value) but, either way, this combination is worth a try.

Manuel Alberto Valero Uribe Catania Italy
Microcontroller drives LC oscillator

In the Figure 1 circuit, if there is an imbalance in the capacitor voltages, charge will flow from one capacitor to the other and a sine wave with frequency:

\[ f = \frac{1}{2\pi \sqrt{LC}} \]

will appear across the inductor.

In the circuit of Figure 2 the comparator senses the waveform and energy is supplied each time the comparator switches. The implementation uses an Atmel AT90S2313 microcontroller, though many other chips will be suitable. The on-chip comparator (pins PB0 and PB1) is configured to interrupt when it toggles, when the interrupt service routine switches PD6 from a high impedance state to either 0 or Vcc for a short period to keep the oscillation going.

This scheme allows an oscillator to be integrated with the microprocessor used to monitor the frequency, as in a metal detector, for example.

Circuit operation is non-critical, though changes may be needed for larger capacitor values. With \( L=2\text{mH} \) and \( C=22\text{nF} \), oscillation was at approximately 33kHz.

During initialization, PD6 is held high for several instructions to start the oscillation.

The code for the interrupt service routine is listed below (too many instructions will limit the upper frequency):

```
AC_in:\n    sbic ACSR,ACO ; If PB0 < PB1, make PD6 OV
    sbic PORTD,6 ; Otherwise make PD6 Vcc
    nop ; Make PD6 an output pin
    nos ; Add or subtract charge
    cbi DDRD,6 ; Make PD6 an input pin again
    cbi PORTD,6 ; Reset PD6
    rei ; Return from interrupt
```

The trace in Figure 3 shows the waveform on pin PB0; the timebase is 5µs per division.

Richard Mullens
Welwyn Garden City
UK

Ultra-simple accelerometer

It is possible to make inexpensive but accurate accelerometers using the new MEMS-based accelerometer chips, now on the market. Here is a simple application of the ADXL103 accelerometer chip from Analog Devices. The ADXL103 is a MEMS (Micro-Electro Mechanical System) device that is capable of measuring accelerations of \( \pm1.7g \) (1g being 9.8m/s²). It has an analogue output, which is \( V_{\text{supply}}/2 \) for an acceleration of zero and swings to either side of that value, depending on the acceleration. The sensitivity of the device is specified to be \( 1V/g \) (typical) at \( V_{\text{supply}} = 5V \), which is high enough for the output to be read directly by a digital multimeter or panel meter. The only requirement is that the input impedance of the ADC should be of the order of tens of kΩ.

Rectangular waveform voltage is applied to the supply and the voltage across the capacitors is monitored. The capacitance change causes the output to be read directly by a digital multimeter or panel meter. The only requirement is that the input impedance of the ADC should be of the order of tens of kΩ.

The circuit operation is non-critical, though changes may be needed for larger capacitor values. With \( L=2\text{mH} \) and \( C=22\text{nF} \), oscillation was at approximately 33kHz.

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    nos ; Add or subtract charge
    cbi DDRD,6 ; Make PD6 an input pin again
    cbi PORTD,6 ; Reset PD6
    rei ; Return from interrupt
```

The trace in Figure 3 shows the waveform on pin PB0; the timebase is 5µs per division.

Richard Mullens
Welwyn Garden City
UK

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Challenging future

By Mike Brookes

Ten years ago, pioneering short-range devices (SRDs) were considered just about capable of opening garage doors, but little else. Alternative high-quality, usually narrowband, devices were expensive and sold only in small quantities. So, SRDs' confinement to a rigidly defined spectrum as secondary occupants seemed reasonable at the time.

Today, highly sophisticated transceivers are available in chip form, featuring frequency agility and programmability, with features such as 'listen before transmit' built in. All of this is available at unit prices of below $10.

This technological explosion/price-implosion has led to rapid expansion of SRDs but, also, applications. This, in turn, has presented regulators with real problems.

The recent workshop at ERO (European Radio Communications Office) devoted to an EC initiative, 'Strategic future for SRDs in Europe' resulted in almost any part of the spectrum up to 1 GHz, without physical component limitation. They will also have an built-in intelligence to detect interference and adjust output power. All this is likely with unit prices still within the $10 band, which will further stimulate demand.

Such freedom, however, brings many other questions for regulators, including Declarations of Conformity within the meaning of the R&TTE Directive. Until now, test houses and manufacturers have been able to define the performance and intent of a radio module, giving regulators a baseline from which to work. Given today's addiction to software downloads from the Internet, it will be difficult for a manufacturer to provide meaningful declarations that cannot be overwritten by replacement software.

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This brings about a challenging future for manufacturers and administrations in controlling the use and spread of these devices.

Logitech is working with Microsoft to build the next-generation Harmony universal remote to control a PC running Microsoft Windows XP Media Center Edition 2005 — and any entertainment devices that may be connected to it. The device is powered by Logitech's patented Smart State Technology and uses a USB connection to interface with the PC for programming the remote to control any electronic component with an infrared receiver. Being Internet-connected, it can access a shared, online database containing information about hundreds of thousands of home stereo components and remote-controlled devices.

Customers of the Harmony remote for Media Center PCs will have their own online home page that details their exact setup and can be viewed and managed through the Windows XP Media Center Edition 2005 interface. The retail version of the Harmony remote will be available in the summer. Price TBA.

HP's iPAQ h2700 series pocket PC line contains a FingerChip sensor from Atmel. It is aimed at providing a secure and convenient way to protect their users' information without the need to manually enter a password. It can also be used in conjunction with a password, if required. The FingerChip sensor uses a patented method for imaging the entire finger. A sweeping motion across the sensor captures successive images (slices), applying software to reconstruct the fingerprint. This method allows the space-efficient FingerChip sensor to return a large, high-quality 500 dots per inch image of the fingerprint. This image is then processed through authentication software, which creates a template to be used for later comparisons.

www.logitech.com

www.hp.com and www.atmel.com

Gadgets
**Clare expands its Horizon**

Clare Instruments has a new set of specialist cable and wiring harness testers for electrical safety. Dubbed Horizon 1500, the series tests variety of applications from simple data cables to complex wiring assemblies used in electrical and electronics systems in the automotive, aerospace, computing, medical, military and telecom industries. The unit is in a rugged benchtop format and includes automatic product-learning, fault location and test report generation, making it suitable for in progress functional and final testing of electrical wiring harness configurations.

The Horizon 1500 series is equipped with 128 high-voltage test points as standard and it can be expanded to 1024 points with high current (up to 1A) and hi pot testing up to 1500VDC and/or 1067VAC. The system has a touch-screen and a hard disc drive for high capacity data storage. 

**Advanced PCB testing from Remploy**

Remploy Electronics has launched an advanced PCB testing service for small and medium sized contract manufacturers. Its facility, which is equipped with some of the latest equipment, including the double-sided flying probe Scorpion FLS 450 in-circuit tester from Scorpion Technologies, enables automatic and simultaneous testing of PCB assemblies. The company says testing is cost-effective and simple to set up, and tests active and passive components and boards featuring fine pitch and flip-chip technologies.

"Companies spend a lot of money in the development and production of today’s complex boards and it makes sound commercial sense to apply the same scrupulous approach to the testing process," said Graham Denny, project engineer for Remploy Electronics. For lease technically demanding boards, Remploy offer an array of testing options including automatic optical inspection (AOI) as well as Wayne Kerr and Schlumberger automatic test equipment.

**Multipath fading emulator**

Electrotob Testing Ltd introduced a new Multipath Fading Emulator for the testing of 2/2.5/3/5G (GSM, GPRS, EDGE, CDMA, CDMA2000, WCDMA, WLAN) wireless networks, terminals and chips.

The new Air Interface Emulator, PROPSim FE, is a tunnery solution that includes all the required test system components, latest multipath fading emulation technology, integrated interference generation and advanced test connection configurability, in a single box.

**Miniature PCB-mounting transducers now on offer from LEM**

The new miniature PCB-mounting current transducers for unipolar ±5V operation from LEM are based on an open-loop technology combined with an ASIC. They have access to an internal voltage reference and come in many ranges. In addition, they come with a five-year warranty. The HX5 series is designed to operate from a single ±5V supply. The units measure 18.5x16.5x10mm and integrate a multi-range primary universe. The part on this conductor allows the HXS 20-NP to be configured as a five, 10 or 20 ARMS nominal model and the HXS 50-NP as a 12.5, 25 or 50 ARMS nominal model, with a measuring span of up to +3 x LV.

The internal reference voltage (2.5V) is provided on a separate pin or can be replaced by an external reference (between 2V and 2.8V). The ASIC used with these transducers is combined with open-loop Hall effect technology, which in turn guarantees better offsets, gain drifts and linearity. It also offers operating temperature ranges that span between -40°C and 850°C.

**200W battery-backed PSU with multiple outputs**

The new Oracle I9 battery-backed switch-mode power supply from Vital Power offers designers greater flexibility by providing one main output, one charger output and up to seven 24V auxiliary outputs. The PSU is available in both 12V and 110V versions and features fan cooling as standard, enabling it to deliver 200W continuously at the maximum permissible ambient temperature of 70°C, with a peak output capability of 300W. In the event of a mains failure, the backup battery supplies power to the load via an internal node, thereby ensuring that the output is maintained without interruption.

The unit is capable of charging "cycling" cells over the full temperature range and can also be configured for either 2- or 3-stage charging to reduce battery recharge times in cyclic applications. The 200-9 features the standard Oracle I9 RS222/RS485 serial communications interface, with a choice of Modbus, Canbus, DeviceNet or 23A protocols. As well as enabling data to be downloaded to a PC, this facility makes it possible for users to input parameters such as battery type and battery test intervals. In addition, the serial interface allows the PSU to be integrated into a SCADA system, if required.

**Alternative ATCA units cooling**

UK-based enclosure manufacturer Rittal has introduced high-capacity RiCool II fans for heat dissipation of up to 3.2kW and above for an entire Advanced TCA (ATCA) shelf. To achieve a reliable system, Rittal has used liquid cooling technology that was developed for cooling multiple high-power servers in image processing applications in conjunction with the Max Planck Institute. The package allows the locating of heat exchangers, away from the rack, office or equipment room, saving on noise and heat build-up.

Rittal expects even higher heat losses to be incurred in the future, as integration levels rise and clock frequencies extend beyond the 10GHz.

**Catalogue offers Narda**

A new catalogue from Link Minicat features over 60 new products from US manufacturer Narda to mark its 50th anniversary. The catalogue consists of 600 pages and it comprises of Narda's entire product range. The catalogue is divided into colour sections for ease of navigation. Covering fibre optics, microwave and mm-wave components, electromagnetic RF switches, power meters and monitors, sapphire products, RF safety products and low-cost of wireless components.

Equally, the catalogue carries specifications, outline drawings, performance charts, applications notes and articles. Also available is a CD version of this catalogue, with information presented in PDF format, featuring a part-number search facility.

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